CS SERIES ELECTROCHEMICAL WORKSTATION

USERS' MANUAL

Wuhan CorrTest Instruments Corp., Ltd.
Wuhan China

CONTENTS

Part 1 Introduction of CS series potentiostat / galvanostat

CS Potentiostat / Galvanostat (electrochemical workstation) contains a fast digital function generator, high-speed data acquisition circuitry, a potentiostat and a galvanostat. With high performance in stability and accuracy with advanced hardware and well-functioned software, it is a comprehensive research platform for corrosion, batteries, electrochemical analysis, sensor, life science and environmental chemistry etc.

Applications

- Electrocatalysis (HER, OER, ORR, CO2RR, NRR)
- Study of Energy materials (Li-ion battery, solar cell, fuel cell, supercapacitors), advanced functional materials
- Corrosion study and corrosion resistance evaluation of metals; quick evaluation of corrosion inhibitors, coatings, and cathodic protection efficiency
- Electrosynthesis, electroplating/electrodeposition, anode oxidation, electrolysis

Specifications

Support 2-, 3- or 4-electrode system
Potential control range: ±10V
Current control range: ±2A
Potential control accuracy: 0.1%×full range±1mV
Current control accuracy: 0.1%×full range
Potential resolution: 10μV(>100Hz), 3μV (<10Hz)
Current sensitivity: 1pA
Potentiostat rise time: <1μs (<10mA), <10μs(<2A)
Reference electrode input impedance: $10^{12}\Omega||20pF$
Current range: 2nA~2A, 10 ranges
Compliance voltage: ±21V
Maximum current output: 2.0A
CV and LSV scan rate: 0.001mV~10,000V/s
CA and CC pulse width: 0.0001~65,000s
Current increment during scan: 1mA@1A/ms
Potential increment during scan: 0.076mV@1V/ms
SWV frequency: 0.001~100 kHz
DPV and NPV pulse width: 0.0001~1000s
AD data acquisition: 16bit@1 MHz,20bit@1 kHz
DA Resolution: 16bit, setup time: 1μs
Minimum potential increment in CV: 0.075mV
IMP frequency: 10μHz~1MHz
Low-pass filters: covering 8-decade
Potential and current range: automatic

EIS specifications

Signal generator:

Frequency range: 10μHz~1MHz

Frequency accuracy: 0.005%

AC signal amplitude: 1mV~2500mV

Signal resolution: 0.1 mV RMS

DC Bias: -10~+10V

Output impedance: 50Ω

Waveform: Sine wave, triangular wave and square wave

Wave distortion: <1%

Scan mode: Logarithmic/linear, increase/decrease

Signal analyzer:

Integral time: minimum: 10ms or the longest time of a cycle

Maximum: 10^6 cycles or 10^5s

Measurement delay: 0~10^5s

DC offset:

Potential automatic compensation range: -10V~+10V

Current compensation range: -1A~+1A

Bandwidth: 8-decade frequency range, automatic and manual setting

System Requirements

Operating System: Windows /7/ 8/10/11

Communication between PC and instrument: USB2.0.

Dimensions(cm):36 ×30×14; weight: 6.5kg

Front panel

Rear panel

LED screen: display the current range, load status, working mode, polarization status

Cell- The electrode cable should be inserted into Cell port here.

AC 220V or 110V: AC 220V or 110V power socket with fuse, 1A fuse in the bottom box.

External control interface: used to synchronously control the external stirrer, motor rotating rate, etc., or as a frequency meter for frequency testing of external signals (can be connected to a quartz crystal microbalance (QCM).

USB: using USB to connect the potentiostat with a computer.

LAN: using an Ethernet cable to connect the potentiostat with a computer. Usually we use USB cable for communication. But single-channel potentiostat can also be connected by Ethernet (there is a LAN port back of single-channel). You should change the IP address of your potentiostat if you use Ethernet, in the same way as bi-, multi- channel elaborated in 1.2.2 part.

Analog input and output: the analog input and output expansion port of the instrument.

3- electrode system Cable connection

Greed WE & white SENSE connect together to working electrode

Red CE connects to the counter electrode

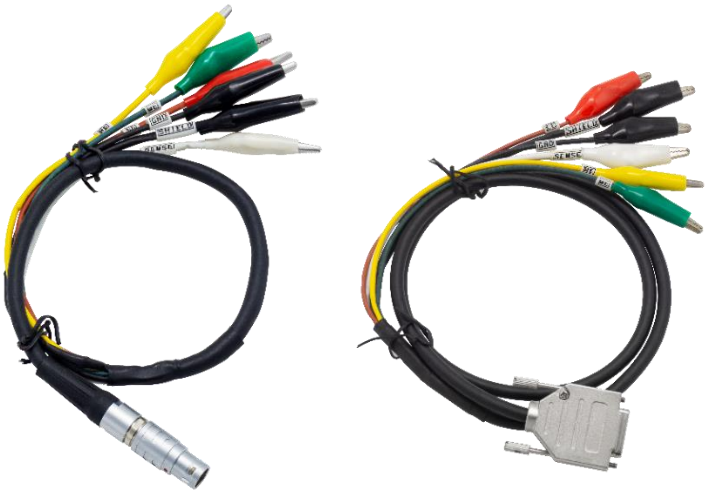
Yellow RE connects to the reference electrode

Black (GND) connects to galvanic electrode WEII in electrochemical noise experiment. If use a Faraday cage, black GND and Shield connect the cage together.

2- electrodes system Cable connection

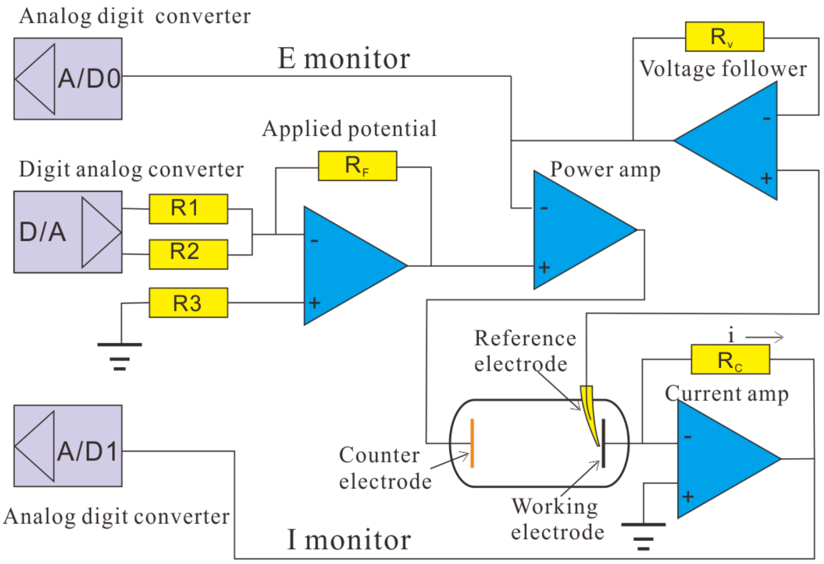
The green WE& white SENSE connect together to WE / anode;

Red CE & yellow RE connect together to cathode.



left: Electrode cable for single-channel and bi-potentiostat
right: Electrode cable for multichannel potentiostat

Schematic diagram



Schematic diagram of CS potentiostat

Standard supply for single-channel potentiostat

Instrument host*1, CS Studio software, Power cable*1, USB cable*1, Electrode cable*2, dummy cell*1, Manual, warranty card

Standard supply for Bipotentiostat

Instrument host*1, CS Studio software, Power cable*1, Ethernet cable*1, Electrode cable*4, dummy cell*2, manual, warranty card

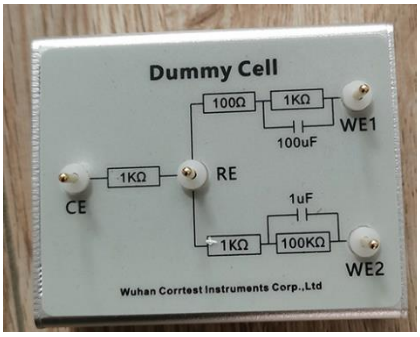
Standard supply for multichannel potentiostat

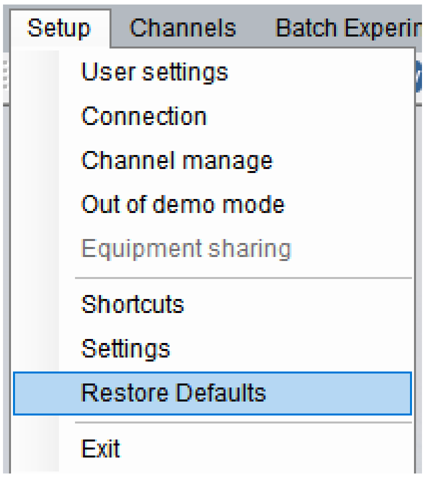
Instrument host*1, CS Studio software, Power cable*1, Ethernet cable*1, Electrode cable*8(4-channel)/16(8-channel), dummy cell*4/8, manual, warranty card

Dummy cell

Dummy cell is a simulation cell. It's used to check whether the potentiostat is normal. When you receive a potentiostat, you can use it to ensure the potentiostat is well-functional. During tests if you find data abnormal or something wrong, you can also use it to check whether it's caused by your testing system, or by the malfunctioning of the instrument.

Connect the green WE & white SENSE alligator to WE1, the yellow alligator to RE, and the red alligator to CE.





Principle:

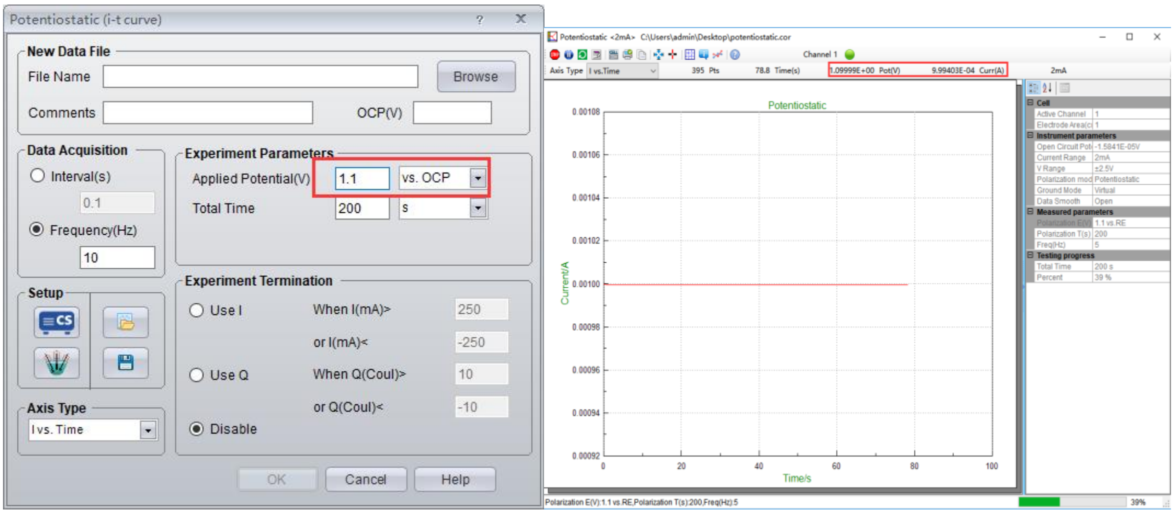
During experiment, the potential and current value should always obey the Ohm law: I= E / R The R is 1.1kΩ for the dummy cell. So if you apply a constant voltage (potentiostatic technique) or a constant current (galvanostatic technique), the voltage and current should be accurately applied and displayed in the software, and the obtained current or voltage value should obey the Ohm law.

We do potentiostatic and galvanostatic test to check the potential and current output of the instrument

Steps:

Open the software, Click setup→Reset Workstation. During experiment, the potential and current value should always obey the Ohm law: I= E / R

Click Experiments→Potentiostatic, set the applied voltage to be 1.1V, start the test. If the displayed potential value is 1.1V, because resistor is 1.1kΩ, and the current should be 1mA. If on the graph the applied potential is 1.1V and the current is 1mA, it means the instrument potential output is normally well.



Potentiostatic (i-t curve)

New Data File
File Name
Comments
OCP(V)

Data Acquisition
○ Interval(s) 0.1
● Frequency(Hz) 10

Experiment Parameters
Applied Potential(V) 1.1 vs. OCP
Total Time 200 s

Experiment Termination
○ Use I When I(mA)> 250 or I(mA)< -250
○ Use Q When Q(Coul)> 10 or Q(Coul)< -10
● Disable

Axis Type I vs. Time

Potentiostatic <2mA> C:\Users\admin\Desktop\potentiostatic.cor

Channel 1

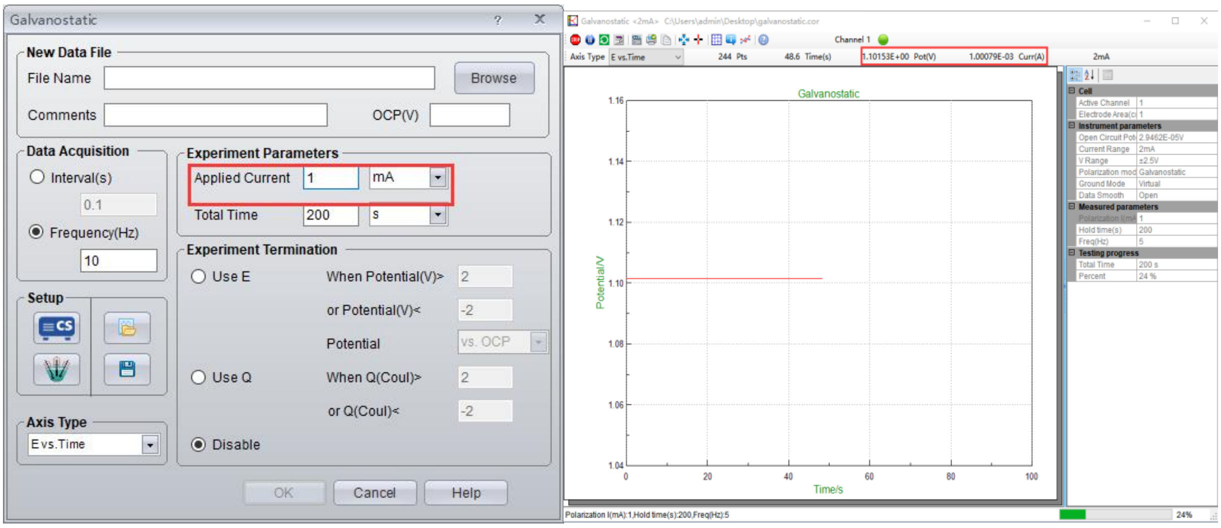
Axis Type I vs.Time 395 Pts 78.8 Time(s) 1.09999E+00 Pot(V) 9.99403E-04 Curr(A) 2mA

Cell	
Active Channel	1
Electrode Area(c	1
Instrument parameters	
Open Circuit Pot	-1.5841E-05V
Current Range	2mA
V Range	±2.5V
Polarization mod	Potentiostatic
Ground Mode	Virtual
Data Smooth	Open
Measured parameters	
Polarization E(V)	1.1 vs.RE
Polarization T(s)	200
Freq(Hz)	5
Testing progress	
Total Time	200 s
Percent	39 %

Polarization E(V):1.1 vs.RE,Polarization T(s):200,Freq(Hz):5

39%

The same way, click Experiments→Galvanostatic, set the applied current to be 1mA, start the test. If the displayed current value is 1mA, and the potential value is 1.1V, it means the instrument current output is normal.



Galvanostatic

New Data File
File Name
Comments
OCP(V)

Data Acquisition
○ Interval(s) 0.1
● Frequency(Hz) 10

Experiment Parameters
Applied Current 1 mA
Total Time 200 s

Experiment Termination
○ Use E When Potential(V)> 2 or Potential(V)< -2 Potential vs. OCP
○ Use Q When Q(Coul)> 2 or Q(Coul)< -2
● Disable

Axis Type E vs. Time

Galvanostatic <2mA> C:\Users\admin\Desktop\galvanostatic.cor

Channel 1

Axis Type E vs.Time 244 Pts 48.6 Time(s) 1.10153E+00 Pot(V) 1.00079E-03 Curr(A) 2mA

Cell	
Active Channel	1
Electrode Area(c	1
Instrument parameters	
Open Circuit Pot	2.9462E-05V
Current Range	2mA
V Range	±2.5V
Polarization mod	Galvanostatic
Ground Mode	Virtual
Data Smooth	Open
Measured parameters	
Polarization I(mA	1
Hold time(s)	200
Freq(Hz)	5
Testing progress	
Total Time	200 s
Percent	24 %

Polarization I(mA):1,Hold time(s):200,Freq(Hz):5

24%

Combining the results, we can say the electrode cable is no problem.

Part 2 CS Studio6 Software

1. Introduction

CS Studio software shipped with the CS electrochemical workstation is an easy-to-use, flexible, and versatile electrochemical tool. It can be applied in many research fields such as corrosion, voltammetry, electroanalysis or battery test, etc. Computer Operating system should be Windows-based. There is no other requirement for computer. A mainstream/ common one in the market is OK.

Interface of CS Studio software

1.1 Electrochemical Techniques

Stable polarization

- Open Circuit Potential (OCP)
- Potentiostatic (I-T curve)
- Galvanostatic
- Potentiodynamic (Tafel plot)
- Galvanodynamic (DGP)

Transient Polarization

- Multi Potential Steps
- Multi Current Steps
- Potential Stair-Step (VSTEP)
- Galvanic Stair-Step (ISTEP)

Chrono Method

- Chronopotentiometry (CP)
- Chronoamperametry (CA)
- Chronocaulometry (CC)

Voltammetry

- Linear Sweep Voltammetry (LSV)
- Cylic Voltammetry (CV)
- Staircase Voltammetry (SCV)
- Square Wave Voltammetry (SWV)
- Differential Pulse Voltammetry (DPV)
- Normal Pulse Voltammetry (NPV)#
- Differential Normal Pulse Voltammetry (DNPV)
- AC Voltammetry (ACV)

- 2nd harmonic AC Voltammetry (SHACV)
- Fourier Transform AC Voltammetry (FTACV)

Electrochemical Impedance Spectroscopy (EIS)

- Potentiostatic EIS (Nyquist, Bode)
- Galvanostatic EIS
- Potentiostatic EIS (Optional freq.)
- Galvanostatic EIS(Optional freq.)
- Mott-Schottky
- Potentiostatic EIS vs. Time (Single freq.)
- Galvanostatic EIS vs. Time (Single freq.)

Corrosion Measurements

- Cyclic polarization curve (CPP)
- Linear polarization curve (LPR)
- Electrochemical Potentiokinetic Reactivation (EPR)
- Electrochemical Noise (EN)
- Zero resistance Ammeter (ZRA)

Battery test

- Battery Charge and Discharge
- Galvanostatic Charge and Discharge (GCD)
- Potentiostatic Charging and Discharging(PCD)
- Potentiostatic Intermittent Titration Technique (PITT)
- Galvanostatic Intermittent Titration Technique (GITT)

Stripping Voltammetry

- Potentiostatic Stripping
- Linear Stripping
- Staircase Stripping
- Square Wave Stripping
- Differential Pulse Voltammetry Stripping
- Normal Pulse Voltammetry Stripping
- Differential Normal Pulse Voltammetry Stripping

Amperometric

- Differential Pulse Amperometry (DPA)
- Double Differential Pulse Amperometry (DDPA)
- Triple Pulse Amperometry (TPA)
- Integrated Pulse Amperometric Detection (IPAD)

Extensions

- Electrochemical Stripping/ Deposition
- Bulk Eletrolysis with Coulometry (BE)
- Rs Measurement

There is the corresponding stripping method.

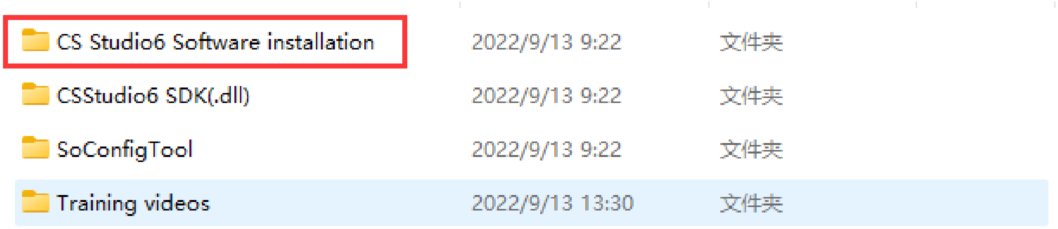
CS Studio software is also equipped with powerful corrosion analysis module. It can calculate the corrosion rate of the material by linear polarization and weak polarization, as well as polarization resistance (R_p), Tafel slope (b_a, b_c), and corrosion current density (i_{corr}) through the non-linear fitting of Tafel plots. In addition, by the built-in electrochemical impedance spectroscopy (EIS)technique, it can measure the double layer capacitance (C_{dl}) and the solution/ concrete resistance(R_s). Moreover,CS Studio software provides as a dual-channel data logger for pH, temperature and some physical quantities records.

1.2 Software Installation

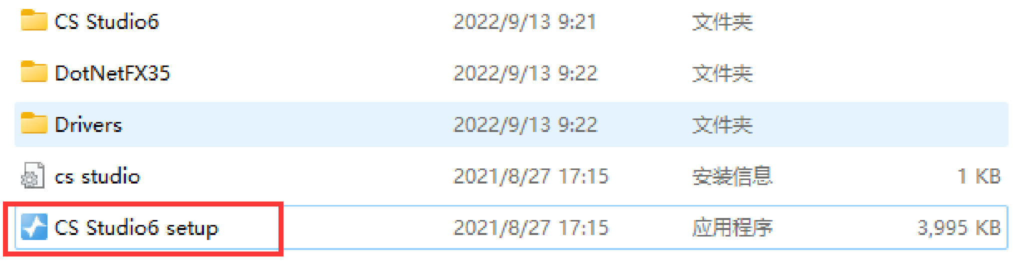
1.2.1 Single-channel models: CS350M/CS310M/CS300M/CS150M/CS100(E)

1. Using the USB cable to connect the potentiostat with a computer.

2. Power on the instrument, open the “software installation” folder in USB flash disk, right click the “CS studio6 setup”, and run as administrator.



CS Studio6 Software installation	2022/9/13 9:22	文件夹
CSStudio6 SDK(.dll)	2022/9/13 9:22	文件夹
SoConfigTool	2022/9/13 9:22	文件夹
Training videos	2022/9/13 13:30	文件夹



CS Studio6	2022/9/13 9:21	文件夹	
DotNetFX35	2022/9/13 9:22	文件夹	
Drivers	2022/9/13 9:22	文件夹	
cs studio	2021/8/27 17:15	安装信息	1 KB
CS Studio6 setup	2021/8/27 17:15	应用程序	3,995 KB

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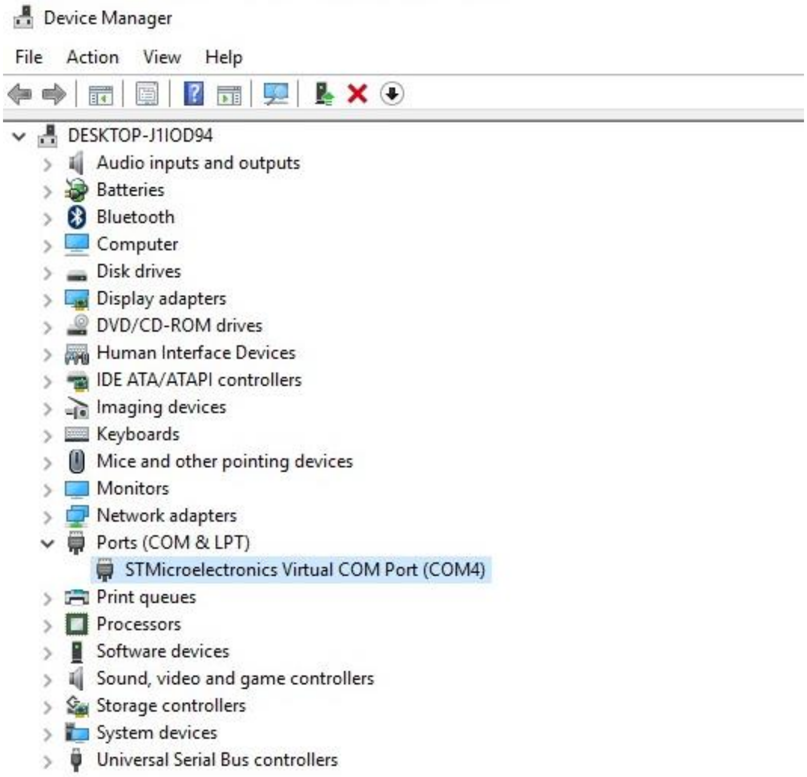
3. Firstly, install the drivers. After finishing it, go to the computer management → device manager→ Ports (COM & LPT). There, it will appear “STM… virtual COM Port(COM x)”. As is shown below.



Device Manager

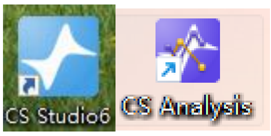
File Action View Help

- DESKTOP-J1IOD94
  - Audio inputs and outputs
  - Batteries
  - Bluetooth
  - Computer
  - Disk drives
  - Display adapters
  - DVD/CD-ROM drives
  - Human Interface Devices
  - IDE ATA/ATAPI controllers
  - Imaging devices
  - Keyboards
  - Mice and other pointing devices
  - Monitors
  - Network adapters
  - Ports (COM & LPT)
    - STMicroelectronics Virtual COM Port (COM4)
  - Print queues
  - Processors
  - Software devices
  - Sound, video and game controllers
  - Storage controllers
  - System devices
  - Universal Serial Bus controllers

4. Secondly, install the runtime environment. If your computer has already installed it, there will be a prompt saying you have already installed.

If it hasn’t been installed in your computer, just follow the steps to finish installation of runtime.

5. Click install CS Studio6. CS Stuido6 is the testing software, and the CS Analysis is the data analysis software.



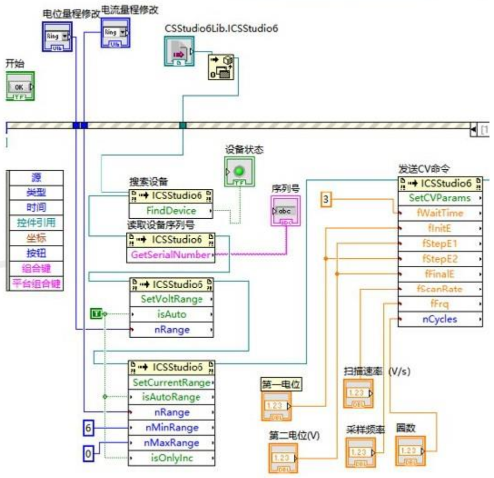
6. Run the software as administrator. Then the model and serial number will be shown. It means the instrument has been successfully connected.

Software development kit(SDK)

The below folder(SDK/.dll) is about the second development kit. We supply it with the software.

We can provide secondary development interfaces, API general interfaces and development examples, and can realize data call for Labview, C, C++, C#, VC and other program, which is convenient for secondary development and test methods customization.

CSStudio6 SDK(.dll)



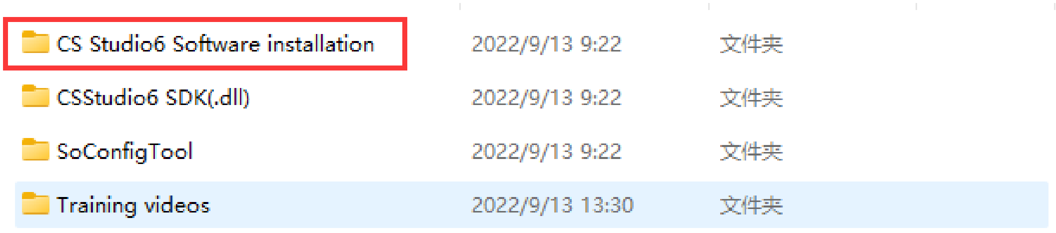
1.2.2 Bipotentiostat & multichannel potentiostat (CS2350M/CS2150M /CS310X)

The installation process is the same for bipotentiostat and multichannel potentiostat

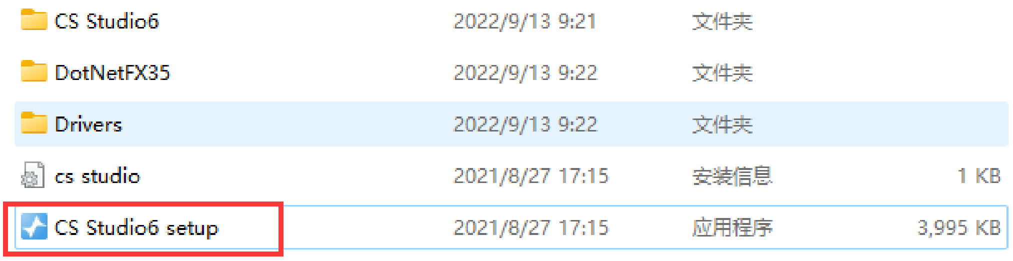
Software installation

(1) Use the Ethernet cable to connect the computer with the instrument. Power on the instrument.

(2) Open the “software installation” folder, right click the “Setup.exe”, and run as administrator.



CS Studio6 Software installation	2022/9/13 9:22	文件夹
CSStudio6 SDK(.dll)	2022/9/13 9:22	文件夹
SoConfigTool	2022/9/13 9:22	文件夹
Training videos	2022/9/13 13:30	文件夹



CS Studio6	2022/9/13 9:21	文件夹	
DotNetFX35	2022/9/13 9:22	文件夹	
Drivers	2022/9/13 9:22	文件夹	
cs studio	2021/8/27 17:15	安装信息	1 KB
CS Studio6 setup	2021/8/27 17:15	应用程序	3,995 KB

CorrTest CS Studio5 Software Installation

CorrTest® 科思特仪器 武汉科思特仪器股份有限公司 WUHAN CORRTEST INSTRUMENTS CORP.,LTD.

○ 简体中文

● English

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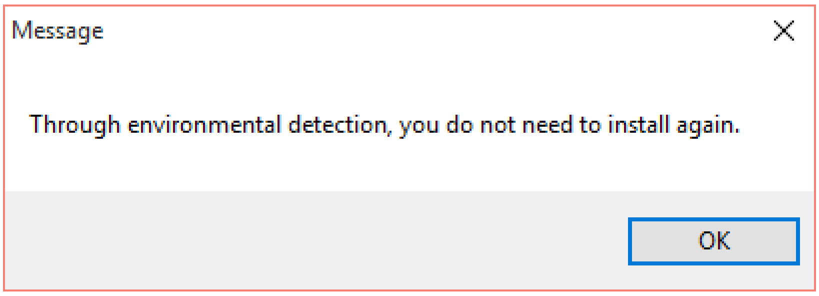
(3) For potentiostat more than one channel, we use Ethernet communication. So there is no need to install drivers. Firstly, install the .net 3.5. If your computer has already installed it, there will be a prompt as follows.

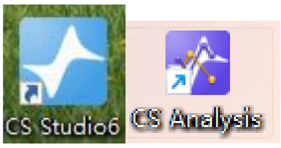


Message

Through environmental detection, you do not need to install again.

If it has not installed in your computer, just follow the steps to finish installation of .net 3.5.

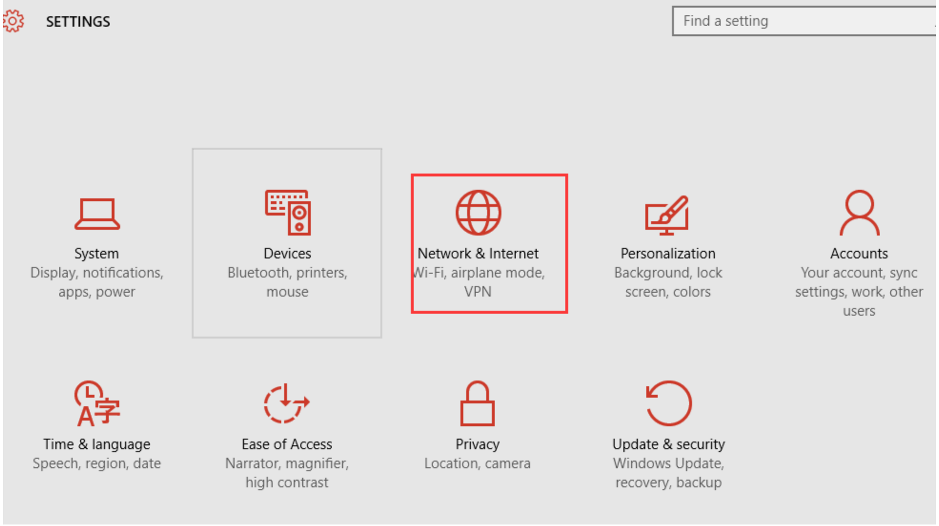
(4) Click install CS Studio6. CS Stuido6 is the testing software, and the CS Analysis is the data analysis software.



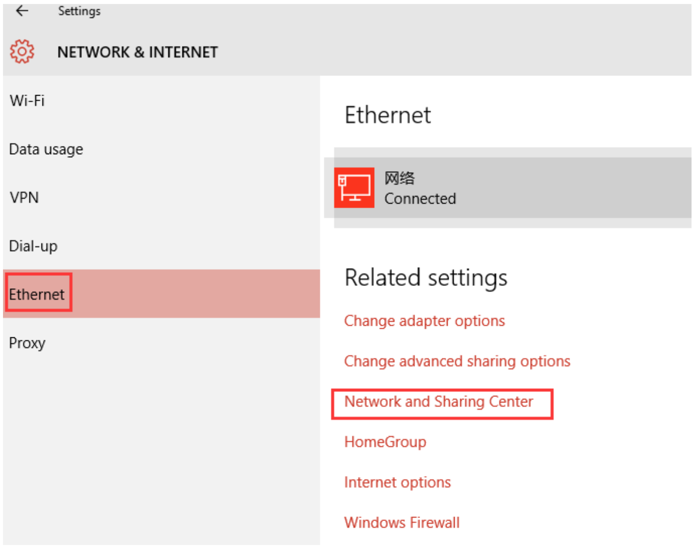
IP address configuration (Windows 10 as an example)

Connecting the instrument (Bipotentiostat or multichannel potentiostat) with computer by Ethernet cable, you should reset the IP address of the computer.

(1) Find the “Network and sharing center”



Then, Ethernet →Network and sharing center



Settings

NETWORK & INTERNET

Wi-Fi
Data usage
VPN
Dial-up
Ethernet
Proxy

Ethernet

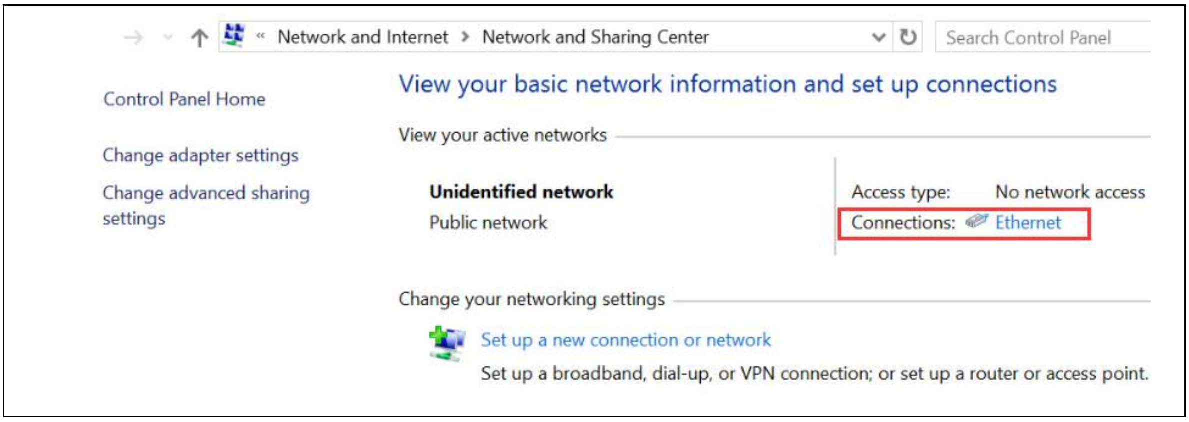
网络
Connected

Related settings

Change adapter options
Change advanced sharing options
Network and Sharing Center
HomeGroup
Internet options
Windows Firewall

(Or  → Network and sharing center)

(2) Click “Ethernet” shown as below:



« Network and Internet › Network and Sharing Center

Search Control Panel

Control Panel Home

Change adapter settings

Change advanced sharing settings

View your basic network information and set up connections

View your active networks

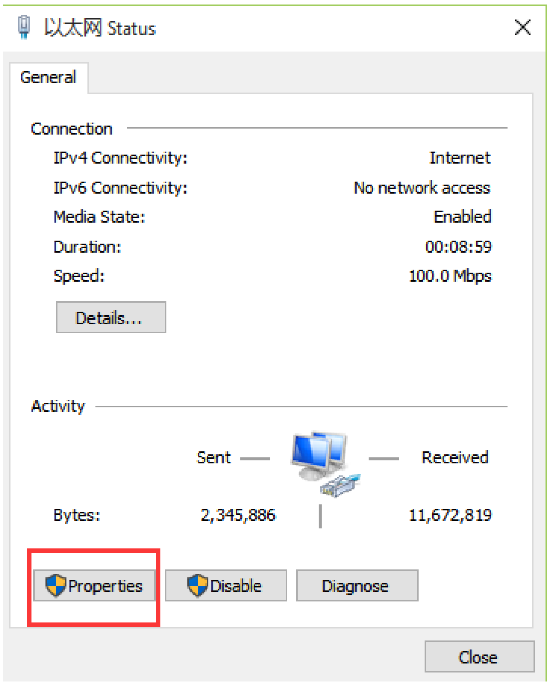
Unidentified network
Public network

Access type: No network access
Connections: Ethernet

Change your networking settings

Set up a new connection or network
Set up a broadband, dial-up, or VPN connection; or set up a router or access point.

(3) Click “Properties”, then check “Internet Protocol version 4(TCP/IPv4)”



以太网 Status

General

Connection

IPv4 Connectivity: Internet

IPv6 Connectivity: No network access

Media State: Enabled

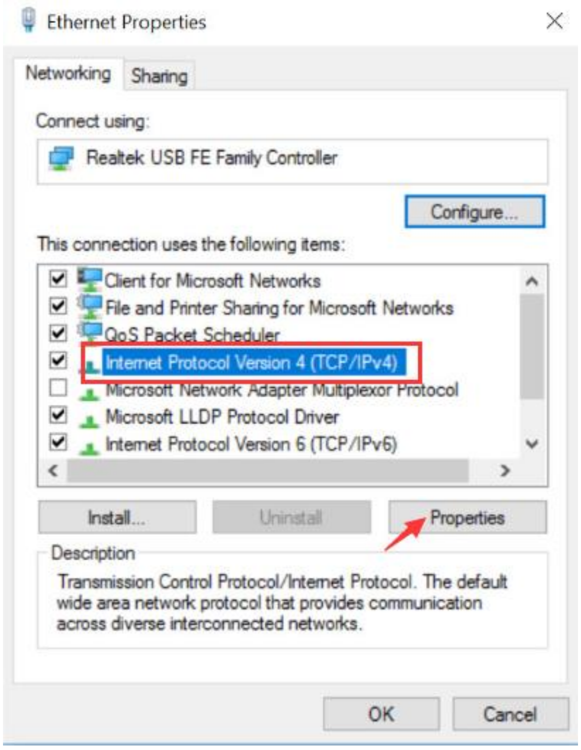
Duration: 00:08:59

Speed: 100.0 Mbps

Activity

Sent — Received

Bytes: 2,345,886 | 11,672,819



Ethernet Properties

Networking | Sharing

Connect using:

Realtek USB FE Family Controller

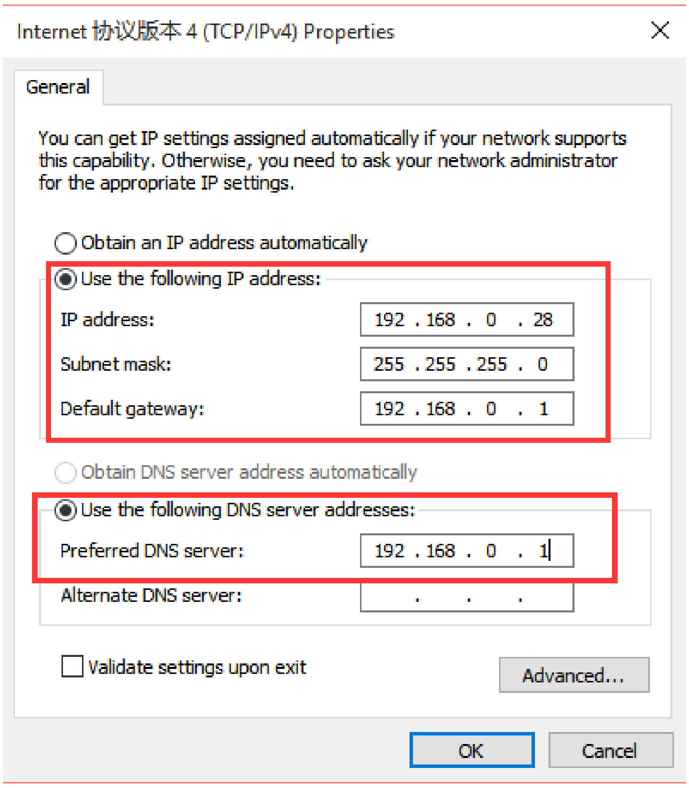
This connection uses the following items:

- ☑ Client for Microsoft Networks
- ☑ File and Printer Sharing for Microsoft Networks
- ☑ QoS Packet Scheduler
- ☑ Internet Protocol Version 4 (TCP/IPv4)
- ☐ Microsoft Network Adapter Multiplexor Protocol
- ☑ Microsoft LLDP Protocol Driver
- ☑ Internet Protocol Version 6 (TCP/IPv6)

Description

Transmission Control Protocol/Internet Protocol. The default wide area network protocol that provides communication across diverse interconnected networks.

(4) Fill in the IP address exactly as below:



Internet 协议版本 4 (TCP/IPv4) Properties

General

You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.

○ Obtain an IP address automatically

● Use the following IP address:

IP address: 192 . 168 . 0 . 28

Subnet mask: 255 . 255 . 255 . 0

Default gateway: 192 . 168 . 0 . 1

○ Obtain DNS server address automatically

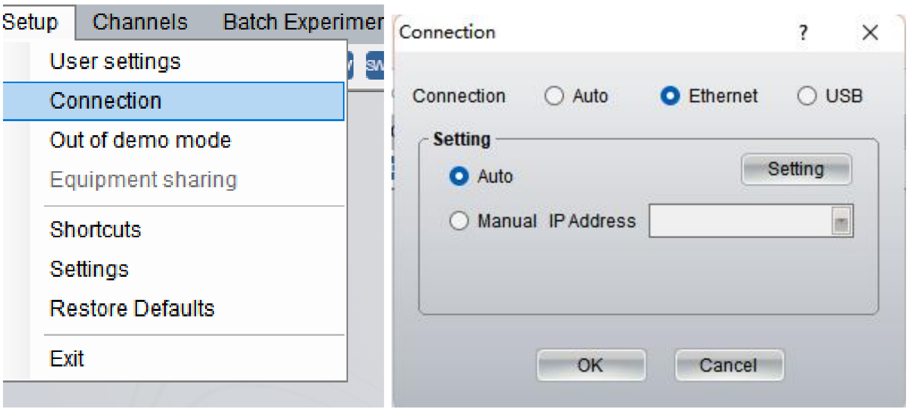
● Use the following DNS server addresses:

Preferred DNS server: 192 . 168 . 0 . 1

Alternate DNS server: . . .

☐ Validate settings upon exit

(5) Open CS Studio6 software, “Setup” → Connection → “Ethernet” →Manual



Connection ○ Auto ● Ethernet ○ USB

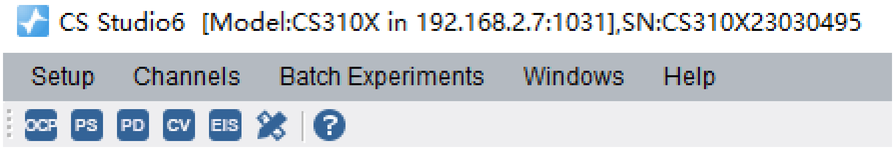
Setting

● Auto

○ Manual IP Address

Please note that for bipotentiostat (CS2350M/CS2150M) and multichannel potentiostat (CS310X), the connection way must be Ethernet. You can check this point firstly in case you find they’re disconnected.

(6) When the bipotentiostat or multichannel potentiostat is successfully connected with the computer, there will be model and serial number shown on the software interface, as is shown below.


CS Studio6 [Model:CS310X in 192.168.2.7:1031],SN:CS310X23030495

1.2.3 Installation Guide for Potentiostat+ Current Booster

Single-channel potentiostat (CS350M/ CS310M/ CS300M etc) can achieve maximum ±2A/10V output when it’s used alone. This value is ±1A/10V for each channel of bipotentiostat (CS2350M/CS2150M) and multichannel potentiostat (CS310X).

A current booster CS2020B can be connected to single-, bi-, or multi-channel potentiostat to boost the current (up to 20A). Please note that one set CS2020B can boost only one channel of bi- / multi-channel potentiostat..

The connection of booster to potentiostat is all the same, take the single-channel CS350M connecting with CS2020B as an example.

Cable connection

DB15 cable: one end inserts into the “Cell” port on front panel of CS350M potentiostat, the other end inserts into “Cable in” on front panel of CS2020B.

CS2020B specialized electrode cables: RE/SENSE electrode + alligator electrode or copper terminal electrode cable (you should choose to use either alligator electrode or copper terminal electrode cable based on your test requirement).

DB9 cable: one end inserts into Misc. I/O on back panel of potentiostat, the other end inserts into Misc. I/O on front panel of CS2020B.

CS2020B Specialized RE/SENSE electrode cable

alligator electrode

copper terminal electrode cable

(you should choose to use either alligator electrode or copper terminal electrode cable based on your test requirement)

Electrode cable connection for potentiostat+CS2020B current booster system

3-electrode system:

Green WE and white SENSE connect together to the working electrode, yellow RE connects to reference electrode, red CE connects to the counter electrode.

2-electrode system:

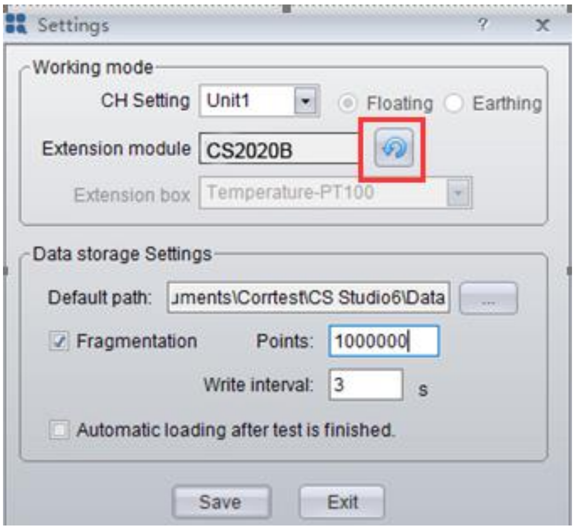
Green WE+ white SENSE connect together to the anode, and yellow RE+ red CE connect together to cathode. White SENSE and yellow RE alligator connect at near/lower position, Green WE and CE alligator is placed at far/upper position respectively, as is shown below:

Potentiostat+CS2020B booster: test the battery core

Software search

Please open the CS Studio6 software, and usually it will automatically find the booster and show related information “CS350M+CS2020B in com x” on the top of the software, meaning the CS350M and CS2020B are both successfully connected.

If it doesn’t show the “CS2020B” on the top of interface, then you should refresh it(the button is marked as below) in “Settings”.



Settings

Working mode

CH Setting: Unit1 ● Floating ○ Earthing

Extension module: CS2020B

Extension box: Temperature-PT100

Data storage Settings

Default path: uments\Corrtest\CS Studio6\Data

☑ Fragmentation Points: 1000000

Write interval: 3 s

☐ Automatic loading after test is finished.

If you don’t want to use the CS2020B booster, and just use the potentiostat alone, then you can power off the CS2020B, unplug the connecting cable between potentiostat and booster, and use the ordinary electrode cable for potentiostat, then restart the software.

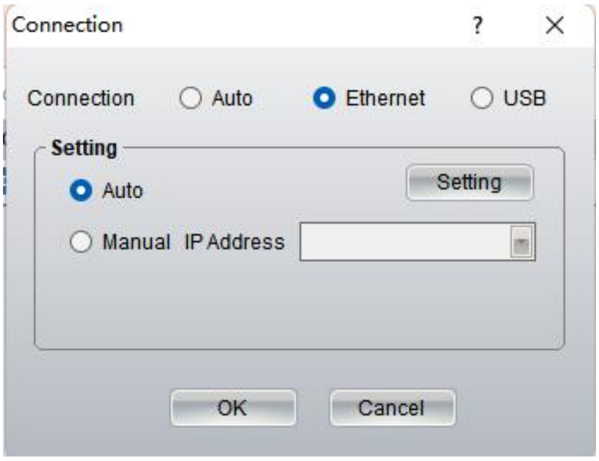
1.3 Setup

1.3.1 Connection

It’s used to modify the communication way of the instrument.

For single channel potentiostat it’s **USB**

For bipotentiostat and multichannel potentiostat, it’s **Ethernet**.



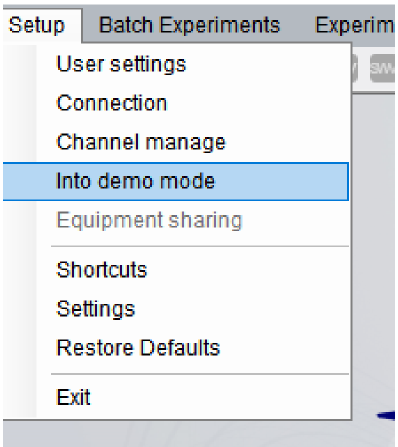
Connection ○ Auto ● Ethernet ○ USB

Setting

● Auto

○ Manual IP Address

1.3.2 Into demo mode

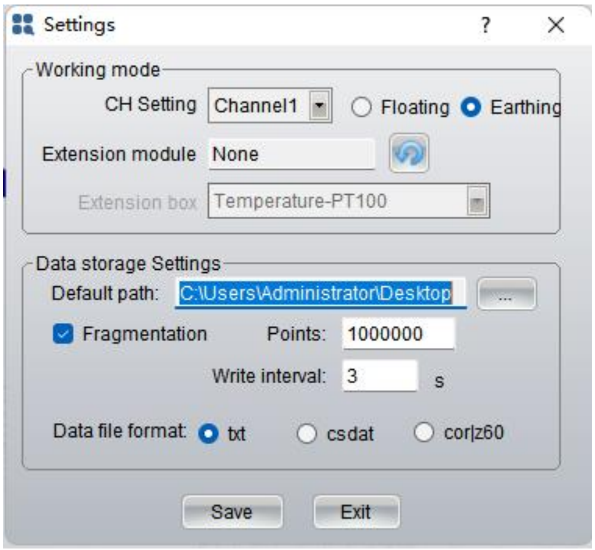


Our software package can be sent to customers to click and view even when they don’t have a potentiostat to be connected. This is helpful when some customers want to get familiar with the instrument and software before purchase. All the techniques/experiment can be clicked and we will also provide some data files so that you can open data in CS Analysis and see how the data is proceeded and analyzed.

1.3.3 Settings

Here you can change the default place for data storage.

Fragmentation is used for big amount data. For each fragment the data points can be set. Default is 1,000,000.



Settings

Working mode

CH Setting: Channel1 ○ Floating ● Earthing

Extension module: None

Extension box: Temperature-PT100

Data storage Settings

Default path: C:\Users\Administrator\Desktop

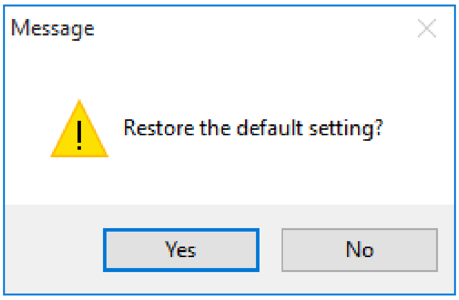
☑ Fragmentation Points: 1000000

Write interval: 3 s

Data file format: ● txt ○ csdat ○ cor|z60

1.3.4 *Restore default*

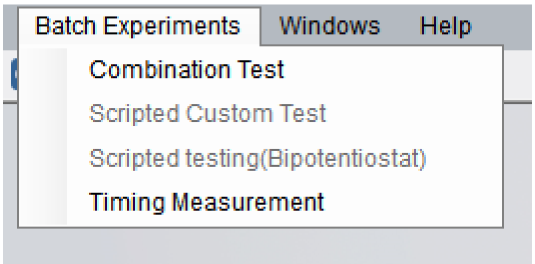
This is to restore to the factory default state. The stored experimental data will not be deleted.



Message

Restore the default setting?

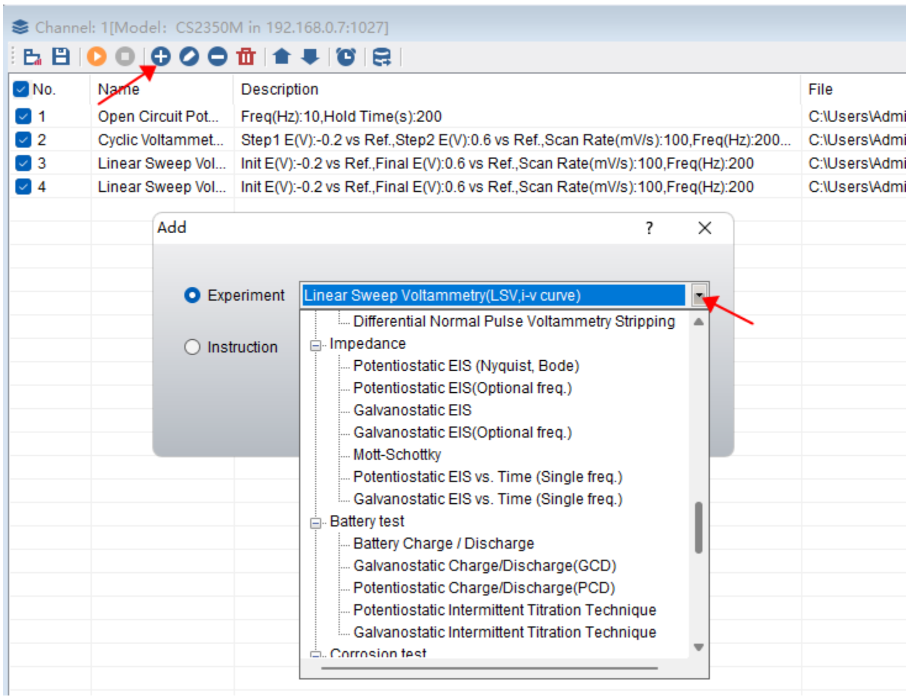
1.4 Batch experiment



1.4.1 *Combination test*

This is a very useful function.

You can add several experiments, for each test you can modify the parameters setting, and the number of cycles can also be set. After setting the experiments and control instructions, click the "OK" button, and the instrument will automatically test and save the data according to the custom requirements. This function can do a complete experiment project without your attendance. You don’t need to wait in the lab all the time and it will complete a series of experiments automatically. It will make the tests efficient and save your time.



Channel: 1[Model: CS2350M in 192.168.0.7:1027]

☑ No.	Name	Description	File
☑ 1	Open Circuit Pot...	Freq(Hz):10,Hold Time(s):200	C:\Users\Admi
☑ 2	Cyclic Voltammet...	Step1 E(V):-0.2 vs Ref.,Step2 E(V):0.6 vs Ref.,Scan Rate(mV/s):100,Freq(Hz):200...	C:\Users\Admi
☑ 3	Linear Sweep Vol...	Init E(V):-0.2 vs Ref.,Final E(V):0.6 vs Ref.,Scan Rate(mV/s):100,Freq(Hz):200	C:\Users\Admi
☑ 4	Linear Sweep Vol...	Init E(V):-0.2 vs Ref.,Final E(V):0.6 vs Ref.,Scan Rate(mV/s):100,Freq(Hz):200	C:\Users\Admi

Add

● Experiment: Linear Sweep Voltammetry(LSV,i-v curve)

○ Instruction

Channel: 1[Model: CS2350M in 192.168.0.7:1027]

Load a test programme. Click this button to import a programme you previously saved and re-test as designed.

Save a test programme

Start the experiment

Stop the experiment

Add an experiment

choose an experiment, and you can modify the parameter setting for this experiment

choose an experiment and remove it from the list of experiments

clear all the experiments

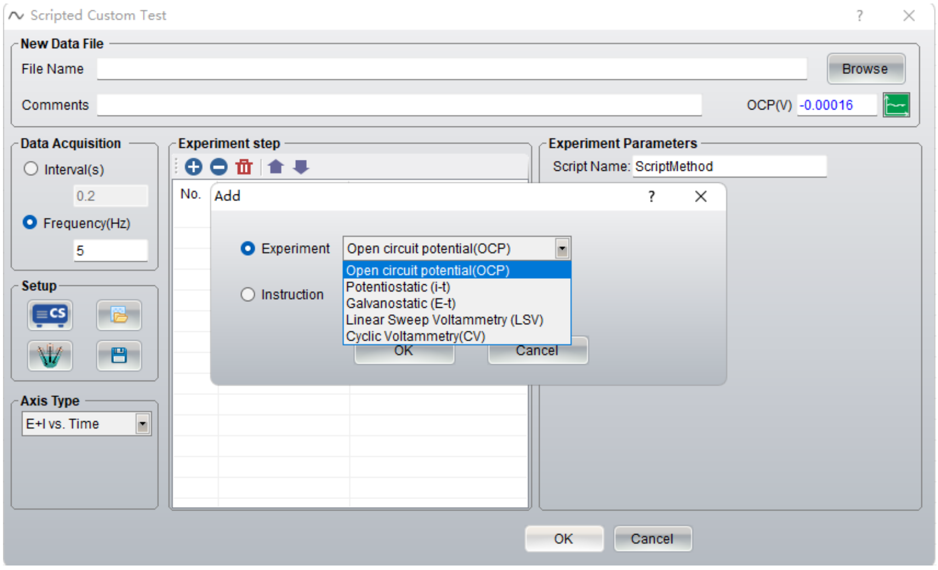
Adjust the order of the instructions and experiments

Timing task

modify storage path of all the files

1.4.2 Scripted custom Test

Similar to the combination test, you can customize your experiment by this function. There are 5 techniques available: OCP, Potentiostatic, galvanostatic, CV and LSV. Different than combination test, for scripted custom test, all the experiments data will be saved in one ".cor" data file, and there is no wait time for experiment switch.



OCP(V) -0.00016

○ Interval(s) 0.2

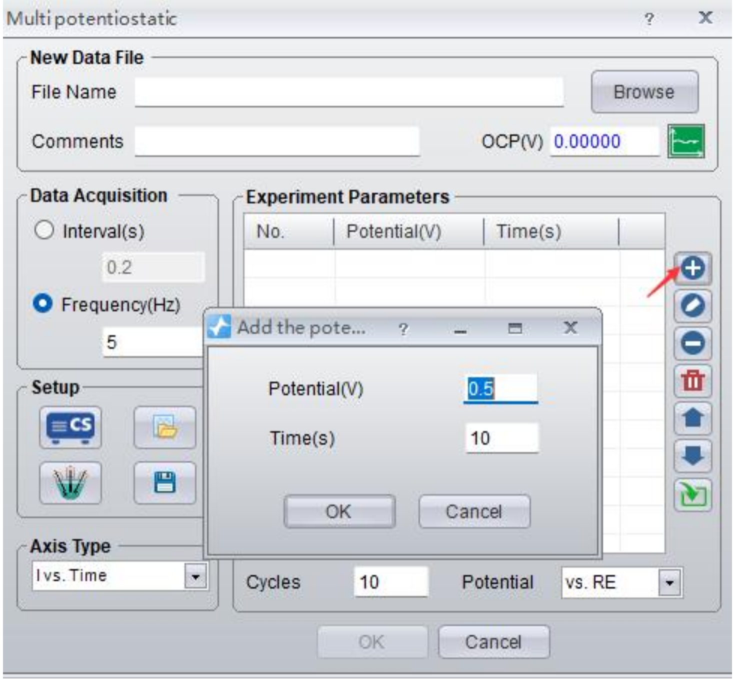
● Frequency(Hz) 5

E+I vs. Time

Script Name: ScriptMethod

● Experiment Open circuit potential(OCP)

Take “potentiostatic” as an example, if you want to apply multi constant potential on the sample continuously you can use this function. Apply a constant potential for a duration, and then apply any other constant potential for any other duration and so on. This will be similar to our “Multi potentiostatic” technique, as below:



OCP(V) 0.00000

○ Interval(s) 0.2

● Frequency(Hz) 5

I vs. Time

Potential(V) 0.5

Time(s) 10

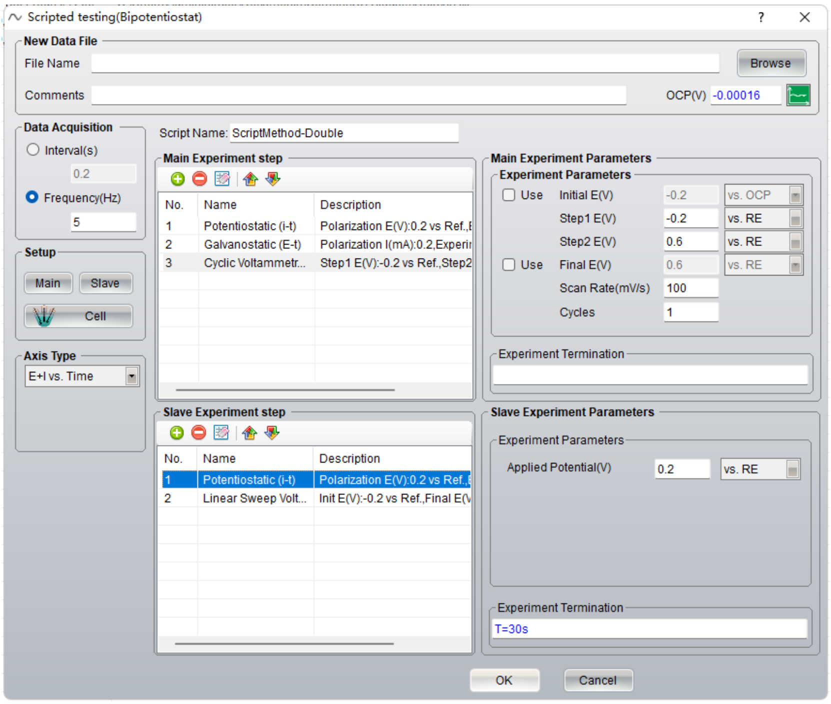
Cycles 10

Potential vs. RE

Multi potentiostatic is the same as CA(Chronoamperometry) in the literatures.

1.4.3 Scripted test (bipotentiostat)

For bipotentiostat and multichannel potentiostat, this function will be activated. It can customize the experiment in both channels. If your instrument is single-channel potentiostat, this function is inactive.



Scripted testing(Bipotentiostat)

New Data File
File Name
Comments
OCP(V) -0.00016

Data Acquisition
○ Interval(s) 0.2
● Frequency(Hz) 5

Axis Type: E+I vs. Time

Script Name: ScriptMethod-Double

Main Experiment step

No.	Name	Description
1	Potentiostatic (i-t)	Polarization E(V):0.2 vs Ref.,E
2	Galvanostatic (E-t)	Polarization I(mA):0.2,Experi
3	Cyclic Voltammetr...	Step1 E(V):-0.2 vs Ref.,Step2

Main Experiment Parameters

Experiment Parameters

☐ Use	Initial E(V)	-0.2	vs. OCP
	Step1 E(V)	-0.2	vs. RE
	Step2 E(V)	0.6	vs. RE
☐ Use	Final E(V)	0.6	vs. RE
	Scan Rate(mV/s)	100	
	Cycles	1	

Experiment Termination

Slave Experiment step

No.	Name	Description
1	Potentiostatic (i-t)	Polarization E(V):0.2 vs Ref.,E
2	Linear Sweep Volt...	Init E(V):-0.2 vs Ref.,Final E(V

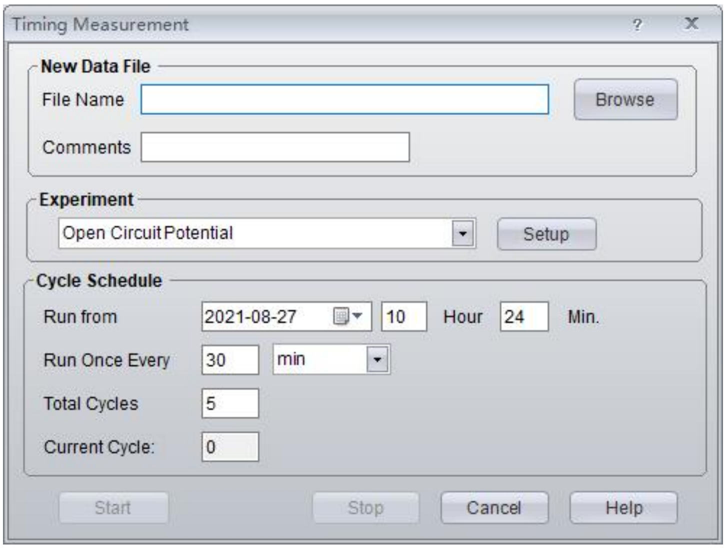
Slave Experiment Parameters

Experiment Parameters

Applied Potential(V) 0.2 vs. RE

Experiment Termination: T=30s

1.4.4 Timing measurement



Timing Measurement

New Data File
File Name
Comments

Experiment: Open Circuit Potential

Cycle Schedule
Run from 2021-08-27 10 Hour 24 Min.
Run Once Every 30 min
Total Cycles 5
Current Cycle: 0

It aims to setting the running mode of a certain experiment. This function allows the user to perform automatic measurement at a set time interval after a specified time. It facilitates the user to track the time change characteristics of a certain testing system. After a file name is specified, the start will be activated.

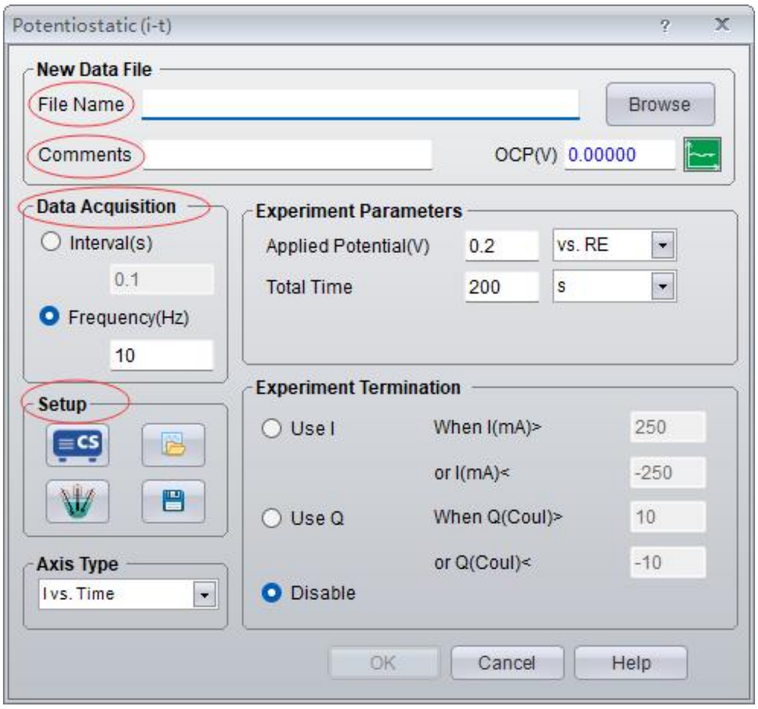
You can specify the exact time the experiment will run from and the intervals for each measurement and the total cycles of the measurement. It also displays the current cycles it has run.

For the experiment involves polarization (such as potentiodynamic, cyclic voltammetry, EIS), after each cycle, the instrument will automatically cut off the polarization and let the cell be in the status of OCP till the next measurement/cycle.

When the times of the measurement reach the total cycles, the window will exit automatically to end the project. The user can judge the measurement time according to the serial number at each data file name.

2. Experiment parameters setting

Take the parameter setting window of the Potentiostat (i-t curve) test as an example:



Potentiostatic (i-t)

New Data File

File Name

Comments

OCP(V) 0.00000

Data Acquisition

○ Interval(s) 0.1

● Frequency(Hz) 10

Experiment Parameters

Applied Potential(V) 0.2 vs. RE

Total Time 200 s

Experiment Termination

○ Use I When I(mA)> 250 or I(mA)< -250

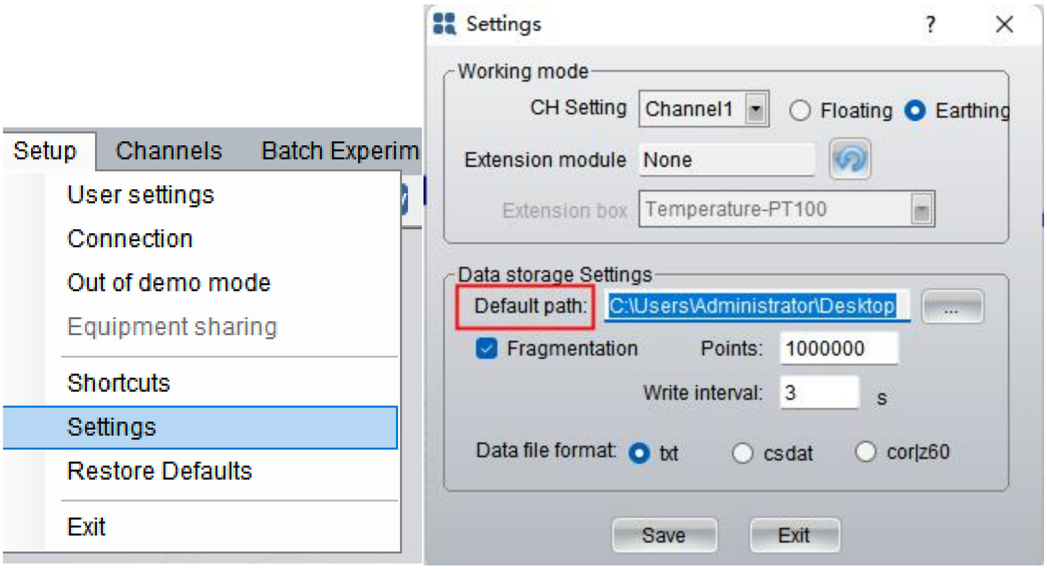
○ Use Q When Q(Coul)> 10 or Q(Coul)< -10

● Disable

Setup

Axis Type I vs. Time

File name: Before test, the OK button is invalid. Only when you enter a file name can this button be activated and then click "OK" to start test. All the data will be saved automatically during test in the place you specified. The data will be saved if electricity suddenly cut off. **You don't need to worry that the data are missed when there is a sudden unexpected power failure. You can click browse and specify the place to save the data.** You can also enter directly, then the default data storage path is as follows:



Settings

Working mode

CH Setting Channel1 ○ Floating ● Earthing

Extension module None

Extension box Temperature-PT100

Data storage Settings

Default path: C:\Users\Administrator\Desktop

☑ Fragmentation Points: 1000000

Write interval: 3 s

Data file format ● txt ○ csdat ○ cor|z60

Comments: the comments will also be saved in the data file. You may enter information such as the solution composition, experiment media etc. Other information such as time and parameters will be automatically saved; you don't need to include them in comments.

Data acquisition

Interval: specifies the time between each sampled data point.

Frequency (Hz): specifies the data points acquired per second (acquisition rate). Please note that the interval cannot be set lower than 0.001s, i.e., the points/second cannot be higher than 1000. Otherwise, the software will automatically set the frequency to be 1kHz (the maximum value allowed).

This is the setting for the instrument.

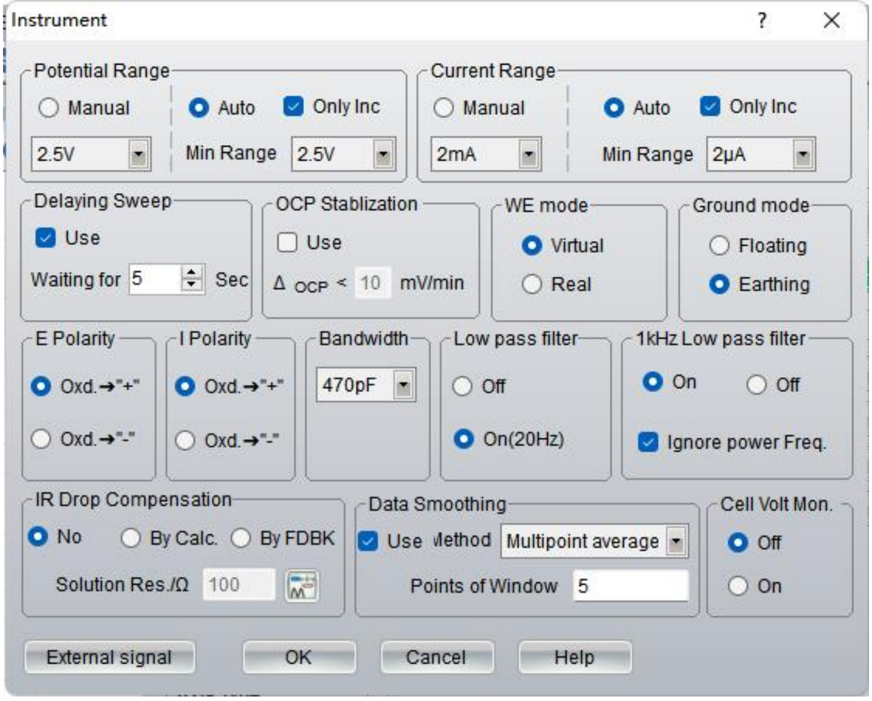
This is the setting for your cell/ testing system.

You can load a .csexp file of saved parameters of a test. If someone else wants to do same experiment and copy your setting, he can directly load the file(.csexp) that you previously saved.

You can save the parameters of a test. It will be a ".csexp" file and you can name it. Then in the future, you can view how your set parameters before.

2.1 Pstat/Gstat(ECS)Setting

Open a technique, and you can do the instrument setting by clicking .



Instrument

Potential Range: ○ Manual 2.5V; ● Auto ☑ Only Inc; Min Range 2.5V

Current Range: ○ Manual 2mA; ● Auto ☑ Only Inc; Min Range 2μA

Delaying Sweep: ☑ Use; Waiting for 5 Sec

OCP Stablization: ☐ Use; Δ OCP < 10 mV/min

WE mode: ● Virtual ○ Real

Ground mode: ○ Floating ● Earthing

E Polarity: ● Oxd.➔"+" ○ Oxd.➔"-"

I Polarity: ● Oxd.➔"+" ○ Oxd.➔"-"

Bandwidth: 470pF

Low pass filter: ○ Off ● On(20Hz)

1kHz Low pass filter: ● On ○ Off; ☑ Ignore power Freq.

IR Drop Compensation: ● No ○ By Calc. ○ By FDBK; Solution Res./Ω 100

Data Smoothing: ☑ Use Method Multipoint average; Points of Window 5

Cell Volt Mon.: ● Off ○ On

Potential Range

Potential ranges are: ±50Mv, ±100mV, ±250mV, ±500mV, ±1V, ±2.5V, ±5V, or ±10V. The default range is ±2.5V. The smaller the range is, the higher the input signal gain, and under small range you can increase the measurement accuracy and signal-noise ratio. Basically when the potential signal input is within ±2.5V, "±2.5V" range is OK. But if the potential is over ±2.5V, you should choose the range to be ±5V. During the experiment, if the potential is over the ±10V(maximum potential), the instrument will automatically stop the polarization and a "Potential overload" error will appear.

Auto The range in the Manual will be the initial range, and the software will select the suitable potential range according to the polarization potential in your test.

When you choose **Auto** range, the minimum potential range **(Min. Range)** will be valid.

"**Only Inc**" means the potential range will be switched only from lower range to higher range.

Current Range

Manual: If check Manual, the drop-down box is activated, and you can choose a suitable current range. If the current in the experiment exceeds the set range, then the software will automatically cut off the polarization and you can just set a higher range and do the test again.

Auto The range in the Manual will be the initial range, and the software will select the suitable current range according to the polarization current in your test.

When you choose Auto range, the minimum current range **(Min. Range)** will be valid. In some high-resistance system, the too small current range will lead to noise.

"**Only Inc**" means the current range will be switched only from lower range to higher range. This is particularly useful for CV experiment. During quick CV test, the current will increase or decrease with the change of the applied potential. If the current range is switched frequently, from lower range to higher, or higher to lower, then there will be noise and influence the curve smoothness. Current switch in one direction will avoid this issue, and ensure that the instrument can switch to higher range timely when the measured current gets high.

In the moment of current range switching, noise will be inevitable. Therefore, it is recommended to choose a fixed current range in quick measurements or under high data acquisition rate.

Delaying sweep

When polarization doesn't start from OCP, a transient polarization may cause a large current, and the value will decrease with time. Therefore, it's necessary to wait for a while before officially recording the experiment data. there should be a quiet time before formally recording data. You can specify the duration of delay for scan. The maximum delay time is 1000s.

During delaying sweep time, the potentiostat is already start polarization and it stays in the initial potential or current, but doesn't start scan. If you think the polarization current is already stable, then you can click Run anytime to start testing.

OCP Stablization

If you check/tick "Use", before test the software will judge whether the OCP of your testing system meets the condition you set. If yes, the experiment will conduct automatically if a data storage path has been set.

WE mode

There are Virtual and Real options. For most stable polarization tests and electrochemical noise test, you should choose "Virtual". For low-resistance system (mΩ or lower), choosing virtual can effectively eliminate the cable wire resistance. "Real" is suitable for the system where working electrode is connected to earth (such as rebar in concrete). For EIS test, you should choose real mode to increase the signal stability. In most cases, you can just keep it as default.

Ground mode

There are Floating and Earth options. Under floating, testing system is completely isolated from the external circuits. For bipotentiostat measurement and electrochemical testing system where working electrode is connected to earth (such autoclave), you should choose "floating". For electrochemical noise test, you should choose "Earth". In most cases, you can just keep it as default.

Bandwidth

Bandwidth setting can change the frequency response bandwidth of the power amplifier in the potentiostat. The higher the capacitance you choose, the narrower the bandwidth of the potentiostat.

If the bandwidth setting is "off", then the power amplifier in the instrument has the best frequency response characteristics; but for some high-resistance systems, oscillation may appear. If you choose the "virtual" mode and choose a low capacitance in bandwidth setting, it is very likely for the instrument to occur oscillation (which can be observed by an oscilloscope), even positive feedback, leading to abnormal working of the potentiostat. In this case, you should decrease the bandwidth, i.e., increase the capacitance.

When increasing the capacitance, the response frequency bandwidth will decrease accordingly, which equals to low-pass filtering of the signals and removing the possible oscillation. Normally, for slow scan experiment, you can choose 10nF~100nF; for fast scan or transient measurements, you can choose 100pF~10nF; for EIS measurements, you may need to choose 100pF~10nF(virtual mode) or 0~1nF(real mode).

Low pass Filter

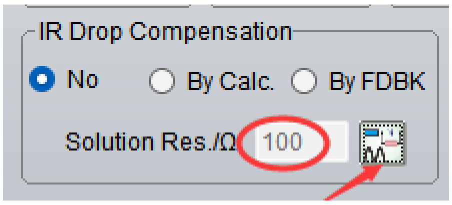
If you check "On", the low-frequency signals can be passed, and signals with frequency higher than the set value will be blocked or weakened.

Notch filter

If you check the notch filter and choose the frequency, the interference of this frequency can be restrained during experiment.

IR Compensation

In high-resistance system, the solution resistance (R_s) is large between the working electrode and the tip of RE Luggin capillary(especially for concrete or coated samples), so IR compensation is recommended. R_s measurement can be done with EIS-V or the method of R_s measurement (Click below).



IR Drop Compensation

● No ○ By Calc. ○ By FDBK

Solution Res./Ω 100

After you get the Rs value and then multiply the compensation coefficient. The following experiment can do the IR compensation.

Click **No** then there is no IR compensation.

By Calc.: post-reaction compensation. The compensation is done after test.

By FDBK: real-time compensation. It does the compensation during the test.

Data smooth

When choosing data smooth, the software will do real-time filtering of the data and get rid of the burrs on the curve. Basically you can check "Use". Please note that when you do transient measurements, we suggest you not use it because it can cause slight distortion of data.

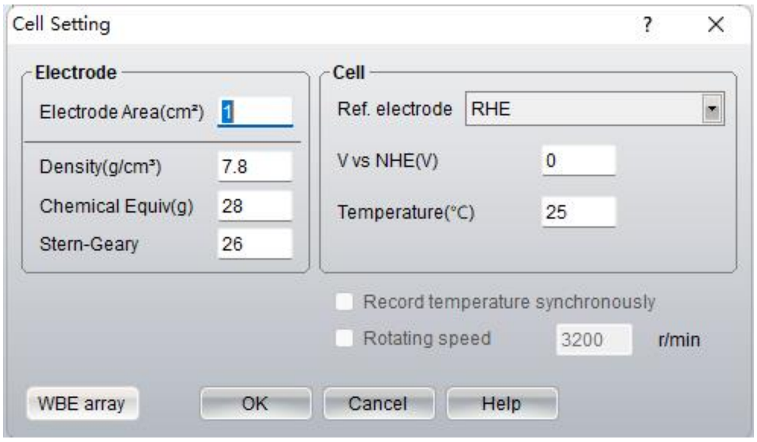
Cell Volt. Mon.

It's used to monitor the compliance voltage in your testing system. Compliance voltage is the voltage between working electrode and counter electrode. If you check "On", the compliance voltage value will be displayed in real time on the right side of the testing window. You can click to view the compliance voltage- time curve. The measured compliance data will be saved in .txt format together with .cor data in the same file.

2.2 Cell Setting

Open a technique, and you can do the cell setting by clicking .

You can enter related information of one or more working electrode(s) and electrolytic cell(s), eg. surface area, material, and temperature... The electrode area, density and chemical equivalent will affect the results of experiment and fitting. Temperature or type of RE will not affect the original data; they are just saved in each data file for info. Meanwhile, these parameters are needed for corrosion rate calculation.


Cell Setting

Electrode
Electrode Area(cm²): 1
Density(g/cm³): 7.8
Chemical Equiv(g): 28
Stern-Geary: 26

Cell
Ref. electrode: RHE
V vs NHE(V): 0
Temperature(°C): 25

☐ Record temperature synchronously
☐ Rotating speed 3200 r/min

Electrode

Electrode Area: the exposed effective area of the working electrode in the solution. Unit is cm^2. Default is 1. If it is 1, the current density will be the same as the measured current value.

Density: the density of the working electrode material. Unit is g/cm^3.

Chemical Equiv. = the molar mass/number of electrons in a reaction. Take the reaction $Fe \rightarrow Fe^{2+}$ for example, the molar mass of pure iron is 55.84g, and the number of electrons in reaction is 2, so the equivalent weight is 55.84/2=27.92g.

Stern- Geary Coef.: in the range of 20 ~28mV.

Cell

Reference electrode: in the dropdown you can choose SCE, Ag/AgCl, Hg/HgO, $Hg/HgSO_4$, $Cu/CuSO_4$... Please note that this is used just for your information remark. It has no influence on the experiment or results. In the future when you check the data file you will know which reference electrode you were using.

V vs. NHE: it is the relative potential of the selected reference electrode vs. NHE.

Temperature: it is the temperature for the electrochemical reaction at present.

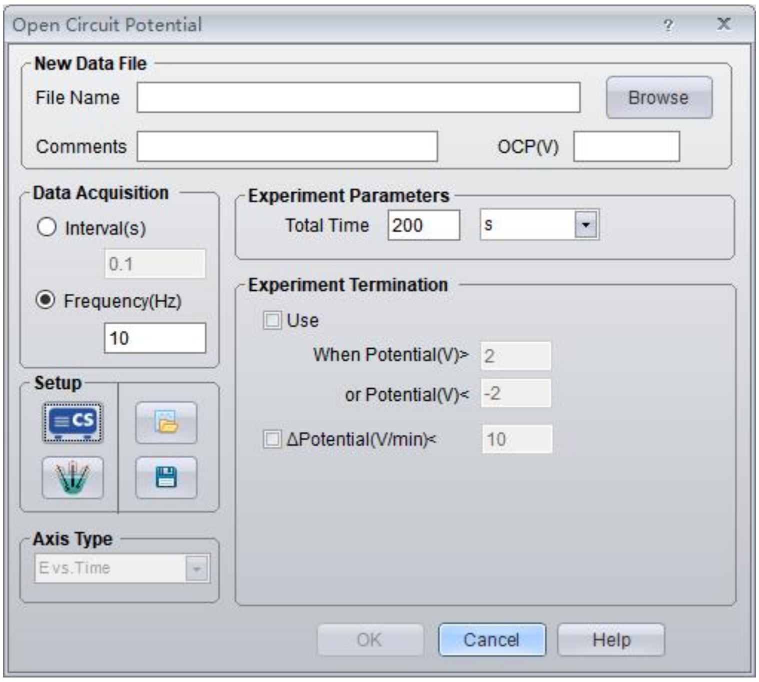
3. Stable Polarization

3.1 Open Circuit Potential

Experiments → Stable Polarization→ Open Circuit Potential

This experiment aims at monitoring the open circuit potential (the potential between WE and RE without any applied electric field) as a function of time.

Before test, the OK button is invalid. Only when you enter a file name can this button be activated. All the data will be saved in this file.



File Name

Comments

OCP(V)

Data Acquisition

○ Interval(s) 0.1

● Frequency(Hz) 10

Experiment Parameters

Total Time 200 s

Experiment Termination

☐ Use

When Potential(V)> 2

or Potential(V)< -2

☐ ΔPotential(V/min)< 10

Axis Type

E vs.Time

File Name

You're suggested to build a new folder for all the data files, then enter a file name before starting the test. You can click "Browse"and find the place where data files to be saved.

CS Studio will automatically append the suffix ".cor" to a file name. So if you input "tutor1", the name of the data file will be shown as "tutor1.cor".

The info in the Comments will be saved in the data file. You can input info. such as the medium, the solution content, etc. Other info. such as the time when you perform the test, and all the related measurement parameters will be automatically saved in the data file. You don't need to enter such information into comments.

Experiment parameters

Total Time: the total duration of the OCP monitoring

Data Acquisition

Choose either "Interval" or "Frequency".

Interval specifies the time between each data point.

Frequency (Hz) specifies the data points acquired per second (acquisition rate).

Please note that the interval cannot be set lower than 0.001s, i.e., the points/second cannot be higher than 1000. Otherwise, the software will automatically set the frequency to be 1000Hz (the maximum value allowed).

Experiment Termination

If the Use is checked, the experiment will be automatically terminated once the OCP meets the condition.

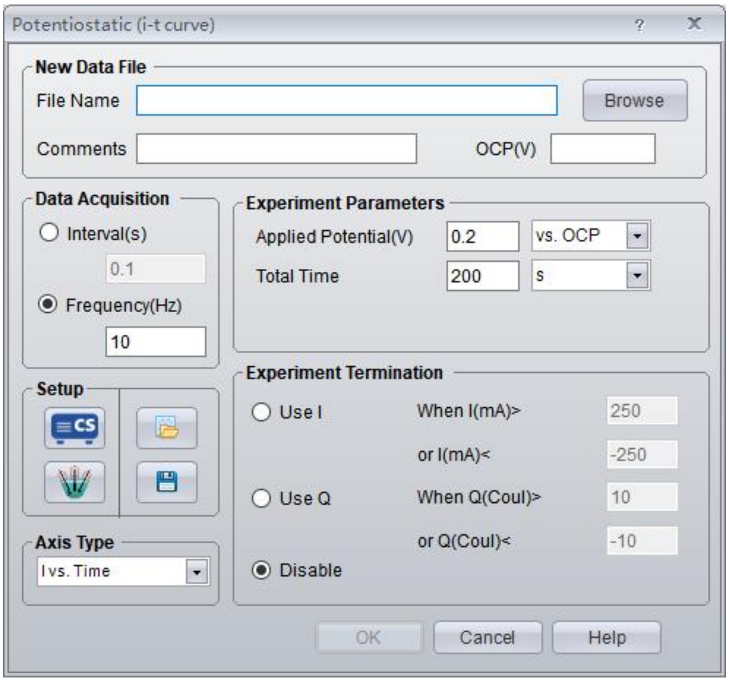
Axis Type

You should set the Axis type for display of each dynamic graph. For OCP, the axis type is "E-Time".

3.2 Potentiostatic (i-t)

Experiments→ Stable Polarization →Potentiostatic (i-t)

In Potentiostatic, the instrument applies a constant polarization potential on the working electrode and monitor the current as a function of time. The polarization duration (Total Time) can be set. You can also let the experiment be automatically terminated when the polarization current or quantity of electric charge reaches to a certain value.



File Name
Comments
OCP(V)

Data Acquisition
○ Interval(s) 0.1
● Frequency(Hz) 10

Experiment Parameters
Applied Potential(V) 0.2 vs. OCP
Total Time 200 s

Experiment Termination
○ Use I When I(mA)> 250
or I(mA)< -250
○ Use Q When Q(Coul)> 10
or Q(Coul)< -10
● Disable

Axis Type I vs. Time

OCP (V) will display the current open circuit potential of the cell (update per second).

Experiment Parameters

Applied Potential is the potential applied on the testing system**.** you can choose “vs. OCP” or “vs. RE”.

vs. OCP: entering a positive value means anodic polarization, negative value means cathodic polarization. The actual potential applied on the working electrode is the algebraic sum of the input value and the current open circuit potential value. For example, enter “0.2”, then the actual potential applied on the working electrode is “0.2V+OCP”.

vs. RE: the polarization potential applied on the working electrode is exactly the value you enter.

Total Time specifies the total time of potentiostatic polarization. Unit is Second, minute or hour.

Experiment Termination

If **Use I** is checked/chosen, the experiment will be automatically terminated once the current is above the high value (anodic current, eg: 250mA in above dialog box) or below the low value (cathodic current, eg: -250mA in above dialog box).

If **Use Q** is checked, the experiment will be automatically terminated once the integral quantity of electric charge (coulombs) reaches over maximum value (positive charge) or below minimum value (negative charge).

If the **Disable** is checked, the experiment will not be terminated until the total time is reached.

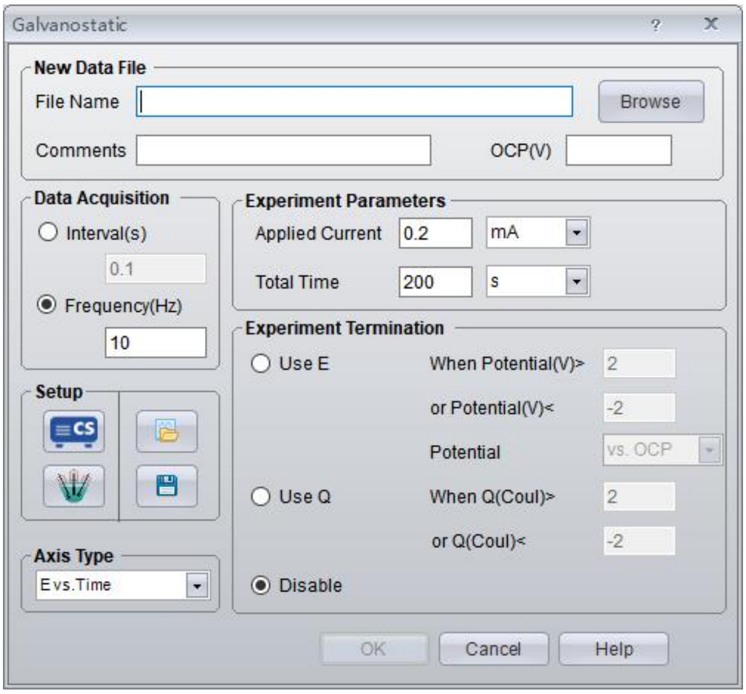
Axis Type

When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats. For the experiment of Potentiostatic, the axis type is “I-Time”.

3.3 Galvanostatic (E-t)

Experiments →Stable Polarization →Galvanostatic (E-t)

In this experiment, the instrument applies a constant polarization current on the working electrode and monitor the potential as a function of time.



Galvanostatic

New Data File
File Name
Comments
OCP(V)

Data Acquisition
○ Interval(s) 0.1
● Frequency(Hz) 10

Experiment Parameters
Applied Current 0.2 mA
Total Time 200 s

Experiment Termination
○ Use E When Potential(V)> 2
or Potential(V)< -2
Potential vs. OCP
○ Use Q When Q(Coul)> 2
or Q(Coul)< -2
● Disable

Axis Type
Evs.Time

OCP (V) will display the current open circuit potential of the cell (update per second).

Experiment Parameters

Applied Current is the current applied on the testing system. Positive value means anodic polarization; negative value means cathodic polarization. Here the value input is the current applied (unit is μA/ mA/ A), not the current density.

The **Total Time** specifies the duration of the galvanostatic test.

Experiment Termination

If **Use E** is checked, the experiment will be automatically terminated once the polarization potential reaches above the high value (eg: 2V in above dialog box) or below the low value ((eg: -2V in above dialog box).

If **Use Q** is checked, the experiment will be automatically terminated once the total integral quantity of electric charge (coulombs) goes over maximum value or below minimum value.

If the **Disable** is checked, the experiment will not be terminated until the total time is reached.

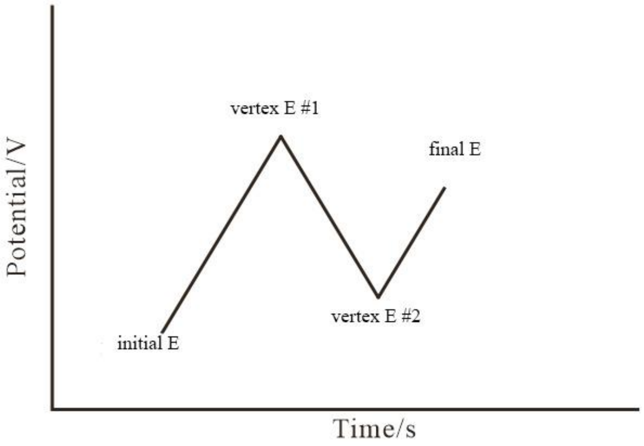
Axis Type

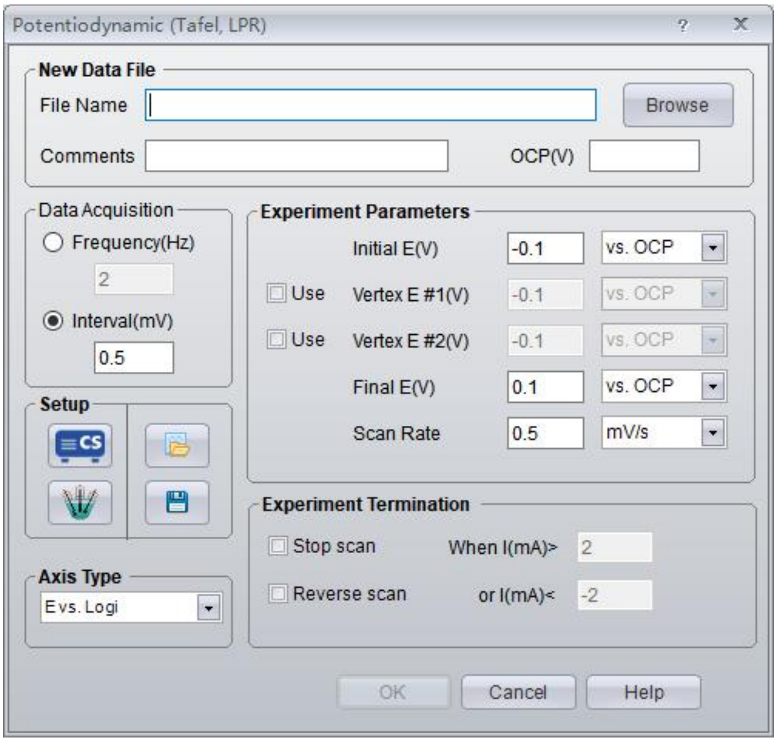
When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats. For the experiment of Galvanostatic, the axis type is “E-Time”.

3.4 Potentiodynamic (Tafel, LPR)

Experiments→ Stable Polarization →Potentiodynamic (Tafel, LPR)

For potentiodynamic, there are up to 4 individual polarization potential set points and can provide versatile scan modes. The scan can be stopped or reversed when current reaches to a certain value, which facilitates the polarization resistance and Tafel slope measurement. The logarithm of current is recorded as a function of potential.




Potentiodynamic (Tafel, LPR)

New Data File
File Name
Comments
OCP(V)

Data Acquisition
○ Frequency(Hz) 2
● Interval(mV) 0.5

Experiment Parameters
Initial E(V) -0.1 vs. OCP
☐ Use Vertex E #1(V) -0.1 vs. OCP
☐ Use Vertex E #2(V) -0.1 vs. OCP
Final E(V) 0.1 vs. OCP
Scan Rate 0.5 mV/s

Experiment Termination
☐ Stop scan When I(mA)> 2
☐ Reverse scan or I(mA)< -2

Axis Type: E vs. Logi

OCP (V) will display the current open circuit potential of the cell (update per second).

Experiment Parameters

If you don't check **Vertex E#1** or **Vertex E#2**, then the scan starts from **Initial E** to **Final E**. For example, if you enter "-0.1" (vs. OCP) in Initial E, and "0.1" (vs. OCP) in Final E, then the potential scan starts from cathodic polarization 100mV to anodic polarization 100mV. If potential is "vs. OCP", then negative sign means cathodic polarization, and positive value means anodic polarization.

Scan Rate: It can only be a positive value. Scan direction is determined by the sign of the applied potential. Scan time of each segment = scan potential range/scan rate.

Experiment Termination

If you check **Stop scan**, when the current is higher than the maximum value (e.g. 2mA) or lower than the minimum set value (e.g.-2 mA), the experiment will be stopped.

If you check the **Reverse scan**, when current reached the range that you set, the scan direction will be reversed from the current potential to initial potential. During the reverse scan, if the current is lower than the minimum value you set, the scan will be automatically stopped.

If neither **Stop scan** nor **Reverse scan** is checked, the experiment will be conducted according to the potential settings. Normally you can use **Stop scan** and set a maximum anodic current to protect the working electrode from excessively high current.

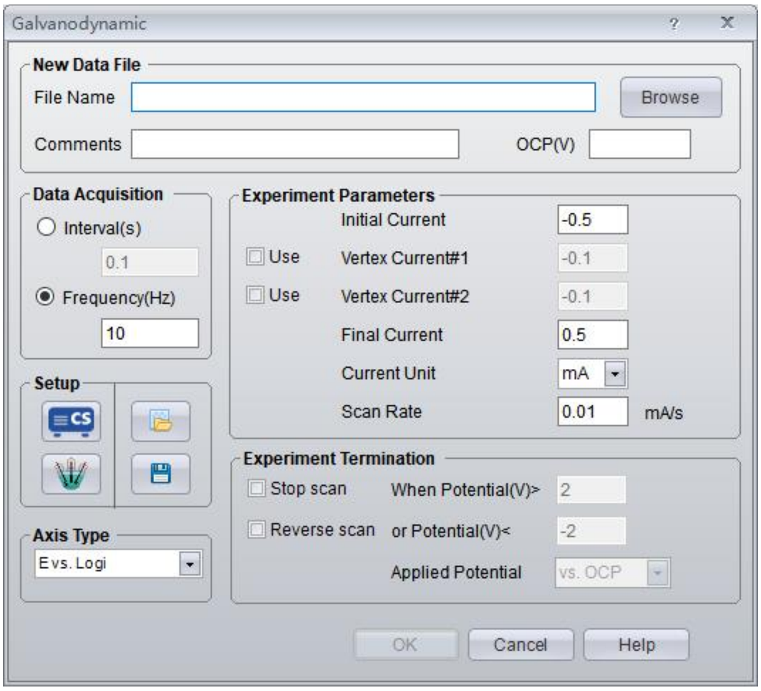
Axis Type

For potentiodynamic, you can choose “E vs. Logi”.

3.5 Galvanodynamic

Experiments →Stable Polarization →Galvanodynamic

For technique of galvanodynamic, there are up to 4 individual polarization current set points. The scan can be stopped or reversed when potential reaches a certain value.



Galvanodynamic

New Data File

File Name

Comments

OCP(V)

Data Acquisition

○ Interval(s) 0.1

● Frequency(Hz) 10

Experiment Parameters

Initial Current -0.5

☐ Use Vertex Current#1 -0.1

☐ Use Vertex Current#2 -0.1

Final Current 0.5

Current Unit mA

Scan Rate 0.01 mA/s

Setup

Axis Type E vs. Logi

Experiment Termination

☐ Stop scan When Potential(V)> 2

☐ Reverse scan or Potential(V)< -2

Applied Potential vs. OCP

OCP will display the current open circuit potential of the cell (update per second).

Experiment Parameters

If you check neither vertex current#1 nor vertex current#2, then the current is scanned directly from **Initial current** towards **Final current**. For example, if you enter “-0.5”(mA) in the initial current, and “0.5”(mA) in the final current, then the current scan is from cathodic polarization 0.5mA to anodic polarization 0.5mA. Negative value means cathodic polarization, and positive value means anodic polarization.

Scan Rate: It can only be a positive value. Scan direction is determined by the sign of the applied current.

Experiment Termination

If check the **Stop scan**, when the final current is reached or the polarization potential meets the condition to terminate the experiment, the scan will be automatically stopped.

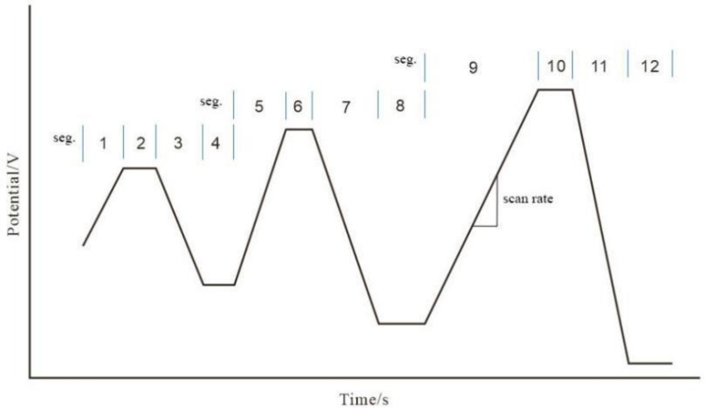
If check the “**Reverse scan**”, when polarization potential reaches the range that you set, the scan direction will be reversed from the current current to initial current; and when the polarization potential is lower than the minimum value you set, the scan will stop.

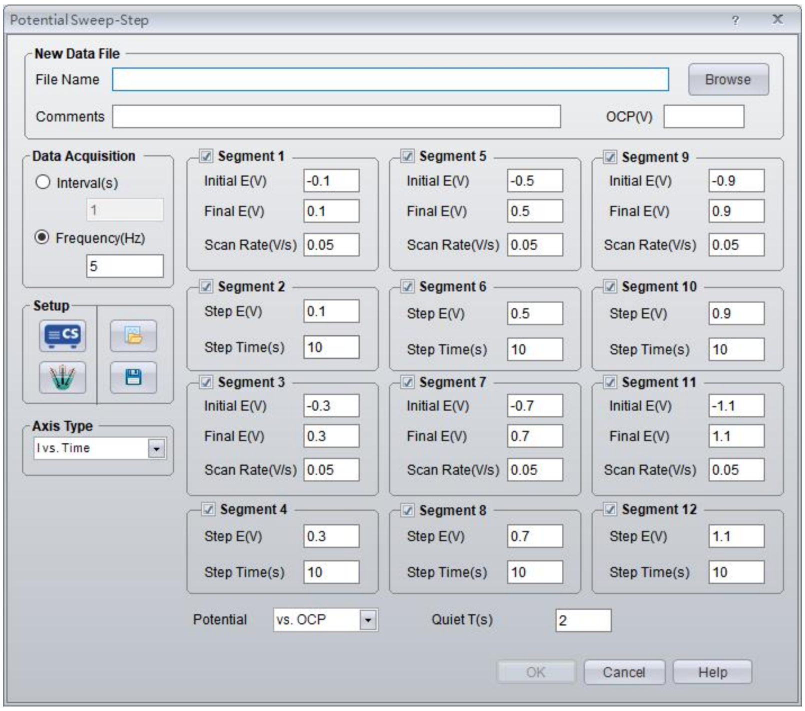
If neither is checked, the experiment will be conducted according to the current settings.

3.6 Potential Sweep Steps

Experiments→ Stable Polarization→Potential Sweep Steps

In Potential Sweep Steps, the instrument gives maximum 6 segments of constant potential steps and 6 segments of potential linear sweep.





New Data File

File Name:

Comments:

OCP(V):

Data Acquisition

○ Interval(s): 1

● Frequency(Hz): 5

Axis Type: I vs. Time

☑ Segment 1		☑ Segment 5		☑ Segment 9	
Initial E(V)	-0.1	Initial E(V)	-0.5	Initial E(V)	-0.9
Final E(V)	0.1	Final E(V)	0.5	Final E(V)	0.9
Scan Rate(V/s)	0.05	Scan Rate(V/s)	0.05	Scan Rate(V/s)	0.05
☑ Segment 2		**☑ Segment 6**		**☑ Segment 10**	
Step E(V)	0.1	Step E(V)	0.5	Step E(V)	0.9
Step Time(s)	10	Step Time(s)	10	Step Time(s)	10
☑ Segment 3		**☑ Segment 7**		**☑ Segment 11**	
Initial E(V)	-0.3	Initial E(V)	-0.7	Initial E(V)	-1.1
Final E(V)	0.3	Final E(V)	0.7	Final E(V)	1.1
Scan Rate(V/s)	0.05	Scan Rate(V/s)	0.05	Scan Rate(V/s)	0.05
☑ Segment 4		**☑ Segment 8**		**☑ Segment 12**	
Step E(V)	0.3	Step E(V)	0.7	Step E(V)	1.1
Step Time(s)	10	Step Time(s)	10	Step Time(s)	10

Potential: vs. OCP

Quiet T(s): 2

Segment	**Parameters**	**Range**	**Remarks**
1, 3, 5, 7, 9, 11	Init E /V	-10~10	Initial potential in sweep segment
	Final E /V	-10~10	Final potential in sweep segment
	Scan rate /V • s^{-1}	10^{-6}~50	Potential scan rate in sweep segment
2, 4, 6, 8, 10,12	Step potential /V	-10~10	potential value in step segment
	Step time /s	0~10000	duration of step segment
1~12	Step potential/V	vs. RE or vs. OCP	choose the potential output mode

Data Acquisition

If **Frequency (Hz)** is chosen, the acquisition rate in points/second is specified.

Axis Type

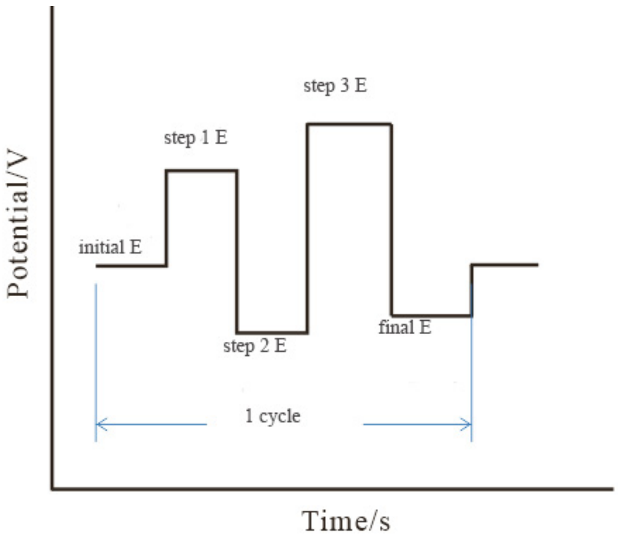
When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats.

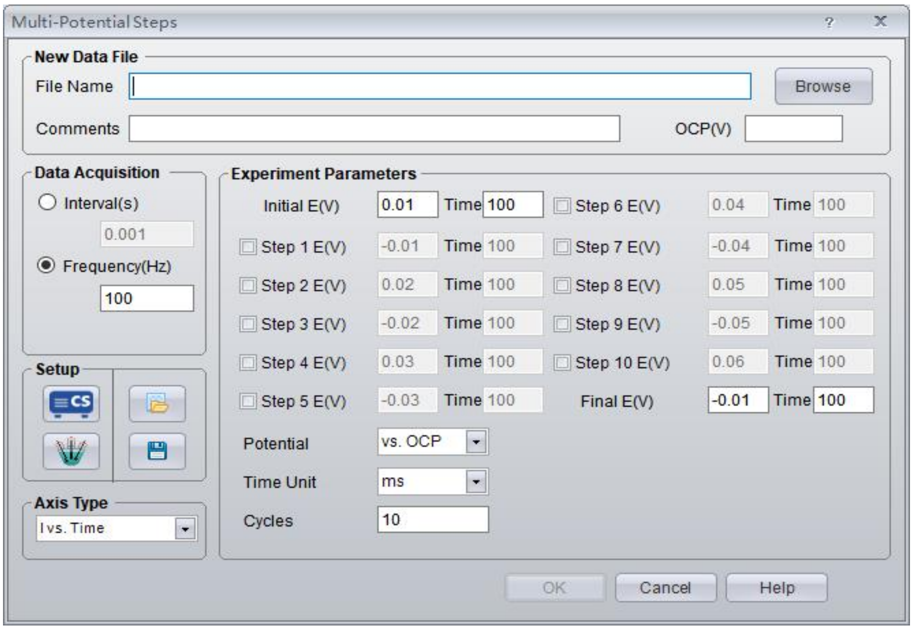
4. Transient Polarization

4.1 Multi-Potential Steps

Experiments→ Transient Polarization→ Multi-potential Steps

In the Multi-potential Steps technique, up to 12 potential steps can be applied and cycled. Current is recorded as a function of time. The instrument will apply constant potentials from the Initial E, then to Step 1 E, Step 2 E, Step 3 E …towards Final E. By not checking or setting the time to be “0”, some segment(s) will be skipped.





New Data File

File Name:

Comments:

OCP(V):

Data Acquisition

○ Interval(s) 0.001

● Frequency(Hz) 100

Setup

Axis Type: I vs. Time

Experiment Parameters

Initial E(V)	0.01	Time 100	☐ Step 6 E(V)	0.04	Time 100
☐ Step 1 E(V)	-0.01	Time 100	☐ Step 7 E(V)	-0.04	Time 100
☐ Step 2 E(V)	0.02	Time 100	☐ Step 8 E(V)	0.05	Time 100
☐ Step 3 E(V)	-0.02	Time 100	☐ Step 9 E(V)	-0.05	Time 100
☐ Step 4 E(V)	0.03	Time 100	☐ Step 10 E(V)	0.06	Time 100
☐ Step 5 E(V)	-0.03	Time 100	Final E(V)	-0.01	Time 100

Potential: vs. OCP

Time Unit: ms

Cycles: 10

OCP will display the current open circuit potential of the cell (update per second).

Experiment Parameters

Potential can be specified as “vs. OCP” or “vs. RE”.

Cycles specifies the number of cycles

Time specifies the duration of a step potential applied by the instrument

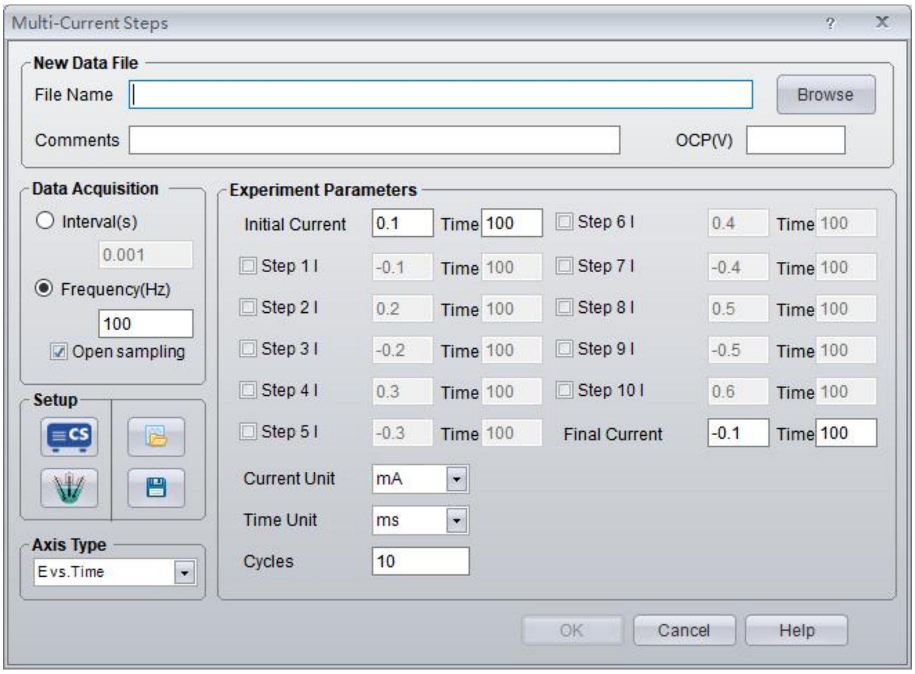
Axis Type

Axis Type is I vs. time for multi-potential steps.

4.2 Multi-Current Steps

Experiments→ Transient Polarization →Multi-Current Steps

In the Multi- Current Steps technique, up to 12 current steps can be applied and cycled. Potential is recorded as a function of time. The instrument will apply constant current from the Initial current, then to Step 1 i, Step 2 i, Step 3i …towards Final current. By not checking or setting the time to be “0”, some segment(s) will be skipped.



Multi-Current Steps

New Data File

File Name

Comments

OCP(V)

Data Acquisition

○ Interval(s) 0.001

● Frequency(Hz) 100

☑ Open sampling

Experiment Parameters

Initial Current	0.1	Time	100	☐ Step 6 I	0.4	Time	100
☐ Step 1 I	-0.1	Time	100	☐ Step 7 I	-0.4	Time	100
☐ Step 2 I	0.2	Time	100	☐ Step 8 I	0.5	Time	100
☐ Step 3 I	-0.2	Time	100	☐ Step 9 I	-0.5	Time	100
☐ Step 4 I	0.3	Time	100	☐ Step 10 I	0.6	Time	100
☐ Step 5 I	-0.3	Time	100	Final Current	-0.1	Time	100

Current Unit: mA

Time Unit: ms

Cycles: 10

Axis Type: E vs.Time

OCP will display the current open circuit potential of the cell (update per second). If the instrument is turned off, this value will be “Not Available”.

Experiment Parameters

Cycles specifies the number of cycles

Time determines the duration of the step current applied by the instrument

Data Acquisition

If **Frequency (Hz)** is chosen, the acquisition rate is set as Points/Second.

Axis Type

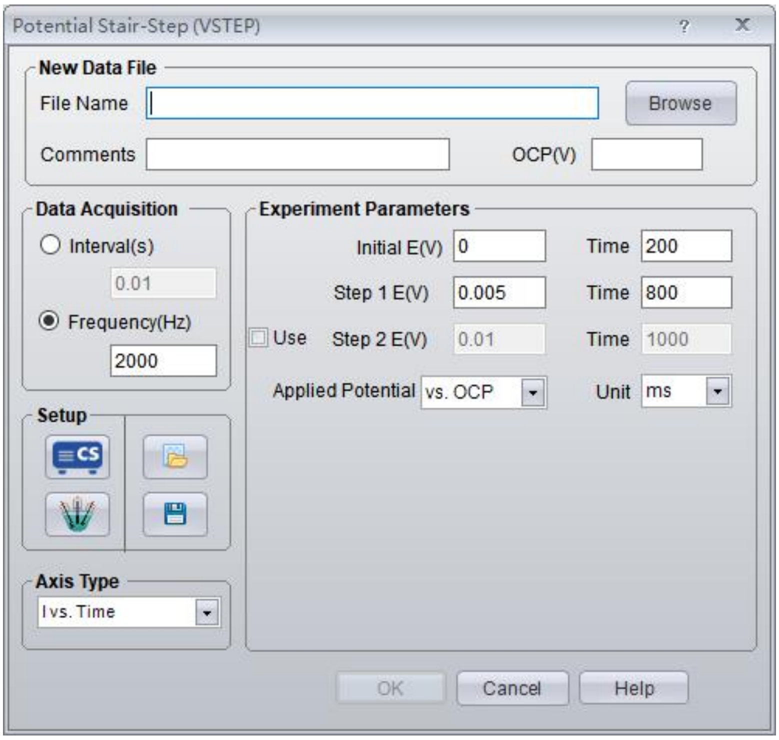
Axis type for multi-current steps is E vs time.

4.3 Potential Stair-Step (VSTEP)

Experiment→Transient Polarization→Potential Stair-Step(VSTEP)

Potential Stair-Step can be used to measure the solution resistance R_s and polarization resistance R_p. It can also be applied to calculate the double-layer capacitance C_{dl}.

There are up to 3 individual potential setpoints for potential Stair-step. If the Use is checked, the mode of the stair step is Initial E→Step1 E→Step2 E.



Potential Stair-Step (VSTEP)

New Data File

File Name

Comments

OCP(V)

Data Acquisition

○ Interval(s) 0.01

● Frequency(Hz) 2000

Experiment Parameters

Initial E(V) 0 Time 200

Step 1 E(V) 0.005 Time 800

☐ Use Step 2 E(V) 0.01 Time 1000

Applied Potential vs. OCP

Unit ms

Axis Type I vs. Time

OCP will display the current open circuit potential of the cell (update per second). If the instrument is turned off, this value will be “Not Available”.

Experiment Parameters

The steps start from Initial E, to Step E1, and then to Step E2. If “Use” is unchecked, the segment of the Step 2 E will be skipped.

Time determines the holding time of a step potential.

Data Acquisition

If **Frequency (Hz)** is chosen, the acquisition rate in points/second is specified. Because the step process is fast, the data acquisition rate is also fast, 1~3000Hz is recommended.

Axis Type

Axis Type is I vs. time.

Pstat/Gstat(ECS)

In step test, because the measuring time is very short, the current range should only be chosen manually in advance, not determined by the software automatically.

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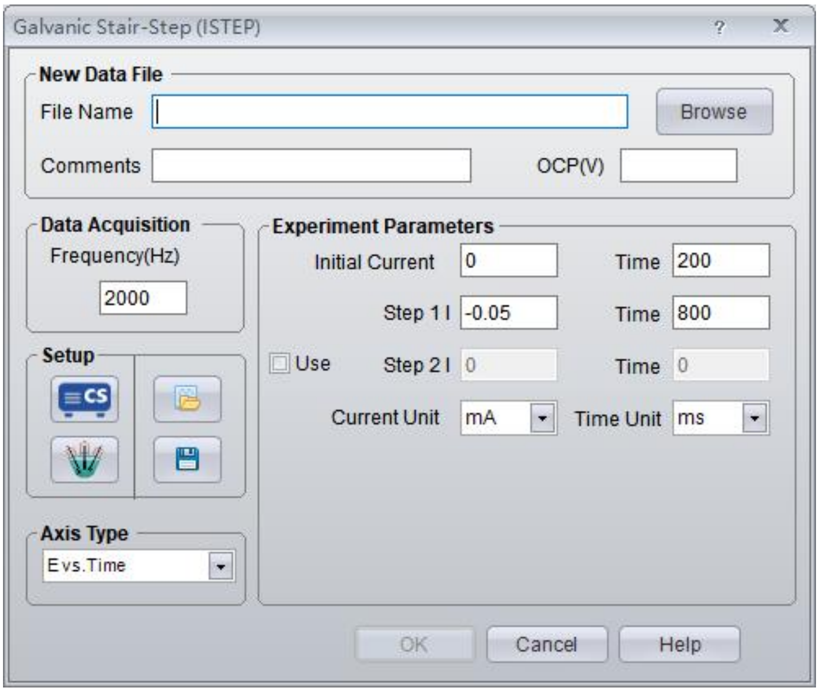
4.4 Galvanic Stair-Step (ISTEP)

Experiments→Transient Polarization→Galvanic Stair-Step (ISTEP)

There are up to 3 individual current setpoints for galvanic Stair-step. If the Use box is checked, the mode of the stair step is Initial current→Step 1 i→Step 2 i



Galvanic Stair-Step (ISTEP)

New Data File

File Name

Comments

OCP(V)

Data Acquisition

Frequency(Hz) 2000

Experiment Parameters

Initial Current 0 Time 200

Step 1 I -0.05 Time 800

☐ Use Step 2 I 0 Time 0

Current Unit mA Time Unit ms

Axis Type E vs.Time

OCP will display the current open circuit potential of the cell (update per second). If the instrument is turned off, this value will be “Not Available”.

Scan Parameters

The steps start from the Initial Current, to Step 1 i, and then to Step 2 i. If the “Use” is not checked, the segment of the Step2 i will be skipped.

The Time determines how long the current will be held at each step.

Data Acquisition

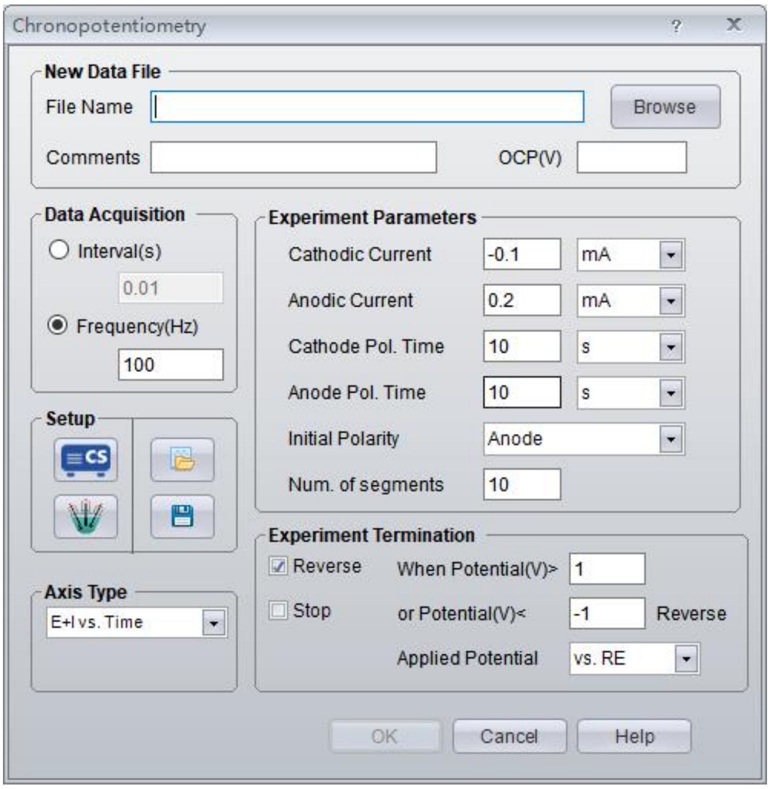
If **Frequency (Hz)** is chosen, the acquisition rate in points/second is specified. Because of the fast process of step, the data acquisition rate is fast too. The frequency is normally set between 1~3000Hz.

5. Chrono Techniques

5.1 Chronopotentiometry(CP)

Experiments→ Chrono Techniques→ Chronopotentiometry (CP)

In Chronopotentiometry (CP), 2 segments of current are applied on the working electrode. Potential is recorded as a function of time.



New Data File

File Name

Comments

OCP(V)

Data Acquisition

○ Interval(s) 0.01

● Frequency(Hz) 100

Axis Type

E+I vs. Time

Experiment Parameters

Cathodic Current -0.1 mA

Anodic Current 0.2 mA

Cathode Pol. Time 10 s

Anode Pol. Time 10 s

Initial Polarity Anode

Num. of segments 10

Experiment Termination

☑ Reverse When Potential(V)> 1

☐ Stop or Potential(V)< -1 Reverse

Applied Potential vs. RE

OCP will display the current open circuit potential of the cell (update per second).

Experiment Parameters

Cathodic/anodic current is applied on the working electrode during the test. There should be a "-" sign for the cathodic current.

Cathode/anode Pol. time is the duration each segment. Second, minute and hour can be selected.

Num. of segments specifies the total number of applied cathodic and anodic current segments.

Parameters	**Range**	**Description**
Cathodic current	-2A~+0A	The cathodic current applied on the working electrode
Anodic current	0A~+2A	The anodic current applied on the working electrode
Cathodic time	>0	Duration of cathodic current
Anodic time	>0	Duration of anodic current
Initial polarity	Anode/cathode	The polarity at the beginning of the experiment
Num. of segment	>0	The total number of applied cathodic and anodic current segments

Experiment Termination

If check **Stop**, the cathodic or anodic polarization will be stopped once the condition is met.

Reverse is used to switch the anodic and cathodic polarization process. For example, as shown in above parameters setting dialog box, if the potential reaches 1V in less than 10s, the instrument will turn to proceed the cathodic polarization. If the potential reaches -1V in less than 10s, the instrument will turn to proceed the anodic polarization.

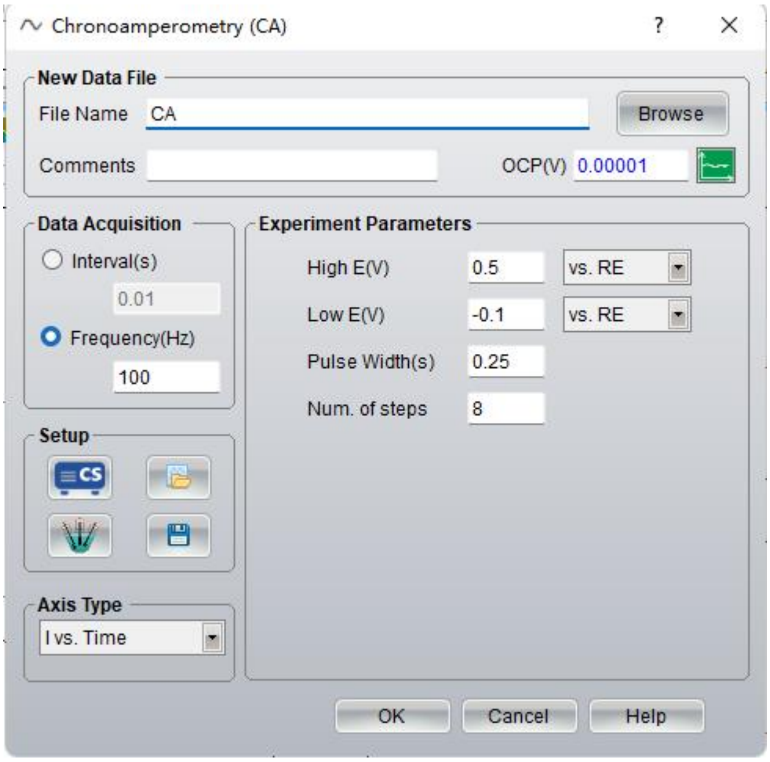
Data Acquisition

If **Frequency(Hz)** is chosen, the acquisition rate in points/second is specified.

5.2 Chronoamperometry(CA)

Experiments→Chrono Techniques→Chronoamperometry(CA)

Chronoamperometry measures the current response as a function of time after applying a single or dual potential step on the working electrode. This method is used to study the electrode process of coupled chemical reactions, especially the reaction mechanism of organic electrochemistry.



Chronoamperometry (CA)

New Data File
File Name: CA
Comments:
OCP(V): 0.00001

Data Acquisition
○ Interval(s): 0.01
● Frequency(Hz): 100

Experiment Parameters
High E(V): 0.5 vs. RE
Low E(V): -0.1 vs. RE
Pulse Width(s): 0.25
Num. of steps: 8

Axis Type: I vs. Time

OCP will display the current open circuit potential of the cell (update per second).

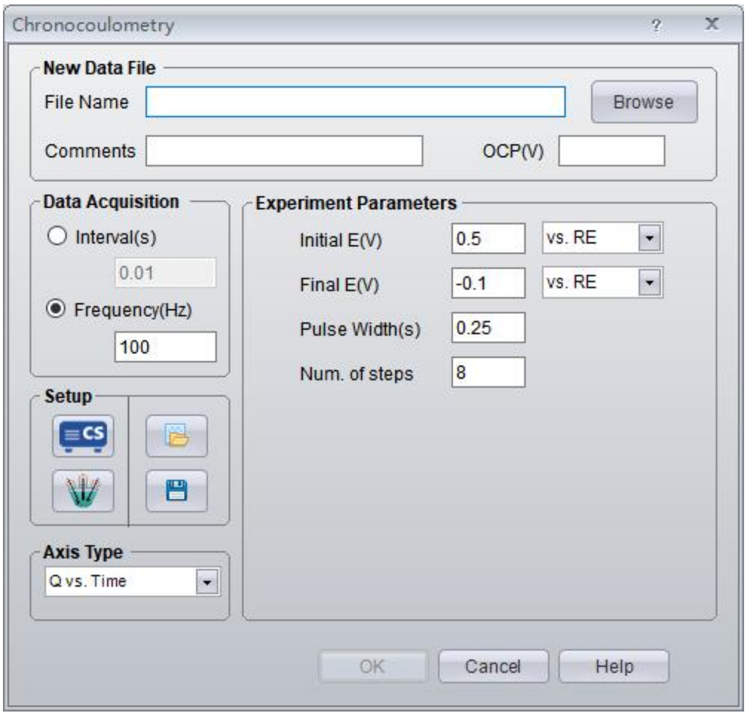
Experiment Parameters

Parameters	Range	Description
High E (V)	-10~10	Upper limit of potential step applied on the WE
Low E (V)	-10~+10	Lower limit of potential step applied on the WE
Pulse width (s)	>0	Potential pulse width
Number of steps	>0	Number of potential steps

5.3 Chronocoulometry(CC)

Experiments→Chrono Techniques→Chronocoulometry(CC)

Chronocoulometry is a method to measure the quantity of electric charges as a function of time after a potential step is applied on the working electrode. This method is used to study the electrode process of coupled chemical reactions, electroactive substance adsorption etc.



File Name:
Comments:
OCP(V):

Data Acquisition
○ Interval(s): 0.01
● Frequency(Hz): 100

Experiment Parameters
Initial E(V): 0.5 vs. RE
Final E(V): -0.1 vs. RE
Pulse Width(s): 0.25
Num. of steps: 8

Axis Type: Q vs. Time

OCP will display the current open circuit potential of the cell (update per second).

Experiment Parameters

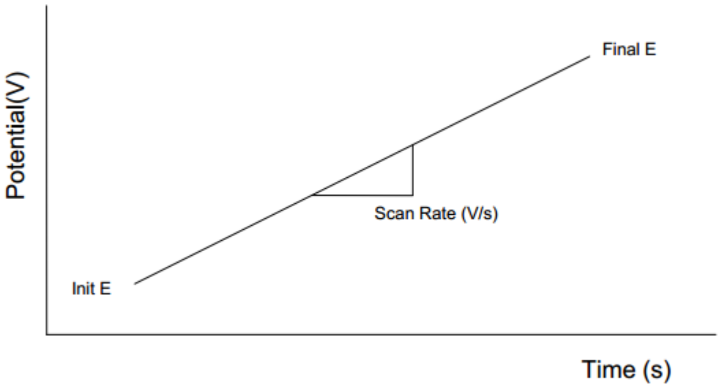
Parameters	**Range**	**Description**
Initial E (V)	-10~+10	The potential applied on the working electrode
Final E (V)	-10~+10	The potential applied on the working electrode
Pulse width(s)	0.01~1000	Duration of the applied potential pulse
Number of steps	>0	Number of potential steps

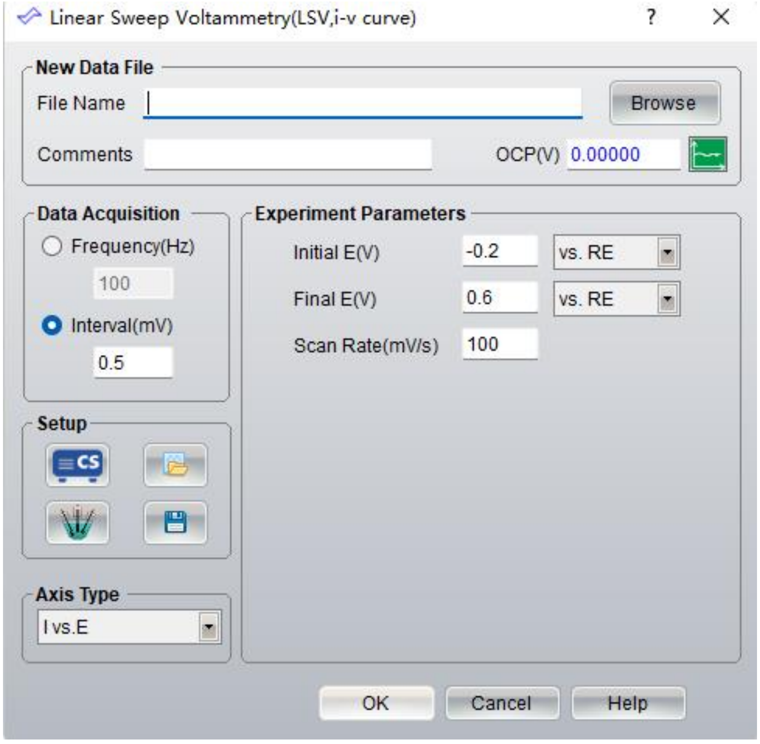
6. Voltammetry

6.1 Linear Sweep Voltammetry(LSV)

Experiments→Voltammetry→Linear Sweep Voltammetry(LSV)

In Linear Sweep Voltammetry (LSV), the potential is scanned from Initial E toward Final E. The following diagram shows the potential waveform applied as a function of time. Current is recorded as a function of potential.





File Name
Comments
OCP(V) 0.00000
○ Frequency(Hz) 100
● Interval(mV) 0.5
Initial E(V) -0.2 vs. RE
Final E(V) 0.6 vs. RE
Scan Rate(mV/s) 100
I vs.E

OCP will display the current open circuit potential of the cell (update per second).

Experiment Parameters

Parameters	Range	Description
Initial E(V)	-10~+10	Initial potential of scan, “vs. OCP” can be chosen.
Final E(V)	-10~+10	Final potential
Scan rate(mV/s)	10^{-3}~$+10^{7}$	The scan rate of the potential
Interval (mV)	> 0.001	Potential difference between two points
Frequency (Hz)	0.01~1000	Specifies how many data points are acquired in 1 second. Either Interval or Frequency should be chosen

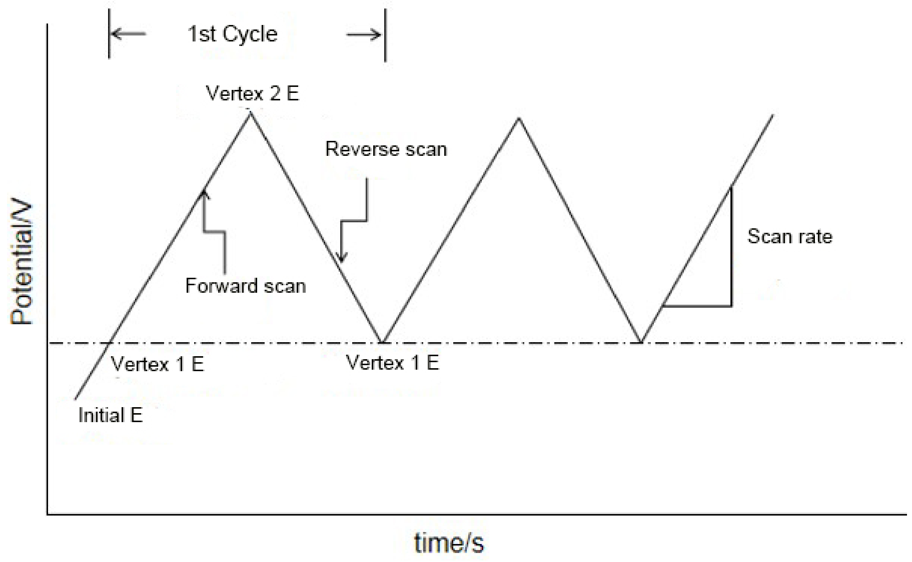
If the Initial/Final E is “vs. OCP”, and you enter “0.2” in initial E, it means the scan is from the potential OCP+0.2V. Positive value means anodic polarization, and negative value means cathodic polarization.

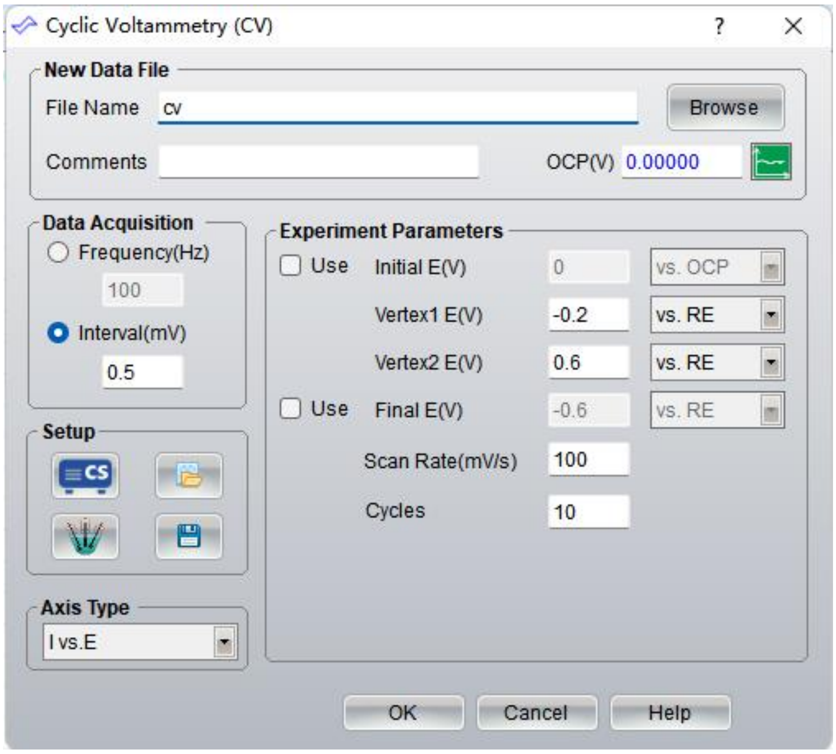
If the Initial/Final E is “vs. RE”, and you enter “0.2” in initial E, it means the scan starts from 0.2V.

6.2 Cyclic Voltammetry(CV)

Experiments →Voltammetry →Cyclic Voltammetry(CV)

In Cyclic Voltammetry (CV), if you check the initial E and final E then the potential is linearly swept from Initial E→Vertex 1 E→ Vertex 2 E→Vertex 1 E…→final E. The following diagram shows the applied potential waveform as a function of time. Current is recorded as a function of potential.





File Name: cv

Comments:

OCP(V): 0.00000

○ Frequency(Hz): 100

● Interval(mV): 0.5

Axis Type: I vs.E

☐ Use Initial E(V): 0 vs. OCP

Vertex1 E(V): -0.2 vs. RE

Vertex2 E(V): 0.6 vs. RE

☐ Use Final E(V): -0.6 vs. RE

Scan Rate(mV/s): 100

Cycles: 10

OCP displays the current open circuit potential of the cell (update per second).

Experiment Parameters

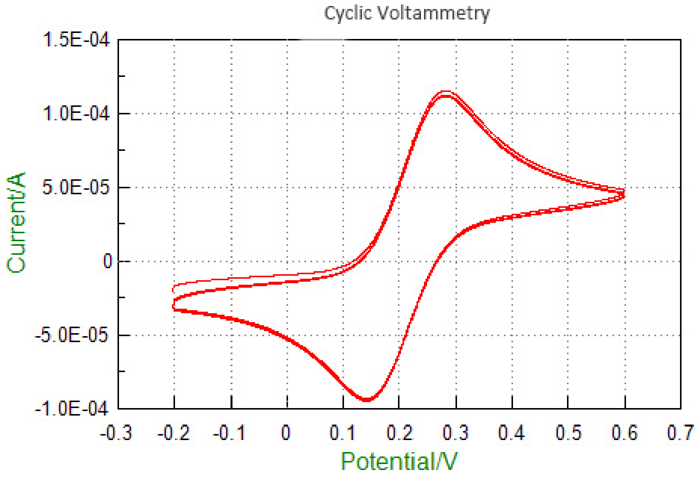
Parameters	**Range**	**Description**
Initial E(V)	-10~10	Initial potential of scan
Vertex1 E(V)	-10~10	Initial potential of the scan (if not checking "Use") or the first vertex potential
Vertex2 E(V)	-10~10	the second vertex potential of the scan
Scan rate (mV/s)	10^{-3}~10^{7}	The scan rate of the potential
Cycles	>0	The number of the cycles
Interval (mV)	> 0.001	Potential difference between two sampling points
Frequency (Hz)	0.01~1000	Specifies how many data points are acquired in 1 second. Either Interval or Frequency should be chosen

CV curve consists of two parts:

a. the lower reduction/cathode segment where the reduction waveform is generated from reduction process of the electroactive material

b. the upper oxidation/anode segment where the oxidation waveform is generated from oxidation process of the reduction products.

CV technique can directly measure the ratio of anodic peak current/cathodic peak current (i_{pc}/i_{pa}) and the difference($\triangle E_p$) between anodic peak potential and cathodic peak potential.



CV curve of glassy carbon electrode in $K_4[Fe(CN)_6]$ solution

CV technique is mainly used for electrochemical theoretical study, such as the electrode process, the absorption phenomenon of electrode etc.

For reversible electrode reaction, $|i_{pc} / i_{pa}| \approx 1$, and

$$E_{pa} = E_{1/2} + \frac{28.25}{n}$$

$$E_{pc} = E_{1/2} - \frac{28.25}{n}$$

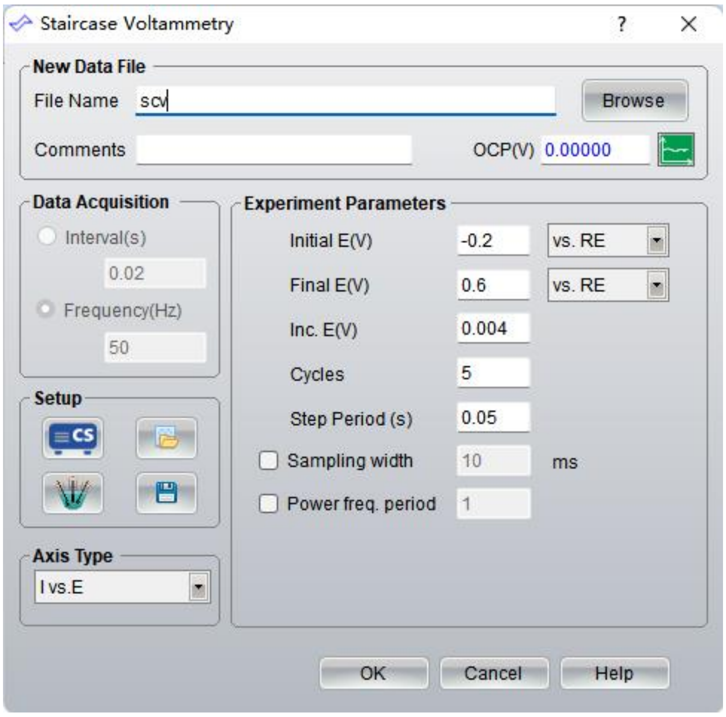
$$\Delta E_p = E_{pa} - E_{PC} = \frac{56.5}{n}$$

6.3 Staircase Voltammetry(SCV)

Experiments →Voltammetry →Staircase Voltammetry(SCV)

In Staircase Voltammetry (SCV), the potential is incremented from Initial E toward Final E, and it may be scanned back. Current is sampled after every potential increment and recorded as a function of potential.

Compared with cyclic voltammetry (CV), the advantage of SCV is that it can minimize the capacitance current generated by the double-layer effect between the working electrode and the solution interface. Therefore, the SCV method can measure the Faradaic current characteristics of the system more accurately. The application scope of SCV and CV is basically the same, such as qualitative and quantitative testing in common electrochemical processes, reversibility judgment of electrode processes, and electrode surface reaction mechanisms study.



Staircase Voltammetry

New Data File

File Name: scv

Comments:

OCP(V): 0.00000

Data Acquisition

○ Interval(s): 0.02

○ Frequency(Hz): 50

Setup

Axis Type: I vs.E

Experiment Parameters

Initial E(V): -0.2 vs. RE

Final E(V): 0.6 vs. RE

Inc. E(V): 0.004

Cycles: 5

Step Period (s): 0.05

☐ Sampling width: 10 ms

☐ Power freq. period: 1

OCP will display the current open circuit potential of the cell (update per second).

Experiment Parameters

Parameters	**Range**	**Description**
Initial E(V)	-10~+10	Initial potential of scan.
Final E(V)	-10~+10	Final potential
Inc. E(V)	0.001~0.05	Incremented potential of each step
Cycles	1~10,000	The number of cyclic staircase waveform
Sampling width(ms)	1~half of step period	Data sampling width for each point
Step period(s)	0.001~100	Potential step period or dropping time

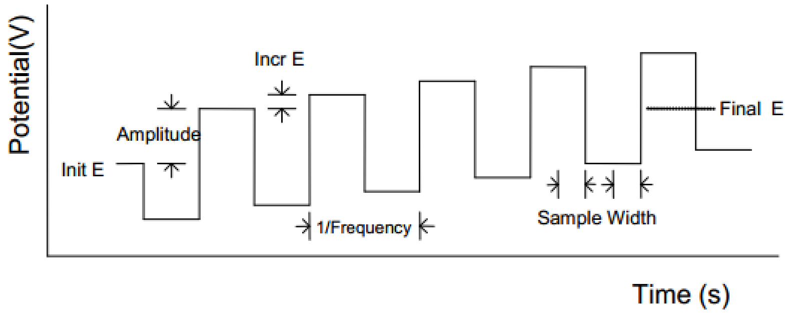
Initial E and Final E should be at least 0.01 V apart. Sampling Width should be no more than half of Step Period; otherwise the system will automatically readjust the former. Data will be acquired at the end of each step. In general, potential is chosen to be vs. RE.

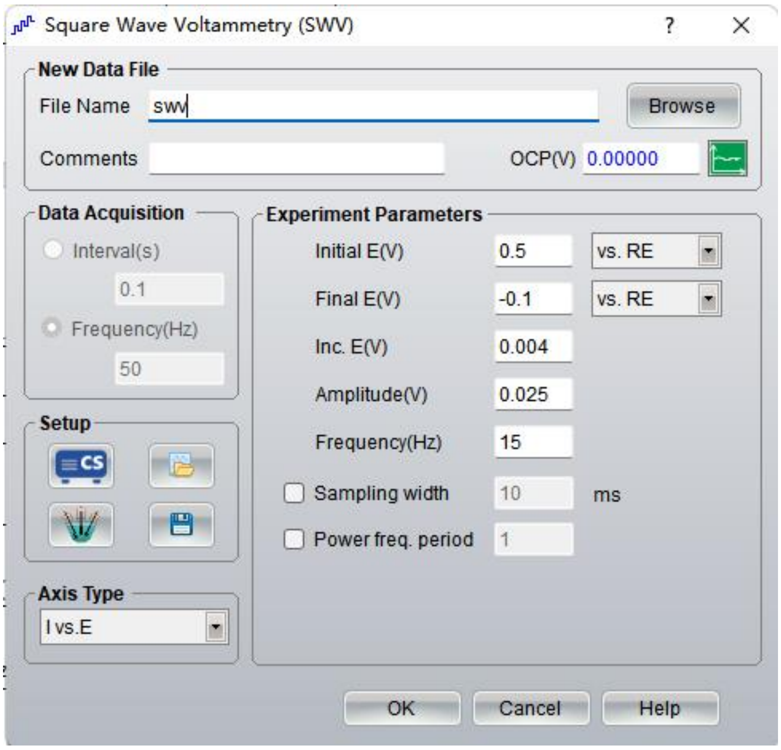
If the Increment E is set too high, the number of acquisition points will be too small to meet the experimental requirements; if the step period is set too low it may exceed the allowance in data acquisition frequency of the instrument. Therefore, in order to obtain good SCV results, you should choose appropriate Increment E and step period, and ensure that the number of experimental points in a single cycle reaches at least 100 points.

6.4 Square Wave Voltammetry(SWV)

Experiments→Voltammetry→Square Wave Voltammetry(SWV)

In Square Wave Voltammetry (SWV), the base potential is incremented from Init E towards Final E. The potentiostat applies a series of forward and reverse pulses (both equal in duration, and defined as a frequency) superimposed on a linear staircase scan. Current is sampled at the final part of the forward and reverse steps. The current difference is recorded as a function of the base potential. The following diagram shows the potential waveform applied as a function of time and the current sampling scheme.




Square Wave Voltammetry (SWV)

New Data File
File Name: swv
Comments:
OCP(V): 0.00000

Data Acquisition
○ Interval(s): 0.1
○ Frequency(Hz): 50

Experiment Parameters
Initial E(V): 0.5 vs. RE
Final E(V): -0.1 vs. RE
Inc. E(V): 0.004
Amplitude(V): 0.025
Frequency(Hz): 15
☐ Sampling width: 10 ms
☐ Power freq. period: 1

Axis Type: I vs.E

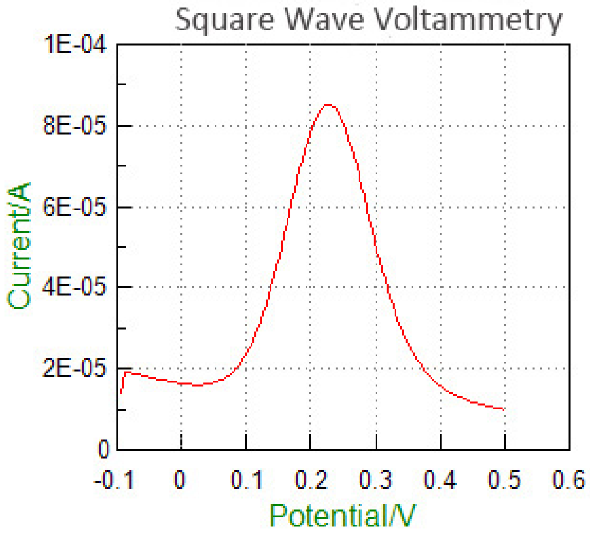
OCP will display the current open circuit potential of the cell (update per second).

Experiment Parameters

Parameters	Range	Description
Initial E (V)	-10~+10	Initial potential of scan.
Final E (V)	-10~+10	Final potential
Inc. E (V)	0.001~0.05	Incremented potential of two adjacent square waves
Amplitude (V)	0.001~0.5	The amplitude of each square wave
Frequency(Hz)	1~100,000	Square wave output frequency
Sampling width	1~ half of 1/frequency	Sampling width of each square wave
Power freq. period	1~ half of 1/frequency	This period cannot be higher than half of 1/frequency Either choose sampling width or power frequency period.

Axis Type

When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats.

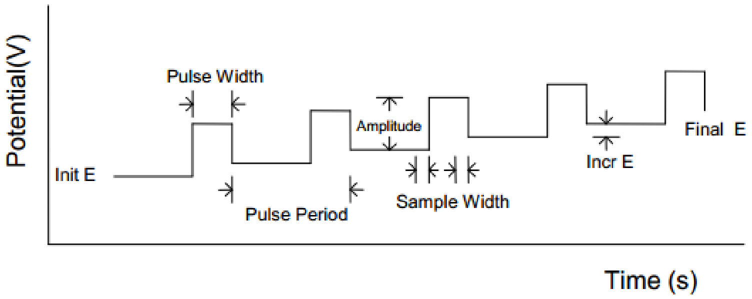


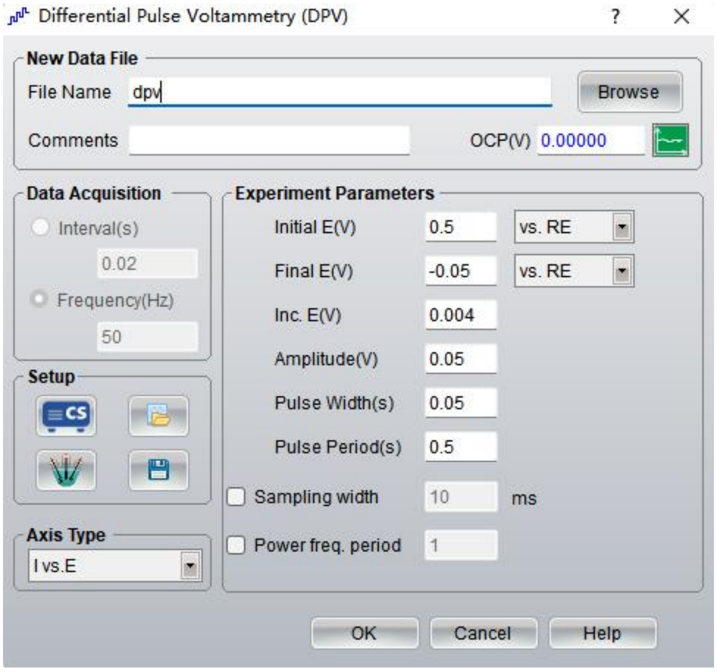
SWV curve in $K_3Fe(CN)_6$system

6.5 Differential Pulse Voltammetry(DPV)

Experiments→ Voltammetry→ Differential Pulse Voltammetry(DPV)

In Differential Pulse Voltammetry (DPV), the base potential is incremented from Init E toward Final E.A potential pulse is applied. Current is sampled before the potential pulse and at the end of the pulse. The difference between these two current samples is recorded as a function of potential. The following diagram shows the potential waveform applied as a function of time and the current sampling scheme.




Differential Pulse Voltammetry (DPV)

New Data File

File Name: dpv

Comments:

OCP(V): 0.00000

Data Acquisition

○ Interval(s): 0.02

○ Frequency(Hz): 50

Experiment Parameters

Initial E(V): 0.5 vs. RE

Final E(V): -0.05 vs. RE

Inc. E(V): 0.004

Amplitude(V): 0.05

Pulse Width(s): 0.05

Pulse Period(s): 0.5

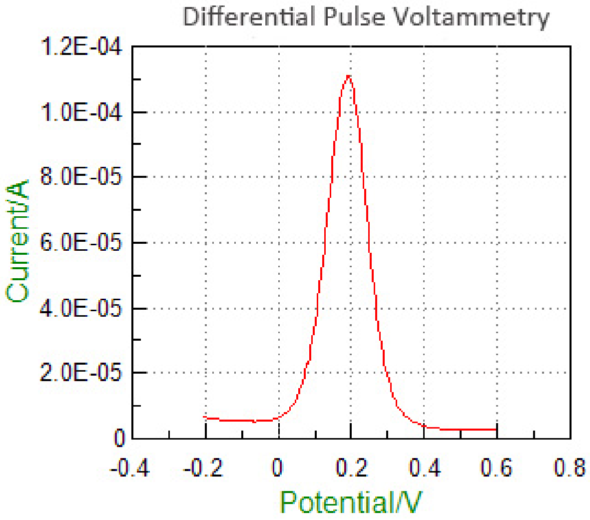
☐ Sampling width: 10 ms

☐ Power freq. period: 1

Axis Type: I vs.E

Scan Parameters

Parameters	**Range**	**Description**
Initial E(V)	-10~ +10	Initial potential
Final E(V)	-10~ +10	Final potential
Inc. E(V)	0.001~0.05	Incremented potential of two adjacent pulses
Amplitude(V)	0.001~0.5	Amplitude of each pulse
Pulse width(s)	0.001~10, or less than half of the pulse period	Pulse holding duration
Pulse period(s)	0.01~50	Potential pulse period or dropping time
Sample width(ms)	1~ half of pulse width	Data sampling width
Sampling width	1~ half of Pulse period	Sampling width of each square wave
Power freq. period	1~ half of Pulse period	This period cannot be higher than half of pulse period. Either choose sampling width or power frequency period.



DPV curve in $K_3Fe(CN)_6$system

For the reversible system, the curve is symmetric, The peak current is directly proportional to the concentration of the measured substance. When the amplitude of the pulse is small, it can be expressed by the following equation:

$$IP = \frac{n^2F^2}{4RT} A\Delta E \sqrt{\frac{D}{\pi t_m}} C$$

Where, ΔE is the amplitude, A is the electrode area, t_m is the time between pulse applying and current sampling. D is the diffusion coefficient of the measured material. From the equation, we can find that the peak current is related to pulse amplitude. But too large amplitude will influence the resolution. Generally, 25~50mV amplitude and 5mV/s scan rate is OK.

DPV technique can effectively eliminate the effect of the background current, which increases measurement sensitivity dramatically. The minimum measured concentration can be 10^{-8} mol/L.

Relationship of peak potential (E_p) of DPV and half-wave potential($E_{1/2}$) of ordinary polarography can be expressed as follows:

$$E_p = E_{1/2} - \frac{\Delta E}{2}$$

There is a useful parameter, the half-peak width($W_{1/2}$) when $I=I_P/2$. When the amplitude is relatively small,

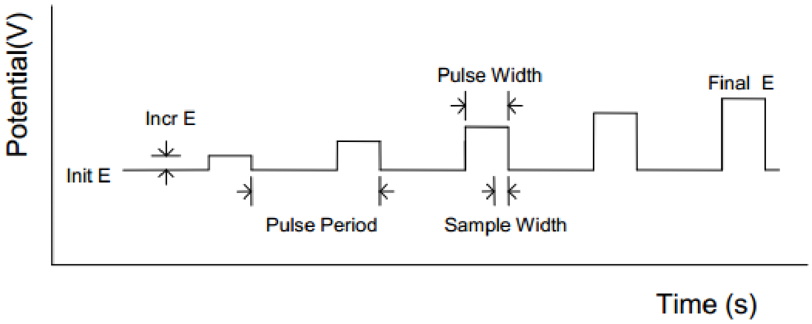
$$W_{1/2} = 3.52\frac{\Delta E}{nF},$$

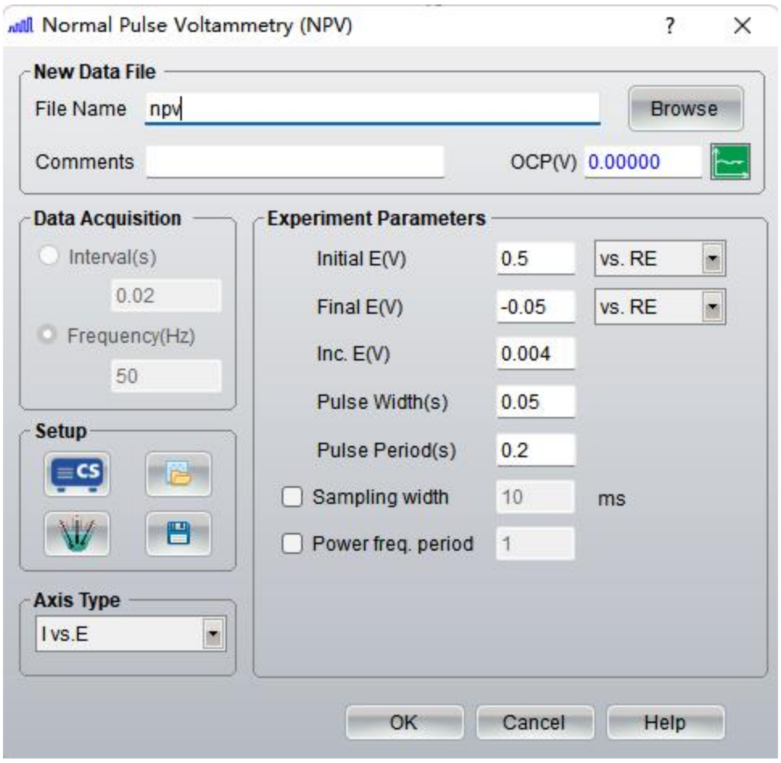
Under 25℃, $W_{1/2}$ is 90.2/n mV. So $W_{1/2}$ can be a supporting measure to calculate the number of transferred electron in reactions.

6.6 Normal Pulse Voltammetry(NPV)

Experiments→Voltammetry→Normal Pulse Voltammetry**(NPV)**

In Normal Pulse Voltammetry (NPV), the base potential is held at Init. E, and a sequence of potential pulses with increasing amplitude is applied. The current at the end of each potential pulse is sampled and recorded as a function of the pulse potential. The pulse always starts from the initial potential. In such a way a discrete, digitized curve is obtained. The initial potential is a very important parameter. It determines the electrode surface state before the Faradaic current flows.





Normal Pulse Voltammetry (NPV)

New Data File

File Name: npv

Comments:

OCP(V): 0.00000

Data Acquisition

○ Interval(s): 0.02

○ Frequency(Hz): 50

Setup

Axis Type: I vs.E

Experiment Parameters

Initial E(V): 0.5 vs. RE

Final E(V): -0.05 vs. RE

Inc. E(V): 0.004

Pulse Width(s): 0.05

Pulse Period(s): 0.2

☐ Sampling width: 10 ms

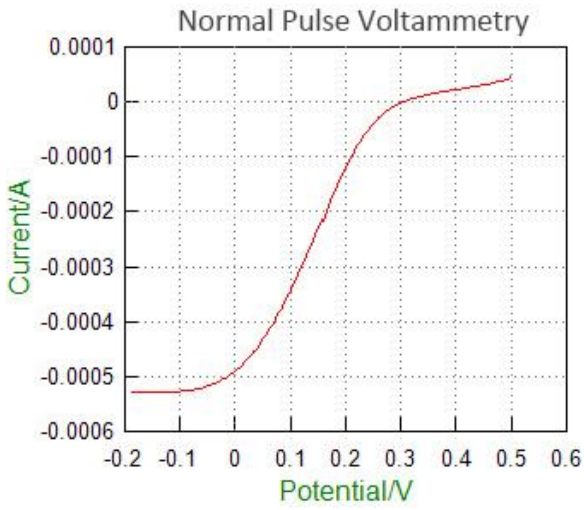
☐ Power freq. period: 1

OCP will display the current open circuit potential of the cell (update per second).

Experiment Parameters

Parameters	**Range**	**Description**
Initial E(V)	-10~10	Initial potential
Final E(V)	-10~10	Final potential
Inc. E(V)	0.001~0.05	Incremented potential of adjacent pulses
Pulse width(s)	0.001~10, or less than half of the pulse period	Potential pulse width
Pulse period(s)	0.01~50	Potential pulse period or dropping time
Sampling width(ms)	1~ half of pulse width	Data sampling width

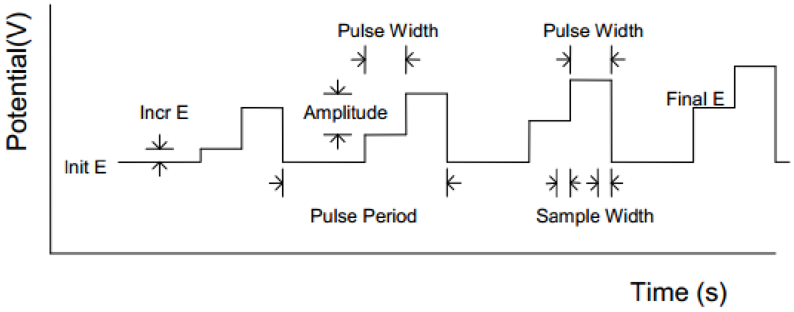
Power freq. period	1~ half of pulse width	This period cannot be higher than half of pulse period. Either choose sampling width or power frequency period.

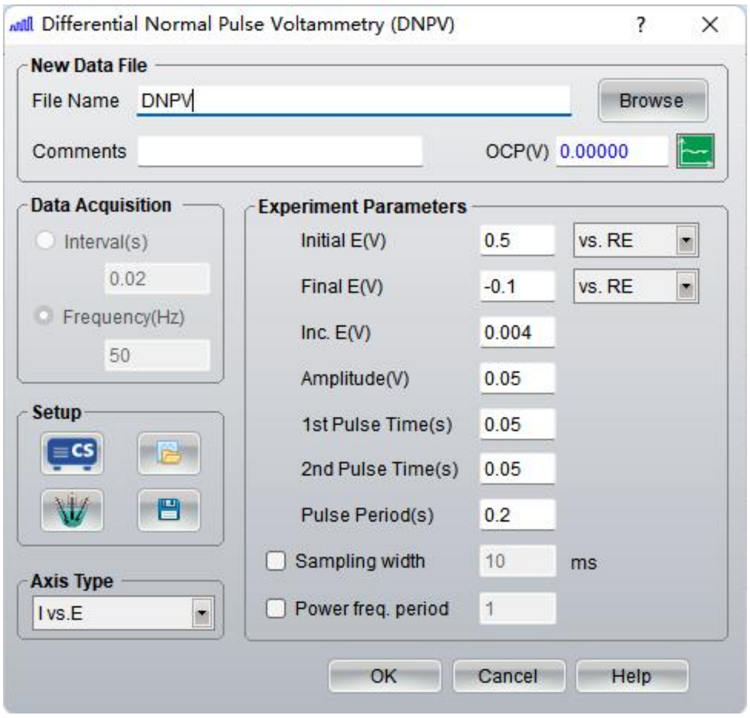


6.7 Differential Normal Pulse Voltammetry(DNPV)

Experiments→ Voltammetry→ Differential Normal Pulse Voltammetry (DNPV)

In DNPV, the base potential is held at Initial E, and a sequence of dual potential pulses is applied. The magnitude of the first pulse increments after every iteration, and the second pulse has a constant amplitude relative to the first. Current is sampled at the end of both potential pulses, and the difference of these two values is recorded as a function of the first pulse potential. The following diagram shows the potential waveform applied as a function of time and the current sampling scheme:





Differential Normal Pulse Voltammetry (DNPV)

New Data File

File Name DNPV

Comments

OCP(V) 0.00000

Data Acquisition

○ Interval(s) 0.02

● Frequency(Hz) 50

Experiment Parameters

Initial E(V) 0.5 vs. RE

Final E(V) -0.1 vs. RE

Inc. E(V) 0.004

Amplitude(V) 0.05

1st Pulse Time(s) 0.05

2nd Pulse Time(s) 0.05

Pulse Period(s) 0.2

☐ Sampling width 10 ms

☐ Power freq. period 1

Axis Type

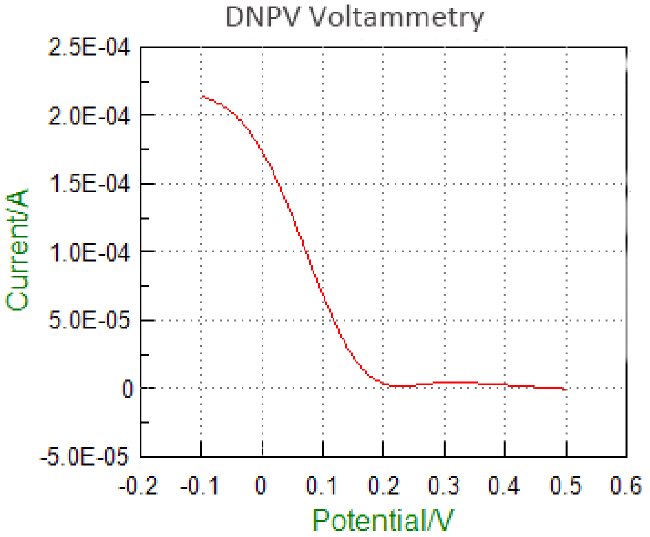
I vs.E

OCP will display the current open circuit potential of the cell (update per second).

Scan Parameters

Parameters	**Range**	**Description**
Initial E(V)	-10~10	Initial potential
Final E(V)	-10~10	Final potential
Inc. E(V)	0.001~0.05	Incremented potential of adjacent pulses
Amplitude(V)	0.001-0.5	Potential pulse amplitude
1st pulse width(s)	0.001~0.02	First potential pulse width
2nd pulse width(s)	0.001~0.02	Second potential pulse width
Pulse period(s)	0.05~50	Potential pulse period or dropping time
Sampling width(ms)	1~ half of pulse width	Data sampling width
Power freq. period	1~ half of pulse width	This period cannot be higher than half of pulse period. Either choose sampling width or power frequency period.

Init E and Final E should be at least 0.01V apart.



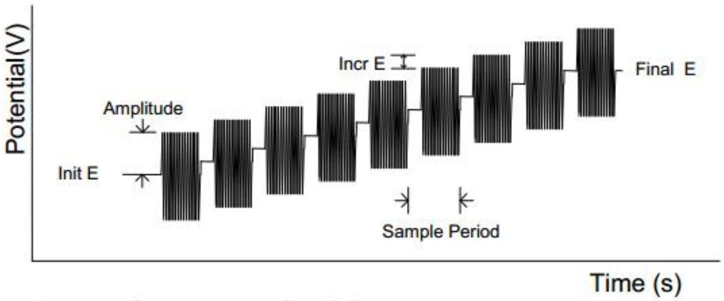
Axis Type

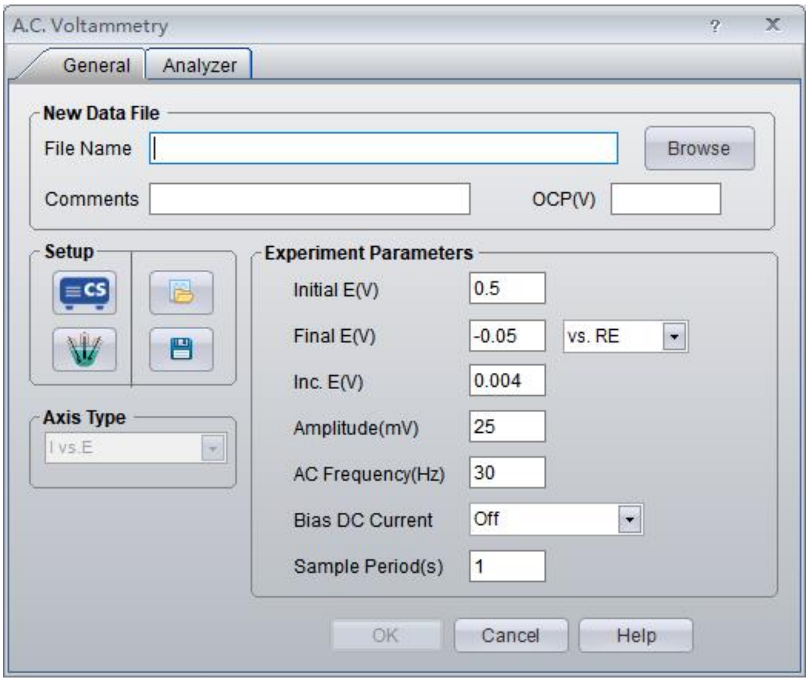
When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats.

6.8 A.C. Voltammetry(ACV)

Experiments→Voltammetry→A.C. Voltammetry(ACV)

In A.C. Voltammetry, the base potential is incremented from Initial E to Final E, and a sequential sine waveform is superimposed. Current is sampled when the AC signal is applied, and it is analyzed using a software lock-in amplifier. During the experiment, only the absolute AC current is displayed.





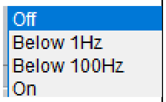
New Data File
File Name
Comments
OCP(V)

Axis Type: I vs.E

Experiment Parameters
Initial E(V): 0.5
Final E(V): -0.05 vs. RE
Inc. E(V): 0.004
Amplitude(mV): 25
AC Frequency(Hz): 30
Bias DC Current: Off
Sample Period(s): 1

OCP will display the current open circuit potential of the cell (update per second). If the instrument is turned off, this value will display “Not Available”.

Experiment Parameters

Parameters	**Range**	**Description**
Initial E(V)	-10~10	Initial potential
Final E(V)	-10~10	Final potential
Inc. E(V)	0.001~0.05	Potential difference between adjacent waves
Amplitude (mV)	1~400	AC amplitude of each waveform
AC frequency (Hz)	0.1~10000	AC frequency
Bias DC	 Off Below 1Hz Below 100Hz On	Superimpose DC current bias in AC signal
Sample period(s)	1~50	Data sampling period or dropping time

Initial E and Final E should be at least 0.01V apart.

Inc. E is the increment potential of each pulse; it can be chosen from 0.001V to 0.05V.

Data Acquisition

If **Frequency(Hz)** is chosen, the acquisition rate in points/second is specified.

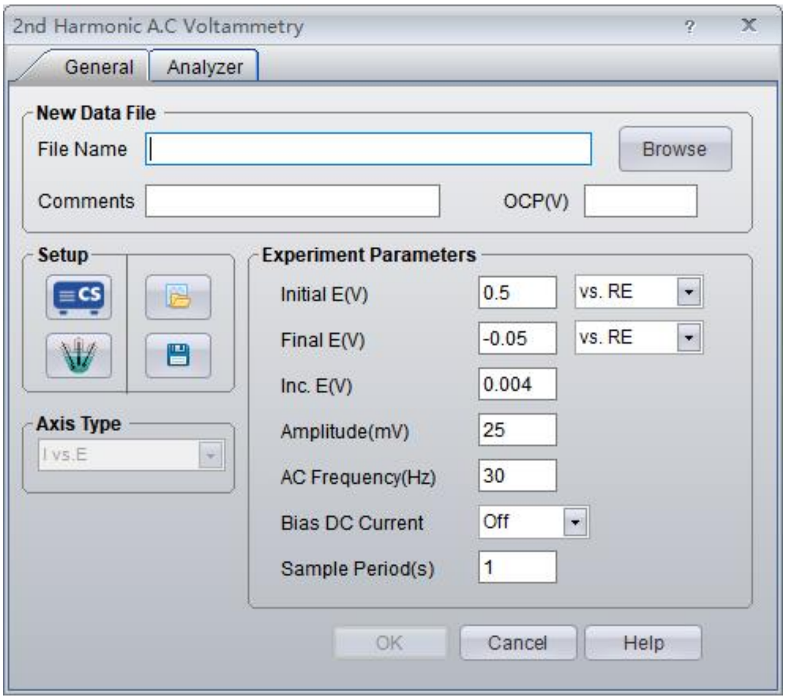
Axis Type

When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats.

6.9 2nd Harmonic A.C. Voltammetry(SHACV)

Experiments→Voltammetry→2nd Harmonic A.C. Voltammetry(SHACV)

SHACV is the same as ACV except that the software analyses the second harmonic AC current. In Second Harmonic AC Voltammetry, the base potential is incremented from Initial E toward Final E, and a sequential sine waveform is superimposed. Current is sampled when the AC signal is applied, and its second harmonic component is analyzed by using a software lock-in amplifier. During the experiment, only the absolute second harmonic AC current is displayed.



2nd Harmonic A.C Voltammetry

General | Analyzer

New Data File

File Name

Comments

OCP(V)

Setup

Axis Type

I vs.E

Experiment Parameters

Initial E(V): 0.5, vs. RE

Final E(V): -0.05, vs. RE

Inc. E(V): 0.004

Amplitude(mV): 25

AC Frequency(Hz): 30

Bias DC Current: Off

Sample Period(s): 1

OCP will display the current open circuit potential of the cell (update per second).

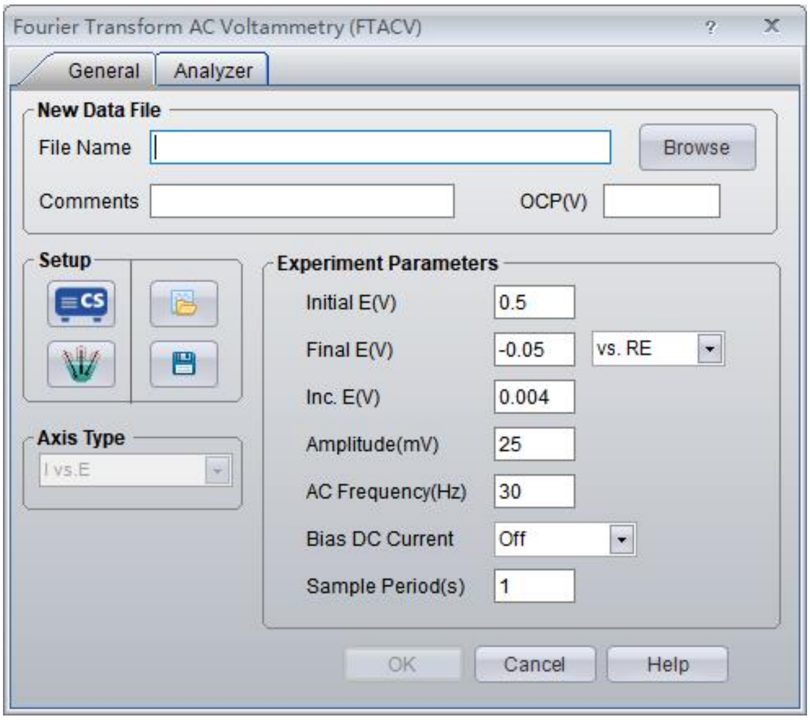
Experiment Parameters

Parameters	**Range**	**Description**
Initial E(V)	-10~ 10	Initial potential
Final E(V)	-10~10	Final potential
Inc. E(V)	0.001~ 0.05	Potential difference between adjacent waves
Amplitude (mV)	1~400	AC amplitude of each waveform
AC frequency (Hz)	0.1~5000	AC frequency
Bias DC current	Off Below 1Hz Below 100Hz On	Enable DC current bias during run
Sample period(s)	1~50	Data sampling period or dropping time

6.10 Fourier Transform AC Voltammetry (FTACV)

Experiments→Voltammetry→ Fourier Transform AC Voltammetry(FTACV)

FTACV is the same as ACV except that after testing the software will do Fourier Transform from the original data and obtain the 2nd, 3rd, 4th, 5th, and 6th harmonics ACV data.



File Name

Comments

OCP(V)

Axis Type: I vs.E

Experiment Parameters

Initial E(V) 0.5

Final E(V) -0.05 vs. RE

Inc. E(V) 0.004

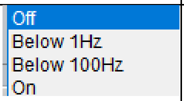
Amplitude(mV) 25

AC Frequency(Hz) 30

Bias DC Current Off

Sample Period(s) 1

Experiment parameters

Parameter	**Range**	**Description**
Initial E(V)	-10~+10	Initial potential
Final E (V)	-10~+10	Final potential
Inc. E (V)	0.001~0.05	Potential difference between adjacent waves
Amplitude (mV)	1~2500	AC amplitude for every waveform
AC frequency(Hz)	0.1~5000	AC frequency
Bias DC current	 Off Below 1Hz Below 100Hz On	Superimpose bias DC current on AC signal
Sample period (s)	1~50	Time of sampling

Initial E and Final E should be at least 0.01 V apart.

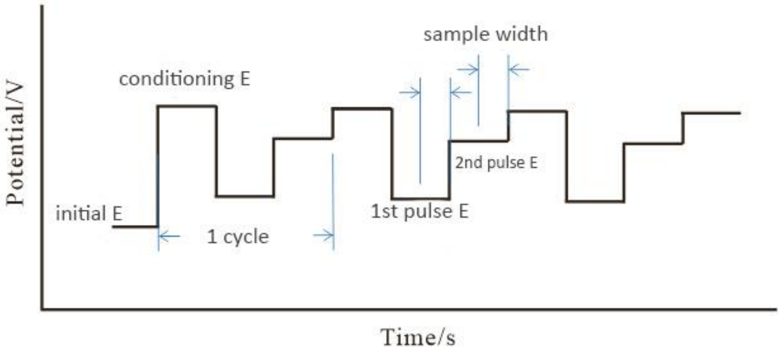
For parameter of Bias DC current, the user can choose among Off, Below 1Hz, Below 100Hz, On.

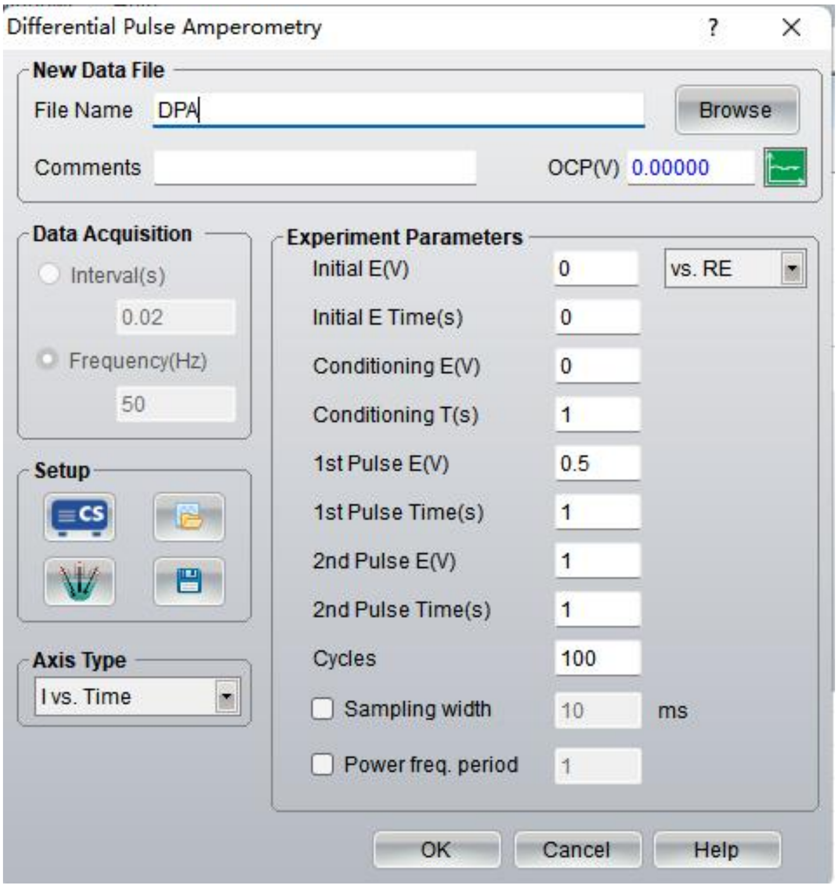
7. Amperometric

7.1 Differential Pulse Amperometry (DPA)

Experiments→Amperometric→Differential Pulse Amperometry (DPA)

In Differential Pulse Amperometry (DPA), a conditioning potential can be applied for electrode conditioning, during which current is not sampled. Two potential pulses are applied after the conditioning step, and the current at the end of each pulse is recorded as a function of time.





File Name: DPA

Comments:

OCP(V): 0.00000

○ Interval(s): 0.02

● Frequency(Hz): 50

Axis Type: I vs. Time

Initial E(V): 0 vs. RE

Initial E Time(s): 0

Conditioning E(V): 0

Conditioning T(s): 1

1st Pulse E(V): 0.5

1st Pulse Time(s): 1

2nd Pulse E(V): 1

2nd Pulse Time(s): 1

Cycles: 100

☐ Sampling width: 10 ms

☐ Power freq. period: 1

Parameter setting for DPA

Experiment parameters

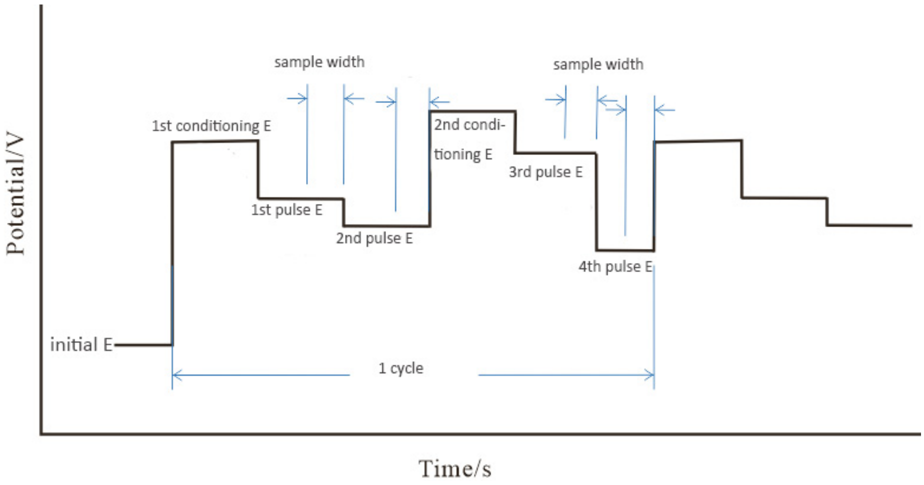
Parameters	Range	Description
Initial E(V)	-10~10	Initial potential
Initial E time (s)	⩾0	The duration of the initial potential. No data acquisition during this process
Conditioning E(V)	-10~10	The electrode conditioning/cleaning potential
Conditioning Time(s)	⩾0	The duration of the conditioning potential. Current is not sampled.
1st pulse potential(V)	-10~10	The 1st pulse potential in each cycle.
1st Pulse Time (s)	0.01~100	The duration of the 1st pulse potential. Current is sampled.
2nd pulse potential	-10~10	The 2nd pulse potential in each cycle.

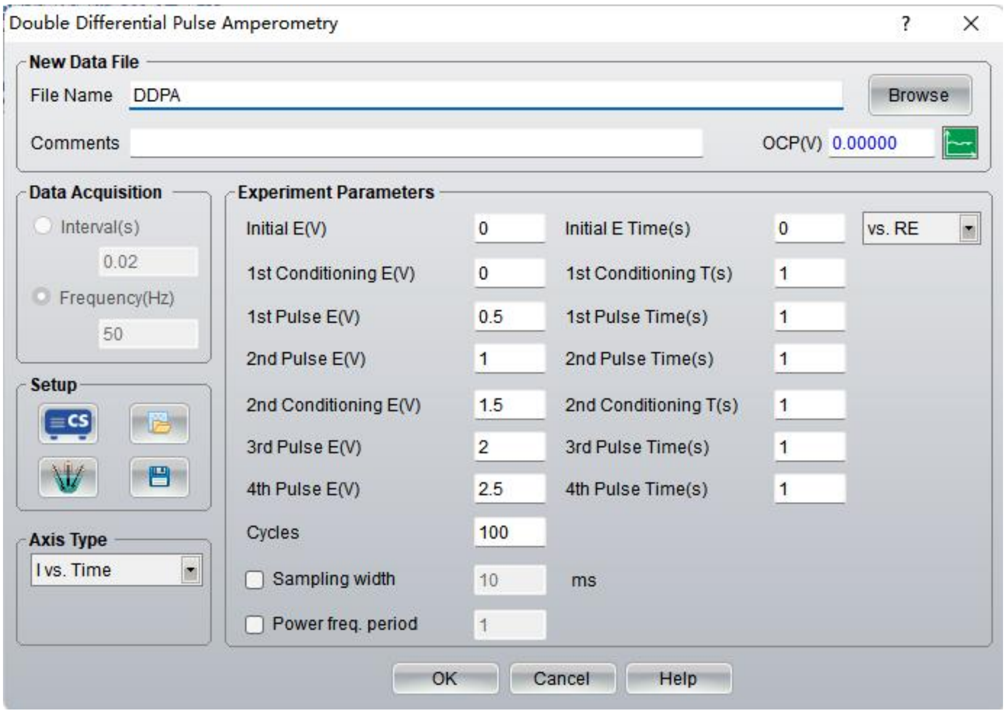
(V)		
2nd Pulse Time (s)	0.01~100	The duration of the 2nd pulse potential. Current is sampled.
Cycles	10~100,000	The total number of cycling.
Sampling width(ms)	1~ half of pulse time	The sampling width of the 1st and 2nd pulse potential in each pulse.

7.2 Double Differential Pulse Amperometry (DDPA)

Experiments→Amperometric→Double Differential Pulse Amperometry (DDPA)

Double Differential Pulse Amperometry (DDPA) alternates between two instances of differential pulse amperometry, with two sets of data recorded and displayed. In each instance, a conditioning potential applied for electrode conditioning, during which current is not sampled. Two potential pulses are applied after the conditioning step, and the current at the end of each pulse is recorded as a function of time. During the experiment, only the difference between the two current samples is displayed.





File Name DDPA

Comments

OCP(V) 0.00000

○ Interval(s) 0.02

○ Frequency(Hz) 50

Axis Type: I vs. Time

Initial E(V) 0 Initial E Time(s) 0 vs. RE

1st Conditioning E(V) 0 1st Conditioning T(s) 1

1st Pulse E(V) 0.5 1st Pulse Time(s) 1

2nd Pulse E(V) 1 2nd Pulse Time(s) 1

2nd Conditioning E(V) 1.5 2nd Conditioning T(s) 1

3rd Pulse E(V) 2 3rd Pulse Time(s) 1

4th Pulse E(V) 2.5 4th Pulse Time(s) 1

Cycles 100

☐ Sampling width 10 ms

☐ Power freq. period 1

Parameter setting window for DDPA

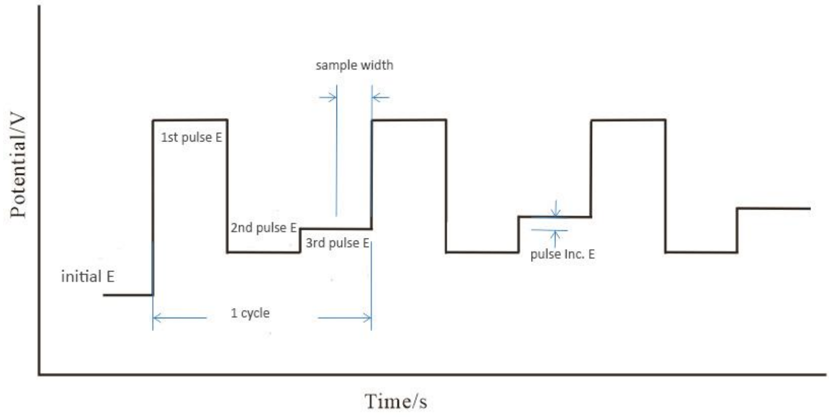
Experiment parameters

Parameter	Range	Description
Initial E(V)	-10~10	Initial potential
Initial pulse width (s)	⩾0	Duration of the initial potential. The current is not sampled.
1st Conditioning E(V)	-10~10	The 1st cleaning potential
1st Conditioning T(s)	⩾0	The duration of the 1st conditioning/cleaning potential. Current is not sampled.
1st pulse E (V)	-10~10	The 1st pulse potential in each cycle
1st Pulse Time (s)	0.01~100	The duration of the 1st pulse potential. Current is sampled.
2nd pulse E (V)	-10~10	The 2nd pulse potential in each cycle
2nd Pulse Time (s)	0.01~100	The duration of the 2nd pulse potential in each cycle. Current is sampled.
2nd Conditioning E(V)	-10~10	The 2nd cleaning/conditioning potential of the experiment
2nd Conditioning T(s)	⩾0	The duration of the 2nd cleaning/conditioning potential. In this process the current is not sampled
3rd pulse E(V)	-10~10	the 3rd pulse potential in each cycle
3rd Pulse Time (s)	0.01~100	The duration of the 3rd pulse potential in each cycle. Current is sampled.
4th pulse E (V)	-10~10	The 4th pulse potential in each cycle
4th Pulse Time (s)	0.01~100	The duration of the 4th pulse potential in each cycle. The current is sampled in this process.
Cycles	10-100,000	Total number of cycling
Sampling width(ms)	1~half of pulse time	The sampling width of pulse potential 1,2,3,4.

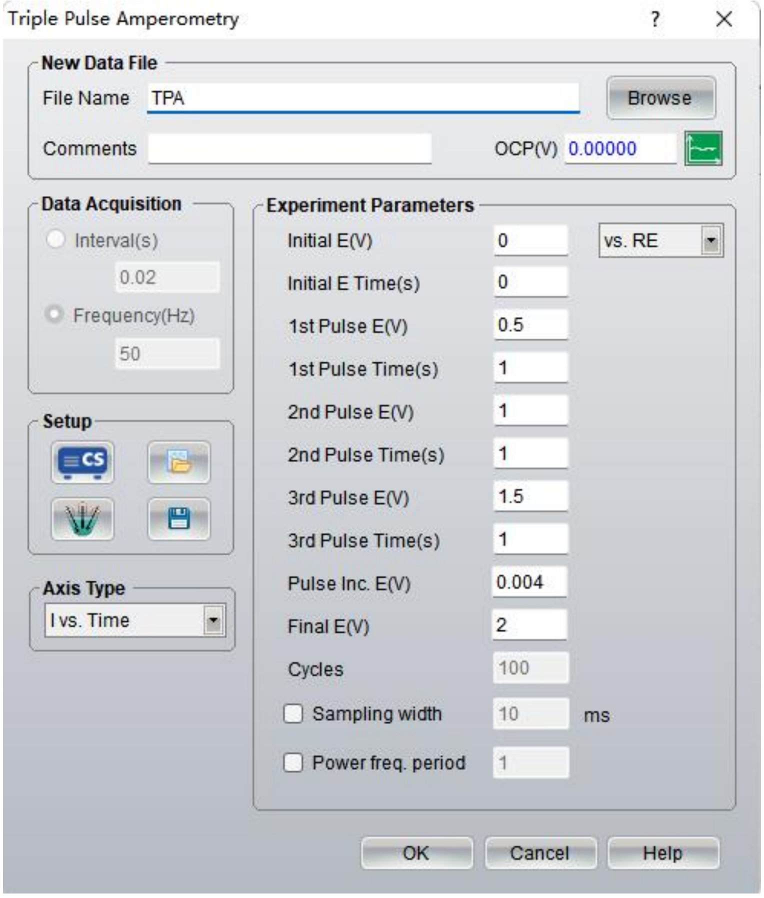
7.3 Triple Pulse Amperometry (TPA)

Experiments→Amperometry→Triple Pulse Amperometry (TPA)

In Triple Pulse Amperometry (TPA), three potential pulses are applied. The first two pulses are for electrode conditioning. Current is sampled at the end of the third potential pulse and recorded as a function of time. The third potential pulse can be constant or incremented after each cycle.



Experiment parameters



Triple Pulse Amperometry

New Data File

File Name: TPA

Comments:

OCP(V): 0.00000

Data Acquisition

○ Interval(s): 0.02

● Frequency(Hz): 50

Axis Type: I vs. Time

Experiment Parameters

Initial E(V): 0 vs. RE

Initial E Time(s): 0

1st Pulse E(V): 0.5

1st Pulse Time(s): 1

2nd Pulse E(V): 1

2nd Pulse Time(s): 1

3rd Pulse E(V): 1.5

3rd Pulse Time(s): 1

Pulse Inc. E(V): 0.004

Final E(V): 2

Cycles: 100

☐ Sampling width: 10 ms

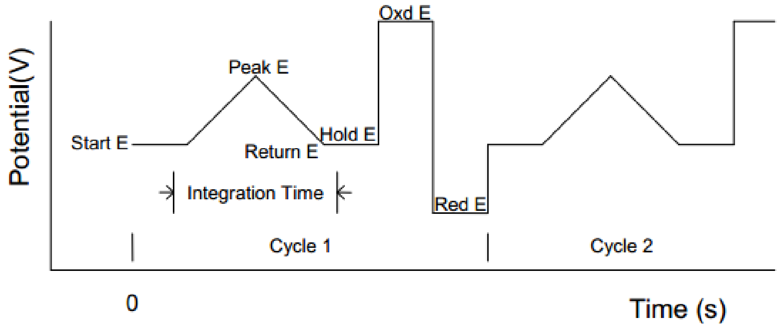
☐ Power freq. period: 1

Parameter	**Range**	**Description**
Initial E(V)	-10~10	The initial potential
Initial E Time (s)	⩾0	The duration of the initial potential. The current is not sampled.
Final E(V)	-10~10	The final potential
1st Pulse E(V)	-10~10	the 1st pulse potential in each cycle
1st Pulse Time (s)	⩾0	The duration of the 1st pulse potential in each cycle.
2nd Pulse E(V)	-10~10	The 2nd pulse potential in each cycle
2nd Pulse Time (s)	⩾0	The duration of the 2nd pulse potential in each cycle. The current is not sampled.
3rd Pulse E(V)	-10~10	the 3rd pulse potential in each cycle
3rd Pulse Time(s)	0.01~100	The duration of the 3rd pulse potential in each cycle. The current is sampled.
3rd Pulse inc. E(V)	0~0.02	Increment potential for third pulse
Final E(V)	-10~10	The final potential
Cycles	10-100,000	Total number of cycling
Sampling width(ms)	1~ half of 3rd pulse width	The sampling width of the 3rd pulse potential in each cycle

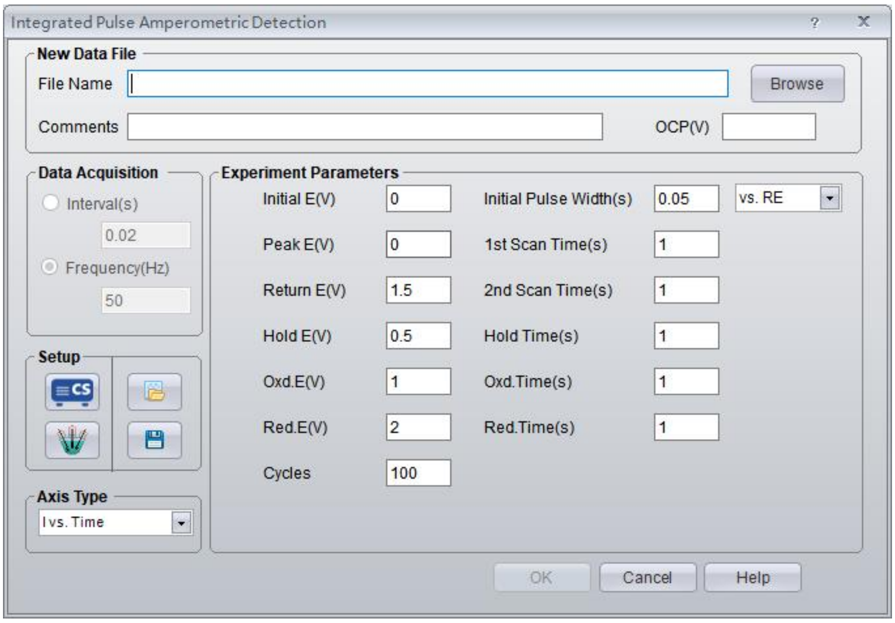
7.4 Integrated Pulse Amperometric Detection (IPAD)

Experiments→Amperometric→Integrated Pulse Amperometric Detection (IPAD)

In Integrated Pulse Amperometric Detection (IPAD), six segments of potential sweeps or steps are applied. Current is sampled and integrated during the first four segments. Electrode conditioning or cleaning occurs during the last two steps. The integrated current is averaged and recorded as a function of time.



Experiment parameters



File Name:

Comments:

OCP(V):

○ Interval(s) 0.02

○ Frequency(Hz) 50

Initial E(V) 0

Peak E(V) 0

Return E(V) 1.5

Hold E(V) 0.5

Oxd.E(V) 1

Red.E(V) 2

Cycles 100

Initial Pulse Width(s) 0.05

vs. RE

1st Scan Time(s) 1

2nd Scan Time(s) 1

Hold Time(s) 1

Oxd.Time(s) 1

Red.Time(s) 1

Axis Type: I vs. Time

Parameter setting window for IPAD

Parameters	Range	Description
Initial E(V)	-5~5	The initial potential
Initial E time(s)	0.05~1	Duration of initial potential (current is sampled and integrated for the last 10ms)
Peak E(V)	-5~5	Potential is scanned Initial E to Peak E
1st scan time(s)	0.1~1	Potential scan time (current integration continues)
Return E(V)	-5~5	Potential is scanned Peak E to Return E

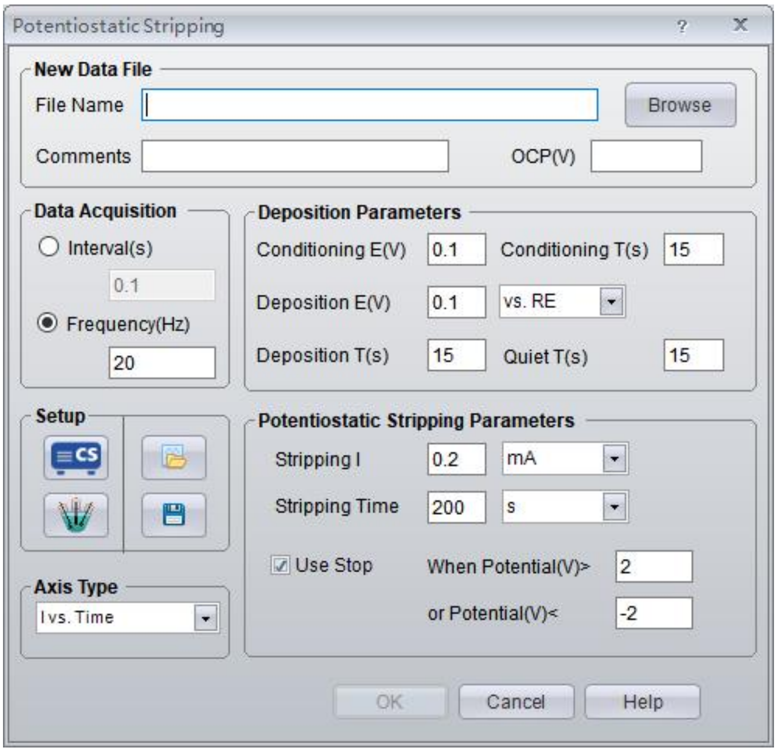
2nd scan time(s)	0.1~1	Scan time from peak E to Return E; The current is sampled and integrated.
Hold E(V)	-5~5	Hold potential (constant)
Hold Time(s)	0.05~1	Hold potential duration (current integration for first 10 ms)
Oxd. E(V)	-5~5	Oxidation potential for electrode treatment
Oxd. Time(s)	0.05~1	Oxidation time duration; The current is not sampled
Red. E(V)	-5~5	Reduction potential for electrode treatment
Red. Time(s)	0.05~1	Reduction time duration. The current is not sampled
Cycles	5-100,000	Number of cycles through six segments

8. Stripping Voltammetry

8.1 Potentiostatic Stripping

Experiments→Stripping Voltammetry→Potentiostatic Stripping

In Potentiostatic Stripping, a constant potential deposition step is first applied, after which the species accumulated at the electrode surface are stripped out by applying a constant current.



New Data File
File Name
Comments
OCP(V)

Data Acquisition
○ Interval(s) 0.1
● Frequency(Hz) 20

Deposition Parameters
Conditioning E(V) 0.1
Conditioning T(s) 15
Deposition E(V) 0.1 vs. RE
Deposition T(s) 15
Quiet T(s) 15

Potentiostatic Stripping Parameters
Stripping I 0.2 mA
Stripping Time 200 s
☑ Use Stop
When Potential(V)> 2
or Potential(V)< -2

Axis Type
I vs. Time

OCP will display the current open circuit potential of the cell (update per second).

Experiment Parameters

Parameters	Range	Description
Conditioning E(V)	-10~10	Cleaning/conditioning potential
Conditioning T(s)	≥0	Cleaning potential duration; the current data is not saved
Deposition E(V)	-10~10	Deposition potential is usually 0.3~0.5V more negative than the redox standard potential, which makes it easy to reduce the tested metal ions.
Deposition Time(s)	≥0	The time of the deposition process
Quiet Time(s)	≥0	Waiting time between deposition and stripping
Stripping I (mA)		Constant current is applied on the working electrode.
Stripping Time(s)	>0	the time of potentiostatic stripping process

Data Acquisition

If Frequency(Hz) is chosen, the acquisition rate in points/second is specified.

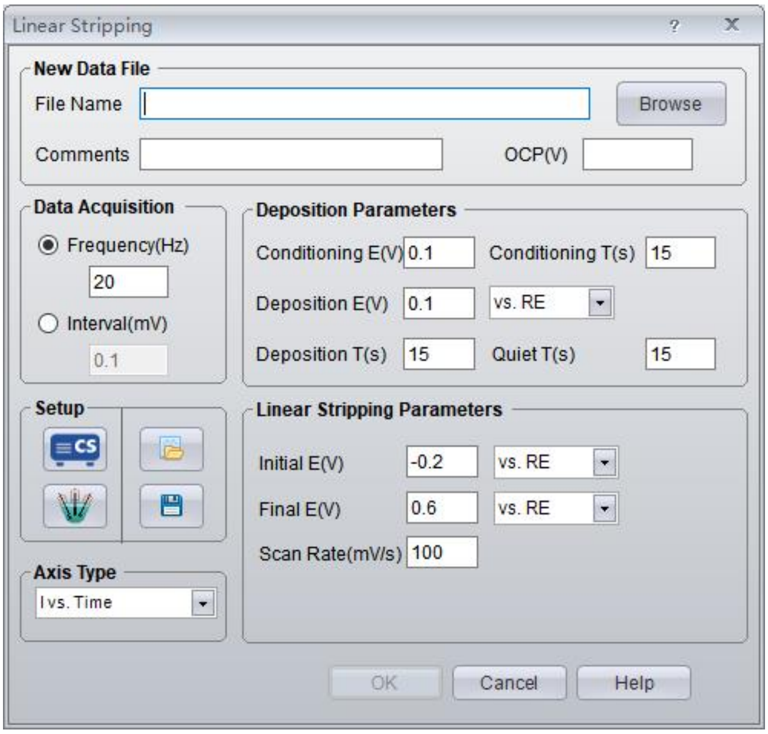
Axis Type:

When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats.

8.2 Linear Stripping Voltammetry

Experiments→Stripping Voltammetry→Linear Stripping Voltammetry

Linear Stripping Voltammetry technique is a high-sensitivity electrochemical method for trace elements analysis. In Linear Stripping, a constant potential deposition step is first applied. After that, the species accumulated on the electrode surface are stripped out by applying a linear potential, which is scanned from an initial potential to a final potential at a defined scan rate.



File Name
Comments
OCP(V)

● Frequency(Hz) 20
○ Interval(mV) 0.1

Axis Type: I vs. Time

Conditioning E(V) 0.1
Conditioning T(s) 15
Deposition E(V) 0.1 vs. RE
Deposition T(s) 15
Quiet T(s) 15

Initial E(V) -0.2 vs. RE
Final E(V) 0.6 vs. RE
Scan Rate(mV/s) 100

OCP will display the current open circuit potential of the cell (update per second).

Parameter	Range	Description
Conditioning E(V)	-10~10	Cleaning/conditioning potential
Conditioning T(s)	≥0	Cleaning potential duration; the current is not sampled.
Deposition E(V)	-10~10	Deposition potential is normally 0.3~0.5V more negative than the redox standard potential, which makes it easy to reduce the tested metal ions.
Deposition Time(s)	>0	The time of the deposition process
Quiet Time(s)	>0	Waiting time after deposition and before stripping
Initial E(V)	-10~10	Initial potential in stripping
Final E(V)	-10~10	Final potential in stripping
Scan Rate(mV/s)	0.01~1000	Scan rate in stripping process

Deposition Parameters

Before the experiment, the surface of working electrode needs cleaning by this conditioning step.

A constant potential deposition step is applied to accumulate species on the working electrode surface. This potential can be specified to choose either “vs. OCP” or “vs. RE”.

The deposition time specifies how long the potential will be held at this step. After deposition, the experiment can be quiet for some time.

Linear Stripping Parameters

A potential can be specified in several ways. If “vs. OCP” is chosen, the specified potential is added to the open circuit potential of the cell. “vs.RE” means selecting an exact potential.

Data Acquisition

If Frequency(Hz) is chosen, the acquisition rate in points/second is specified.

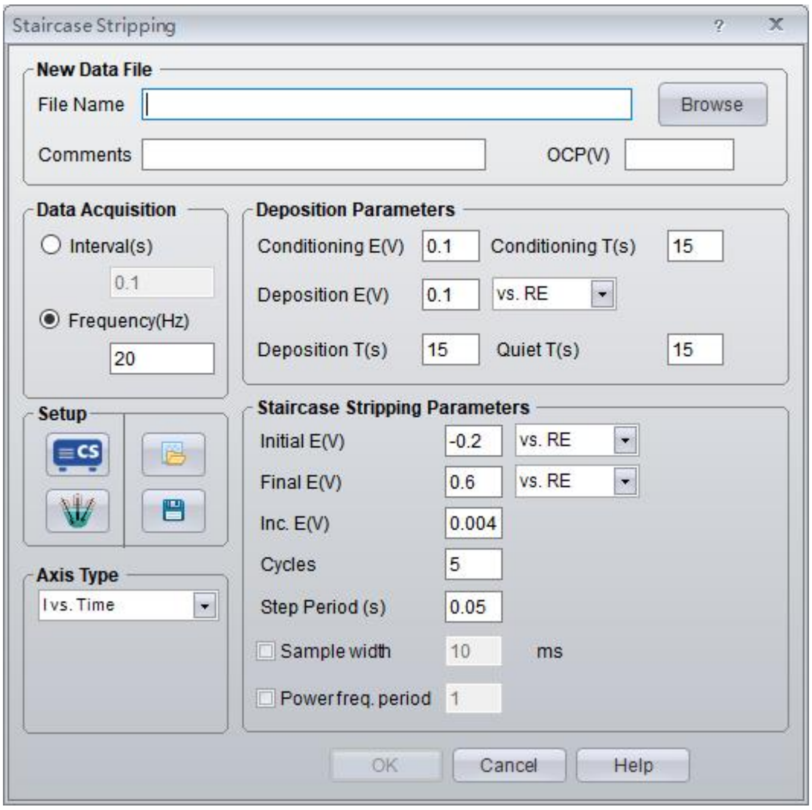
Axis Type

When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats.

8.3 Staircase Stripping Voltammetry

Experiments→Stripping Voltammetry→Staircase Stripping

In Staircase Stripping, a constant potential deposition step is applied. After that the species accumulated on the electrode surface are stripped out by applying a staircase potential, which is incremented from Initial E toward Final E at a defined increment. It’s similar to linear stripping. Staircase stripping is considered to be a derivative of linear sweep stripping.



Staircase Stripping

New Data File

File Name

Comments

OCP(V)

Data Acquisition

○ Interval(s) 0.1

● Frequency(Hz) 20

Deposition Parameters

Conditioning E(V) 0.1

Conditioning T(s) 15

Deposition E(V) 0.1 vs. RE

Deposition T(s) 15

Quiet T(s) 15

Setup

Axis Type

I vs. Time

Staircase Stripping Parameters

Initial E(V) -0.2 vs. RE

Final E(V) 0.6 vs. RE

Inc. E(V) 0.004

Cycles 5

Step Period (s) 0.05

☐ Sample width 10 ms

☐ Power freq. period 1

OCP will display the current open circuit potential of the cell (update per second). If the instrument is turned off, this value will display “Not Available”.

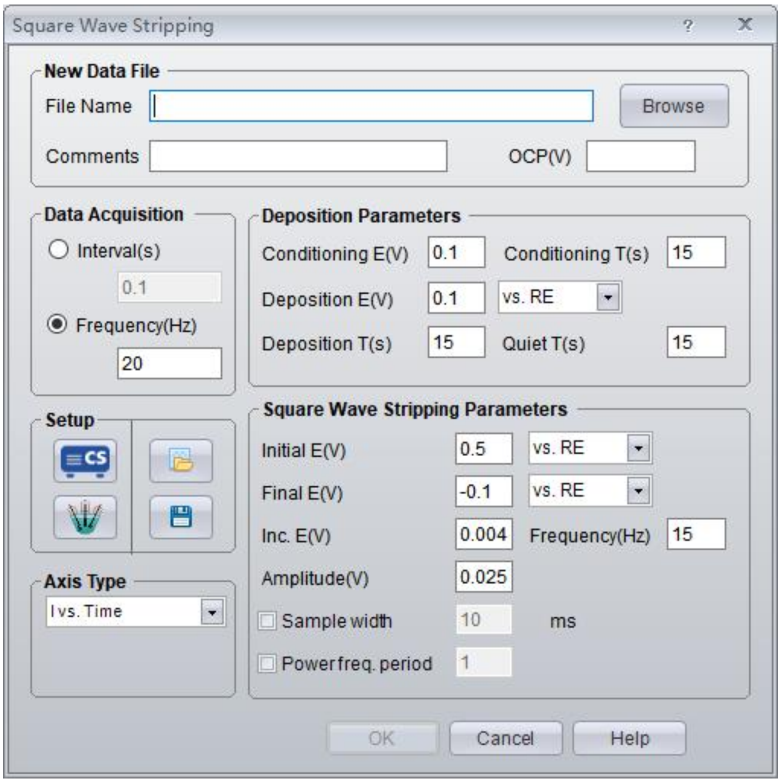
Parameter	Range	Description
Conditioning E(V)	-10~10	Cleaning/conditioning potential
Conditioning T(s)	⩾0	Cleaning potential duration; the current is not sampled.
Deposition E(V)	-10~10	Deposition potential is normally 0.3~0.5V more negative than the redox standard potential, which makes it easy to reduce the tested metal ions.
Deposition Time(s)	>0	The time of the deposition process
Quiet Time(s)	>0	Waiting time after deposition and before stripping
Initial E(V)	-10~10	Initial potential in stripping
Final E(V)	-10~10	Final potential in stripping
Inc. E(V)	0.001~0.05	Increment potential during each step
Cycles	1~10000	The number of cycling of the stair steps

8.4 Square wave stripping Voltammetry(SWSV)

Experiments→ Stripping Voltammetry→ Square Wave Stripping Voltammetry(SWSV)

This is an extension of the Square Wave Voltammetry technique. It works identically to Square Wave Voltammetry except it includes an “deposition” step.

In Square wave stripping voltammetry (SWSV), a square wave signal with a certain amplitude and frequency is superimposed on the working electrode during the stripping process. During heavy metal ions detection, a double-layer capacitor is created between the electrode and the electrolyte at the contact surface. This capacitor is formed as a result of the ions deposited on the electrode surface. When recording the current during the stripping, the charge and discharge of the capacitor can bring interference to the current generated in the electrolytic cell. The square wave stripping voltammetry can reduce such interference by adding a certain square wave signal to the scanning voltage.



Square Wave Stripping

New Data File

File Name

Comments

OCP(V)

Data Acquisition

○ Interval(s) 0.1

● Frequency(Hz) 20

Deposition Parameters

Conditioning E(V) 0.1

Conditioning T(s) 15

Deposition E(V) 0.1 vs. RE

Deposition T(s) 15

Quiet T(s) 15

Square Wave Stripping Parameters

Initial E(V) 0.5 vs. RE

Final E(V) -0.1 vs. RE

Inc. E(V) 0.004

Frequency(Hz) 15

Amplitude(V) 0.025

☐ Sample width 10 ms

☐ Powerfreq. period 1

Axis Type

I vs. Time

OCP will display the current open circuit potential of the cell (update per second). If the instrument is turned off, this value will display “Not Available”.

Parameter	Range	Description
Conditioning E(V)	-10~10	Cleaning/conditioning potential
Conditioning T(s)	≥0	Cleaning potential duration; the current is not sampled.
Deposition E(V)	-10~10	Deposition potential is normally 0.3~0.5V more negative than the redox standard potential, which makes it easy to reduce the tested metal ions.
Deposition Time(s)	>0	The time of the deposition process
Quiet Time(s)	>0	Waiting time after deposition and before stripping
Initial E(V)	-10~10	Initial potential in stripping
Final E(V)	-10~10	Final potential in stripping
Inc. E(V)	0.001~0.05	Increment potential during each step
Amplitude(V)	0.001-0.5	The amplitude of each square wave signal
Frequency(Hz)	1-100,000	The output frequency square wave signal

Deposition E: a suitable potential should be applied to make heavy metal ions accumulate on the electrode through a reduction reaction.

Deposition Time: the longer the deposition time is, the more heavy metal ions are to be deposited, the greater the current will be during electrolytic stripping, and the better the detection effect will be. Due to the limited number of ions in the solution, the amount of ions deposited will not change after a certain period of time.

Inc.E: the increment potential of the base stair step during the stripping process. the amplitude value of the voltage signal changes each time. **Inc.E** and square wave **frequency** jointly determine the potential scan rate which has an impact on the detection effect. Generally, the faster the rate is, the greater the peak current will be, but the more interference noise there will be.

Amplitude: selecting an appropriate amplitude can improve detection accuracy.

Quiet time: The purpose is to stabilize the tested ions deposited on the electrode, which can reduce the disturbance and interference of other factors during detection.

Data Acquisition

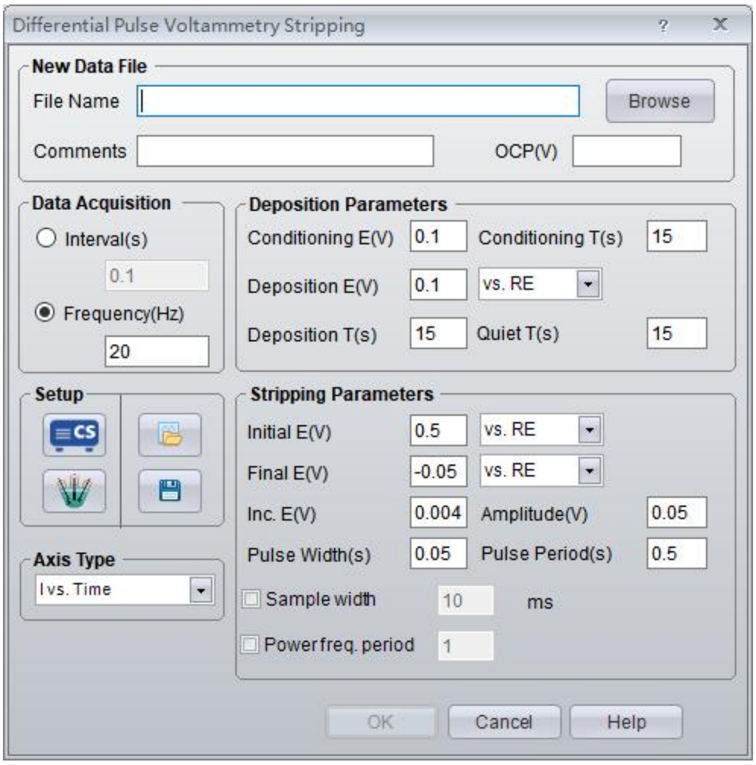
If **Frequency (Hz)** is chosen, the acquisition rate in points/second is specified.

Axis Type

When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats.

8.5 Differential Pulse Stripping Voltammetry

Experiments→Stripping Voltammetry→Differential Pulse Voltammetry Stripping



File Name
Comments
OCP(V)

Data Acquisition
○ Interval(s) 0.1
● Frequency(Hz) 20

Deposition Parameters
Conditioning E(V) 0.1
Conditioning T(s) 15
Deposition E(V) 0.1 vs. RE
Deposition T(s) 15
Quiet T(s) 15

Stripping Parameters
Initial E(V) 0.5 vs. RE
Final E(V) -0.05 vs. RE
Inc. E(V) 0.004
Amplitude(V) 0.05
Pulse Width(s) 0.05
Pulse Period(s) 0.5
☐ Sample width 10 ms
☐ Powerfreq. period 1

Axis Type
I vs. Time

OCP will display the current open circuit potential of the cell (update per second). If the instrument is turned off, this value will display “Not Available”.

Data Acquisition

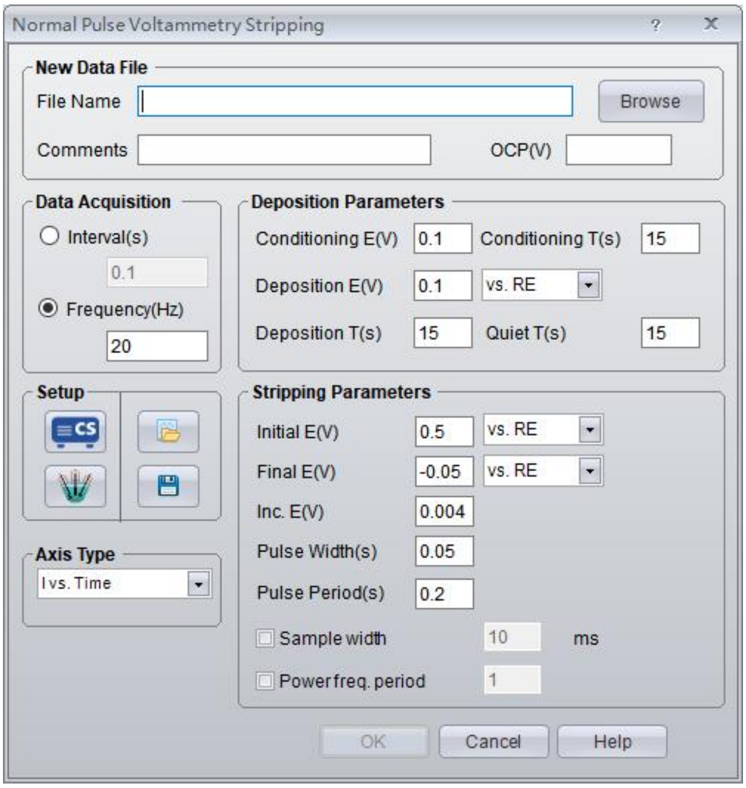
If **Frequency(Hz)** is chosen, the acquisition rate in points/second is specified.

Axis Type

When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats.

8.6 Normal Pulse Stripping Voltammetry

Experiments →Stripping Voltammetry→Normal Pulse Voltammetry Stripping



New Data File

File Name

Comments

OCP(V)

Data Acquisition

○ Interval(s) 0.1

● Frequency(Hz) 20

Deposition Parameters

Conditioning E(V) 0.1

Conditioning T(s) 15

Deposition E(V) 0.1 vs. RE

Deposition T(s) 15

Quiet T(s) 15

Setup

Axis Type

I vs. Time

Stripping Parameters

Initial E(V) 0.5 vs. RE

Final E(V) -0.05 vs. RE

Inc. E(V) 0.004

Pulse Width(s) 0.05

Pulse Period(s) 0.2

☐ Sample width 10 ms

☐ Power freq. period 1

OCP will display the current open circuit potential of the cell (update per second). If the instrument is turned off, this value will display “Not Available”.

Data Acquisition

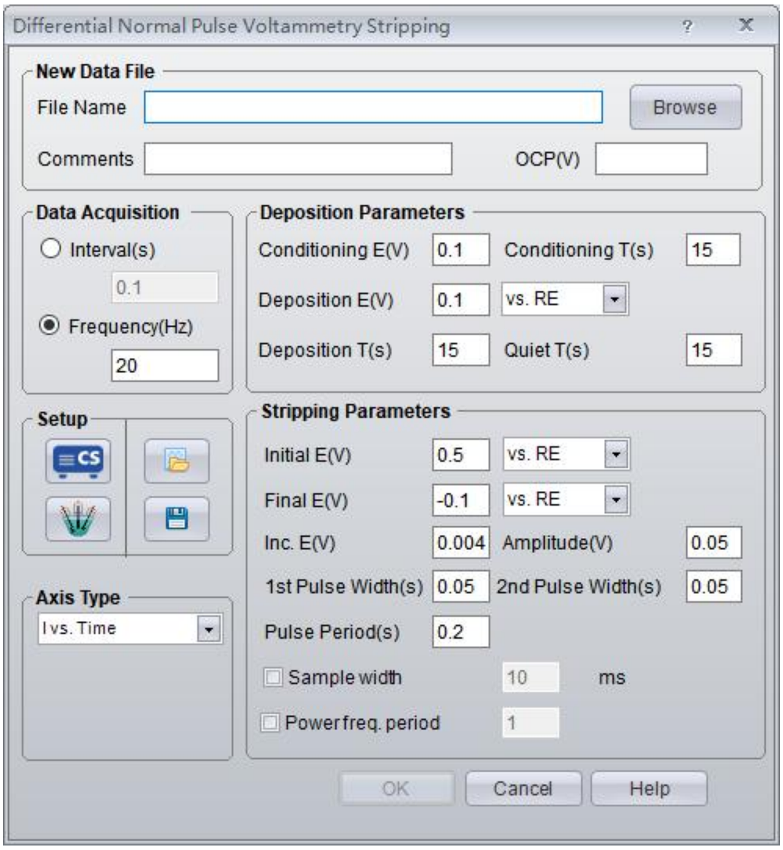
If **Frequency(Hz)** is chosen, the acquisition rate in points/second is specified.

Axis Type

When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats.

8.7 Differential Normal Pulse Stripping Voltammetry

Experiments→Stripping Voltammetry→Differential Normal Pulse Voltammetry Stripping



Differential Normal Pulse Voltammetry Stripping

New Data File
File Name
Comments
OCP(V)

Data Acquisition
○ Interval(s) 0.1
● Frequency(Hz) 20

Deposition Parameters
Conditioning E(V) 0.1
Conditioning T(s) 15
Deposition E(V) 0.1 vs. RE
Deposition T(s) 15
Quiet T(s) 15

Setup

Axis Type
I vs. Time

Stripping Parameters
Initial E(V) 0.5 vs. RE
Final E(V) -0.1 vs. RE
Inc. E(V) 0.004
Amplitude(V) 0.05
1st Pulse Width(s) 0.05
2nd Pulse Width(s) 0.05
Pulse Period(s) 0.2
☐ Sample width 10 ms
☐ Power freq. period 1

OCP will display the current open circuit potential of the cell (update per second). If the instrument is turned off, this value will display “Not Available”.

Data Acquisition

If Frequency(Hz) is chosen, the acquisition rate in points/second is specified.

Axis Type

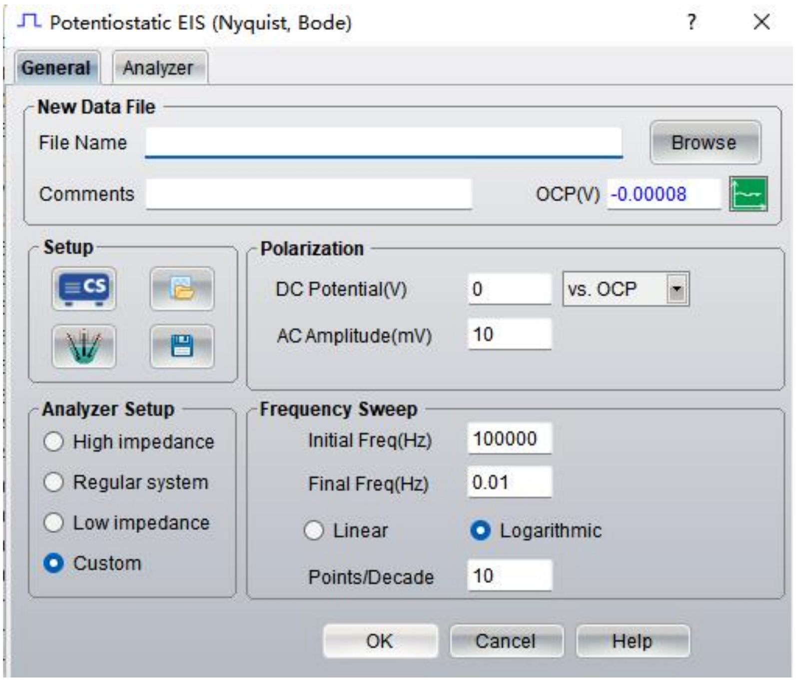
When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats.

9. Impedance(EIS)

9.1 Potentiostatic EIS (Nyquist, Bode)

Experiments →Impedance →Potentiostatic EIS (Nyquist, Bode)

Potentiostatic EIS measures the impedance spectroscopy of the electrochemical system in a frequency range. Nyquist and Bode plot can be obtained.



New Data File

File Name

Comments

OCP(V) -0.00008

Polarization

DC Potential(V) 0 vs. OCP

AC Amplitude(mV) 10

Analyzer Setup

- ○ High impedance
- ○ Regular system
- ○ Low impedance
- ● Custom

Frequency Sweep

Initial Freq(Hz) 100000

Final Freq(Hz) 0.01

○ Linear ● Logarithmic

Points/Decade 10

OCP will display the current open circuit potential of the electrolytic cell (update per second). OCP is useful for the user to judge whether the working electrode is stable for impedance test.

File Name

The user should enter a file name to save data before starting the test. If you enter a name and click OK, the data will be saved automatically during test in default data storage path(setup→ settings→ data storage setting→default path).You can also click “Browse”, and choose the storage path as you want.

CS Studio will automatically append the suffix “.z60” to a file name. For example, if you input “tutor1”, the name of the data file will be shown as “tutor1.z60”.

Polarization

DC potential: the DC polarization potential applied on the working electrode during impedance test. If the EIS test is conducted under open circuit potential, here enter “0” and select “vs. OCP”.

If you choose “vs. OCP” then the instrument will automatically apply value of OCP+ DC potential on the working electrode.

If the test needs to be carried out at a certain potential (such as-0.5V vs. SCE), you can select “vs. RE” and enter “-0.5”, then the instrument will polarize the working electrode to be -0.5V.

AC amplitude is the amplitude of the electrochemical impedance excitation signals. For example, E=0.012sin(ωt) V means AC signal amplitude is 12mV. For high-impedance system, amplitude is usually set 20mV or 50 mV. For regular system it’s suggested set 10 mV. For low-impedance system we suggest 5 mV.

Frequency Sweep

Frequency sweep starts from the **initial frequency** to the **final frequency**, and the mode can be either **linear** or **logarithmic**.

If you choose linear, the measured points will be evenly distributed between the initial frequency and final frequency. Usually, this mode is not selected unless for special requirements.

Logarithmic is mostly selected. The sampling data points will be evenly distributed in frequency logarithmic axis (Bode plot). It is particularly useful when there is 2 to 5 orders between initial and final frequency. For example, if the frequency range is from100kHz to 0.01Hz, and you set “10” in points/decade, then the measured points will be evenly distributed between initial and final frequency, 70 points in total. The users usually choose this mode.

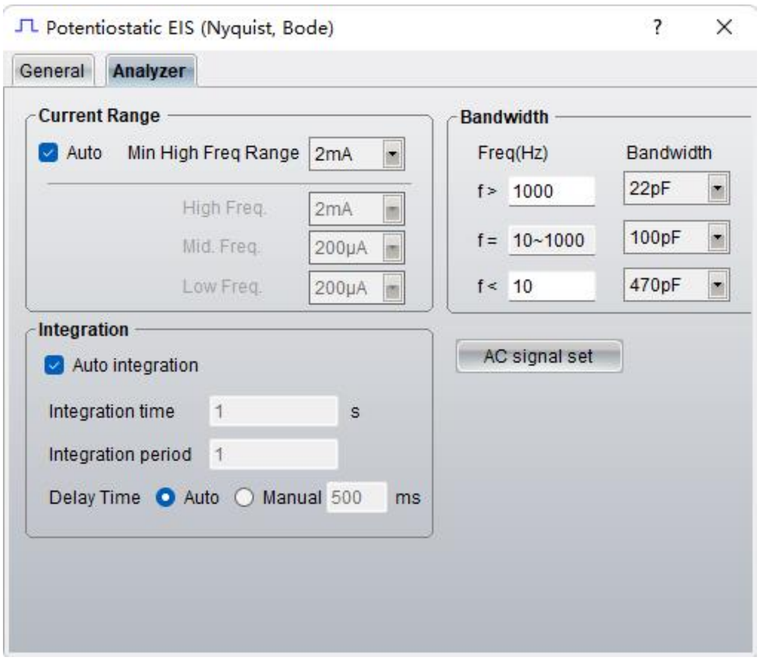
High impedance: suitable for high impedance system such as coating

Regular system: suitable for some ordinary systems

Low impedance: suitable for low impedance systems, such as cylindrical battery 18650, pouch battery

Custom: the user can adjust the bandwidth capacitance and current range in Analyzer for above systems

Analyzer



Current Range
☑ Auto
Min High Freq Range: 2mA
High Freq.: 2mA
Mid. Freq.: 200μA
Low Freq.: 200μA

Bandwidth

Freq(Hz)		Bandwidth
f>	1000	22pF
f=	10~1000	100pF
f<	10	470pF

Integration
☑ Auto integration
Integration time: 1 s
Integration period: 1
Delay Time: ● Auto ○ Manual 500 ms

Current range

The user can set current range automatically/manually. If select "Auto", you need to set a minimum current range in high frequency segment. In the above dialog box, for instance, when the frequency is over 1000Hz, the auto current range should be no lower than 2mA.

The high frequency is defined by the user. In the above picture, f >1000Hz is high frequency region, f <10Hz is low frequency region, and 10~1000 Hz is defined to be middle frequency region.

If the curve in high frequency region is not satisfactory, then the user can uncheck "Auto" and use manual setting. For example, in above picture, under manual setting, the current range is 2mA(f >1000Hz), 200 μ A (f <10Hz and f =10Hz ~1000Hz)

Because the impedance characteristics are different for working electrode in high and low frequency signals, the current range should be set accordingly to improve measurement accuracy. Generally, current range at low frequency should be smaller than that at high frequency. If the current range is set inappropriately, the EIS plot may appear large noise. If the current range is changed frequently, there will be obvious noise on the curve, then you should check if the current range is suitable. You can observe signal amplitude of the waveform graph.

Bandwidth

The higher the selected capacitance value is, the narrower the bandwidth will be. The performance in high-frequency will weaken, but stability will be improved.

Bandwidth is set based on the critical frequency f_c. If the measurement frequency is higher than f_c, normally you should choose a small capacitance (or turn it off) to avoid false impedance spectra in high frequency region. But for high impedance system, it may result in oscillation. You may have to increase the capacitance. To check if oscillation occurs, you can observe the signal amplitude of the waveform.

Integration Time

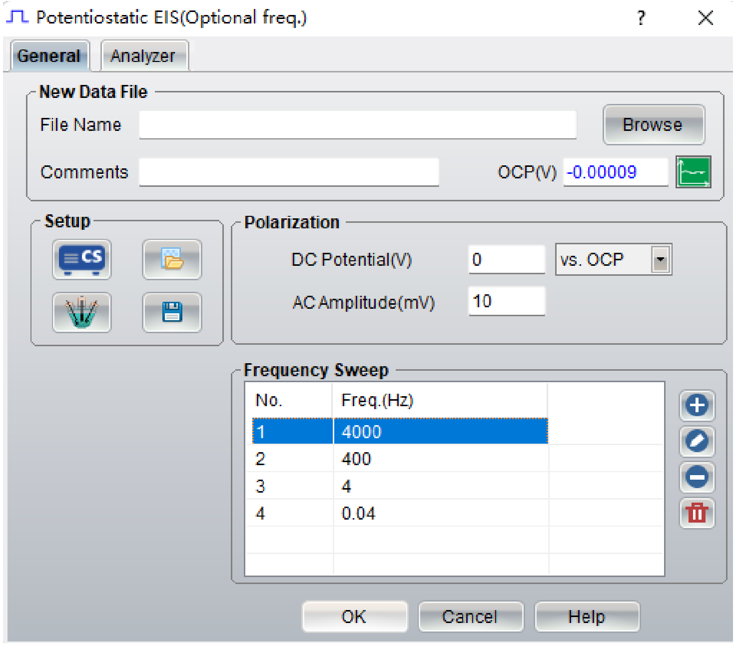
The impedance measurement accuracy can be improved by increasing the integration time. You can set the integration time to be the number of cycles or seconds. It specifies the time spent on each frequency point. The longer the integration time is, the higher the measurement accuracy will be, and the more time it will take.

Delay time is the waiting time between measurement of two frequency points.

9.2 Potentiostatic EIS (Optional freq.)

Experiments →Impedance → Potentiostatic EIS (Optional freq.)

It also obtains the Nyquist and Bode plot. In this technique, the EIS test is conducted under fixed frequencies as you want to set, which improves test efficiency.



OCP(V) -0.00009

DC Potential(V) 0 vs. OCP

AC Amplitude(mV) 10

No.	Freq.(Hz)
1	4000
2	400
3	4
4	0.04

⊕ : Add the frequencies you want to test

✎: Select a row and modify the frequency

⊖: Select a row and remove it

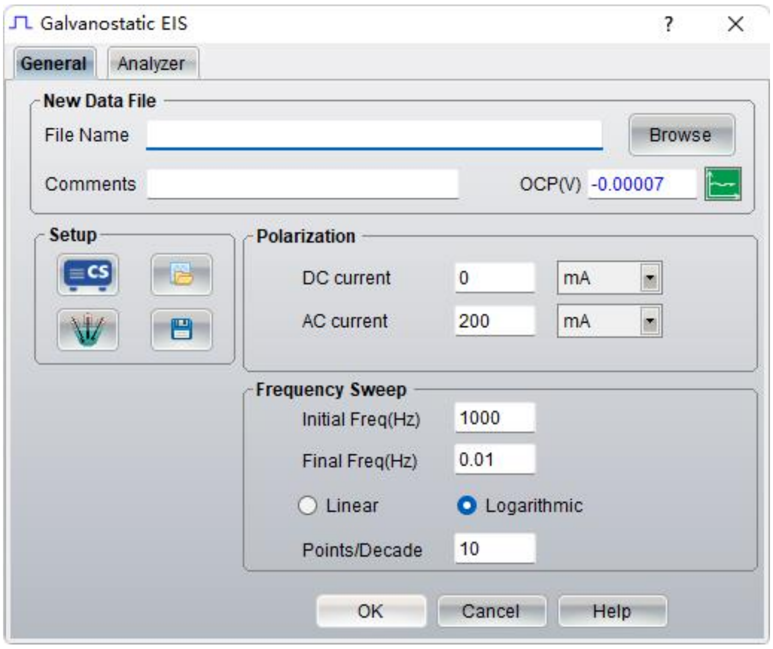
🗑: Clear all the set frequencies at a click.

9.3 Galvanostatic EIS

Experiments →Impedance → Galvanostatic EIS

In Galvanostatic EIS a AC current excitation signal is applied on the tested system. It measures the AC voltage with the change of frequency. Galvanostatic EIS can be used for many areas such as the battery, electrode dynamics, industrial electrolysis etc.

Galvanostatic EIS outputs a complex impedance spectrum. The EIS is plotted in Nyquist, bode. Impedance analysis can provide such information as polarization resistance (R_P), double-layer capacitance (C_{dl}) solution resistance (R_S), dynamics information.



File Name

Comments

OCP(V) -0.00007

DC current 0 mA

AC current 200 mA

Initial Freq(Hz) 1000

Final Freq(Hz) 0.01

○ Linear ● Logarithmic

Points/Decade 10

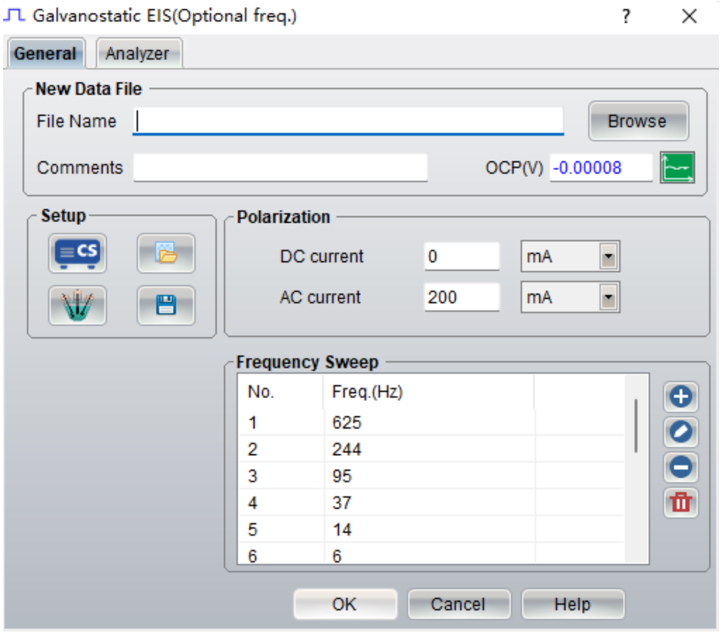
DC current: The polarization DC current applied on the working electrode during EIS test

AC current: the amplitude of the AC current excitation signal. For example, I=0.05sin(ωt) A, means the amplitude is 50mA.

9.4 Galvanostatic EIS (Optional freq.)

Experiments →Impedance → Galvanostatic EIS (Optional freq.)

In this technique, the EIS test is conducted under fixed frequencies as you want to set, which improves test efficiency.



File Name

Comments

OCP(V) -0.00008

DC current 0 mA

AC current 200 mA

No.	Freq.(Hz)
1	625
2	244
3	95
4	37
5	14
6	6

⊕ : Add the frequencies you want to test

✎: Select a row and modify the frequency

⊖: Select a row and remove it

🗑: Clear all the set frequencies at a click.

9.5 Mott-Schottky

Experiments→ Impedance→Mott-Schottky

It is to do EIS at different DC polarization potentials under a fixed frequency. The potential is stepped from initial potential to final potential with an set increment potential. Mott-Schottky plot is widely used to study the semiconductor characteristics of passivation film on the metal surface. It can determine the carrier type, carrier concentration and the flat band potential.

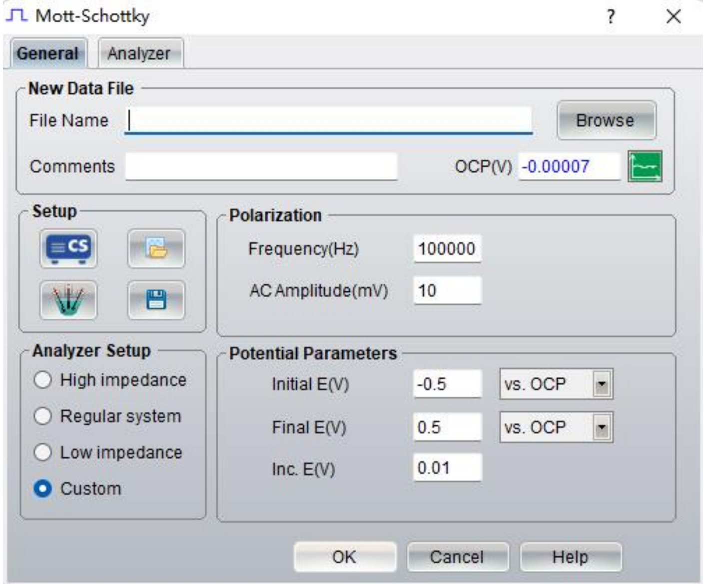
When the passivation film contacts the solution and the space charge of the passivation film is depleted, there is the following linear relationship for space charge capacitance (C_{sc}) and the measured voltage (V_m):

$$C_{sc}^{-2} = \frac{2}{eN_d\varepsilon\varepsilon_0 A^2}\left(V_m - V_{fb} - \frac{kT}{e}\right) \quad \text{n-type semiconductor} \qquad (1)$$

$$C_{sc}^{-2} = \frac{-2}{eN_a\varepsilon\varepsilon_0 A^2}\left(V_m - V_{fb} + \frac{kT}{e}\right) \quad \text{p-type semiconductor} \qquad (2)$$

Where, V_{fb} is flat band potential, N_d and N_a are the carrier concentration of donor and acceptor, respectively; ε is the relative permittivity, ε_0 is the vacuum permittivity, A the electrode surface area, k is Boltaman constant, T is absolute temperature, e is the quantity of electric charge.

The passivation film has a double-layer structure. Due to the different composition and crystal structure of the inner and outer layers of the passivation film, the semiconductor types of the inner and outer layers are also different, resulting in the formation of two space charge layers inside the passivation film, namely the space charge layer at the solution/passivation film interface and the pn junction capacitance at the inner/outer layer interface. Due to the small size of the passivation film and pn capacitance, high-frequency sine waves are generally used for Mott-Schottky measurement



File Name

Comments

OCP(V) -0.00007

Frequency(Hz) 100000

AC Amplitude(mV) 10

○ High impedance

○ Regular system

○ Low impedance

● Custom

Initial E(V) -0.5 vs. OCP

Final E(V) 0.5 vs. OCP

Inc. E(V) 0.01

OCP will display the actual open circuit potential of the electrolytic cell (update per second). This is particularly useful for the user to determine whether the working electrode is stable for impedance test.

Polarization

Frequency: frequency of sine wave

AC Amplitude specifies amplitude of sine wave

Potential Parameters

Initial E is the initial DC potential applied on the working electrode in impedance test.

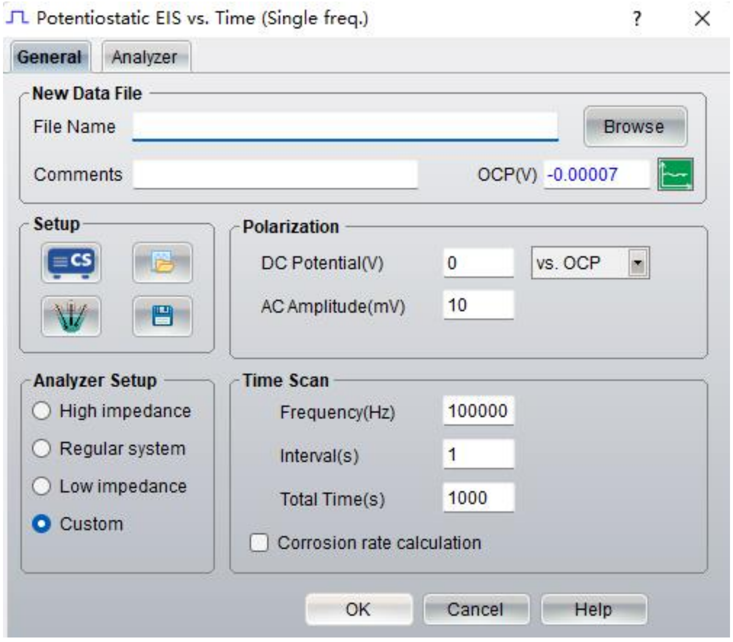
Final E is the final DC potential applied on the working electrode

Inc. E is the potential increment. Potential is incremented with the form of stairsteps.

9.6 Potentiostatic EIS vs Time(Single freq.)

Experiments →Impedance → Potentiostatic EIS vs. Time (Single freq.)

It measures the single frequency impedance characteristics of the system as a function of time under AC potential excitation signals. It studies the dynamic processes of some systems, such as conductivity, corrosion rate.



File Name

Comments

OCP(V) -0.00007

DC Potential(V) 0 vs. OCP

AC Amplitude(mV) 10

○ High impedance

○ Regular system

○ Low impedance

● Custom

Frequency(Hz) 100000

Interval(s) 1

Total Time(s) 1000

☐ Corrosion rate calculation

OCP will display the current open circuit potential of the electrolytic cell (update per second). This is particularly useful for the user to judge whether the working electrode is stable for impedance test.

Polarization

DC potential is the DC polarization potential on the working electrode during impedance test.

AC amplitude is the amplitude of the electrochemical impedance excitation signals.

Time Scan

In Impedance vs. Time scan, **frequency** of sine wave is constant.

Interval - interval for each single-frequency measuring point.

Total time- the total time of measurement.

Corrosion rate calculation

Check this option, the software will calculate the corrosion rate after testing. You can view the curve after the test. The user needs to input relevant information about the working electrode and the electrolytic cell in **cell setting** before testing, such as surface area, material density, chemical equivalent, temperature, and Sterm coefficient (B value). Generally, B value is 26 mV for the activation system, 52 mV for the passivation system; 18 mV for acidic system, 26 mV for neutral system, and 52 mV for alkaline system. Reasonable value is generally between 20~28mV.

Corrosion rate is calculated according:

$$\mathrm{Icorr} = \frac{B}{R}$$

Whereas, I_{corr} is the corrosion current rate, unit is A/cm^2

B is the Sterm coefficient,

R is the impedance, unit is Ω/cm^2

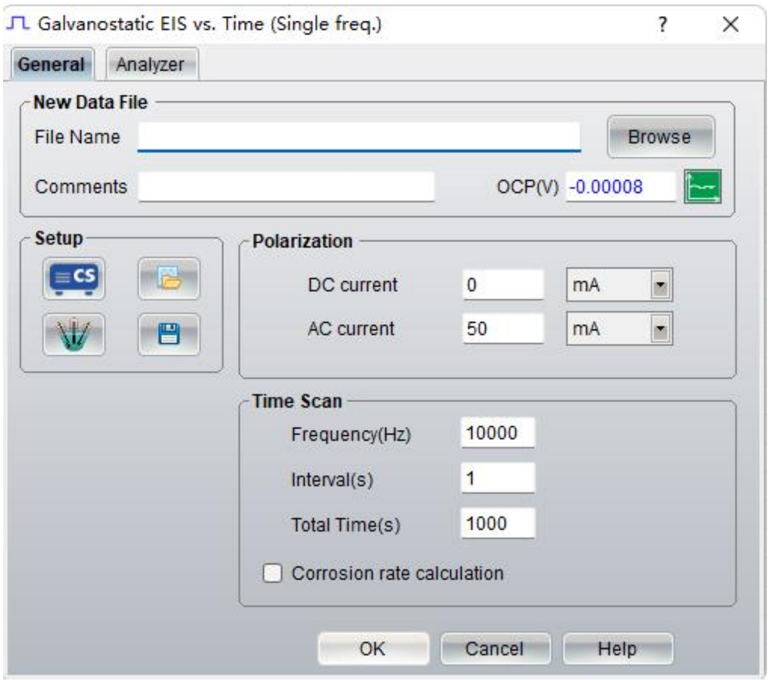
MPY =I_{corr}(A/cm^2)×chemical equivalent (g/mol)×393.7(mil/cm)÷density(g/cm^3)×365×24×3600(s/Y)÷96500(C/mol);

mm/a = MPY÷39.37(mil/mm).

9.7 Galvanostatic EIS vs. Time (Single freq.)

Experiments →Impedance → Galvanostatic EIS vs. Time (Single freq.)

It measures the single frequency impedance characteristics of the system as a function of time under AC current excitation signals. It studies the dynamic processes of some systems, such as conductivity, corrosion rate.



File Name

Comments

OCP(V) -0.00008

DC current 0 mA

AC current 50 mA

Frequency(Hz) 10000

Interval(s) 1

Total Time(s) 1000

☐ Corrosion rate calculation

DC current is the DC polarization current on the working electrode during impedance test.

AC current is the amplitude of the electrochemical impedance excitation signals.

Time Scan

In Impedance vs. Time scan, **frequency** of sine wave is constant.

Interval - interval for each single-frequency measuring point.

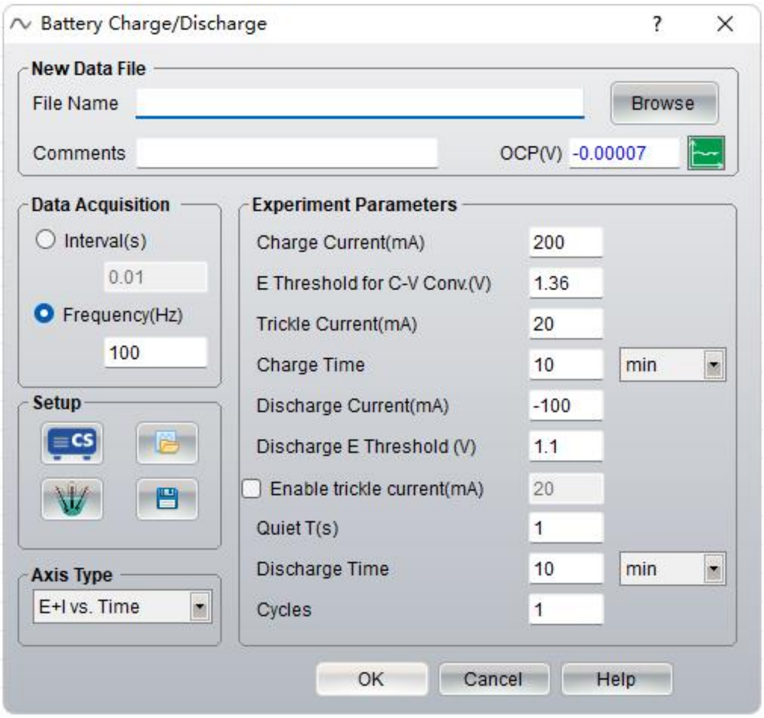
Total time- the total time of measurement.

10. Battery Test

10.1 Battery Charge/Discharge

Experiments→ Battery test→ Battery Charge/Discharge

It is used to test the charge and discharge characteristics of rechargeable battery and its lifetime.



Battery Charge/Discharge

New Data File

File Name

Comments

OCP(V) -0.00007

Data Acquisition

○ Interval(s) 0.01

● Frequency(Hz) 100

Setup

Axis Type: E+I vs. Time

Experiment Parameters

Charge Current(mA): 200

E Threshold for C-V Conv.(V): 1.36

Trickle Current(mA): 20

Charge Time: 10 min

Discharge Current(mA): -100

Discharge E Threshold (V): 1.1

☐ Enable trickle current(mA): 20

Quiet T(s): 1

Discharge Time: 10 min

Cycles: 1

Experiment parameters

Charge current: Connect the WE alligator to anode, and the RE & CE together to the cathode, if the OCP is positive, then a positive value entering means charging process.

E-Threshold for C-V Conv. is the voltage where charge process is changed from constant current mode to constant voltage mode. Normally in the early stage of charge, it is constant current charge mode. Once the battery voltage is higher than the E-Threshold voltage, it will convert to constant voltage mode. At this moment, the charge current will gradually decrease with time. When it falls to the **trickle current** (usually 10% ~ 20% of the charge current), the software will automatically stop charging.

Charge Time: the duration of charge

Discharge current: Connect the WE alligator to anode, and the RE & CE together to the cathode, if the OCP is positive, then a negative value entering means discharging process.

Discharge E threshold: During discharge process, when the voltage drops to this threshold voltage, the battery will stop discharge.

Check then Enable trickle current then during constant voltage discharge, when the current drops to this trickle current value the software will automatically stop discharging.

Quiet time - it specifies the interval from the state of charging to discharging. The battery is under open circuit during this time.

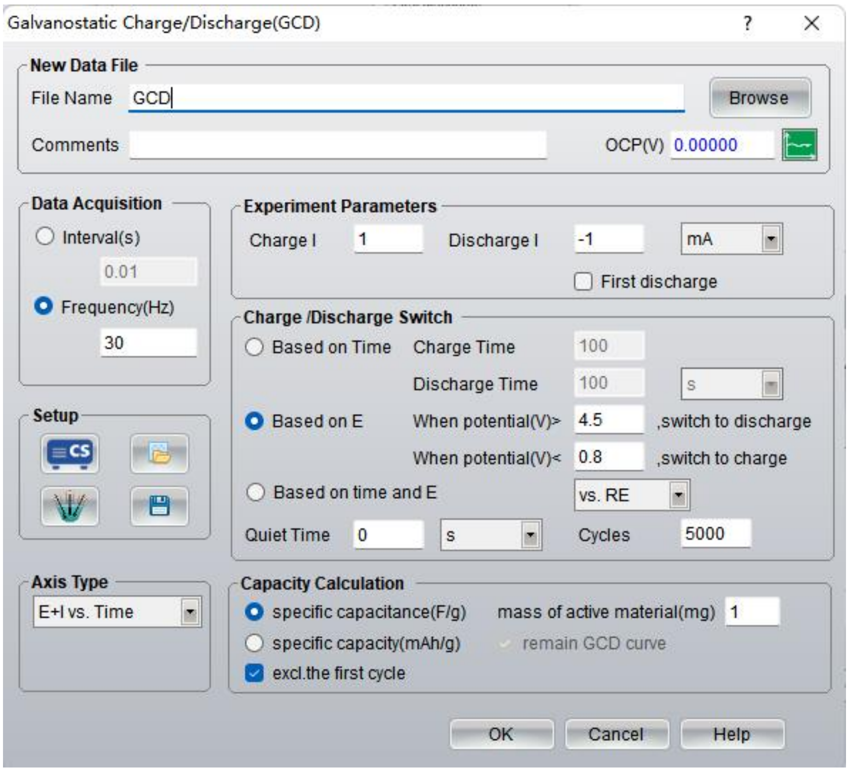
Discharge time -When the discharge time is reached, even the specified threshold voltage hasn’t been reached yet, the discharge process will be stopped, and turn to charge.

Cycles - a complete cycle includes a charging & discharging process. This parameter specifies the total number of cycles throughout the experiment. When the number is reached, the experiment will be stopped.

10.2 Galvanostatic Charge/Discharge (GCD)

Experiments→ Battery test→ Galvanostatic Charge/Discharge(GCD)

It measures cyclic charge-discharge characteristics of the electrode materials (such as secondary battery or supercapacitor electrode material) under a constant current. It tests the cycle lifespan of the electrode material.



Galvanostatic Charge/Discharge(GCD)

New Data File

File Name: GCD

Comments:

OCP(V): 0.00000

Data Acquisition

○ Interval(s): 0.01

● Frequency(Hz): 30

Experiment Parameters

Charge I: 1

Discharge I: -1

mA

☐ First discharge

Charge /Discharge Switch

○ Based on Time — Charge Time: 100; Discharge Time: 100 s

● Based on E — When potential(V)> 4.5 ,switch to discharge; When potential(V)< 0.8 ,switch to charge

○ Based on time and E

vs. RE

Quiet Time: 0 s

Cycles: 5000

Axis Type

E+I vs. Time

Capacity Calculation

● specific capacitance(F/g)

○ specific capacity(mAh/g)

mass of active material(mg): 1

☑ excl.the first cycle

Experiment parameters

Charge I: if the WE alligator connects to anode, a positive value means “charge”.

Discharge I: if the WE alligator connects to anode, a negative value means “discharge”.

First discharge: Default is charge firstly. The user can check **first discharge** and then it will do discharge firstly.

Charge / Dischare switch

Based on Time

It specifies the duration of the process of charge and discharge. Charge(discharge) will be stopped and it will turn to discharge(charge) if the time is reached. After the duration of discharge, a cycle is finished. It will go to the charge process again.

Based on E

The user should set the turning point voltage where charge stops and discharge begins, or the discharge stops and charge begins.

Based on Time and E

When either condition is met, the charge/discharge process will switch.

Cycles- a complete cycle includes a charge and a discharge process. It specifies the total number of cycles conducted throughout the experiment. When this number is met, the experiment will be stopped.

Quiet time: the intervals between charge and discharge. During the quiet duration the battery is under open circuit state, and there is no polarization from the instrument. if you set 0, meaning there is no wait time between charge and discharge.

Capacity calculation

Mass of active material: you should enter the mass of active material. This is a necessary parameter for capacity calculation.

Specific capacitance /specific capacity: You should choose either of them. The user can find the relevant data in the saved .dat data file.

Specific capacitance is calculated according to the following formula:

$$C=\frac{I\Delta t}{m\Delta V}$$

Where, I is charging(discharging) current. Δt is charging(discharging) time, ΔV is charging(discharging) potential difference, m is the mass of active material (Please note: m cannot be 0, otherwise the software will give an error prompt.)

Through many times of cyclic measurement, we can evaluate the cyclic lifespan of the battery, capacitors etc. By observing whether the charging and discharging curve are symmetric, we can judge whether charging and discharge, or the electrochemical reactions are reversible.

Charge-discharge efficiency (η) is calculated according to:

$$\eta=\frac{C_{dis}}{C_{ch}}\times 100\%$$

When change current = discharge current, $\eta=\frac{\Delta t_{dis}}{\Delta t_{ch}}\times 100\%$

Where, C_{ch}, C_{dis} is the charging capacitance and discharging capacitance, respectively.

Δt_{dis} Δt_{ch}, is discharging and charging time, respectively. They are displayed on the software.

On the testing winder, the specific capacity and efficiency curve are displayed. The user can find the relevant data in the saved .dat data file.

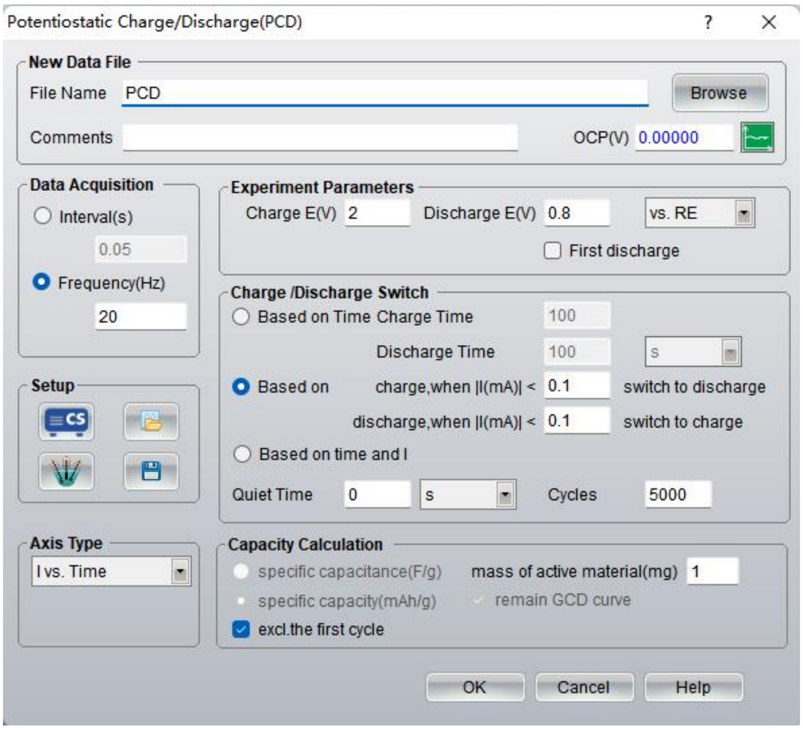
Excl. the first cycle: This is checked as default

Remain GCD curve: after checking it, the efficiency curve will be saved during test

10.3 Potentiostatic charge and discharge (PCD)

Experiments→ Battery test→ Potentiostatc Charge/Discharge(PCD)

This technique aims to checking the charge and discharge characteristic of the battery, and test the service life of the battery.



Potentiostatic Charge/Discharge(PCD)

New Data File

File Name: PCD

Comments:

OCP(V): 0.00000

Data Acquisition

○ Interval(s): 0.05

● Frequency(Hz): 20

Experiment Parameters

Charge E(V): 2

Discharge E(V): 0.8

vs. RE

☐ First discharge

Charge /Discharge Switch

○ Based on Time Charge Time: 100

Discharge Time: 100 s

● Based on charge,when |I(mA)| < 0.1 switch to discharge

discharge,when |I(mA)| < 0.1 switch to charge

○ Based on time and I

Quiet Time: 0 s

Cycles: 5000

Axis Type: I vs. Time

Capacity Calculation

○ specific capacitance(F/g)

○ specific capacity(mAh/g)

mass of active material(mg): 1

☑ remain GCD curve

☑ excl.the first cycle

Experiment parameters

Charge E (V): charge under a constant voltage.

Discharge E (V): discharge under a constant voltage.

First discharge: Default is charge firstly. The user can check **first discharge** and then it will do discharge firstly.

Charge / discharge switch

Based on Time: You can set the time for each process. When the time is up it will change from charge to discharge or from discharge state to charge.

Based on I: When the absolute value of current meets the condition for switch, it will go to a different process.

Based on Time and E

When either condition is met, the charge/discharge process will switch.

Quiet time: the intervals between discharge and charge. During the quiet time the battery is under open circuit state, and there is no polarization from the instrument.

Cycles: A cycle includes a charge and discharge process. When the number of charge-discharge process reaches this number you set, the whole test will be ended.

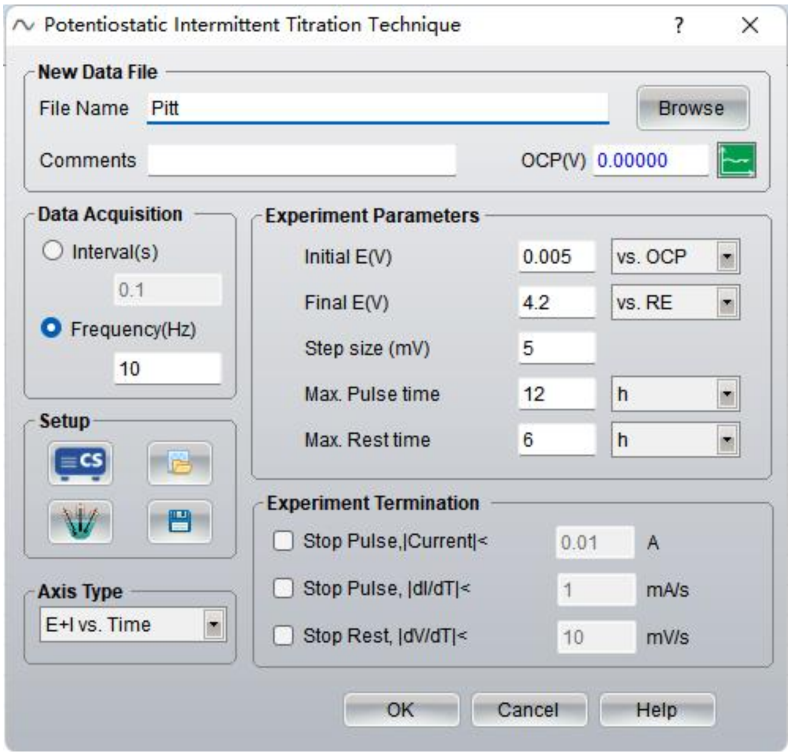
Capacity calculation

Specific capacitance and specific capacity not check as default. After the test, you can find the related calculation result in the data .dat

10.4 Potentiostatic Intermittent Titration Technique (PITT)

Experiments→ Battery test→ Potentiostatic Intermittent Titration Technique (PITT)

PITT techniques is used to test the charge and discharge characteristics of the battery, and the ion diffusion coefficient is further obtained, which reflects the reaction rate of the battery electrode reaction.



Potentiostatic Intermittent Titration Technique

New Data File

File Name: Pitt

Comments:

OCP(V): 0.00000

Data Acquisition

○ Interval(s): 0.1

● Frequency(Hz): 10

Axis Type: E+I vs. Time

Experiment Parameters

Initial E(V)	0.005	vs. OCP
Final E(V)	4.2	vs. RE
Step size (mV)	5	
Max. Pulse time	12	h
Max. Rest time	6	h

Experiment Termination

☐ Stop Pulse,|Current|<	0.01	A
☐ Stop Pulse, |dI/dT|<	1	mA/s
☐ Stop Rest, |dV/dT|<	10	mV/s

Experiment parameters

Step size: the potential difference of two adjacent pulses. It should be a positive value. When the initial E is higher than the final E, means under discharge. When initial E is lower than final E, means under charge.

Max. Pulse time: Pulse potential maximum holding time

Max. Rest time: Maximum Rest time. During Rest, there is no polarization from the instrument, and the battery is under OCP.

Experiment termination

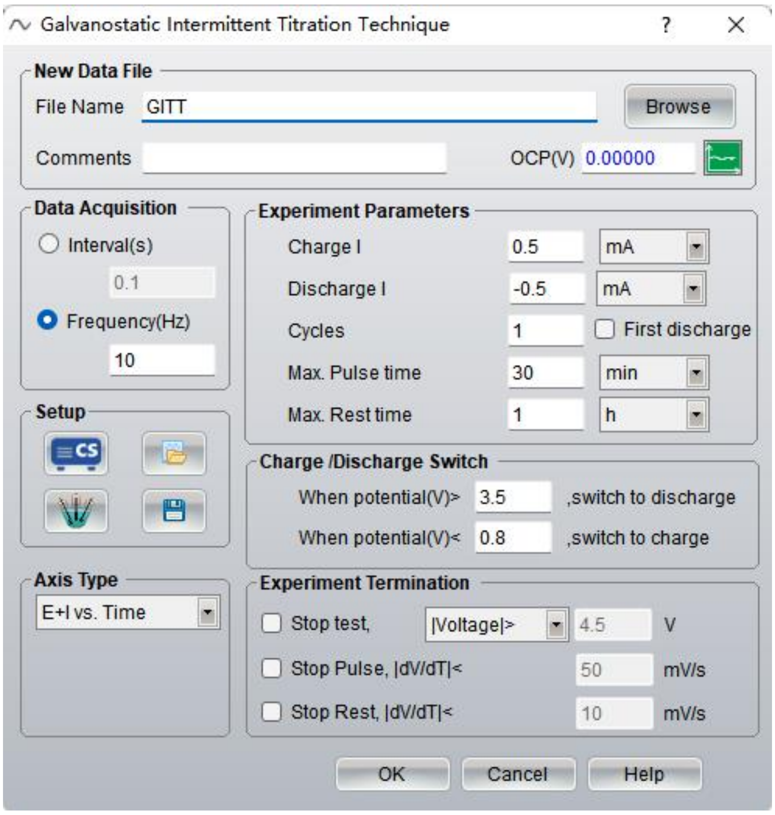
Stop Pulse, |Current|: The user can check the Enable box. When the absolute value of current is lower than the set value, then pulse will be stopped

Stop Pulse, |dI/dT|: The user can check the Enable box. When the absolute value of the current change per unit time is less than the set value, the pulse process stops

Stop Rest, | dV/dT|: The user can check the Enable box. When the absolute value of the potential change per unit time is less than the set value, the Rest process stops

10.5 Galvanostatic Intermittent Titration Technique (GITT)

Experiments→ Battery test→ Galvanostatic Intermittent Titration Technique (GITT)



Galvanostatic Intermittent Titration Technique

New Data File

File Name: GITT

Comments:

OCP(V): 0.00000

Data Acquisition

○ Interval(s): 0.1

● Frequency(Hz): 10

Experiment Parameters

Charge I: 0.5 mA

Discharge I: -0.5 mA

Cycles: 1 ☐ First discharge

Max. Pulse time: 30 min

Max. Rest time: 1 h

Charge /Discharge Switch

When potential(V)> 3.5 ,switch to discharge

When potential(V)< 0.8 ,switch to charge

Axis Type: E+I vs. Time

Experiment Termination

☐ Stop test, |Voltage|> 4.5 V

☐ Stop Pulse, |dV/dT|< 50 mV/s

☐ Stop Rest, |dV/dT|< 10 mV/s

Experiment parameters

Charge I: If the WE alligator connects to the anode, then a positive value means charge.

Discharge I: If the WE alligator connects to the anode, then a negative value means discharge.

First discharge: First charge is the default setting. The user can check **first discharge**

Cycles: the number of the cycles. A complete cycle includes a charge and a discharge.

Max. Pulse time: the maximum holding time of each pulse current

Max. Rest time: the maximum holding time of each rest. During rest, the system is under OCP.

Charge/Discharge Switch

The user can set the condition for charge and discharge switch

Experiment termination

Stop test: The user can check the Enable box. When the absolute value of the voltage is less or higher than the set value, the test will stop.

Stop Pulse: The user can check the Enable box. When the absolute value of the potential change per unit time is less than the set value, the Pulse process will stop.

Stop Rest: The user can check the Enable box. When the absolute value of the potential change per unit time is less than the set value, the Rest process will stop.

11. Corrosion Test

11.1 Open Circuit Potential (OCP)

Please see 3.1

11.2 Potentiodynamic(Tafel, LPR)

Please see 3.4

11.3 Linear polarization curve (LPR)

Please see 6.1

11.4 Potentiostatic EIS(Nyquist, Bode)

Please see 9.1

11.5 Mott-Schottky

Please see 9.5

11.6 Potentiostatic (i-t)

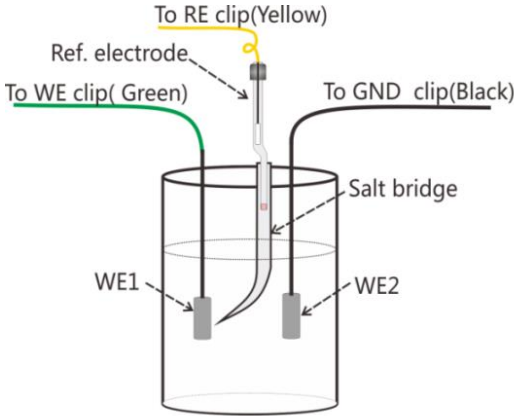
Please see 3.2

11.7 Electrochemical Noise (ECN)

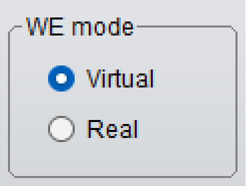
Experiments→Corrosion test→Electrochemical Noise

This method is mainly used to monitor noise potential and the noise current (zero resistance current or galvanic current) as a function of time. Monitoring time can be set.

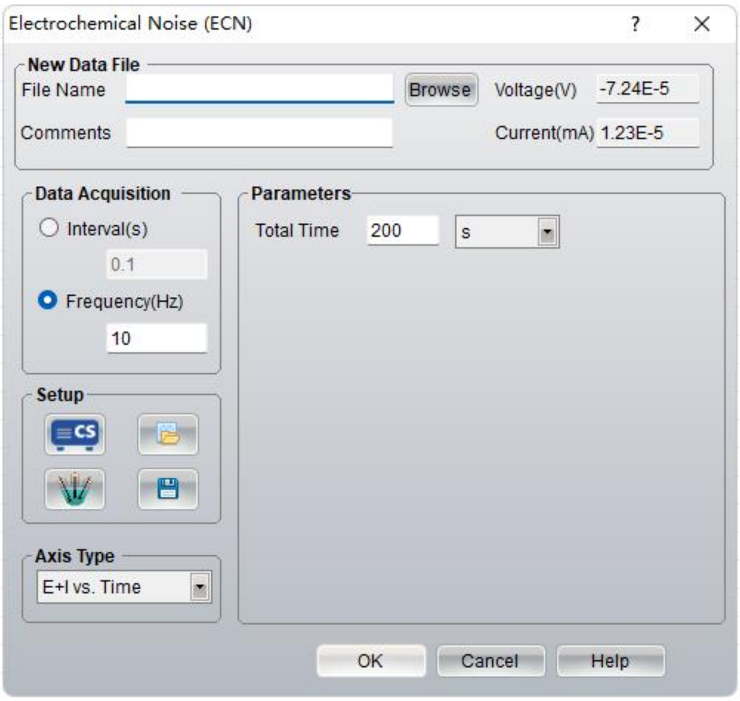
The ECN is different from other techniques in that it isn't in the state of polarization. In the noise/galvanic current measurement, the working electrode (galvanic) I is connected to the green WE alligator&white sense of the electrode cable, and working (galvanic) electrode II is connected to the black clamp (GND alligator), and the reference electrode is connected to the yellow RE alligator.



Please note: in the instruments setting ≡CS, you should choose "Virtual" in WE model for ECN test.


WE mode
● Virtual
○ Real

Run the CS Studio software, select electrochemical noise (ECN).



File Name

Comments

Voltage(V) -7.24E-5

Current(mA) 1.23E-5

○ Interval(s) 0.1

● Frequency(Hz) 10

Total Time 200 s

Axis Type: E+I vs. Time

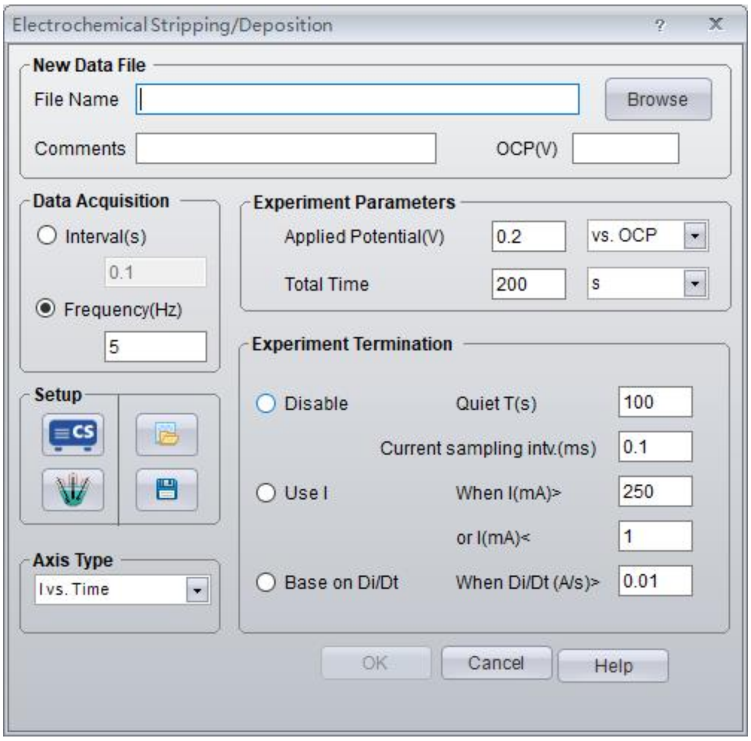
Voltage displayed in the software dialog box is the mixed potential

Current is the galvanic current. If the current value is positive, it means the working /galvanic electrode I (connects with WE alligator + sense) is anode and the working (galvanic)II(connects with GND alligator) is cathode. The current flows from electrode I to electrode II.

11.8 Electrostripping/Deposition

Experiments→Corrosion test→ Electrochemical Stripping/Deposition

A constant polarization potential is applied on the working electrode, and monitor the current as a function of time. The user can set a polarization time or set the conditions to terminate the experiment.



File Name

Comments

OCP(V)

○ Interval(s) 0.1

● Frequency(Hz) 5

Applied Potential(V) 0.2 vs. OCP

Total Time 200 s

○ Disable — Quiet T(s) 100

Current sampling intv.(ms) 0.1

○ Use I — When I(mA)> 250

or I(mA)< 1

○ Base on Di/Dt — When Di/Dt (A/s)> 0.01

Axis Type: I vs. Time

Experiment Parameters

Applied potential(V): the potential applied to the measured system. For CS series electrochemical workstation, if the polarization potential is "vs. OCP", then negative value means cathodic polarization, and positive value means anodic polarization. The user can select "vs. OCP", or "vs. RE"

Total time- you can specify the duration of potentiostatic polarization

Experiment Termination

Use I: If the user check it and set the quiet time and current sampling interval, the software will automatically terminate potentiostatic polarization test once the polarization current is higher than the specified higher value (anodic current) or lower than the specified lower value (cathodic current).

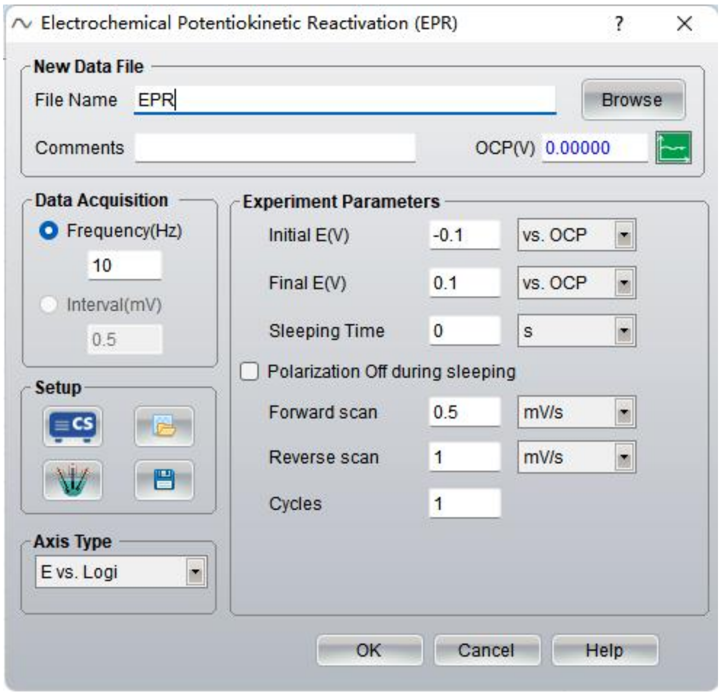
Based on Di/Dt: the program will automatically terminate potentiostatic polarization test once the Di/Dt is higher than the set value.

Disable: The experiment will not be terminated till the total time is reached.

11.9 Electrochemical Potentiokinetic Reactivation (EPR)

Experiments→Corrosion test→Electrochemical Potentiokinetic Reactivation

This technique can be applied to evaluate susceptibility to intergranular corrosion. It can be evaluated by I_a/I_r (activation peak current/reactivation peak current), or the ratio Q_a/Q_r.



New Data File
File Name EPR
Comments
OCP(V) 0.00000

Data Acquisition
● Frequency(Hz) 10
○ Interval(mV) 0.5

Axis Type: E vs. LogI

Experiment Parameters
Initial E(V) -0.1 vs. OCP
Final E(V) 0.1 vs. OCP
Sleeping Time 0 s
☐ Polarization Off during sleeping
Forward scan 0.5 mV/s
Reverse scan 1 mV/s
Cycles 1

Parameters setting

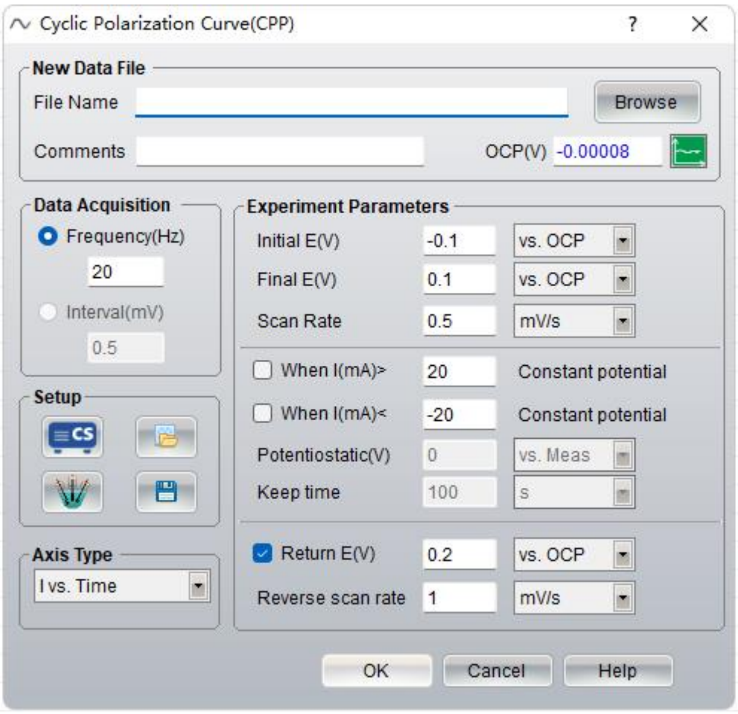
Initial E/Final E/Forward scan rate/Reverse scan rate: please refer to the parameter setting in technique Potentiodynamic.

Sleeping Time: the time interval between forward scan and Reverse scan

Cycles: The total number of cycles. After the total cycles is met, the experiment will stop. One complete cycle is composed of a forward scan and a reverse scan.

11.10 Cyclic polarization Curve (CPP)

Experiments→Corrosion test→ Cyclic polarization Curve(CPP)



Cyclic Polarization Curve(CPP)

New Data File
File Name:
Comments:
OCP(V): -0.00008

Data Acquisition
● Frequency(Hz): 20
○ Interval(mV): 0.5

Axis Type: I vs. Time

Experiment Parameters
Initial E(V): -0.1 vs. OCP
Final E(V): 0.1 vs. OCP
Scan Rate: 0.5 mV/s
☐ When I(mA)> 20 Constant potential
☐ When I(mA)< -20 Constant potential
Potentiostatic(V): 0 vs. Meas
Keep time: 100 s
☑ Return E(V): 0.2 vs. OCP
Reverse scan rate: 1 mV/s

Initial E, final E and scan rate: you can refer to contents in potentiodynamic

Condition to apply a constant potentiostat:

If you check **When I(mA) >**, it means when the current is higher than the set value, the instrument will apply a constant potential. The user can set the value and duration of the constant potential. Similarly, if you check **When I(mA) <**, the instrument will apply a constant potential when the current is lower than the set value.

If you don’t choose any condition, it will not proceed the potentiostatic process.

Potentiostatic: if you set vs. Meas, the potential the instrument apply is the sum of the instantaneous potential when potentiodynamic turns to potentiostatic and the setting value here in potentiostatic. If vs. OCP, the potential the instrument apply is the sum of OCP and the setting value. If vs. RE, the potential the instrument apply is the setting value.

Keep time: the duration of the constant potential being applied.

Return E: the reverse scan potential

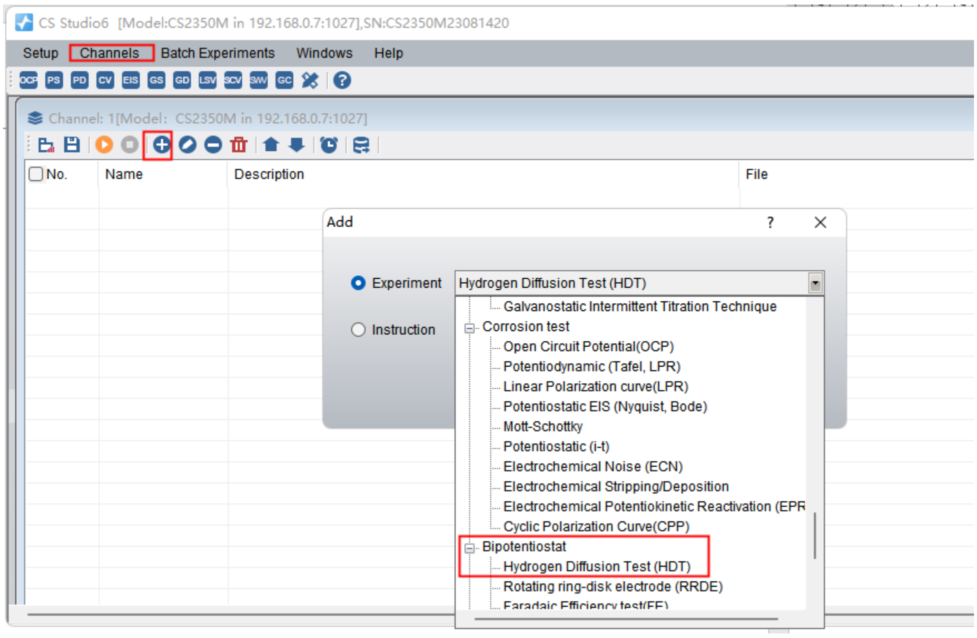
Reverse scan rate: the scan rate from final potential to return E

12. Bipotentiostat

12.1 Hydrogen Diffusion Test (HDT)

Experiments→ Bipotentiostat→ Hydrogen diffusion Test(HDT)

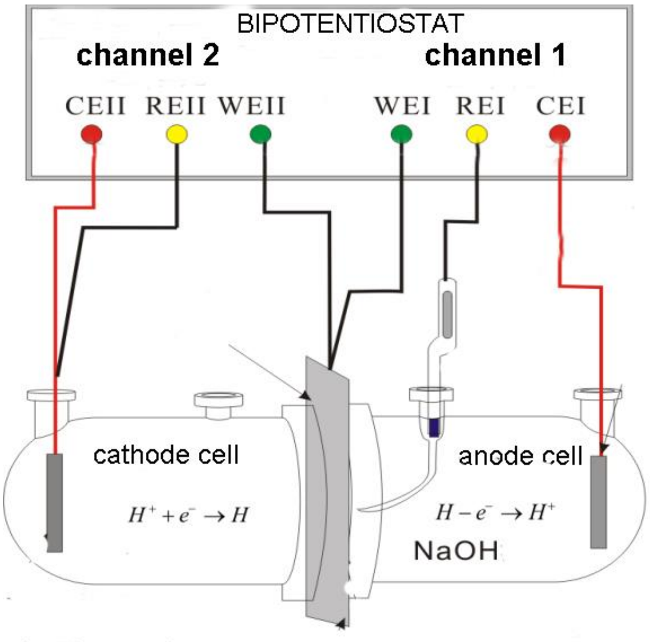
Hydrogen diffusion test requires a potentiostat with at least 2 channels. Our bipotentiostat model CS2350M/CS2150M are typically used. A multichannel potentiostat can also do it. You should set floating for the bipotentiostat in instrument setting.

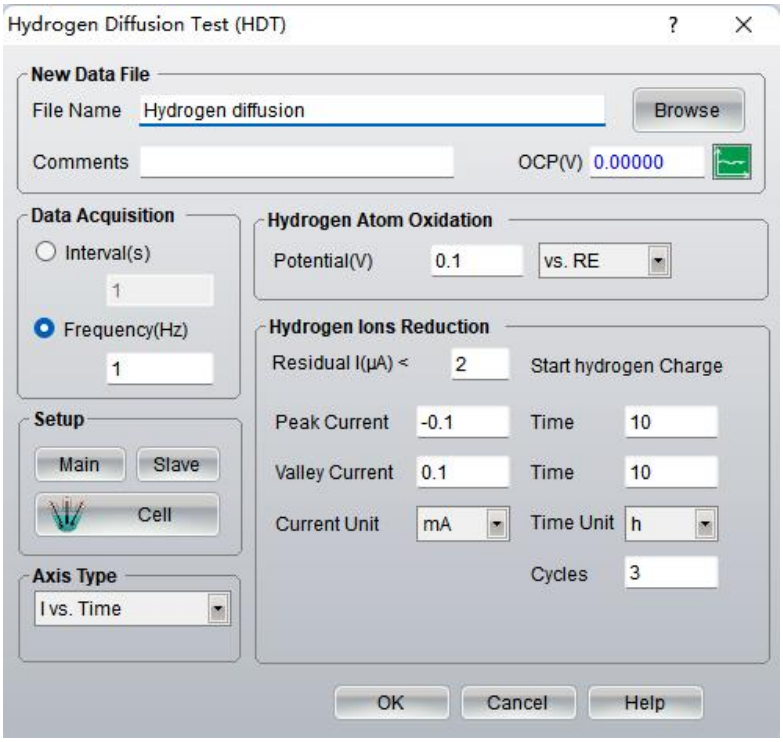


Hydrogen Diffusion Test (HDT) requires a set of H-cells which consist of two cells. For each cell, there is a set of reference &counter electrode, and they share a working electrode, which is usually a thin metal plate put in the middle. Anode cell is connected to channel #1(Cell 1 port on the front panel of bipotentiostat). Cathode cell is connected to channel #2(Cell 2 port).

The wiring connection of the bipotentiostat with H-cells is as follows:

The green WE and white SENSE should always connect together to the working electrode.





Hydrogen Diffusion Test (HDT)

New Data File
File Name: Hydrogen diffusion
Comments:
OCP(V): 0.00000

Data Acquisition
○ Interval(s): 1
● Frequency(Hz): 1

Hydrogen Atom Oxidation
Potential(V): 0.1 vs. RE

Hydrogen Ions Reduction
Residual I(μA) < 2 Start hydrogen Charge
Peak Current: -0.1 Time: 10
Valley Current: 0.1 Time: 10
Current Unit: mA Time Unit: h
Cycles: 3

Axis Type: I vs. Time

Hydrogen Atoms Oxidation (channel#1)

Potential (V): in anode cell, bipotentiostat channel #1 applies a polarization potential on the working electrode at the hydrogen current detection side. This potential makes the working electrode (metal plate) under anodic polarization. A positive value should be set so that hydrogen atoms can be oxidized to ions.

The anodic current will decline dramatically at the beginning, then slowly remain a stable value.

Hydrogen Ions Reduction (channel#2)

Residual I: When the residual current is lower than the set value, the instrument channel #2 starts galvanostatic polarization in cathode cell for hydrogen charging.

At the beginning, the main channel (channel #1) will firstly start potentiostatic polarization, making the hydrogen atoms in the metal fully diffuse onto the oxidation surface to be oxidized. It takes a relatively long time. Normally when the residual current is lower than 1~2μA/cm^2 (threshold of residual current), it's considered that hydrogen atoms in the metal are almost totally oxidized. Hydrogen charging current varies between the peak current and the valley current. Basically 10~20 minutes later (depending on the material and thickness of the metal), the anodic current detected in the main channel will increase gradually and finally keep stable, as hydrogen atoms diffuse and reach to the opposite side of the metal and are oxidized to form anodic current.

Peak current: the constant current applied on the working electrode for a period of **time** during hydrogen charging stage. It should be a negative value, because hydrogen ions should be reduced to atoms which diffuse to opposite side in anode cell.

Valley current: After the time of Peak current polarization is reached, the valley current is applied for a period of **time**. If it's a negative value, means continue to do hydrogen charging. If it's a positive value, then it consumes hydrogen atoms.

Cycles: it specifies the total number of cycles. A complete cycle includes hydrogen charging under peak current and hydrogen charging valley current.

Main/Slave settings

For bipotentiostat, the "main channel" and "slave channel"settings can be same or different.

Please choose “Floating” in Ground mode.

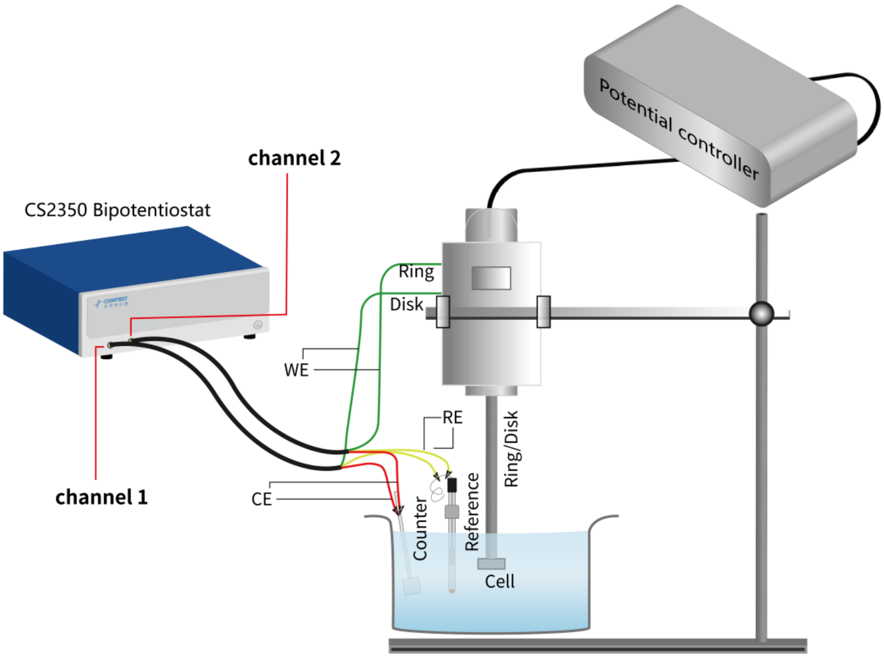
12.2 Rotating ring-disk Electrode (RRDE)

Experiments → Bipotentiostat → Rotating ring-disk electrode(RRDE)

CS2350M bipotentiostat can be used with any RRDE rotator to conduct RRDE experiment.

Disk working electrode and ring working electrode are two independent working electrode in concentric circle. Disk and ring should be controlled at different polarization potential to ensure that reaction products on disk can arrive in ring electrode for further redox reactions and be detected.

RRDE system should be connected to the bipotentiostat. The channel #2 controls the potential difference between disk and ring.



The main channel(channel#1) adopts the common three-electrode mode:

CE alligator(red) connects to the counter electrode

RE alligator(yellow) connects to the reference electrode

Green WE &white SENSE alligators connect together to the disk

The slave channel(channel#2) also adopts three-electrode mode:

CE alligator(red) connects to the same counter electrode

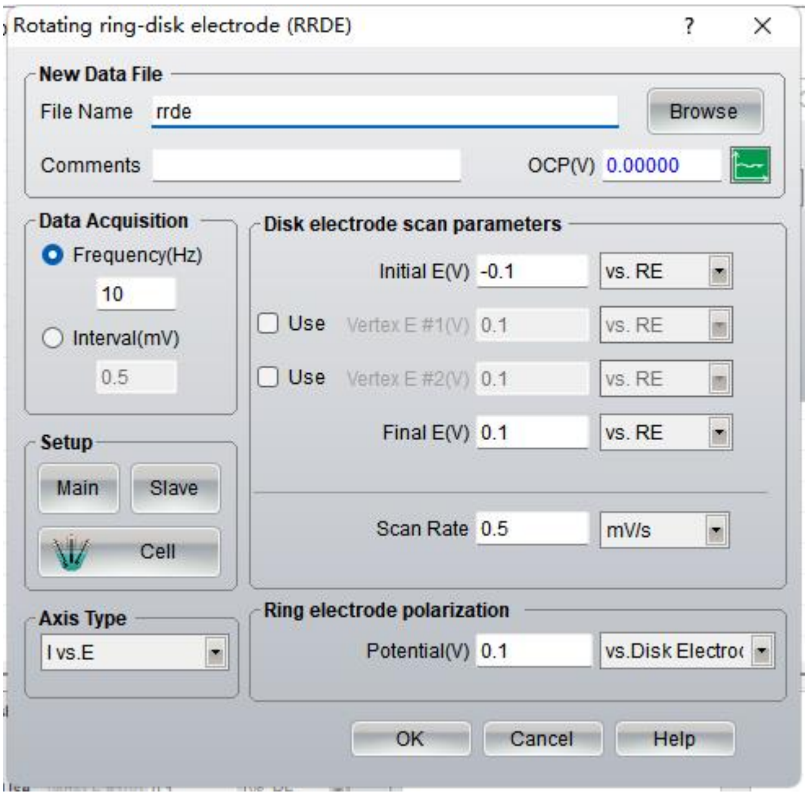
RE alligator(yellow) connects to the same reference electrode

Green WE &white SENSE alligators connect together to the ring

The intermediate products generated during polarization on disk will be further oxidized or reduced on the ring owing to the potential difference. Current on the ring is measured and displayed by slave channel (channel #2).

For RRDE test, the disk is the main working electrode, and the ring is used to detect the intermediate product. Potentiodynamic test is usually conducted on the disk, and the potential difference between ring and disk is set to be a constant value.

There are two groups of data: one is the polarization potential (E_d) and polarization current (I_d)on the disk (main channel /channel #1). The second group is the polarization potential E_r(fixed) and the current I_r on the ring (slave channel /channel #2).



Rotating ring-disk electrode (RRDE)

New Data File

File Name: rrde

Comments:

OCP(V): 0.00000

Data Acquisition

● Frequency(Hz): 10

○ Interval(mV): 0.5

Disk electrode scan parameters

Initial E(V): -0.1 vs. RE

☐ Use Vertex E #1(V): 0.1 vs. RE

☐ Use Vertex E #2(V): 0.1 vs. RE

Final E(V): 0.1 vs. RE

Scan Rate: 0.5 mV/s

Setup

Axis Type: I vs.E

Ring electrode polarization

Potential(V): 0.1 vs.Disk Electro(

Disk electrode scan parameters

Similar to potentiodynamic scan, up to 4 independent polarization potentials can be set on disk electrode.

Ring electrode polarization

Potential —polarization potential of ring electrode vs. the disk electrode, with unit of V.

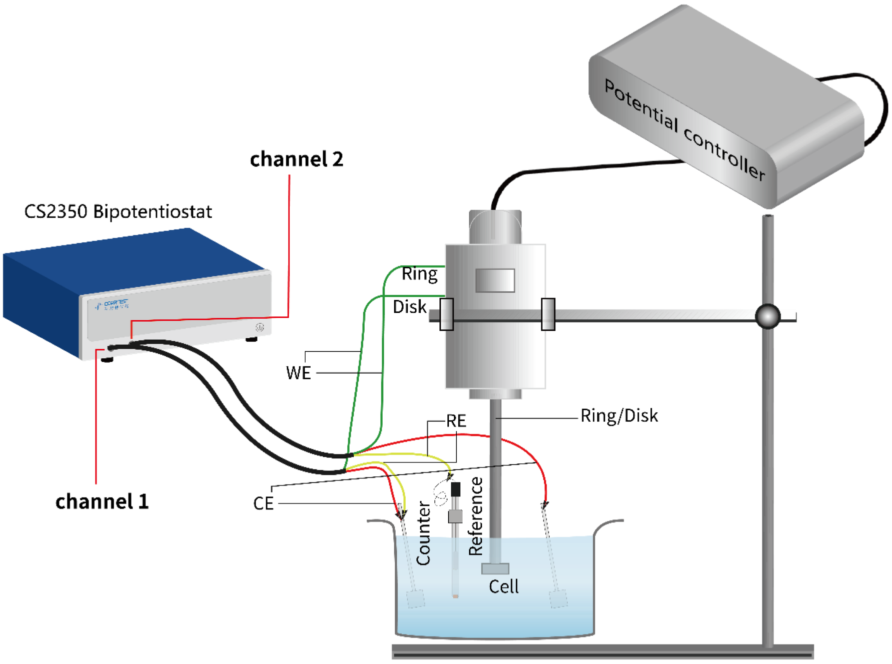
Main/Slave

For bipotentiostat, you need to do settings for the main & slave channel respectively.

12.3 Faradaic Efficiency(FE)

Experiments → Bipotentiostat → Faradaic Efficiency(FE)

Faradaic efficiency (FE) is the percentage of actual and theoretical productions, i.e., the utilization efficiency of energy conversion, and is used to evaluate the performance of catalysts in electrocatalytic reactions.

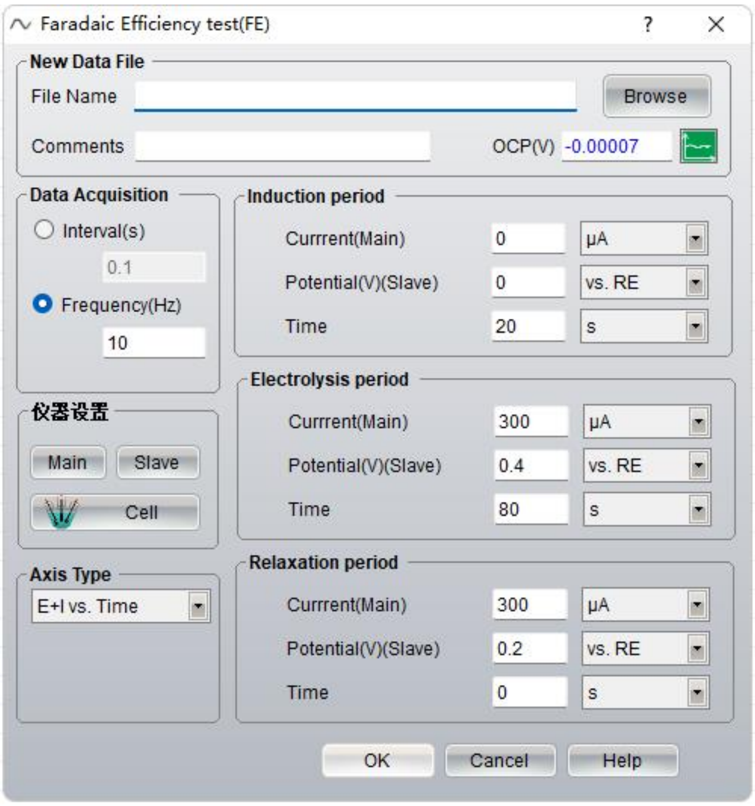


To do the Faradaic efficiency test, you will need a bipotentiostat and a RRDE rotator equipment. The wiring is shown in above diagram.

Channel 1(main): the working electrode alligators (WE+SENSE) connect together to the disk, the reference electrode (RE) and CE alligators clamp together to a counter electrode

Channel 2(slave): working electrode alligators (WE+SENSE) connect together to the ring, the RE alligator connects to the reference electrode, and the CE alligator connects to the other counter electrode.

A constant current is added on the disk for OER reaction to produce oxygen, and a constant voltage is applied on the ring for the ORR reaction to consume oxygen. Faradaic efficiency (FE) can be calculated based on the disk current, ring current, and the collection efficiency of the disk and ring electrodes.



Faradaic Efficiency test(FE)

New Data File

File Name

Comments

OCP(V) -0.00007

Data Acquisition

○ Interval(s) 0.1

● Frequency(Hz) 10

仪器设置

Axis Type

E+I vs. Time

Induction period

Currrent(Main) 0 µA

Potential(V)(Slave) 0 vs. RE

Time 20 s

Electrolysis period

Currrent(Main) 300 µA

Potential(V)(Slave) 0.4 vs. RE

Time 80 s

Relaxation period

Currrent(Main) 300 µA

Potential(V)(Slave) 0.2 vs. RE

Time 0 s

Users can set the current range switching, low-pass filter switch, data smoothing, etc. through the "Main" and "Slave" buttons. Note that the grounding mode must be **floating**.

13. Misc. Techniques

13.1 Electrochemical Noise (ECN)

Please see 11.7

13.2 Electrochemical Stripping/Deposition

Please see 11.8

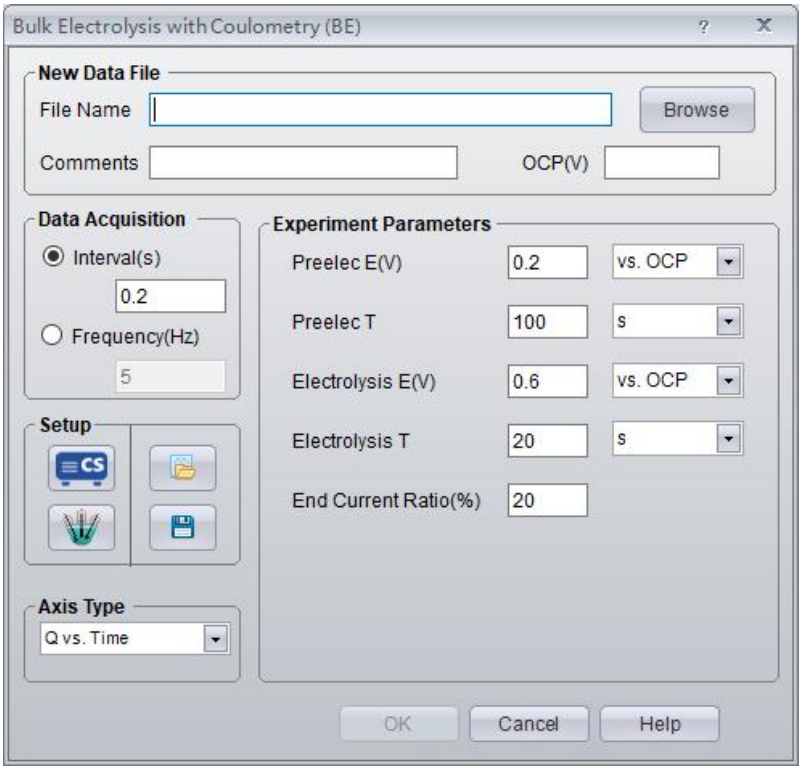
13.3 Electrochemical Potentiokinetic Reactivation (EPR)

Please see 11.9

13.4 Bulk Electrolysis with Coulometry (BE)

Experiments →Misc.Techniques →Bulk Electrolysis with Coulometry(BE)

In Bulk Electrolysis with Coulometry (BE), a constant potential is applied and the integrated charge is recorded as a function of time.



File Name

Comments

OCP(V)

● Interval(s) 0.2

○ Frequency(Hz) 5

Preelec E(V) 0.2 vs. OCP

Preelec T 100 s

Electrolysis E(V) 0.6 vs. OCP

Electrolysis T 20 s

End Current Ratio(%) 20

Q vs. Time

Parameters setting

Preelec E(V): the potential in pre-electrolysis process.

Preelec T: duration of the pre-electrolysis process.

Electrolysis E(V): the potential in electrolysis process.

Electrolysis T: duration of the process of electrolysis.

End current ratio (%): One condition to terminate the electrolysis process.

Electrolysis T and End current ratio jointly determine the termination of electrolysis.

Data Acquisition

If Frequency (Hz) is chosen, the acquisition rate in points/second is specified.

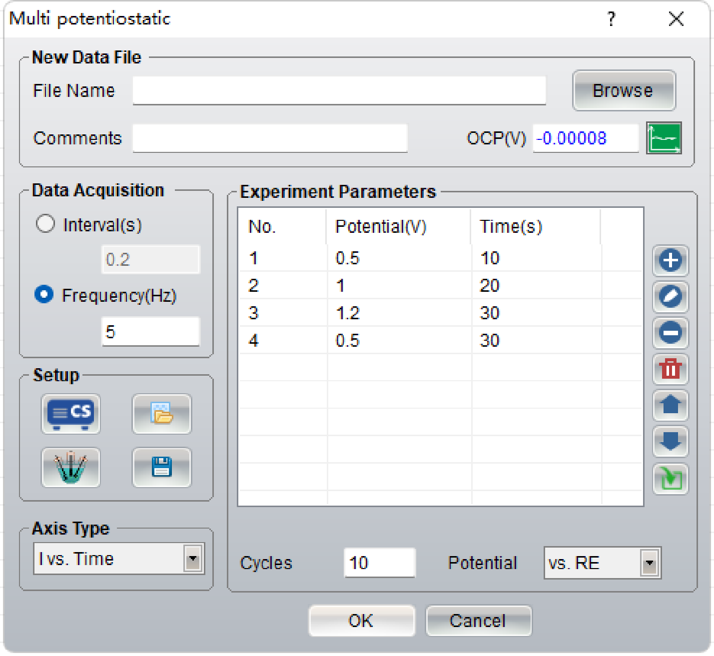
Axis Type

When the experiment is performed, the data will be displayed as specified by the Axis Type. CorrView can be later used to display the data in other formats.

13.5 Cyclic Polarization Curve (CPP)

Please see 11.10

13.6 Multi potentiostatic



File Name:

Comments:

OCP(V): -0.00008

○ Interval(s): 0.2

● Frequency(Hz): 5

Axis Type: I vs. Time

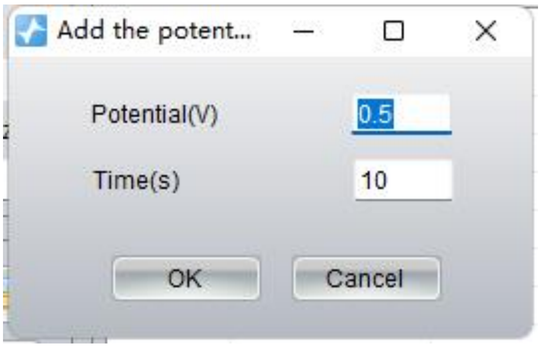
No.	Potential(V)	Time(s)
1	0.5	10
2	1	20
3	1.2	30
4	0.5	30

Cycles: 10

Potential: vs. RE

As its name suggests, multi potentiostatic aims to achieving custom measurements that set multi fixed potentials, multi duration and can do the cycling.

⊕ Set the value of the potential and duration



Potential(V): 0.5

Time(s): 10

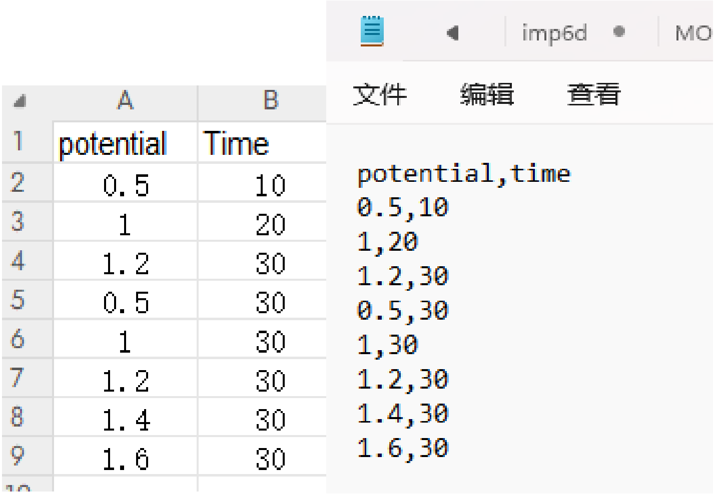
✎ Modify potential and duration

⊖ Remove the selected row

🗑 Remove all rows of projects

⬆⬇ move up or down to adjust the order

↘ You can fill out all the potentials and duration in advance in Excel(saved as csv format) or txt and then import the file(csv/txt) through this icon then all the data be set in the software. It's usually when there are a large number of potentials to be set.



	A	B
1	potential	Time
2	0.5	10
3	1	20
4	1.2	30
5	0.5	30
6	1	30
7	1.2	30
8	1.4	30
9	1.6	30

```
potential,time
0.5,10
1,20
1.2,30
0.5,30
1,30
1.2,30
1.4,30
1.6,30
```

Part 3 CS Analysis tool

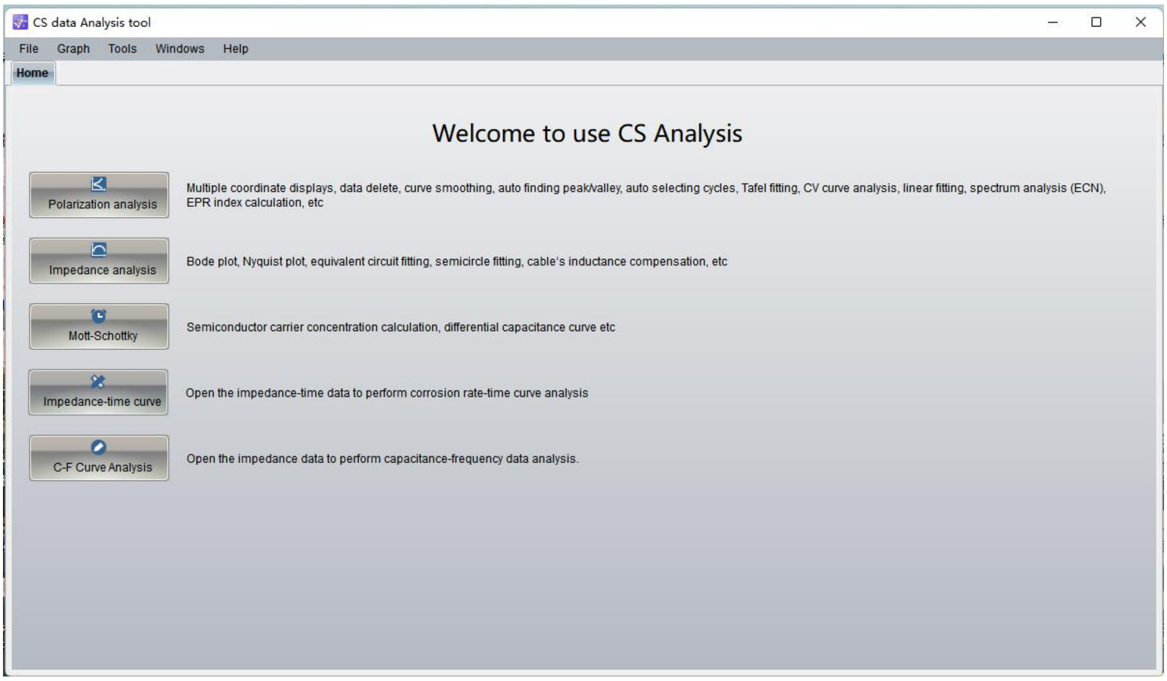
When you install the CS studio6, an individual CS analysis tool will be created automatically.

CS Analysis

The CS Analysis is used to complete analysis for the data measured by Corrtest Potentiostat/Galvanostat/Electrochemical Workstation. It's compatible to all data formats such as .txt, .csdat, .cor, and. z60.

The CS Analysis tool has powerful data analysis functions. It can do polarization curve fitting, calculate the polarization resistance R_p, Tafel slope b_a, b_c, corrosion current density i_{corr}, and self corrosion potential, etc. Based on the electrode parameters set by the user, the corrosion rate can also be calculated. It can perform FFT spectrum analysis on electrochemical noise data;

CS Analysis can do equivalent circuit fitting on impedance data and automatically provide values for each element; It can do fitting and analysis on Mott-Schottky data, and the user can select n-type or p-type semiconductor to obtain the carrier concentration and flat band potential.



Welcome to use CS Analysis

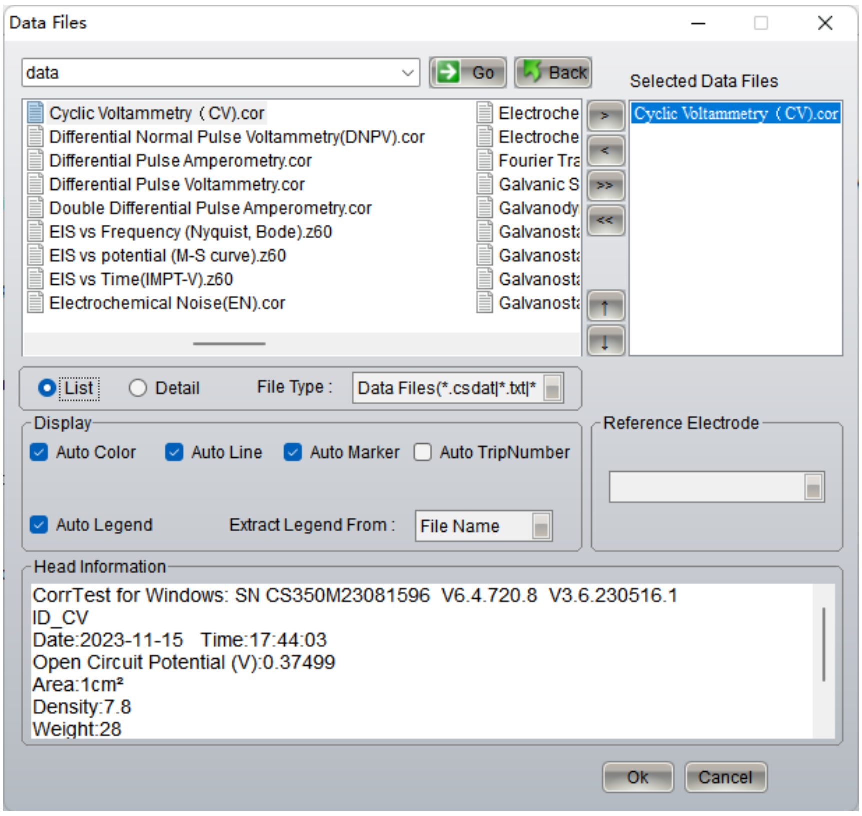
Polarization analysis	Multiple coordinate displays, data delete, curve smoothing, auto finding peak/valley, auto selecting cycles, Tafel fitting, CV curve analysis, linear fitting, spectrum analysis (ECN), EPR index calculation, etc
Impedance analysis	Bode plot, Nyquist plot, equivalent circuit fitting, semicircle fitting, cable's inductance compensation, etc
Mott-Schottky	Semiconductor carrier concentration calculation, differential capacitance curve etc
Impedance-time curve	Open the impedance-time data to perform corrosion rate-time curve analysis
C-F Curve Analysis	Open the impedance data to perform capacitance-frequency data analysis.

Interface of CS Analysis

14. File

14.1 Open file

Click Open file , the user can open any data file of .txt/.csdat/.cor/.z60 format. Select one or multi data files and click then you will have the data file(s) selected. Click OK to open the data and see the graph.



data

Cyclic Voltammetry（CV).cor
Differential Normal Pulse Voltammetry(DNPV).cor
Differential Pulse Amperometry.cor
Differential Pulse Voltammetry.cor
Double Differential Pulse Amperometry.cor
EIS vs Frequency (Nyquist, Bode).z60
EIS vs potential (M-S curve).z60
EIS vs Time(IMPT-V).z60
Electrochemical Noise(EN).cor
Electroche
Electroche
Fourier Tra
Galvanic S
Galvanody
Galvanosta
Galvanosta
Galvanosta
Galvanosta

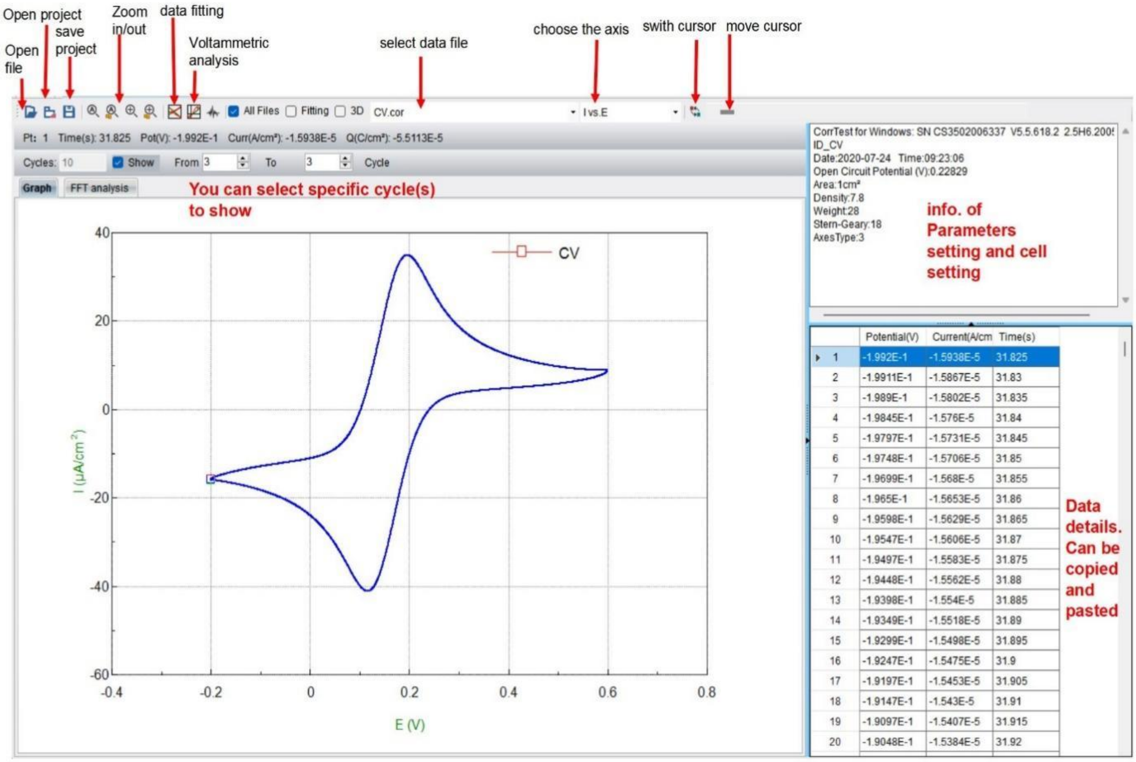
Selected Data Files: Cyclic Voltammetry（CV).cor

● List ○ Detail File Type : Data Files(*.csdat|*.txt|*

Display
☑ Auto Color ☑ Auto Line ☑ Auto Marker ☐ Auto TripNumber
☑ Auto Legend Extract Legend From : File Name

Reference Electrode

Head Information
CorrTest for Windows: SN CS350M23081596 V6.4.720.8 V3.6.230516.1
ID_CV
Date:2023-11-15 Time:17:44:03
Open Circuit Potential (V):0.37499
Area:1cm²
Density:7.8
Weight:28



Pt: 1 Time(s): 31.825 Pot(V): -1.992E-1 Curr(A/cm²): -1.5938E-5 Q(C/cm²): -5.5113E-5

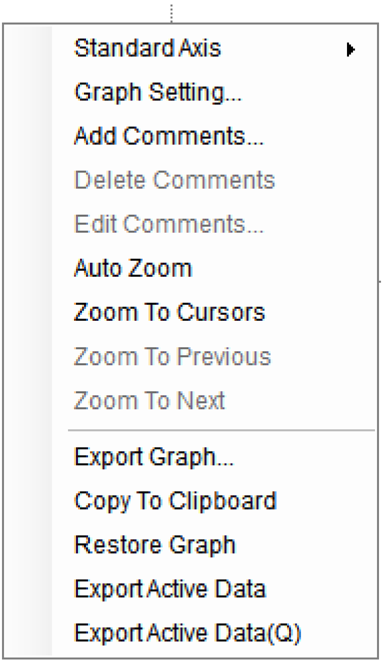
Cycles: 10 ☑ Show From 3 To 3 Cycle

CorrTest for Windows: SN CS3502006337 V5.5.618.2 2.5H6.200
ID_CV
Date:2020-07-24 Time:09:23:06
Open Circuit Potential (V):0.22829
Area:1cm²
Density:7.8
Weight:28
Stern-Geary:18
AxesType:3

	Potential(V)	Current(A/cm	Time(s)
1	-1.992E-1	-1.5938E-5	31.825
2	-1.9911E-1	-1.5867E-5	31.83
3	-1.989E-1	-1.5802E-5	31.835
4	-1.9845E-1	-1.576E-5	31.84
5	-1.9797E-1	-1.5731E-5	31.845
6	-1.9748E-1	-1.5706E-5	31.85
7	-1.9699E-1	-1.568E-5	31.855
8	-1.965E-1	-1.5653E-5	31.86
9	-1.9598E-1	-1.5629E-5	31.865
10	-1.9547E-1	-1.5606E-5	31.87
11	-1.9497E-1	-1.5583E-5	31.875
12	-1.9448E-1	-1.5562E-5	31.88
13	-1.9398E-1	-1.554E-5	31.885
14	-1.9349E-1	-1.5518E-5	31.89
15	-1.9299E-1	-1.5498E-5	31.895
16	-1.9247E-1	-1.5475E-5	31.9
17	-1.9197E-1	-1.5453E-5	31.905
18	-1.9147E-1	-1.543E-5	31.91
19	-1.9097E-1	-1.5407E-5	31.915
20	-1.9048E-1	-1.5384E-5	31.92

The data details on the right side can be selected, copied(ctrl+C) and pasted(ctrl+V).

Put your cursor at any place of the graph area, and right click to activate the following menu:



Standard Axis: you can specify the axis type

Graph setting: set the A and Y-axis width and scale etc

Add comments: add comments and it will directly display on the graph

Auto zoom: Auto adjust the size of the graph

Zoom to cursors: left-click the mouse, choose an area and then release it to zoom a regional graph

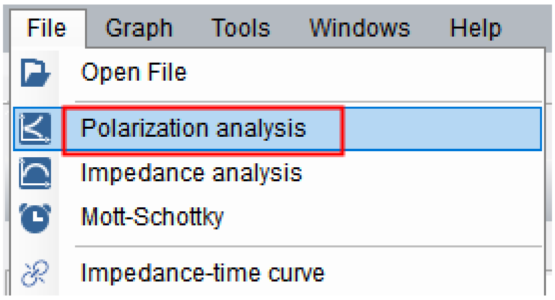
Export graph: export the current graph. The default format is .wmf.

Copy to Clipboard: copy the current graph and paste to clipboard

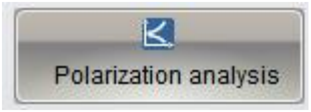
Restore graph: restore the graph to original state

Export active data: export the current active data. For instance, if you choose to show only the 3rd circle of a CV curve (as is shown in above picture), then you can export and get the raw data of only 3rd cycle by “export active data”. You can choose the format to be .csdat, .txt or .cor.

14.2 Polarization analysis



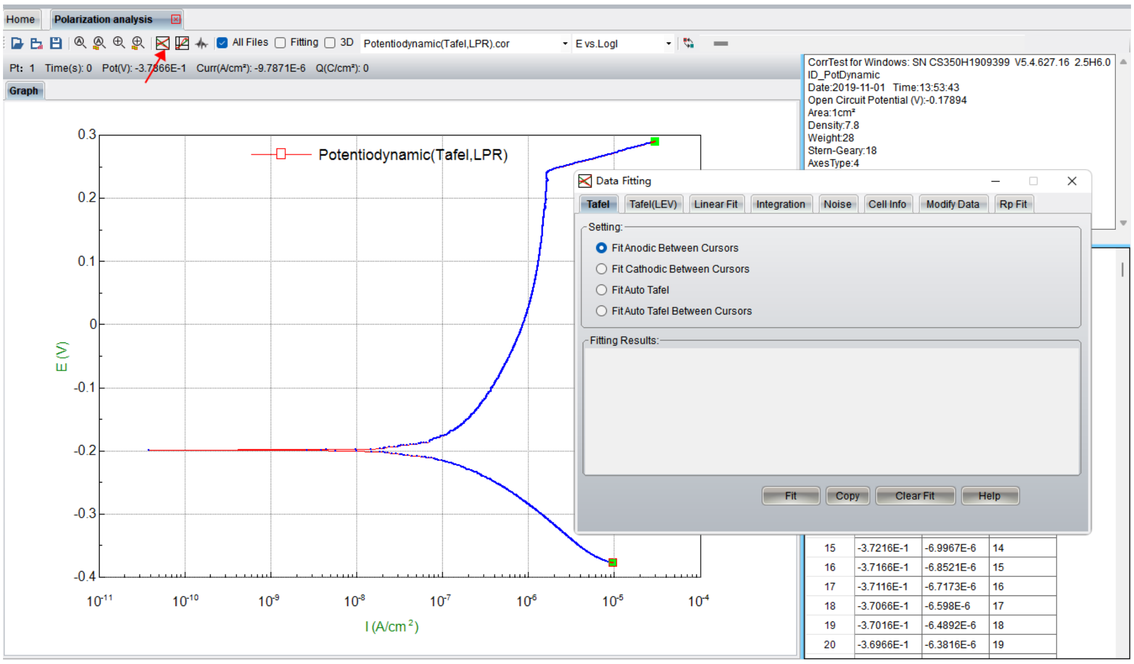
or



14.2.1 Data fitting

The user can open the polarization curve data files and do the fitting and analysis from

"Data Fitting"



Pt: 1 Time(s): 0 Pot(V): -3.7866E-1 Curr(A/cm²): -9.7871E-6 Q(C/cm²): 0

CorrTest for Windows: SN CS350H1909399 V5.4.627.16 2.5H6.0
ID_PotDynamic
Date:2019-11-01 Time:13:53:43
Open Circuit Potential (V):-0.17894
Area:1cm²
Density:7.8
Weight:28
Stern-Geary:18
AxesType:4

Setting:
● Fit Anodic Between Cursors
○ Fit Cathodic Between Cursors
○ Fit Auto Tafel
○ Fit Auto Tafel Between Cursors

Fitting Results:

15	-3.7216E-1	-6.9967E-6	14
16	-3.7166E-1	-6.8521E-6	15
17	-3.7116E-1	-6.7173E-6	16
18	-3.7066E-1	-6.598E-6	17
19	-3.7016E-1	-6.4892E-6	18
20	-3.6966E-1	-6.3816E-6	19

Tafel

It provides 4 methods. The anodic/cathodic fitting is based on linear fitting principle:

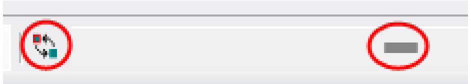
$$i = i_0\left[10^{\frac{E-E_0}{B_a}} - 10^{\frac{-(E-E_0)}{B_c}}\right]$$

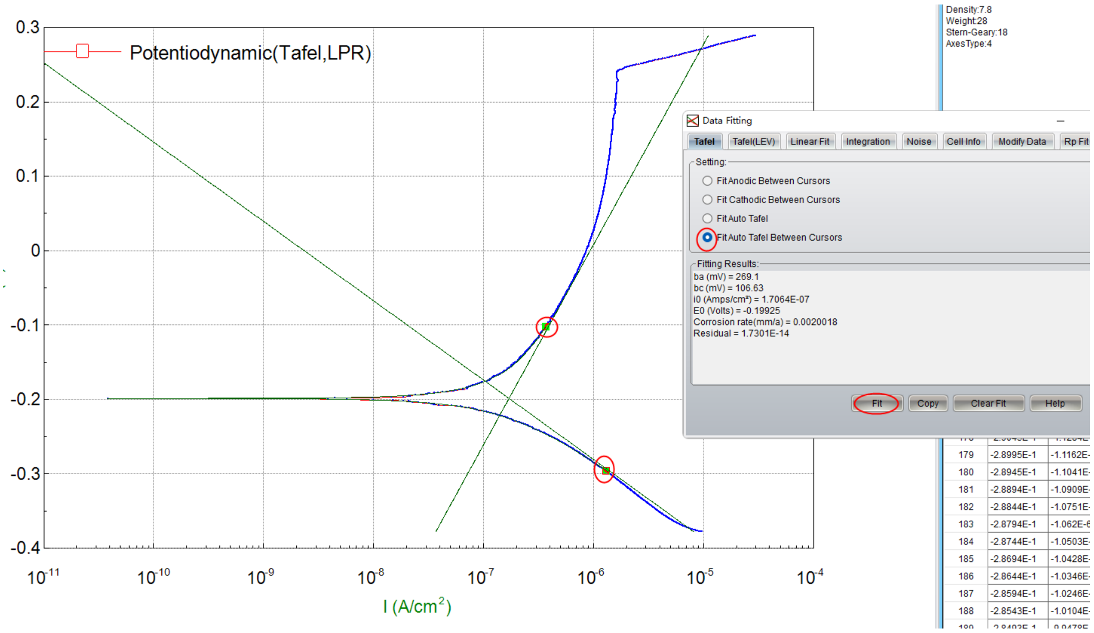
Fit Auto Tafel

By Fit Auto Tafel, the software will find the data points in range of +/-200mV around open circuit potential.

Fit Auto Tafel between cursors

By this method, you can use the below buttons to choose the potential area you want to fit and do the fitting. Usually +/-100mV around open circuit potential is recommended.





Density:7.8
Weight:28
Stern-Geary:18
AxesType:4

Setting:
○ Fit Anodic Between Cursors
○ Fit Cathodic Between Cursors
○ Fit Auto Tafel
● Fit Auto Tafel Between Cursors

Fitting Results:
ba (mV) = 269.1
bc (mV) = 106.63
i0 (Amps/cm²) = 1.7064E-07
E0 (Volts) = -0.19925
Corrosion rate(mm/a) = 0.0020018
Residual = 1.7301E-14

179	-2.8995E-1	-1.1162E-
180	-2.8945E-1	-1.1041E-
181	-2.8894E-1	-1.0909E-
182	-2.8844E-1	-1.0751E-
183	-2.8794E-1	-1.062E-6
184	-2.8744E-1	-1.0503E-
185	-2.8694E-1	-1.0428E-
186	-2.8644E-1	-1.0346E-
187	-2.8594E-1	-1.0246E-
188	-2.8543E-1	-1.0104E-

Tafel (LEV) Least square method

This method is usually used to do fitting of multi parameters, such as 4-, or 5- parameters fitting. It employs Levenberg-Marquardt fitting. If i_L is not used, then the equation is:

$$i = i_0\left[10^{\frac{E-E_0}{\beta_a}} - 10^{\frac{-(E-E_0)}{\beta_c}}\right]$$

If using the i_L, then the fitting equation is as follows:

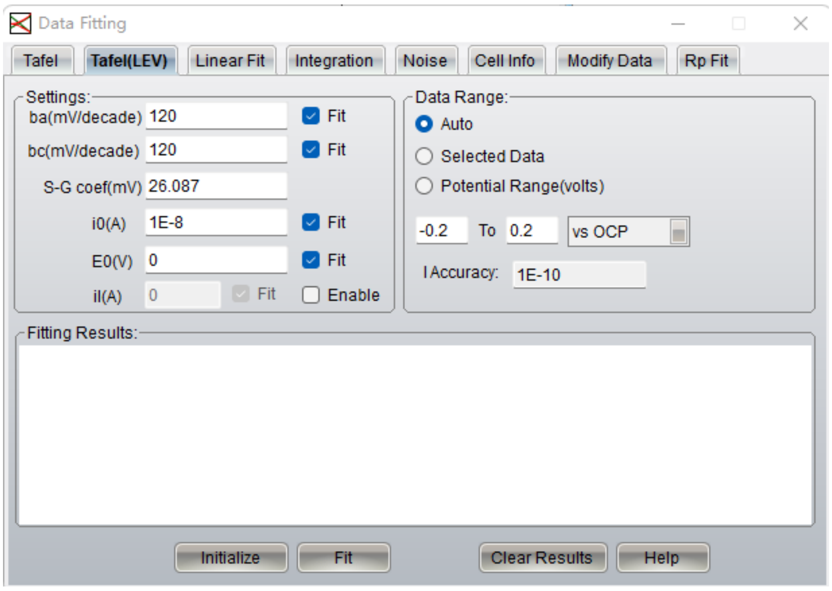
$$i = i_{corr}\left[e^{\frac{E-E_0}{\beta_a}} - \frac{e^{-\frac{E-E_0}{\beta_c}}}{1-\frac{i_0}{i_L}\left(1-e^{-\frac{E-E_0}{\beta_c}}\right)}\right]$$

During fitting, you must assign an initial value to the program.

After obtaining B_a, B_c, Stern-Geary coefficient is calculated according to the following formula:

$$B = \frac{\beta_a \times \beta_c}{\beta_a + \beta_c} = \frac{b_a \times b_c}{2.303(b_a + b_c)}$$

If the data range is set “Auto”, CS Analysis will automatically find the OCP, then choosing +/- 250mV range around OCP. If you don’t think it’s a suitable range, you can re-choose a range by locating the cursor in the curve. Then only data points between the two cursors are involved in the computing.



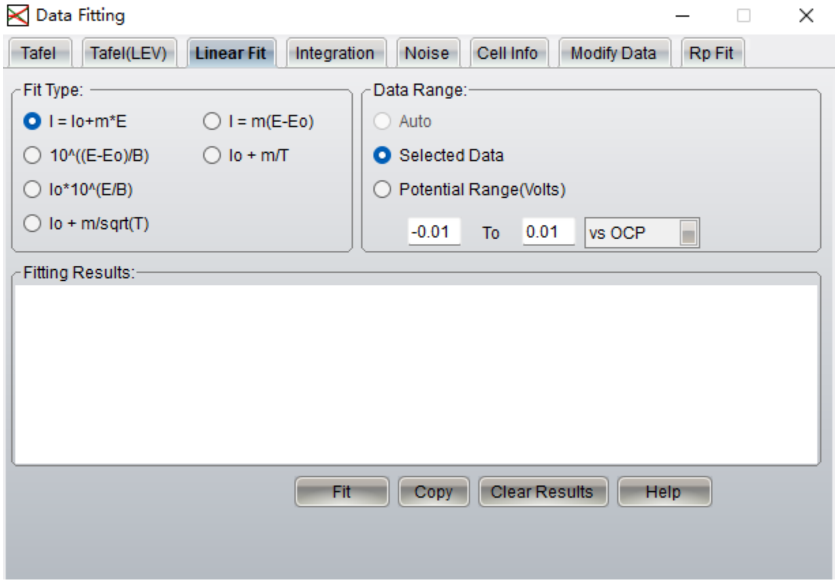
Settings:
ba(mV/decade) 120 ☑ Fit
bc(mV/decade) 120 ☑ Fit
S-G coef(mV) 26.087
i0(A) 1E-8 ☑ Fit
E0(V) 0 ☑ Fit
il(A) 0 ☑ Fit ☐ Enable

Data Range:
● Auto
○ Selected Data
○ Potential Range(volts)
-0.2 To 0.2 vs OCP
I Accuracy: 1E-10

Fitting Results:

Linear fit

There are 6 fit types, but the latter five methods are converted from the first one, i.e., according to linear equation: y = a + bx.



Fit Type:
● I = Io+m*E
○ I = m(E-Eo)
○ 10^((E-Eo)/B)
○ Io + m/T
○ Io*10^(E/B)
○ Io + m/sqrt(T)

Data Range:
○ Auto
● Selected Data
○ Potential Range(Volts)
-0.01 To 0.01 vs OCP

Fitting Results:

Linear fit principle

The linear fitting is based on the least square method.

$$\theta(\mathrm{a,b}) = \sum_{k=1}^{n} (y_k - a - bx_k)^2$$

By computing the acquired data points, we can obtain the value of a,b to make the minimum θ(a,b).

$$\begin{cases} \dfrac{\partial\theta(a,b)}{\partial a} = -2\sum_{k=1}^{n}(y_k - a - bx_k) = 0 \\ \dfrac{\partial\theta(a,b)}{\partial b} = -2\sum_{k=1}^{n}(y_k - a - bx_k)x_k = 0 \end{cases}$$

Expand the equation:

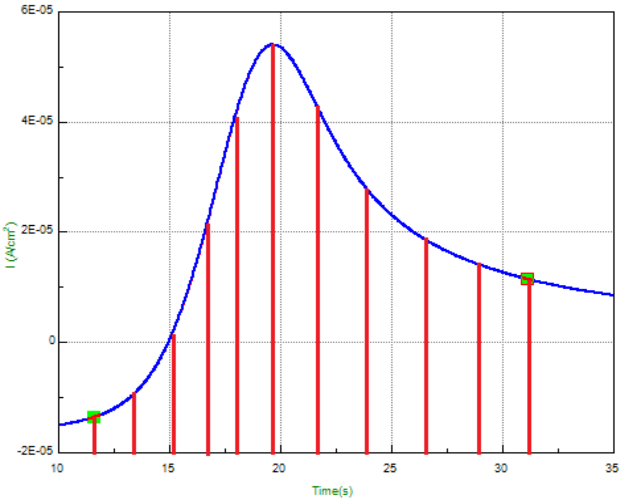
$$\begin{cases} na+\left(\sum_{k=1}^{n} x_k\right)b=\sum_{k=1}^{n} y_k \\ \left(\sum_{k=1}^{n} x_k\right)a+\left(\sum_{k=1}^{n} x_k^2\right)b=\sum_{k=1}^{n} x_k y_k \end{cases}$$

Integration

There are two kinds of integration, with background and without background. The calculation way is basically the same, using trapezoidal integration.

Q (Quantity of electric charges)-without background

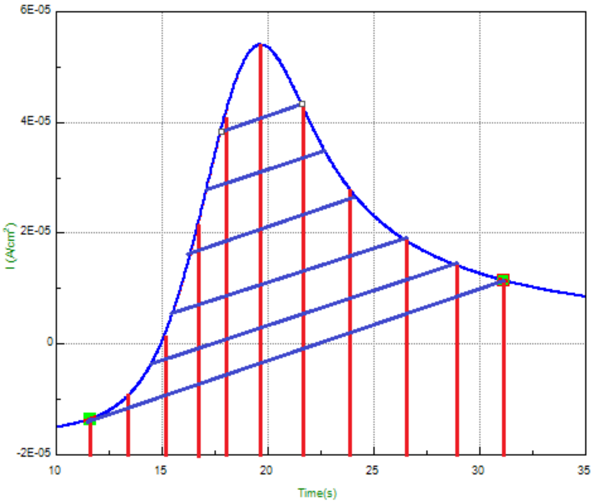
Trapezoidal integration means to calculate the area of the trapezoid constituted by two adjacent points, that is, do trapezoidal integration for every data point on the i-t curve. The current value is the bottoms, and the time difference (Δt) is the height (see the picture as below). The sum of each trapezoidal area is the quantity of electric charges.



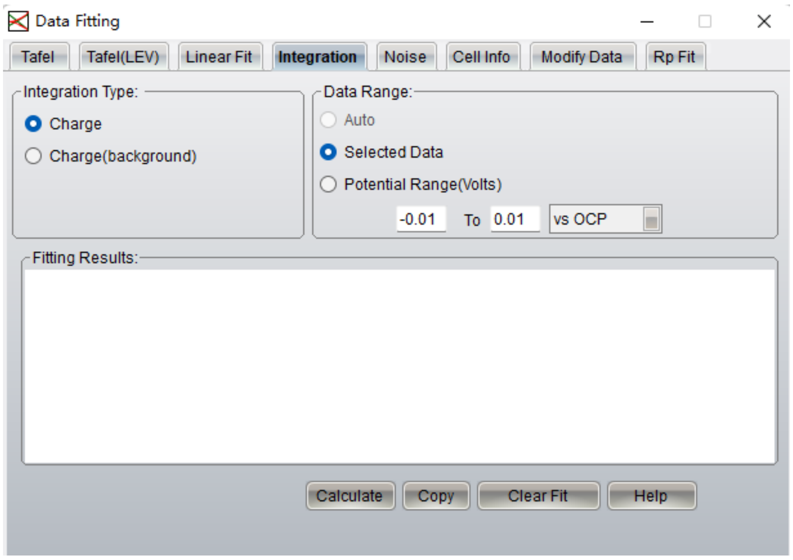
Q integration area diagram

Q (with background)

As shown in below picture, the area of the gird is to be obtained.



Q integration(with background) area



Integration Type:
- ● Charge
- ○ Charge(background)

Data Range:
- ○ Auto
- ● Selected Data
- ○ Potential Range(Volts)

-0.01 To 0.01 vs OCP

Noise

We can use the method of root-mean-square (RMS) to calculate the noise between cursors, and show the results.

E-RMS represents the RMS value of the potential noise after removing the background.

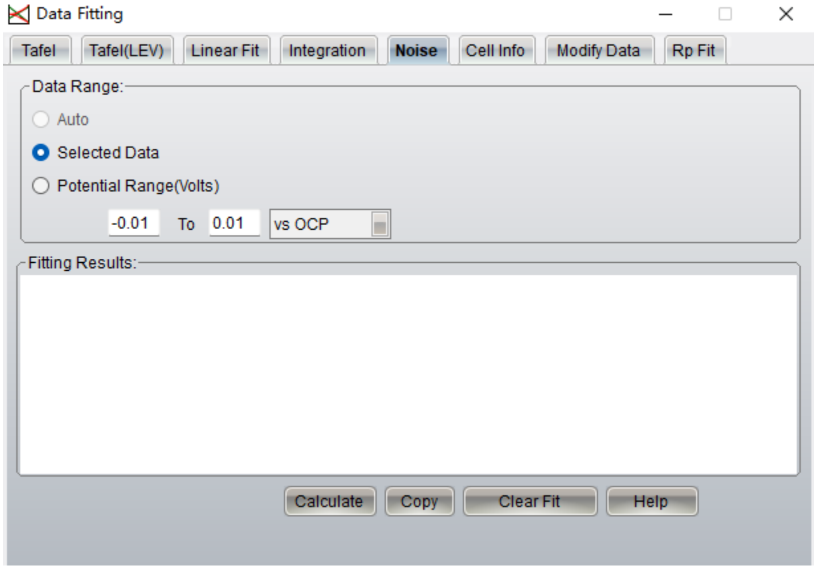
I-RMS represents the RMS value of the current noise after removing the background.

The formula is as follows:

$$\mathrm{RMS} = \sqrt{\frac{\sum_{i=1}^{n} x_i^2}{n}}$$

Where, n is the number of data points involved in the calculation, x_i is the #i data value.

Note: The results of the calculation strongly depend on the quality of data, sampling rate, filter and ambient noise etc. The validity of results depends entirely on the user’s judgment.



Data Range:
- ○ Auto
- ● Selected Data
- ○ Potential Range(Volts)

-0.01 To 0.01 vs OCP

Cell info

You can refer to 2.2 cell setting.

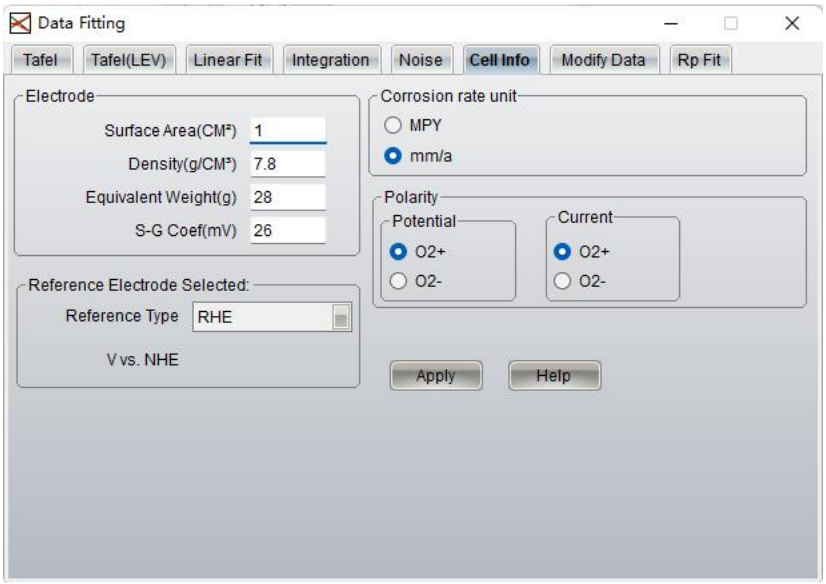
Surface Area: the exposed effective area of the working electrode in the solution. Unit is cm^2. Default is 1. If it is 1, the current density will be the same as the measured current value.

Density: the density of the working electrode material. Unit is g/cm^3.

Chemical Equiv. = the molar mass/number of electrons in a reaction. Take the reaction $Fe \rightarrow Fe^{2+}$ for example, the molar mass of pure iron is 55.84g, and the number of electrons in reaction is 2, so the equivalent weight is 55.84/2=27.92g.

Stern- Geary Coef.: in the range of 20 ~28mV.

Without above data, the user can only calculate the R_p and Tafel slope, and cannot obtain the corrosion rate value.



Electrode
Surface Area(CM²) 1
Density(g/CM³) 7.8
Equivalent Weight(g) 28
S-G Coef(mV) 26

Reference Electrode Selected:
Reference Type RHE
V vs. NHE

Corrosion rate unit
○ MPY
● mm/a

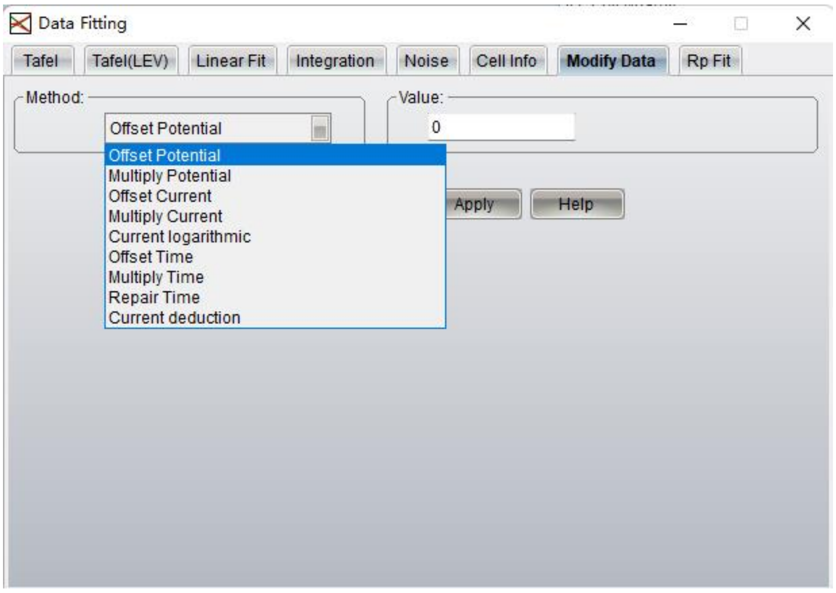
Polarity
Potential
● O2+
○ O2-
Current
● O2+
○ O2-

The “polarity” determines how to interpret positive or negative potential/current. When using the normal (O2+) rule, a more positive potential will generate greater oxidation driving force, and the generated current will also be positive. In a typical water environment (pH=0), when the electrode potential is +1.23V (vs. hydrogen standard electrode), oxygen will precipitate on the surface of the working electrode. If the reverse (O2-) is used, a more negative potential will generate a greater oxidation driving force, and the current will also be negative. In a typical water environment (pH=0), the electrode potential is -1.23V (vs. hydrogen standard electrode), and oxygen will precipitate on the surface of the working electrode.

Modify data

It’s used to modify the original data. It will change the data and graph according to the “Method” and “Value” you specify.

In the method, Offset means “plus”. For instance, if you want to do subtraction, just enter a negative value in “Offset”.



Method: Offset Potential

Value: 0

Rp Fit

Polarization resistance(R_p) is the slope of the E-I curve near the open circuit potential.

If the data range is set to be “auto”, CS Analysis will automatically find the open circuit potential (current is around 0), and choose data range of 20mV at each side of the OCP. If you don’t think this is an appropriate range, you can re-position the mouse on the curve to select a desired data range.

Fitting results:

R_p (Ohms/cm^2): slope of the curve

E_0(V): The potential where polarization current changes direction. They usually keep in accordance with the OCP of the system.

I_0(A/cm^2): current density is computed based on the Stern-Geary equation (Stern-Geary, J. Electrochem.Soc. 104,561957)

$$i_{corr} = \frac{\beta_a \times \beta_c}{\beta_a + \beta_c} \times \frac{1}{R_p}$$

Because the Tafel slope (b_a /b_c) cannot be obtained directly in linear polarization area, CS Analysis program assumes it to be 0.12V/dec, thus for Stern Geary coefficient:

$$B = \frac{\beta_a \times \beta_c}{\beta_a + \beta_c} = \frac{b_a \times b_c}{2.303(b_a + b_c)}$$

Basically, B value is 26 mV for the activation system, 52 mV for the passivation system; 18 mV for acidic system, 26 mV for neutral system, and 52 mV for alkaline system. Reasonable value is generally between 20~28mV.

Then,

$$I_{corr}(\mathrm{mA/cm^2}) = \frac{26\mathrm{mV}}{\mathrm{R_P}}$$

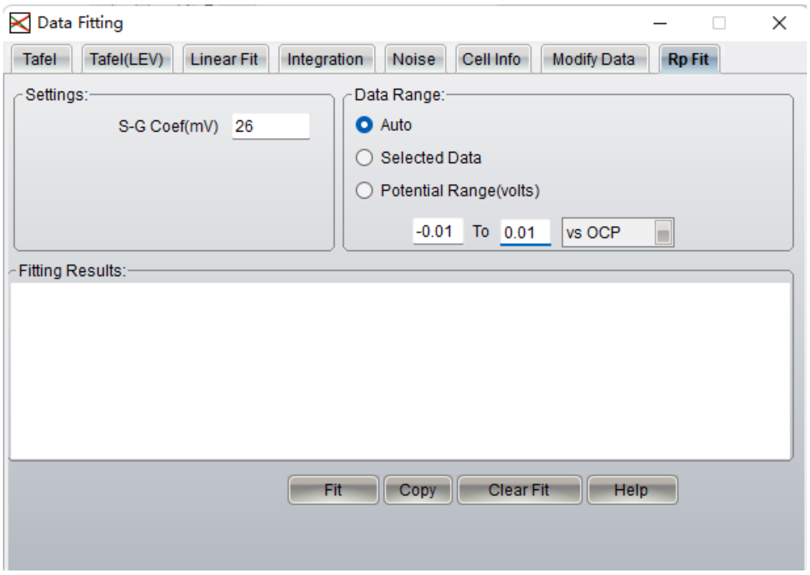
Corrosion rate is calculated according:

MPY =I_{corr}(A/cm^2)×chemical equivalent (g/mol)×393.7(mil/cm)÷density(g/cm^3)×365×24×3600(s/Y)÷96500(C/mol);

mm/a = MPY÷39.37(mil/mm).

For carbon steel,1mm/a = 11.73×I_{corr} (mA/cm^2), 1MPY = 462.2×$I_{cor\,r}$(mA/cm^2)

Therefore, only after the electrode data info are set can the corrosion rate of metal be calculated.

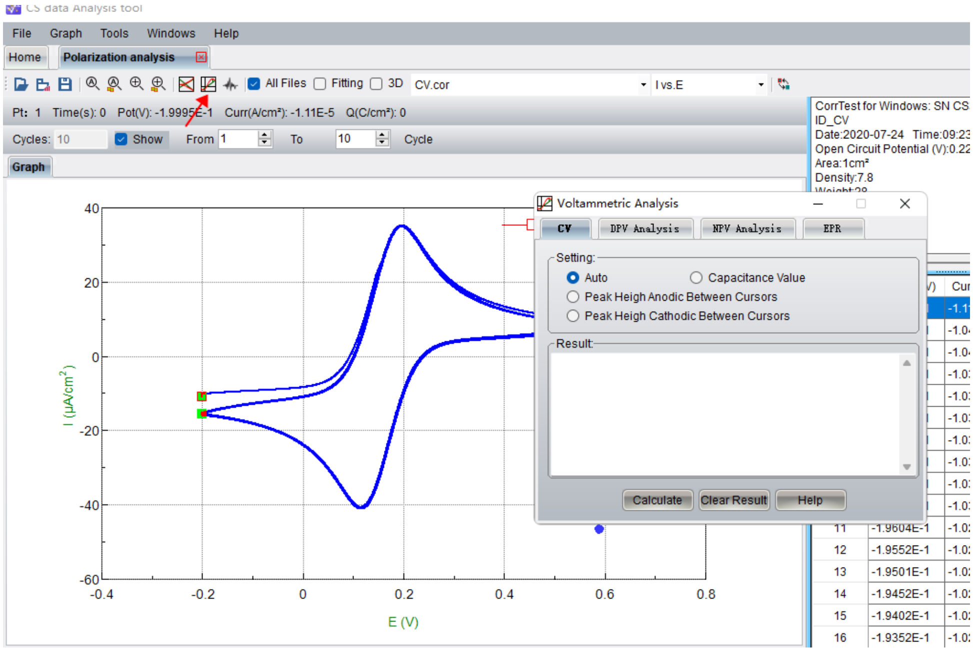


Settings:
S-G Coef(mV) 26

Data Range:
● Auto
○ Selected Data
○ Potential Range(volts)
-0.01 To 0.01 vs OCP

14.2.2 Voltammetry Analysis

In the menu of “voltammetry analysis” , there are: CV, DPV, NPV and EPR index calculation.



☑ All Files ☐ Fitting ☐ 3D CV.cor I vs.E

Pt: 1 Time(s): 0 Pot(V): -1.9995E-1 Curr(A/cm²): -1.11E-5 Q(C/cm²): 0

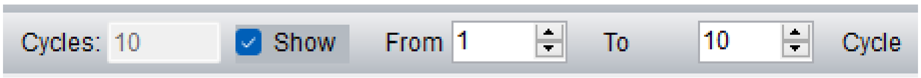
Cycles: 10 ☑ Show From 1 To 10 Cycle

CorrTest for Windows: SN CS
ID_CV
Date:2020-07-24 Time:09:23
Open Circuit Potential (V):0.22
Area:1cm²
Density:7.8

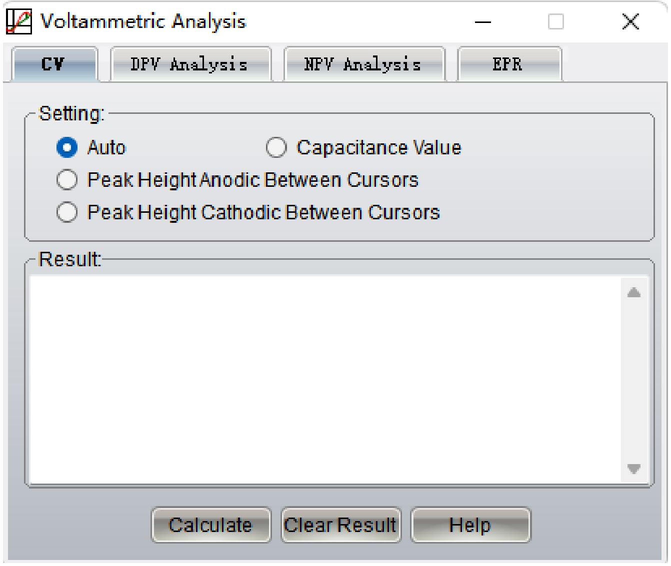
Setting:
● Auto ○ Capacitance Value
○ Peak Heigh Anodic Between Cursors
○ Peak Heigh Cathodic Between Cursors

Cyclic Voltammetry

If the number of cycles is more than 2, then there is a button “Show”. Check it, you can show specific cycle(s). If you want to show just one cycle, such as the 3rd cycle, then you can set from “3” to “3” cycle.



Cycles: 10 ☑ Show From 1 To 10 Cycle



Voltammetric Analysis

Setting:

● Auto ○ Capacitance Value

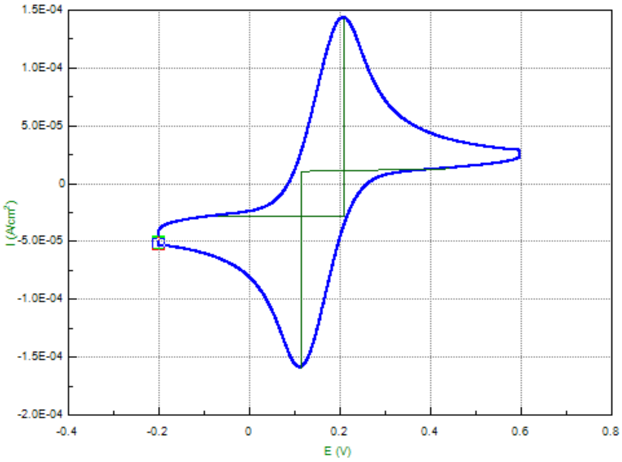
○ Peak Height Anodic Between Cursors

○ Peak Height Cathodic Between Cursors

Result:

Auto

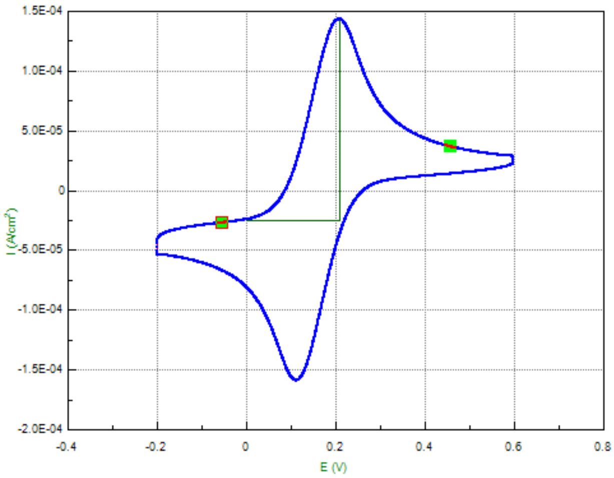
Because there may be multi cycles, the CS Analysis provides a method to find the peak: Firstly divide the data points cycle by cycle, then find the peak and valley of each cycle, and find a baseline which parallels to the X axis, obtaining the peak height and half-peak area. You can also find the peak and baseline manually.



CV auto analysis

Peak Height Anodic between Cursors

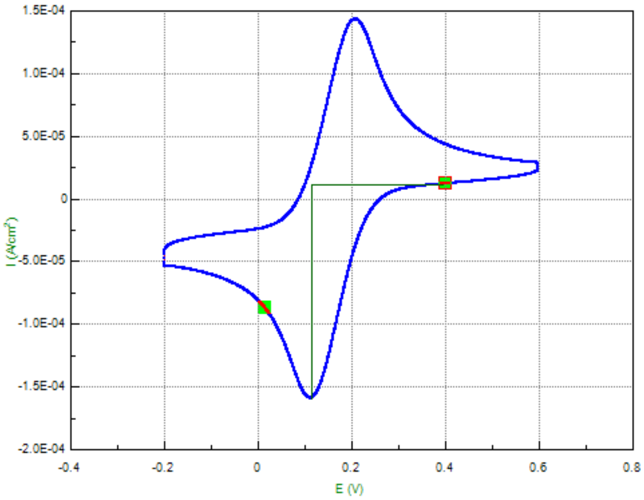
Through swap cursor and the move bar , the user can locate the beginning and end position for the anodic peak. The software will find the highest point as the peak. The peak height and half-peak area can be calculated.



Anodic peak interface between cursors

Peak Height Cathodic between Cursors

Through swap cursor ⇆ and the move bar ▬, the user can locate the beginning and end position for the cathodic peak. Then the software will find the peak height and the half-peak area according to the baseline and the bottom point.



Cathodic peak interface between cursors

In CV analysis, in order to show the height line, the coordinate axis must be I - E.

Capacitance value

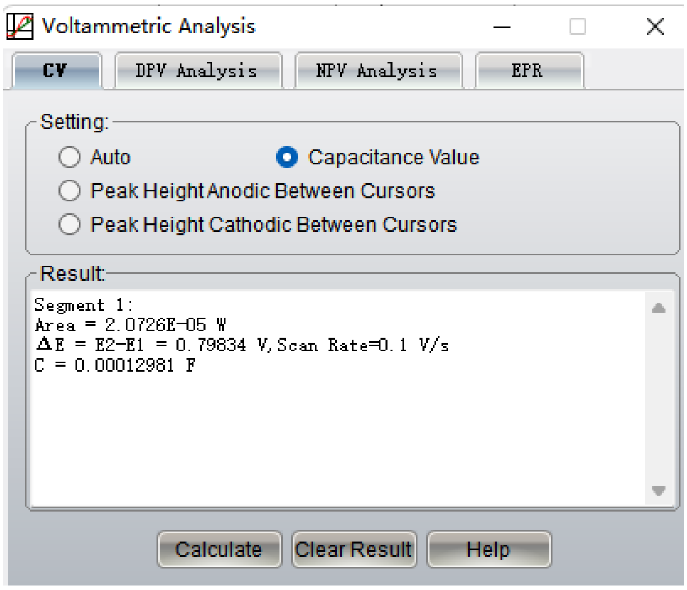
For CV graph, you can calculate the capacitance according to the following formula:

$$\mathrm{C} = \frac{\int_{E_1}^{E_2} i dE}{2v\Delta E}$$

Where, E_1, E_2 is the minimum, maximum potential in CV scan;

$\Delta E = E_2 - E_1$, v is the scan rate

The result is shown like this:



Setting:

○ Auto ● Capacitance Value

○ Peak Height Anodic Between Cursors

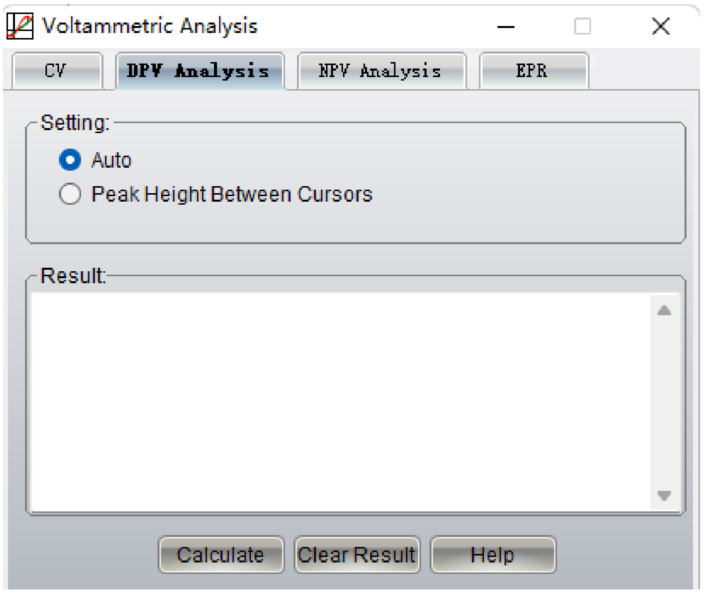
○ Peak Height Cathodic Between Cursors

Result:

```
Segment 1:
Area = 2.0726E-05 W
ΔE = E2-E1 = 0.79834 V,Scan Rate=0.1 V/s
C = 0.00012981 F
```

Differential Pulse Voltammetry (DPV)

It provides two methods: Auto and Peak height between cursors.



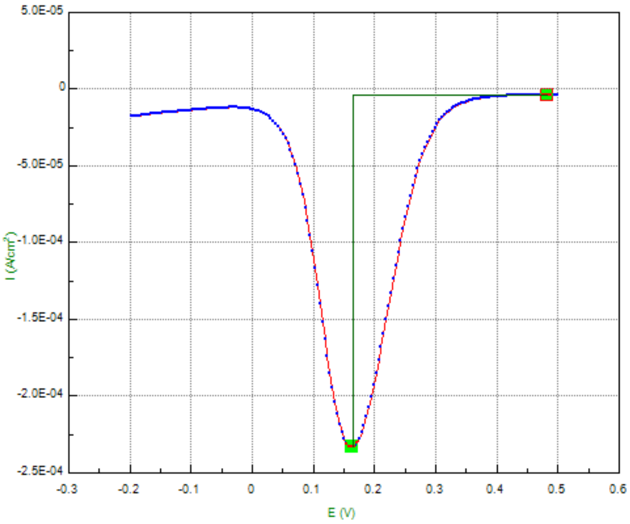
Setting:

● Auto

○ Peak Height Between Cursors

Auto

The CS Analysis will automatically find the maximum current value as the peak height, and find the place where the slope is near to zero to be the baseline, then calculate the peak height and half-peak area.



DPV curve in $K_3Fe(CN)_6$ system

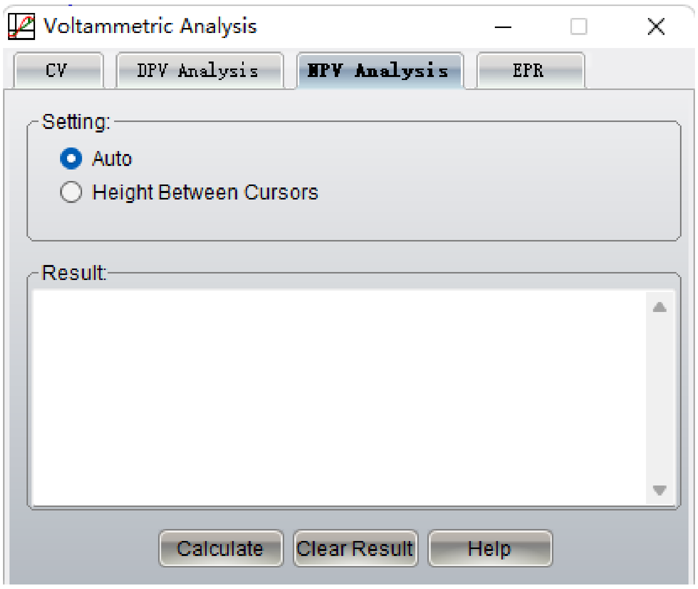
Peak Height Between Cursors

Because by Auto there will be error or it's not desirable, then we supply manual method. Using swap cursor ⇄ and the move bar ▬ to locate the beginning and ending points, the software will then find the peak height and half-peak area based on the baseline and highest point.

In voltammetric analysis, in order to show the height line, the coordinate must be I-E.

Normal Pulse Voltammetry(NPV)

It supplies two methods: Auto and Height between cursors.



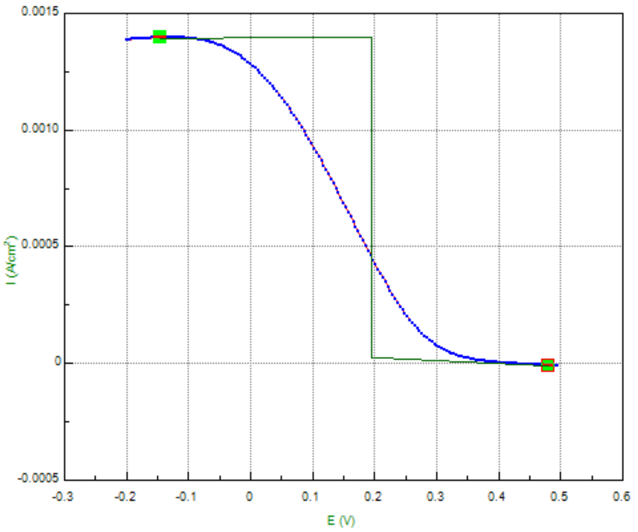
Setting:

● Auto
○ Height Between Cursors

Result:

Auto

The CS Analysis firstly find the median current, and then regard the lines that most parallel to X-axis as the baselines, then calculate the height.

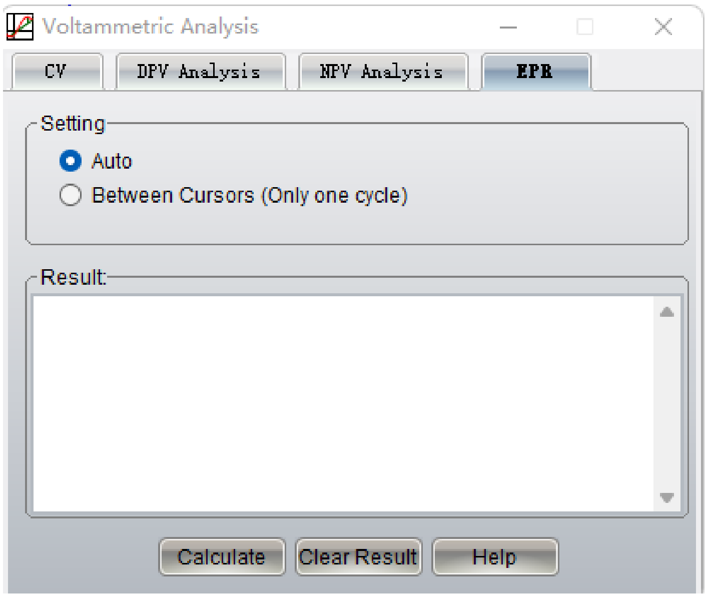


NPV curve in $K_3Fe(CN)_6$ system

Height between cursors(manual)

Find the median current of the data points of a whole segment, and make the baseline of the point where the cursor is on, then calculate the height between two baselines.

EPR



Voltammetric Analysis

Setting

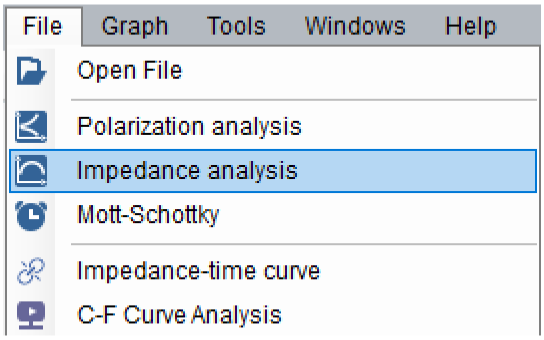
● Auto

○ Between Cursors (Only one cycle)

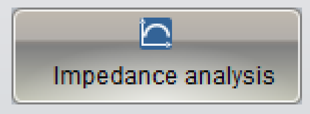
Result:

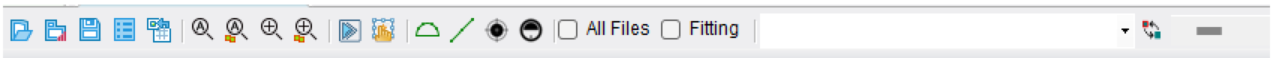
14.3 Impedance Analysis

The user can do EIS analysis by Impedance analysis.



or



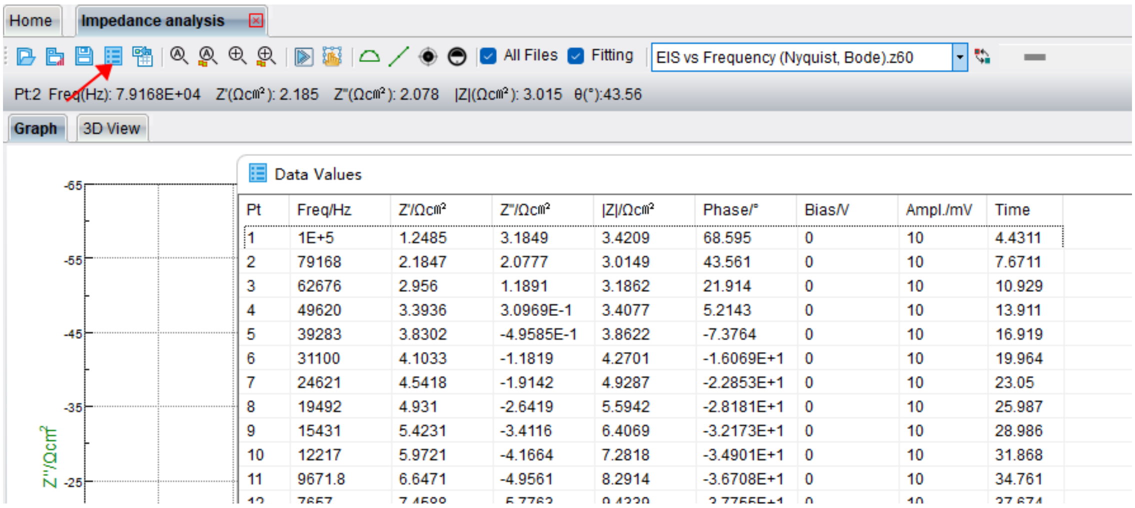


Open an EIS file

Open project

Save project

Data value. Click this button, the user can see the data details, as is shown in below. The data can be copied(ctrl+C). and pasted(ctrl+V).



Pt:2 Freq(Hz): 7.9168E+04 Z'(Ωcm²): 2.185 Z''(Ωcm²): 2.078 |Z|(Ωcm²): 3.015 θ(°):43.56

Pt	Freq/Hz	Z'/Ωcm²	Z''/Ωcm²	|Z|/Ωcm²	Phase/°	Bias/V	Ampl./mV	Time
1	1E+5	1.2485	3.1849	3.4209	68.595	0	10	4.4311
2	79168	2.1847	2.0777	3.0149	43.561	0	10	7.6711
3	62676	2.956	1.1891	3.1862	21.914	0	10	10.929
4	49620	3.3936	3.0969E-1	3.4077	5.2143	0	10	13.911
5	39283	3.8302	-4.9585E-1	3.8622	-7.3764	0	10	16.919
6	31100	4.1033	-1.1819	4.2701	-1.6069E+1	0	10	19.964
7	24621	4.5418	-1.9142	4.9287	-2.2853E+1	0	10	23.05
8	19492	4.931	-2.6419	5.5942	-2.8181E+1	0	10	25.987
9	15431	5.4231	-3.4116	6.4069	-3.2173E+1	0	10	28.986
10	12217	5.9721	-4.1664	7.2818	-3.4901E+1	0	10	31.868
11	9671.8	6.6471	-4.9561	8.2914	-3.6708E+1	0	10	34.761

Data export. The data can be exported and saved in different format, such as .csdat, .txt, .z60.

Zoom in/out

Quick fit

Equivalent Circuit fitting

Circle fit

Line fit

Area correction

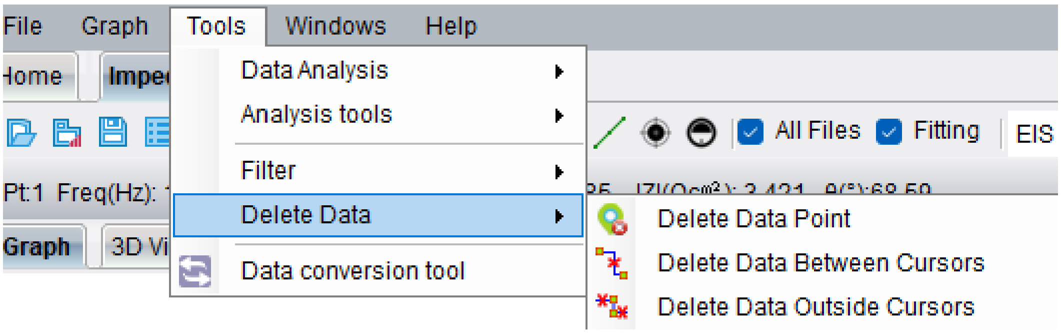
cable compensation

swap cursor

move bar. Swap cursor and move bar are used together to choose a segment for fitting

Delete Data

You can use “swap cursor” and “move bar” to select a segment that you don’t need to fit, and then “delete data”.



Quick fit

For simple impedance curve, the end user can click and chooose suitable circuit for quick fitting, as is shown in below:

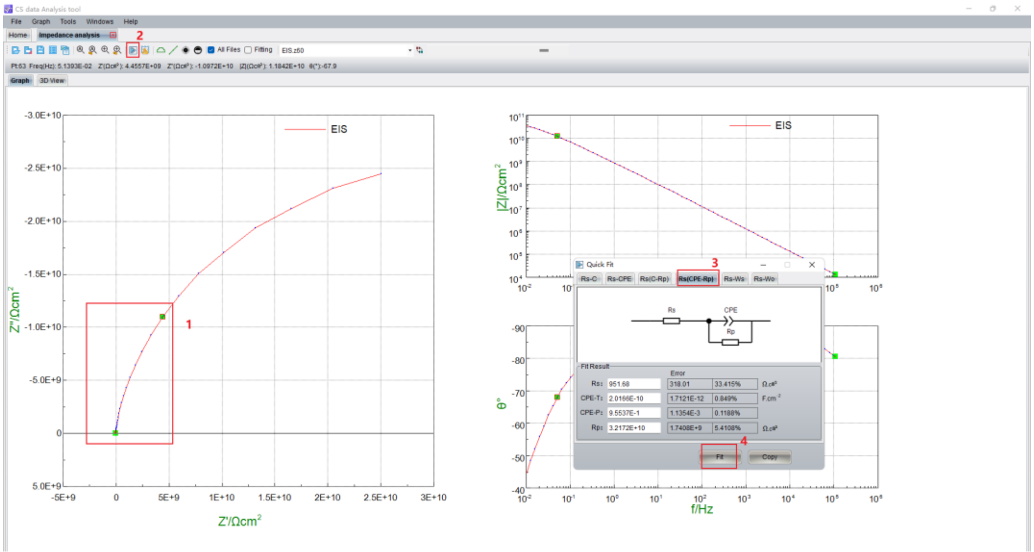
Equivalent circuit fitting

For complex impedance curve, the user should do quick fit for each segment to confirm the initial value of each segment, and then use equivalent circuit fitting for whole fitting.

(1) Use swap cursor and move bar to choose a segment to be fitted, see area marked “1” in below picture.

(2) Click button for quick fit, see “2”.

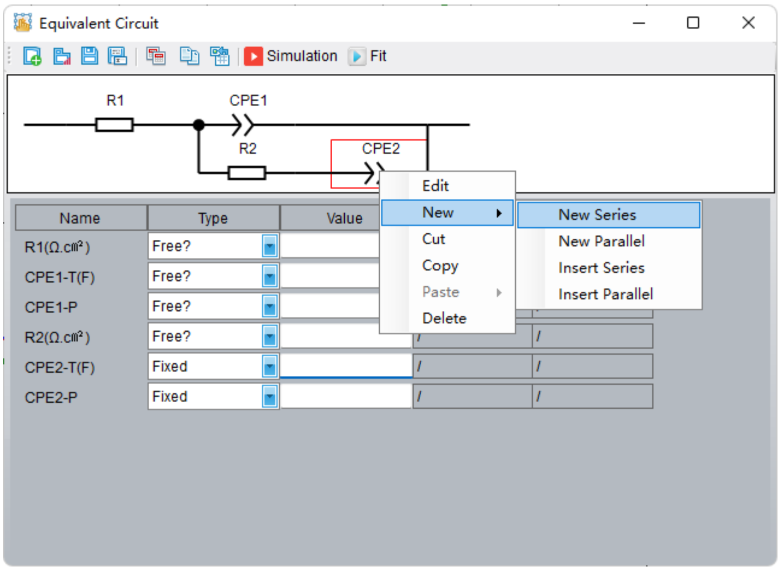
(3) Choose suitable equivalent elements, as is shown in “3”, and obtain the initial value of equivalent circuit.



Pt:63 Freq(Hz): 5.1393E-02 Z'(Ωcm²): 4.4557E+09 Z''(Ωcm²): -1.0972E+10 |Z|(Ωcm²): 1.1842E+10 θ(°):-67.9

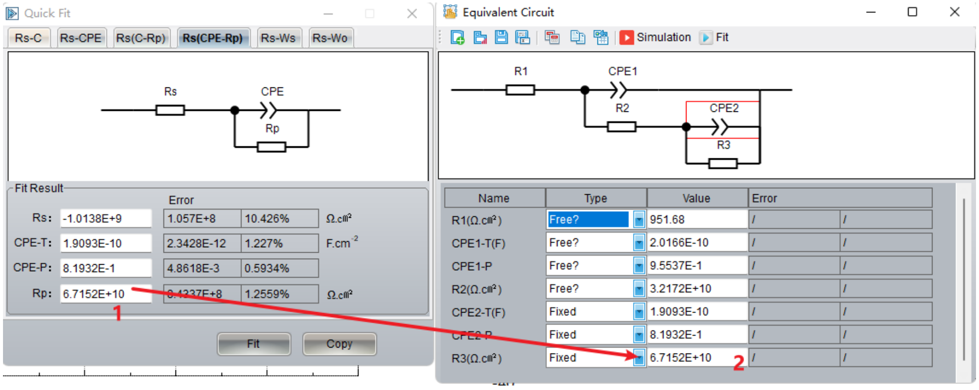
		Error		
Rs:	951.68	318.01	33.415%	Ω.cm²
CPE-T:	2.0166E-10	1.7121E-12	0.849%	F.cm⁻²
CPE-P:	9.5537E-1	1.1354E-3	0.1188%	
Rp:	3.2172E+10	1.7408E+9	5.4108%	Ω.cm²

Click to build suitable equivalent circuit, as is shown in below picture. Put cursor on blank area of the circuit frame, right-click and choose the suitable element and circuit.



Name	Type	Value		
R1(Ω.cm²)	Free?			
CPE1-T(F)	Free?			
CPE1-P	Free?			
R2(Ω.cm²)	Free?		/	/
CPE2-T(F)	Fixed		/	/
CPE2-P	Fixed		/	/

Drag/Move the results from Quick Fit (marked “1”) to place “2”, as is shown in below picture:



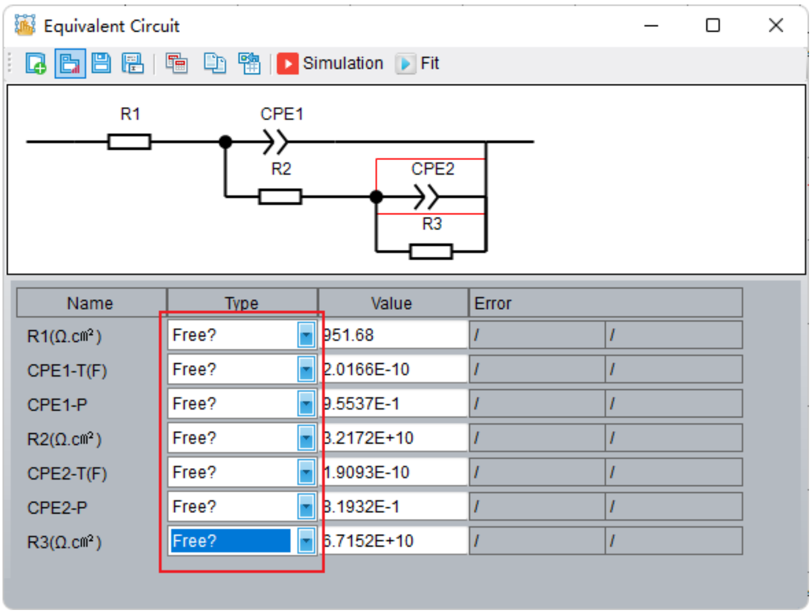
Fit Result

		Error		
Rs:	-1.0138E+9	1.057E+8	10.426%	Ω.cm²
CPE-T:	1.9093E-10	2.3428E-12	1.227%	F.cm⁻²
CPE-P:	8.1932E-1	4.8618E-3	0.5934%	
Rp:	6.7152E+10	8.4237E+8	1.2559%	Ω.cm²

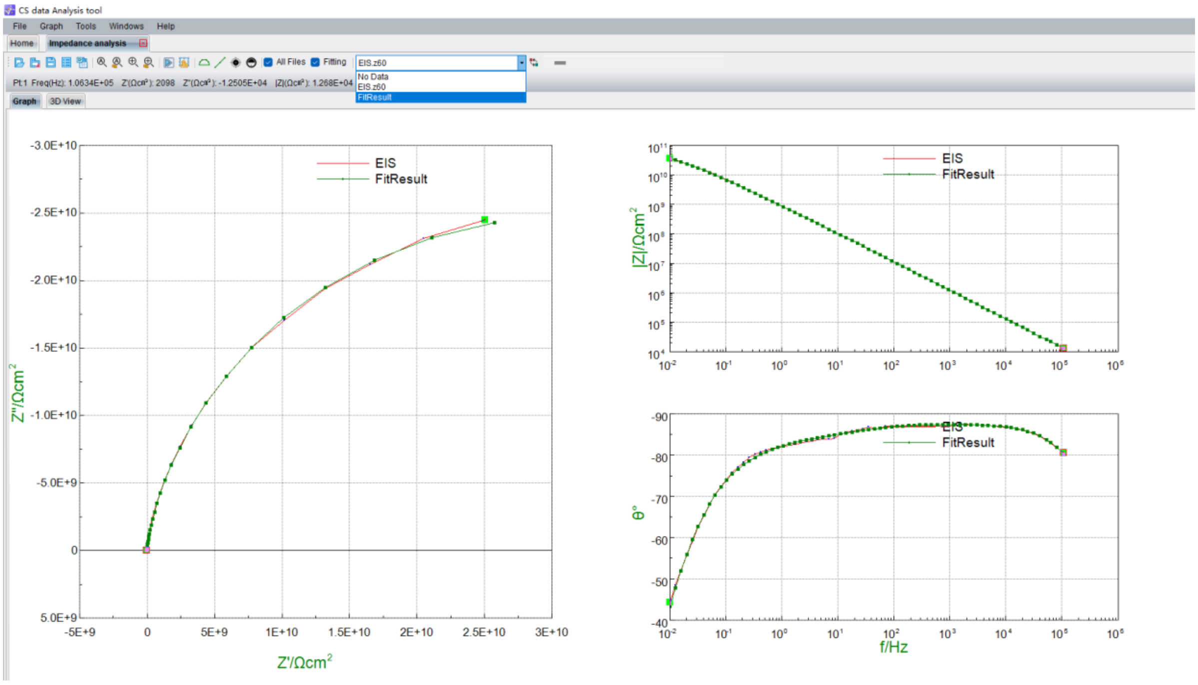
Name	Type	Value	Error	
R1(Ω.cm²)	Free?	951.68	/	/
CPE1-T(F)	Free?	2.0166E-10	/	/
CPE1-P	Free?	9.5537E-1	/	/
R2(Ω.cm²)	Free?	3.2172E+10	/	/
CPE2-T(F)	Fixed	1.9093E-10	/	/
CPE2-P	Fixed	8.1932E-1	/	/
R3(Ω.cm²)	Fixed	6.7152E+10	/	/

Use the same way for to fit other segments, and obtain the final equivalent circuit.

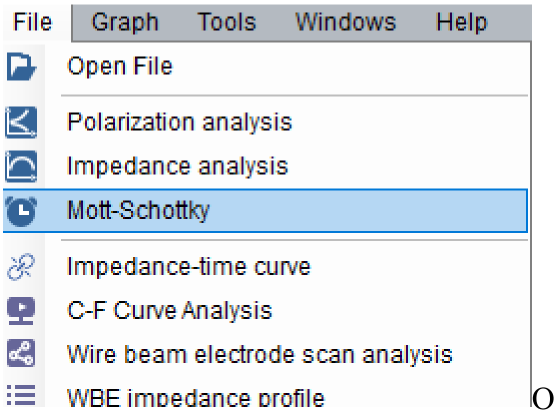
Change from “fixed” to “free?”, and select the whole curve, then click ▶ Fit. The fitting result is as shown in the green curve. You can click to export the fitting data.



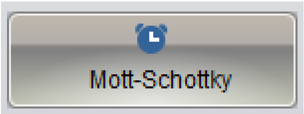
Name	Type	Value	Error	
R1(Ω.cm²)	Free?	951.68	/	/
CPE1-T(F)	Free?	2.0166E-10	/	/
CPE1-P	Free?	9.5537E-1	/	/
R2(Ω.cm²)	Free?	3.2172E+10	/	/
CPE2-T(F)	Free?	1.9093E-10	/	/
CPE2-P	Free?	8.1932E-1	/	/
R3(Ω.cm²)	Free?	6.7152E+10	/	/



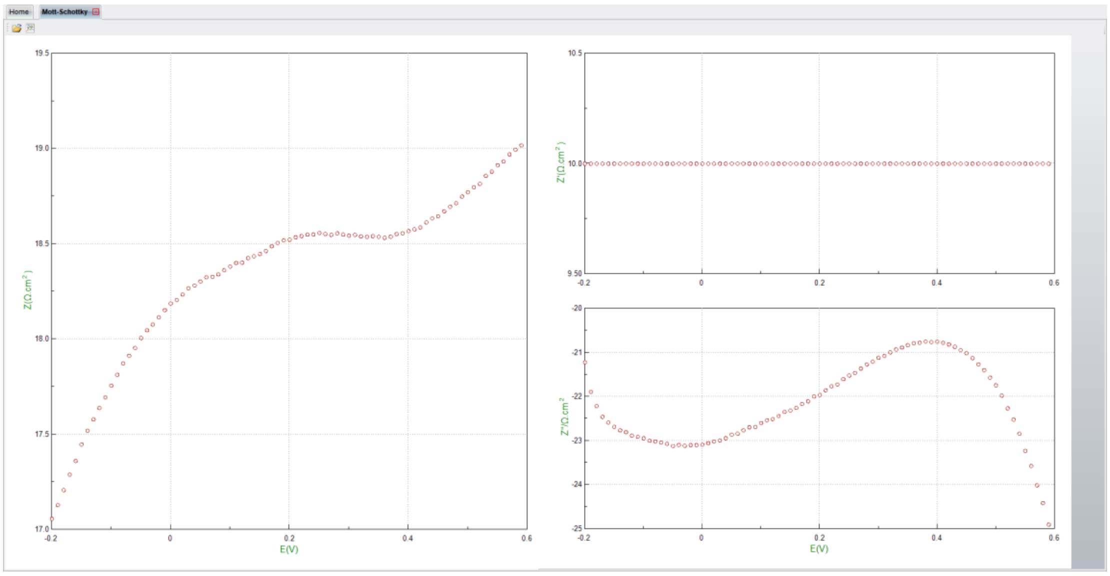
14.4 Mott-Schottky

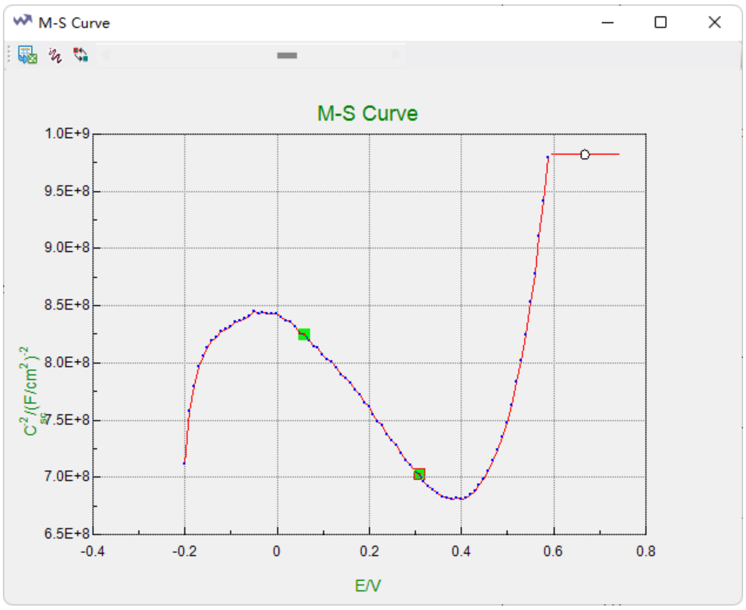


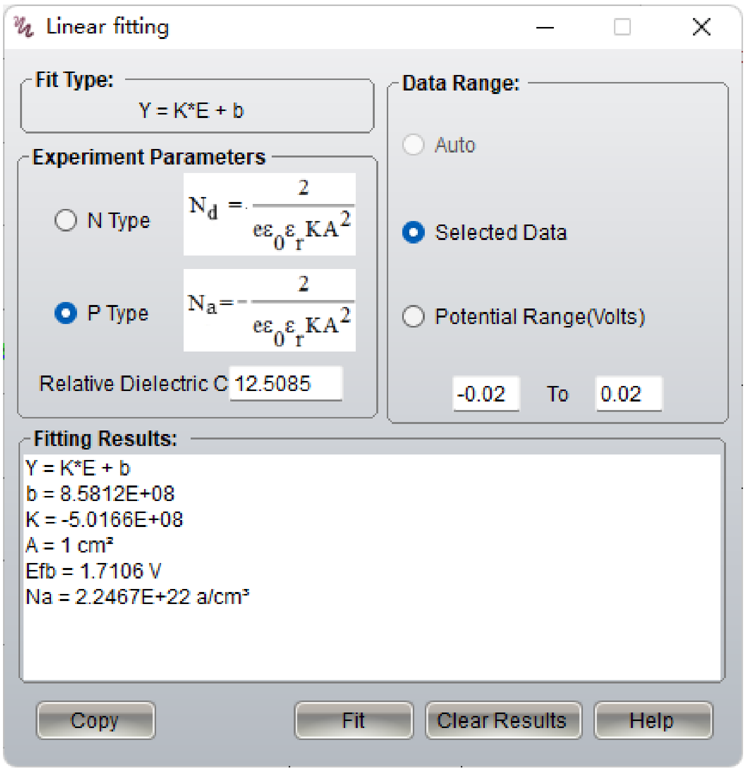
Or



After open the Mott-Schottky analysis interface, click to choose an Mott-Schottky data file, and then click to open the Mott-Schottky fitting interface. Click to do the fitting. Click to export the fitting result with Excel format.


Home
Mott-Schottky
19.5
19.0
18.5
18.0
17.5
17.0
Z(Ω.cm²)
-0.2
0
0.2
0.4
0.6
E(V)
10.5
10.0
9.50
Z'(Ω.cm²)
-20
-21
-22
-23
-24
-25
Z''/Ω.cm²
E(V)


M-S Curve
M-S Curve
1.0E+9
9.5E+8
9.0E+8
8.5E+8
8.0E+8
7.5E+8
7.0E+8
6.5E+8
C²/(F/cm²)⁻²
-0.4
-0.2
0
0.2
0.4
0.6
0.8
E/V



Fit Type: Y = K*E + b

Experiment Parameters

○ N Type $N_d = \frac{2}{e\varepsilon_0\varepsilon_r KA^2}$

● P Type $N_a = -\frac{2}{e\varepsilon_0\varepsilon_r KA^2}$

Relative Dielectric C 12.5085

Data Range:

○ Auto

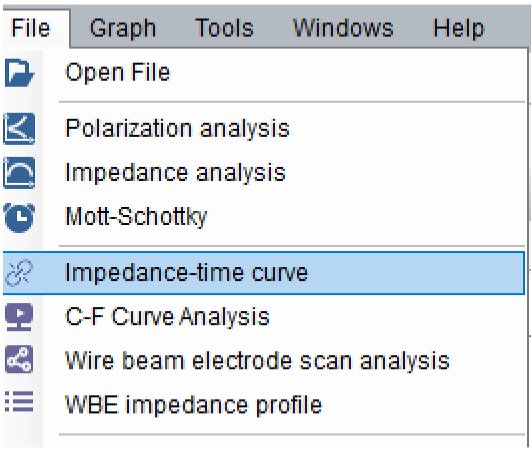
● Selected Data

○ Potential Range(Volts) -0.02 To 0.02

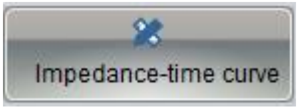
Fitting Results:

Y = K*E + b
b = 8.5812E+08
K = -5.0166E+08
A = 1 cm²
Efb = 1.7106 V
Na = 2.2467E+22 a/cm³

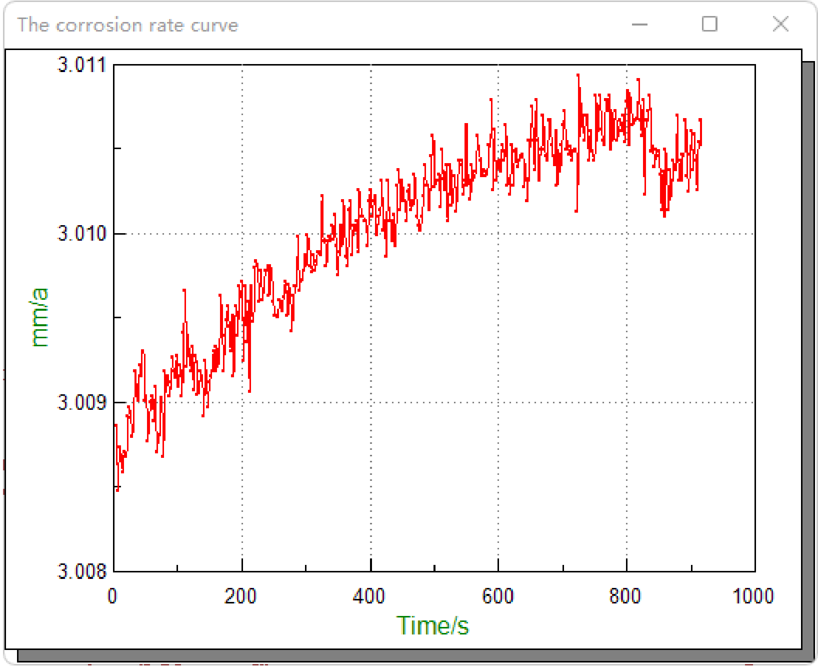
14.5 Impedance-time Curve

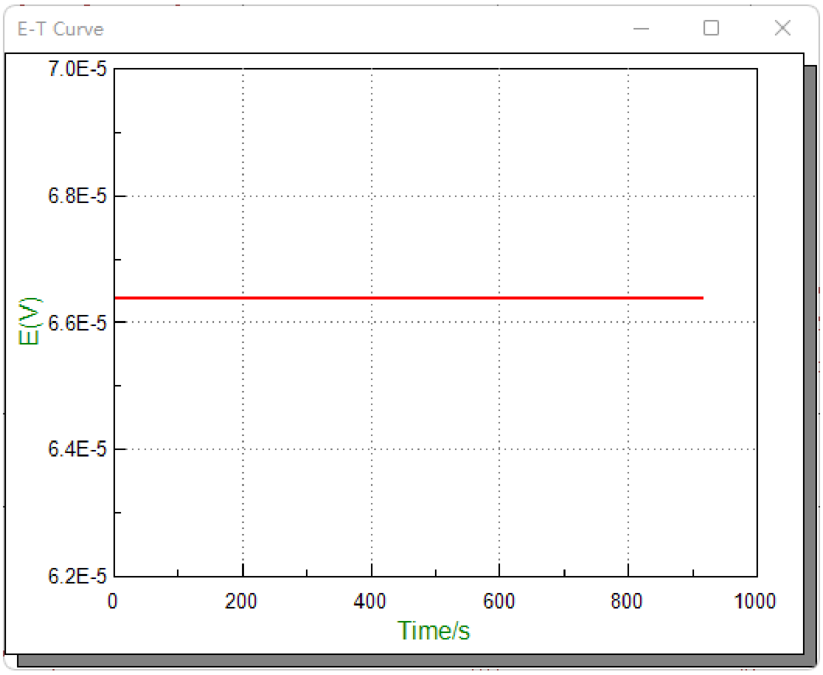


or

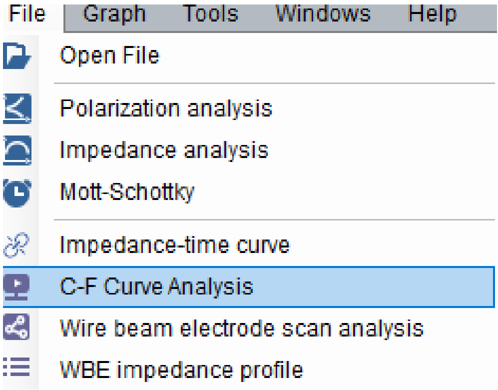


In Impedance-time curve analysis interface, click to choose a data file. Click to view the corrosion rate -time curve. Click to open the potential -time curve.

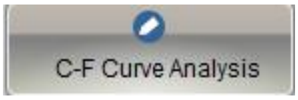




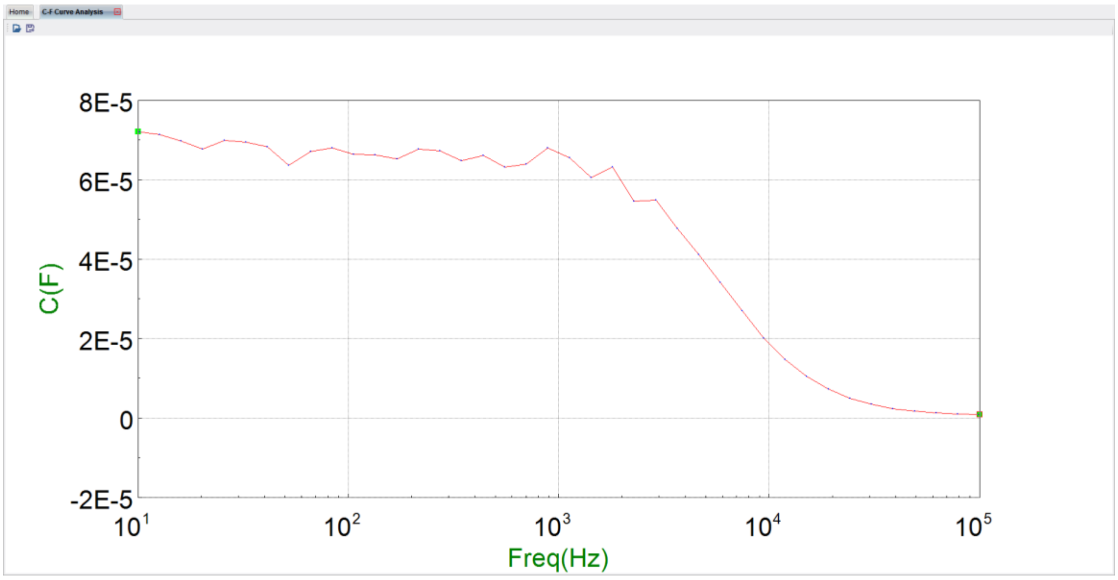
14.6 C-F Curve analysis (Capacitance-frequency analysis)



or

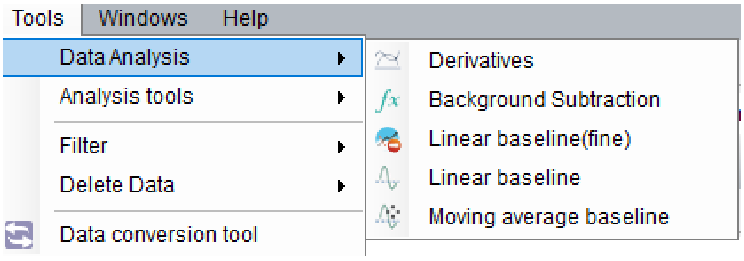


After EIS test, the user can do Capacitance-frequency analysis. Click to choose an EIS data file, and obtain the Capacitance-frequency curve. Click to save the data.



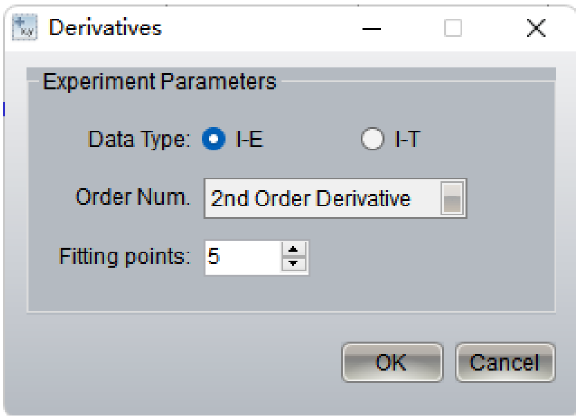
15. Tools

15.1 Data Analysis



Derivatives

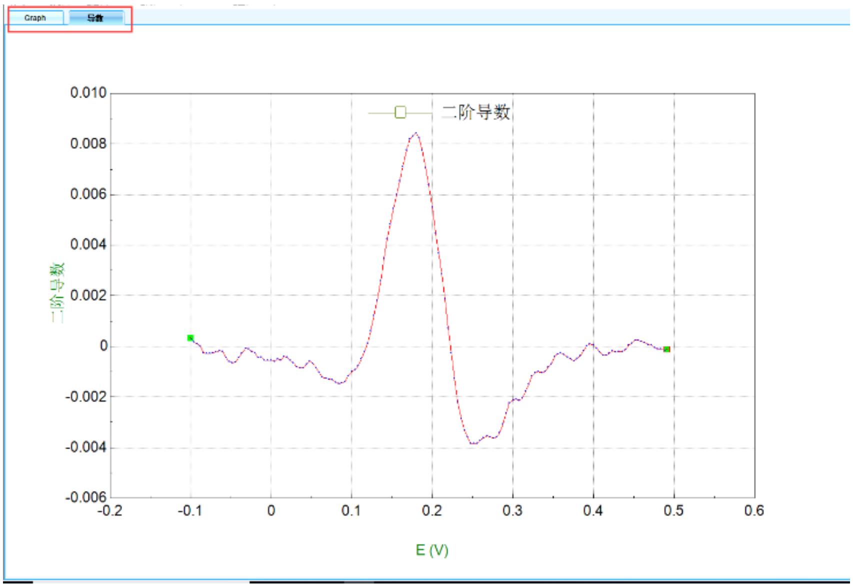
Open a data file, and click “Derivatives”, set the order and fitting points, and then click OK to obtain the Derivatives graph.



Data Type: ● I-E ○ I-T

Order Num. 2nd Order Derivative

Fitting points: 5

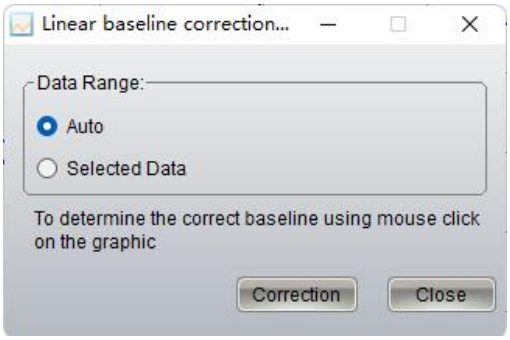


Background subtraction

Open a data file and click this to get the graph after background subtraction.

Linear baseline (fine)

You can adjust the baseline by this.



Data Range:

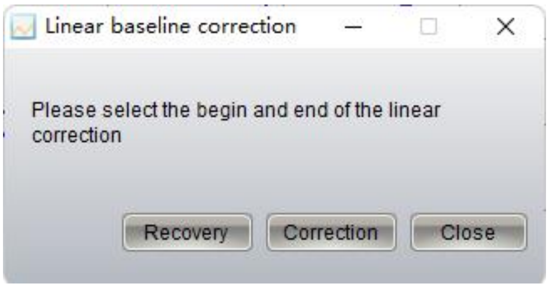
● Auto

○ Selected Data

To determine the correct baseline using mouse click on the graphic

Linear baseline

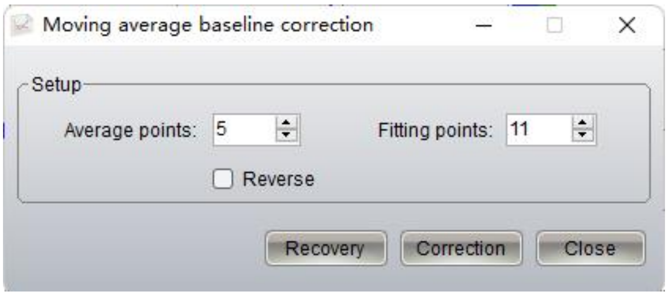
You can correct the baseline by this.



Please select the begin and end of the linear correction

Moving average baseline

Open a data file, click moving average baseline, enter average points and fitting points, and then you can do correction on the curve.


Moving average baseline correction

Setup

Average points: 5

Fitting points: 11

☐ Reverse

15.2 Analysis tool

Automatically find Peak

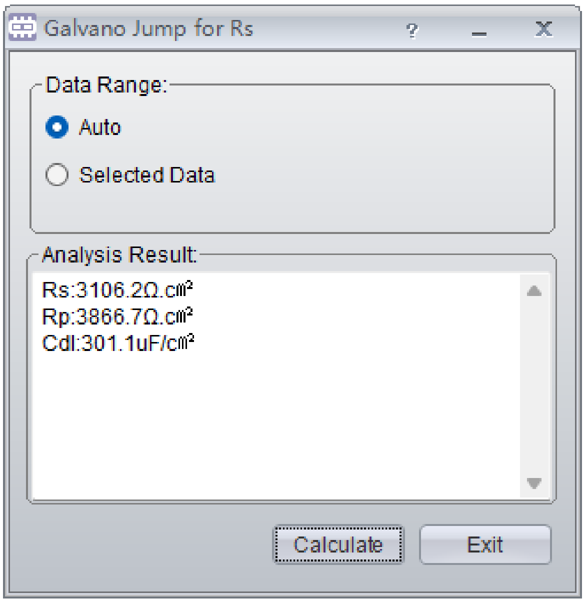
Use the cursor to choose a segment on the curve, click this to automatically find the peak.

Automatically find Trough

Use the cursor to choose a segment on the curve, click this to automatically find the trough.

Galvano Jump for R_s

It’s used for ISTEP data.


Galvano Jump for Rs

Data Range:

● Auto

○ Selected Data

Analysis Result:

Rs:3106.2Ω.cm²
Rp:3866.7Ω.cm²
Cdl:301.1uF/cm²

15.3 Filter

Two different digital filtering methods are available to eliminate burrs or noise in the data file. You should find the suitable method according to the type of noise.

The first type is “Remove burrs”. It is especially suitable to data file that includes abnormal burrs. For every data point in the file, you can firstly choose 5 points(current point, the 2 points before it, and 2 points after it), delete the maximum and minimum one, then make the average of the left three points as the new value. Using this method to handle every data point, you can effectively remove the burrs resulted from range change of the potentiostat and the interference noise caused by repeated on-off of the temperature controller, or the discrete noise signals.

The second type is “5 to 25 point smoothing”. This method employs Savitzky Golay(SG) smoothing algorithm to remove the random noise. (“Smoothing and Differentiation of Data by Simplified Least Squares Procedures”, Analytical Chemistry, Vol. 36, No. 8, July 1964, page 1627).

If you need to use both of the two methods, you must first use “Remove burrs”.

These smoothing methods do not change the saved data file. But if you use filter and then switch to another data file (via the active data selection box), you will be prompted to save the modified data as a new file.

If you need to return to the original data, you can select the same file from the active data selection box. When the software prompts you to save the modified data file, click “No”. Note: Please use the filter with cautiousness. The better way is to resolve the noise problem instead of covering it. Improper usage of the filter may lead to missing of some important information (such as the potential and current peak formed by passivation film rupture on the surface of the electrode). Before using the digital filter, it is suggested that you check the actual noise level of the potentiostat output signals by an oscilloscope so as to determine whether to use the filter.

15.4 Delete data

It supplies three methods: delete data point, delete data between cursors, and delete data outside cursors. After the data is deleted, the source file will be unchanged. The data after modification can also be saved via “Tools” → “Data Export”.

Delete Data Point

Considering that there may be an abnormal data point in a data file, you can use this command to delete it. After the data point is deleted, the source file will be unchanged. The data after modification can be saved via “Tools” → “Data Export”.

Delete data between cursors

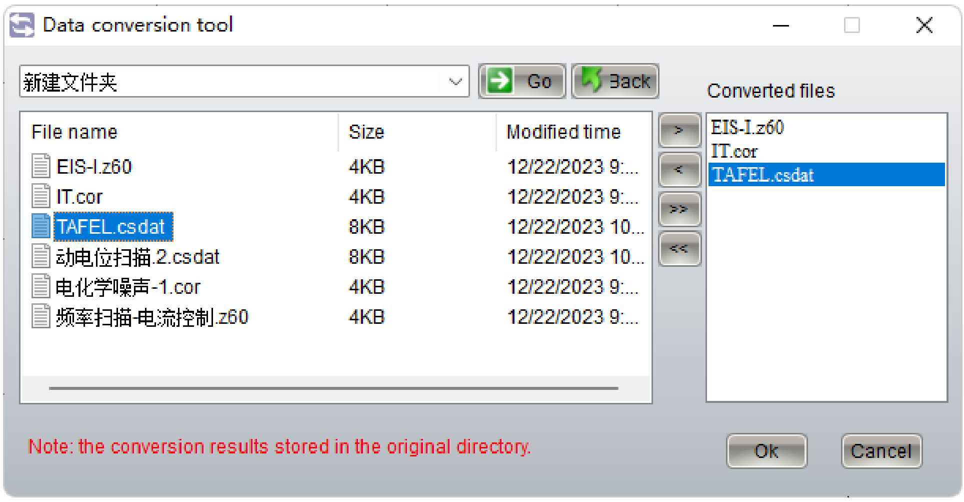
You can use this command to delete all data points between two cursors. After the data segment is deleted, the source file will be unchanged. The data after modification can also be saved via “Tools” → “Data Export”.

Delete Data outside cursors

In an experiment (eg. Voltammetry stripping test), it is possible that there is only a segment of data that is valid, then using this command, all the invalid data points (outside the two cursors) can be selected and deleted. After deletion, the source file will be unchanged. The data after modification can also be saved via “Tools” → “Data Export”.

15.5 Data conversion tool

You can use this tool to concert the data of .csdat,.cor,.z60 format to .txt format. The obtained .txt data will be automatically saved in the save place. .TXT data can be opened in notepad, Excel and Origin.



新建文件夹

File name	Size	Modified time
EIS-I.z60	4KB	12/22/2023 9:...
IT.cor	4KB	12/22/2023 9:...
TAFEL.csdat	8KB	12/22/2023 10...
动电位扫描.2.csdat	8KB	12/22/2023 10...
电化学噪声-1.cor	4KB	12/22/2023 9:...
频率扫描-电流控制.z60	4KB	12/22/2023 9:...

Converted files:
EIS-I.z60
IT.cor
TAFEL.csdat

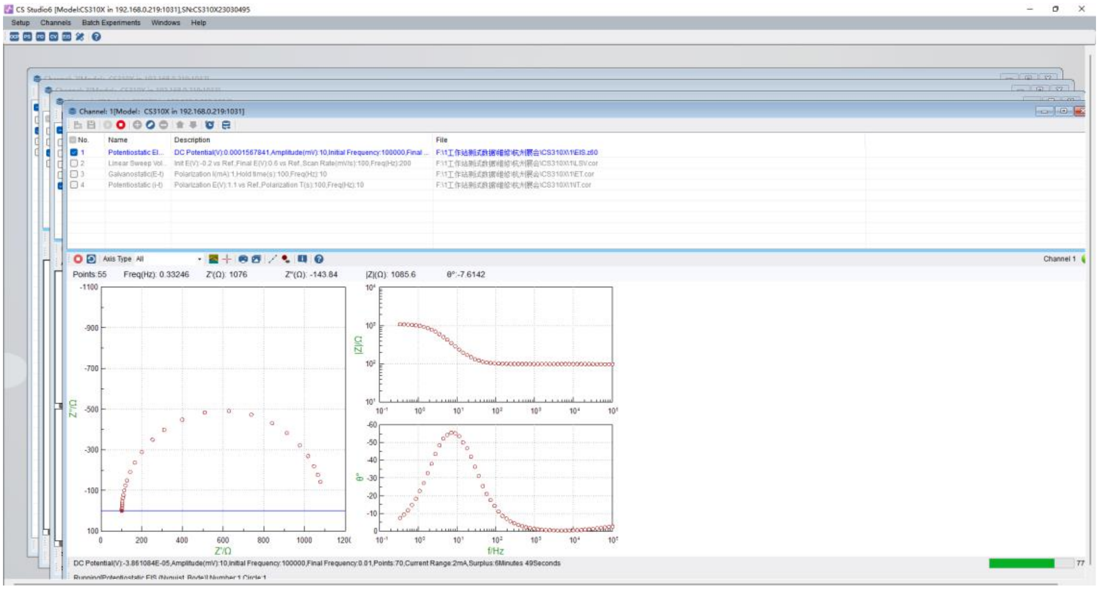
Note: the conversion results stored in the original directory.

16. Windows

This option is used to manage all current project subforms.

Cascade

All sub-windows are displayed in the form of Cascade. This is especially useful when you’re using a bipotentiostat or multichannel potentiostat and run the experiment in each channel.



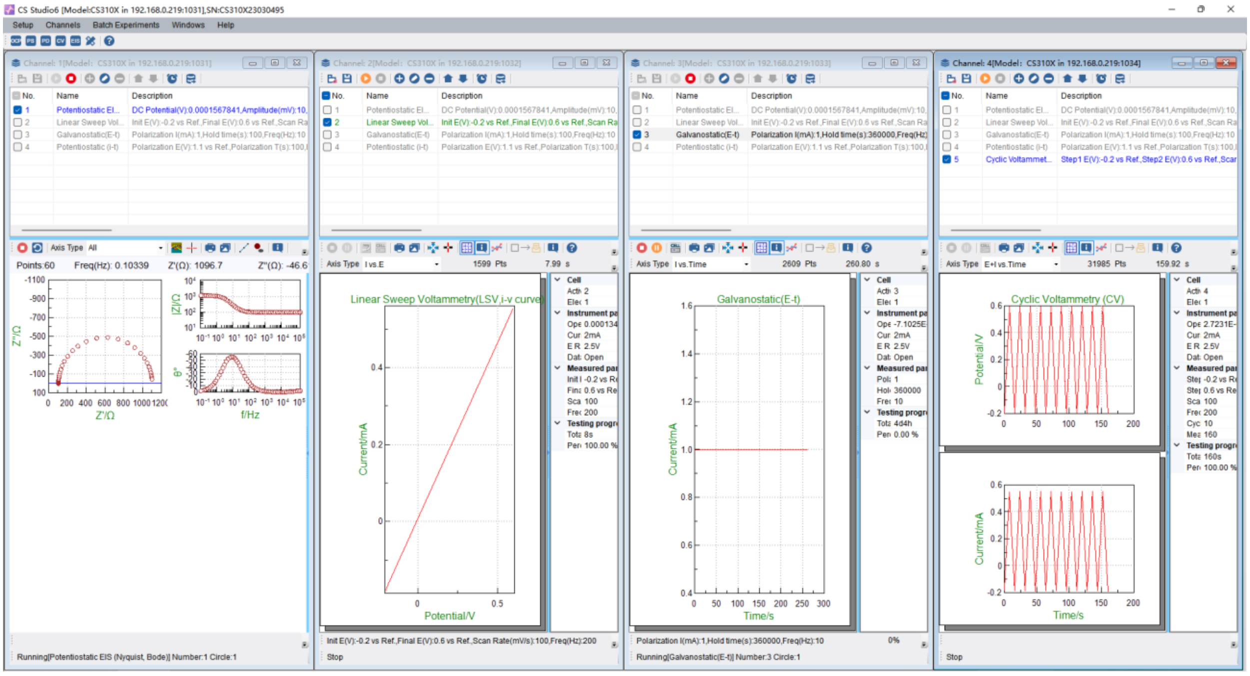
No.	Name	Description	File
☑ 1	Potentiostatic EI...	DC Potential(V):0.0001567841,Amplitude(mV):10,Initial Frequency:100000,Final ...	F:\1\工作站测试数据维修\杭州展会\CS310X\1\EIS.z60
☐ 2	Linear Sweep Vol...	Init E(V):-0.2 vs Ref.,Final E(V):0.6 vs Ref.,Scan Rate(mV/s):100,Freq(Hz):200	F:\1\工作站测试数据维修\杭州展会\CS310X\1\LSV.cor
☐ 3	Galvanostatic(E-t)	Polarization I(mA):1,Hold time(s):100,Freq(Hz):10	F:\1\工作站测试数据维修\杭州展会\CS310X\1\ET.cor
☐ 4	Potentiostatic (I-t)	Polarization E(V):1.1 vs Ref.,Polarization T(s):100,Freq(Hz):10	F:\1\工作站测试数据维修\杭州展会\CS310X\1\IT.cor

Points:55 Freq(Hz): 0.33246 Z'(Ω): 1076 Z''(Ω): -143.84 |Z|(Ω): 1085.6 θ°:-7.6142

DC Potential(V):-3.861084E-05,Amplitude(mV):10,Initial Frequency:100000,Final Frequency:0.01,Points:70,Current Range:2mA,Surplus:6Minutes 49Seconds

Tile

All sub-windows are displayed in the form of Tile. For example, in below picture, you can view the testing status of each channel for the 4-channel potentiostat.



Close all

Close all project subforms.

17. Help

Skin: default is silver. You can adjust the background color of the software. Purple, blue, green, silver are optional.

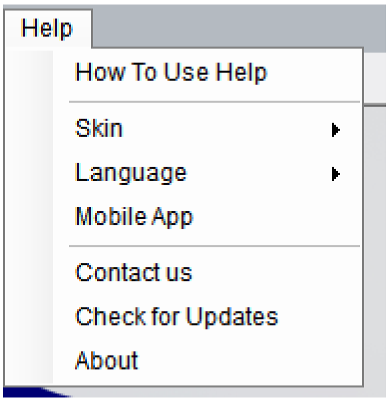
Language: English and Chinese optional

Contact us: click to go to our company website, showing the contact info.

Mobile App: for portable potentiostat CS100/CS100E, you can not only run the experiment connecting a computer, but also download the mobile app to run on mobile phone. This is especially useful if you will carry the potentiostat for field/ in-situ measurement. There is a built-in li-ion battery inside the CS100/CS100E to support outside use.

Check for update: click to update the software to the latest version. Pls make sure there is internet access for your computer

About: the version of the software, hardware, the serial no. etc of the instrument.



18. Service & Contact us

After-sales Service:

1. Warranty period: 5 years. During this period, all service including repair is FREE.
2. Provide installation guidance and manual, software installation video.
3. Lifetime free software upgrading of the same model and technical service

Contact

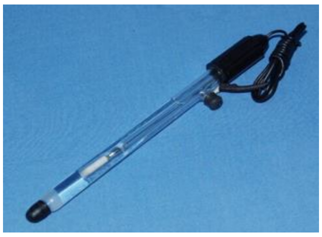
Email: sales2@corrtest.com.cn,
service@corrtest.com.cn,

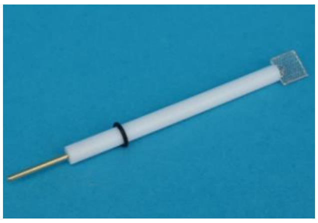
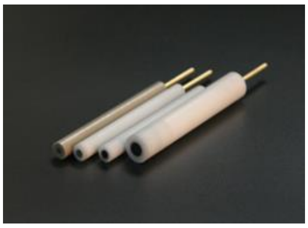
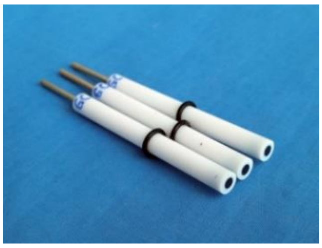
Phone/whatsapp: +86 13469965984
Website: www.corrtestinstruments.com/en

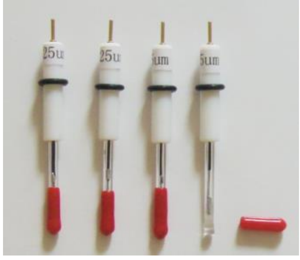
19. Appendix-electrochemical accessories

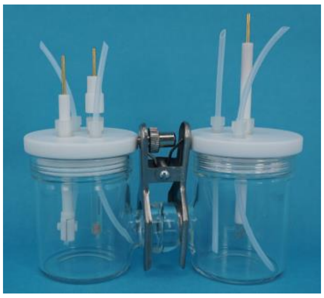
Appendix

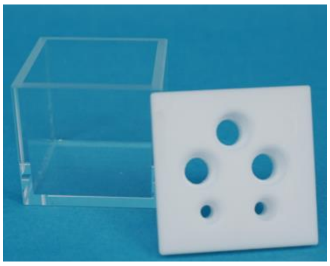
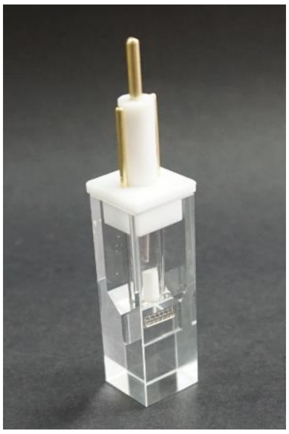
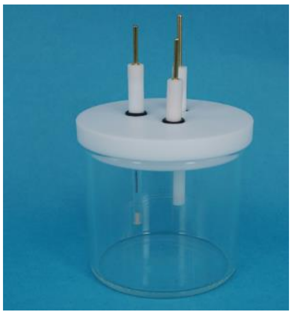
Electrochemical Accessories

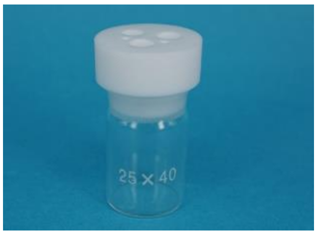
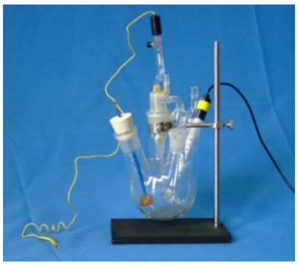
Model	Product	Picture	Specification
CS900	CS900 Saturated Calomel Electrode		Saturated KCl refilling solution
CS901	Ag/AgCl reference electrode		Ø4mm/Ø6mm 3.5M KCl refilling solution
CS902	Hg/HgO reference electrode		Suitable for alkaline/base solution 1M KOH refilling solution
CS903	Mercury/Mercurous sulfate electrode		suitable in acid solution Saturated K2SO4 refilling solution
CS905	Non-aqueous Ag/Ag^+ reference electrode		Ø4mm/Ø6mm
CS910	Platinum conductivity electrode		
CS911	Platinum plate electrode **Size can be customized		99.95%,10x10x0.1mm
			99.95%,10x10x0.2mm
			99.95%,20x20x0.1mm
			99.95%,20x20x0.2mm
			99.95%,20x20x0.3mm

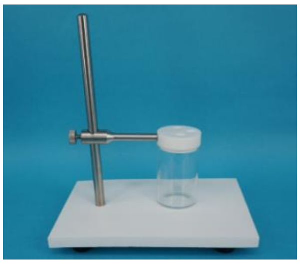
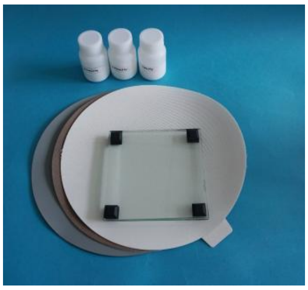
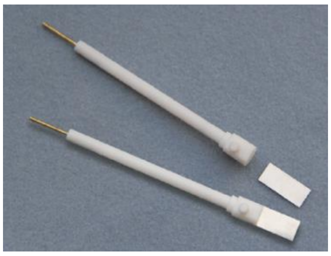
CS912	Platinum wire counter electrode		99.95%, Ø 0.5x37mm(wire)
CS913	Platinum mesh electrode		10*10mm
			20*20mm
CS915	Graphite rod		Φ4 / 6mm, length 150mm
CS916	Graphite electrode		Ø2~ Ø5mm
CS920	Glassy carbon working Electrode		Ø3mm
			Ø2mm
			Ø4mm/Ø5mm
			Ø6mm
CS920L	L-shape glassy carbon working electrode		Ø3mm
			Ø2mm
			Ø4mm/Ø5mm
CS921	Metal Electrode		Carbon steel, stainless steel, copper Working area: 0.5cm^2
CS922	Platinum working electrode		99.95%, Ø2mm
			99.95%, Ø3mm

CS923	Gold working electrode		99.95%, Ø2mm
			99.95%, Ø3mm
CS924	Silver working electrode		Ø2mm / Ø3mm
	Titanium WE		Ø2mm / Ø3mm
	Copper WE		Ø2mm / Ø3mm
	Aluminum WE		Ø2mm / Ø3mm
	Nickel WE		Ø2mm / Ø3mm
	Zinc WE		Ø2mm / Ø3mm
	Cadmium WE		Ø2mm
	Iron WE		Ø2mm
	Palladium WE		Ø2mm/ Ø3mm
CS925	Pt micro electrode		10μm/25μm
CS926	Gold micro electrode		12.5μm/25μm
CS930	Glass electrolytic Cell, 4 ports **Include salt bridge and gas inlet/outlet pipe		150ml
			250ml
			500ml
			1000ml

CS9305	Corrosion Cell, 5 ports 500mL Includes all the electrodes		The cell kit includes: A specimen holder (1cm2 working area) * 1 Graphite rods *2 Pt plate electrode*2 (10*10*0.1mm) Saturated calomel electrode *1 Salt bridge*1 F-shape gas inlet and outlet*1
CS931	Jacketed glass cell (None-sealed) **Holes on the lid can be tailored. No include the electrodes shown in the pic.		50ml
			100ml
			150ml
CS931S	Jacketed glass cell (Sealed) **Holes on the lid can be tailored. No include the electrodes shown in the pic.		50ml
			100ml
			150ml
CS932	H- cells (None-sealed)		None-sealed Volume:50~250mL (each cell, PTFE caps. The two cells are separated by ion membrane which is prepared by user.
CS932S	H- cells (sealed) **Holes on the lid can be tailored. No include the electrodes shown in the pic.		Sealed 50~250 mL (each cell) PTFE caps The two cells are separated by ion membrane which is prepared by user.
CS933			30*30*30mm

	Photoelectrochemical cell(quartz) **Hols on the lid can be tailored.		40*40*40mm
			50*50*50mm
CS9331 Non-sealed	Photoelectrochemical cell **Holes on the lid can be tailored. No include the electrodes shown in the pic. For working electrode, you're recommended to use L-shape electrodes, or the CS945 electrode clamp. 50ml 100ml 150ml	 Sealed	*Glass cell, Teflon cap, Quartz light window (dia. 24mm).
CS9331S (Sealed)			
CS9330	Spectroelectrochemical cell (cuvette cell kit)		This kit includes: Quartz cuvette 12.5*12.5*42mm, Teflon cap, Pt mesh(WE), Pt wire counter electrode(CE), Ag/AgCl reference electrode(RE), Purge tube optical path: 8*6.5*1mm
CS934	Coating evaluation cell (Paint test cell)		10mL Working area is 1cm^2
CS935	Electrolytic cell (None-sealed) **Holes on the lid can be tailored. No include the electrodes shown in the pic.		50mL/100mL
			150mL/200mL/250mL
	Seal electrolytic cell		50mL

CS935S	** Holes on the lid can be tailored. No include the electrodes shown in the pic.		100mL
			150mL
			250mL
CS936	Flat corrosion cell -None-jacketed		working area is 1cm^2 including: Ag/AgCl reference electrode Counter electrode: Pt mesh*1 (20*20mm)
	Flat corrosion cell -Jacketed		Jacketed, water circulation for temperature control working area is 1cm^2 including: Ag/AgCl reference electrode *1 counter electrode: Pt mesh *1 (20*20mm)
CS937	Glass cell + Teflon cap		Glass cell: 10ml Diameter of the three holes: φ6.35mm, φ6.35mm, φ6mm
CS940	Cell stand 1		Match CS930 glass cell Base material: carbon steel. Not included the cell and electrodes which are for demonstration

CS941	Simple Cell Stand		Base material: PTFE provide 2 pieces cells (30ml)
CS942	Electrode polishing kit		Alpha alumina powder 0.05μm,0.3μm,1μm, 10g each Nylon polishing pad (Ø200mm) *1 Microcloth polishing pad (Ø200mm)*1 Carbimet disks (1200-4000 grit, Ø200mm)*1 -Glass plate*2
CS942	Faraday cage		25*25*30cm
CS945	Specimen clamp **The price is for one electrode		Suitable for plate specimen with thickness: < 1mm.
CS946	Specimen holder		Effective Working area is 1cm2. Round specimen: diameter: 11.5~15mm, Thickness 0.1 ~ 5mm. Only One face of the sample contacts with the solution. PVDF rod diameter 10mm, length 100mm

Wuhan Corrtest Instruments Corp., Ltd.

Rm 501, Dingye Hall B, International Enterprise Center,
Optics valley Ave., East Lake High-tech Dev. Zone, Wuhan, China, 430074

TEL: 027-67849450

http://www.corrtest.com.cn