

CS SERIES ELECTROCHEMICAL WORKSTATION

USERS' MANUAL

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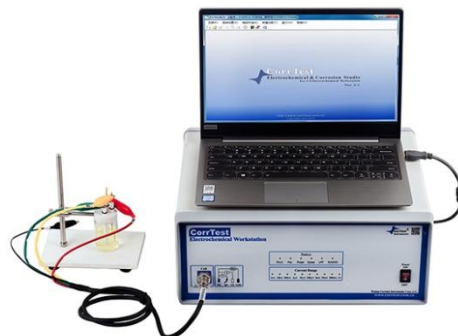
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Part 1 Introduction of CS series potentiostat / galvanostat

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

- ①Electrosynthesis, electrodeposition (electroplating), anodic oxidation, etc.
- ②Electrochemical analysis and sensor;
- ③Battery (Li-ion battery, solar battery, fuel cell, supercapacitor), new materials, optoelectronic materials;
- ④Corrosion mechanism of metals in water, concrete and soil;
- ⑤Fast evaluation of corrosion inhibitor, water stabilizer, coating and cathodic protection efficiency.

Specifications

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

EIS specs

Signal generator:

Frequency range: $10\mu\text{Hz} \sim 1\text{MHz}$

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: 10⁶ cycles or 10⁵s

Measurement delay: 0~10⁵s

DC offset:

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

Current compensation range: -1A~+1A

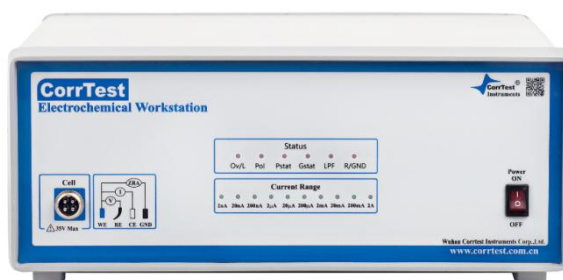
Bandwidth: 8-decade frequency range, automatic and manual setting

System Requirements

Operating System: Windows XP / Vista / 7 / 8 / 10.

Communication between PC and instrument: USB2.0.

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



Front panel of CS single channel potentiostat / galvanostat

Electrode cable

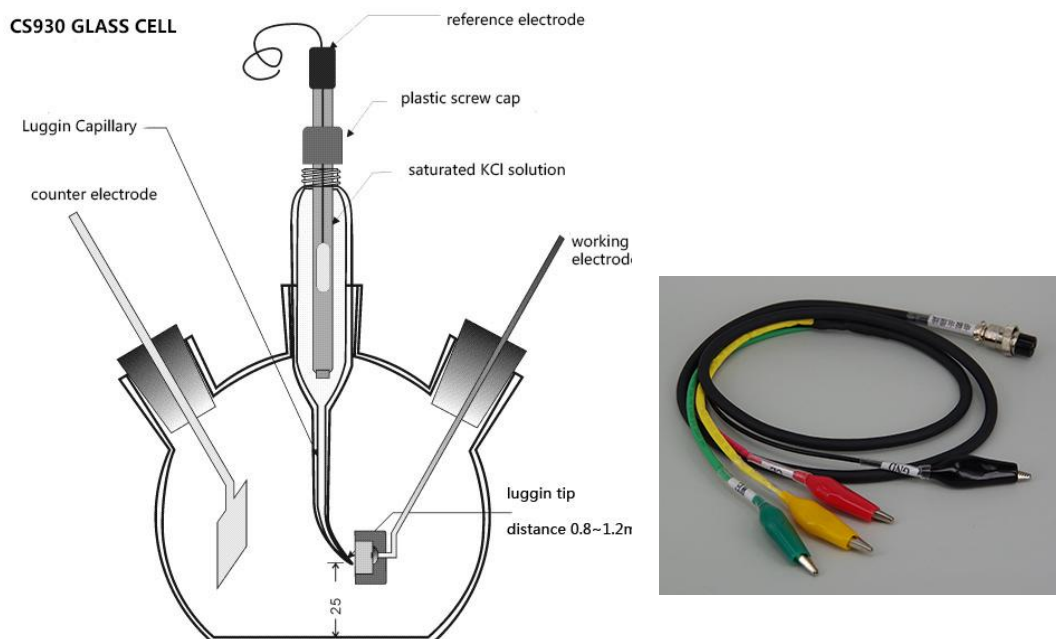
1. Three electrodes system

Insert the reference electrode, counter electrode and working electrode into the cell.

Green lead clamps to WE, Red lead connects to CE, and yellow lead connects to RE. Black GND is usually idle. If the open circuit potential (OCP) display is reasonable, it means the cell system is in normal state.

The black lead is used on below occasions:

- (1) In electrochemical noise or ZRA test. Green lead connects to WE I, black lead connects to WE II. Yellow lead connects to RE. Red lead is idle.
- (2) If the system requires to connect ground or a Faraday cage, use the black clamp.



2. Two electrodes system

The green lead connects to WE or anode; red lead & yellow lead together connect to another electrode or cathode.

Indicator light

Ov/L—output current is over 120% of the full range when this indicator light is on.

Pol— the electrode is on the state of polarization.

Pstat—working mode of potentiostat

Gstat— working mode galvanostat.

LPF—light is on when open low pass filter which can reduce the instrument's bandwidth and enhance the stability.

Current range— shows the present current range.

ON/OFF— power on and power off.



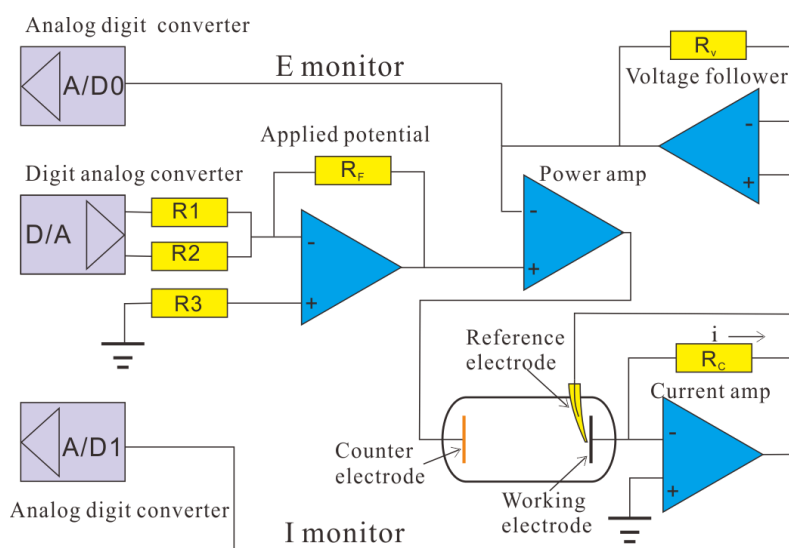
Rear panel of CS single channel potentiostat galvanostat

AC 220V – the power cable port. (note: we know the power system is 110V in some countries such as USA, Canada, we will make the instrument compatible with 110V system accordingly in such countries.)

Floating/Earth -floating mode is suitable for testing system where the working electrode is connected with earth, like high-pressure autoclave, buried steel structure.

Signal I/O – expansion port for analog input/output. P1 can output analog waveform, such as sawtooth wave, sine wave; P2 is the grounding point for all output signals; P3 & P4 is to record the external analog signals, such as the temperature, pH sensor etc.

Schematic diagram



Schematic diagram of CS potentiostat

Shipment list

Manual ×1

Part 2 CS Studio Software

1. Introduction

CS Studio software shipped with the CS electrochemical workstation is an easy-to-use, flexible, and versatile electrochemical tool and can be applied in many research fields from corrosion, voltammetry, electroanalysis to battery test, etc. There is no special requirement for computer, a mainstream/ common one is OK.



Interface of CS Studio software

1.1 Electrochemical Techniques

There is the corresponding stripping method.

Stable polarization: Open Circuit Potential (OCP), Potentiostatic (I-T curve), Galvanostatic, Potentiodynamic (Tafel), Galvanodynamic, Potential Sweep-step

Transient polarization: Multi-Potential Steps, Multi-Current Steps, Potential Stair-Step (VSTEP), Galvanic Stair-Step (ISTEP)

Chrono Methods: Chronopotentiometry (CP), Chronoamperometry (CA), Chronocoulometry (CC)

Voltammetry: Cyclic Voltammetry (CV), Linear Sweep Voltammetry (LSV), Staircase Voltammetry (SCV)#, Differential Pulse Voltammetry (DPV)#, Normal Pulse Voltammetry (NPV)#, Square wave voltammetry (SWV)#, AC voltammetry (ACV)#, Differential Normal Pulse Voltammetry (DNPV)#, 2nd Harmonic A. C. Voltammetry (SHACV), Fourier Transform AC Voltammetry (FTACV)

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

Impedance: EIS vs Frequency (IMP), EIS vs Time (IMPT), EIS vs Potential (IMPE)

Corrosion testing: Cyclic polarization curve (CPP), Linear polarization curve (LPR), Electrochemical Noise (EN), Zero Resistance Ammeter (ZRA), Electrochemical Potentiokinetic Reactivation (EPR)

Battery testing: Battery charge and discharge, Galvanostatic charge and discharge(GCD)

Bipotentiostat: Hydrogen diffusion (HDT), Rotating ring-disk Electrode(RRDE)

Extensions: Data Logger, Disc machine control, Bulk electrolysis with Coulometry

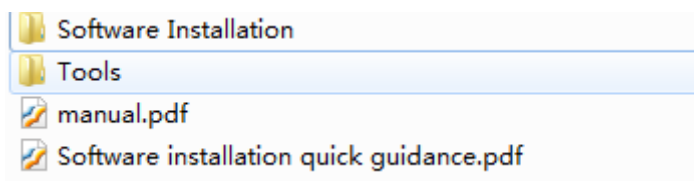
CS Studio software is also equipped with powerful corrosion analysis module. It can calculate the corrosion rate of the material by linear polarization and weak polarization, as well as polarization resistance (R_p), Tafel slope (b_a , b_c), and corrosion current density (i_{corr}) through the non-linear 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 CS single channel models-USB(CS350/CS310/CS300/CS150/CS120)

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

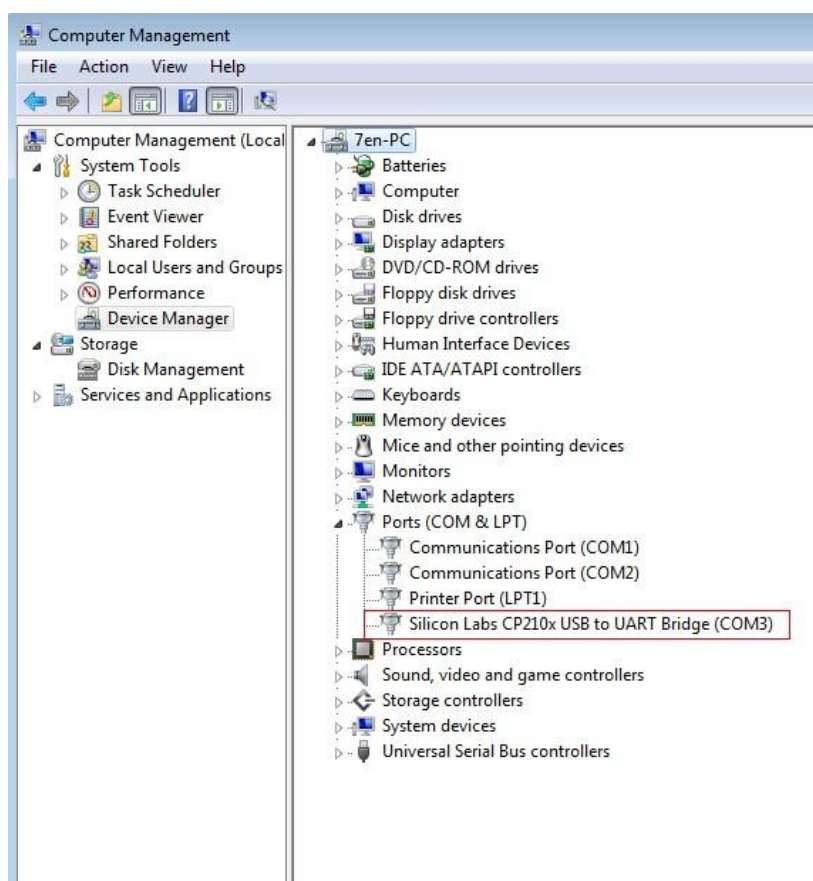
2. Power on the instrument, open the “software installation” folder in the CD and USB flash disk., right click the “Setup.exe”, and run as administrator.



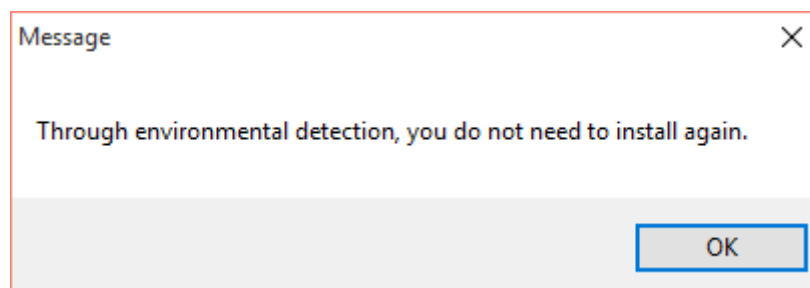
CS Studio5	2019/8/8 9:41	文件夹	
DotNetFX35	2019/8/8 9:41	文件夹	
Drivers	2019/8/8 9:41	文件夹	
DriversForXp	2019/8/8 9:41	文件夹	
SoConfig	2019/8/8 9:41	文件夹	
sxsForWin8	2019/8/8 9:41	文件夹	
sxsForWin10	2019/8/8 9:41	文件夹	
sxsForWin10-New	2019/8/8 9:41	文件夹	
clean	2017/3/23 9:27	Windows 批处理...	1 KB
Setup.exe	2019/8/7 15:52	应用程序	3,769 KB
Setup	2017/6/29 13:56	安装信息	1 KB
sxs8	2019/5/8 16:57	Windows 批处理...	1 KB
sxs10	2019/5/8 16:58	Windows 批处理...	1 KB
sxs10-New2-x64	2019/8/7 13:41	Windows 批处理...	1 KB
sxs10-New2-x86	2019/8/7 13:42	Windows 批处理...	1 KB
sxs10-New-x64	2019/5/8 17:58	Windows 批处理...	1 KB
sxs10-New-x86	2019/5/8 17:58	Windows 批处理...	1 KB



3. Firstly, install the drivers. After finishing it, go to the computer management → device manager → Ports (COM & LPT). There, it will appear “Silicon Labs CP210x USB to UART Bridge(COM x)”. As is shown below, the X is 3.

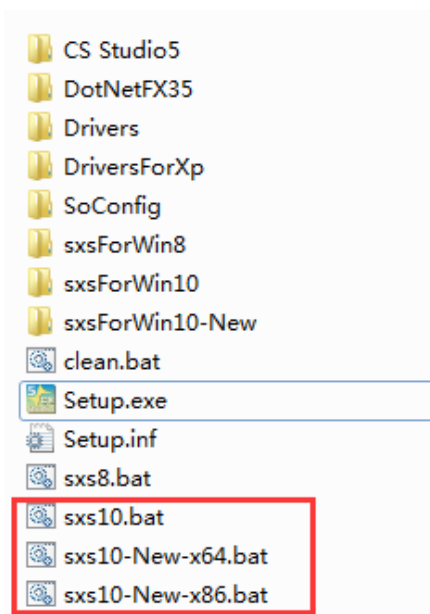


4. Secondly, install the .net 3.5. If your computer has already installed it, there will be a prompt as follows.

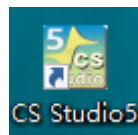


If it hasn't been installed in your computer, just follow the steps to finish installation of .net 3.5.

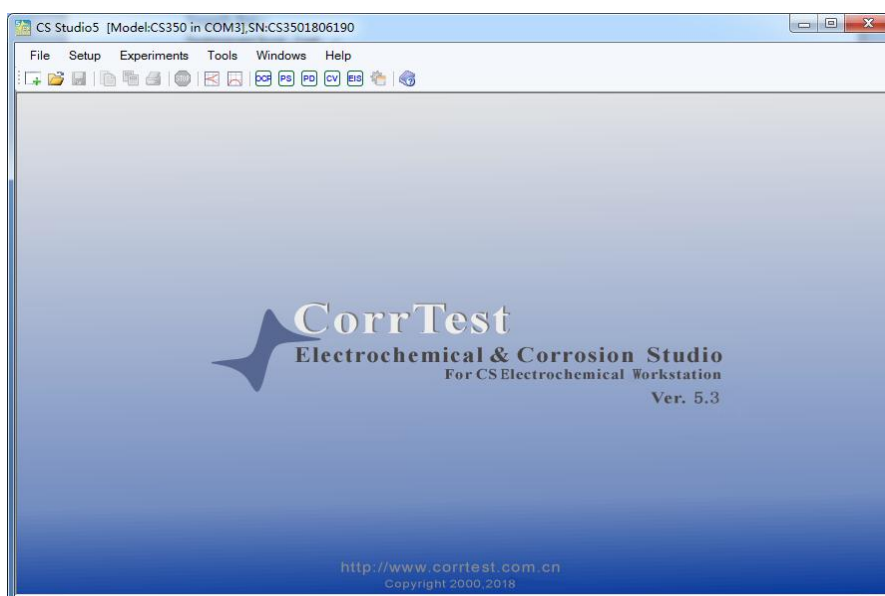
Notice: If your operating system is windows 10 and it appears error when you follow above step, then you have to finish installation of .net 3.5 through below tools. Please try one by one till you success. Remember to "run as administrator".



5. Click install CS Studio5. Created a shortcut is on the desktop.



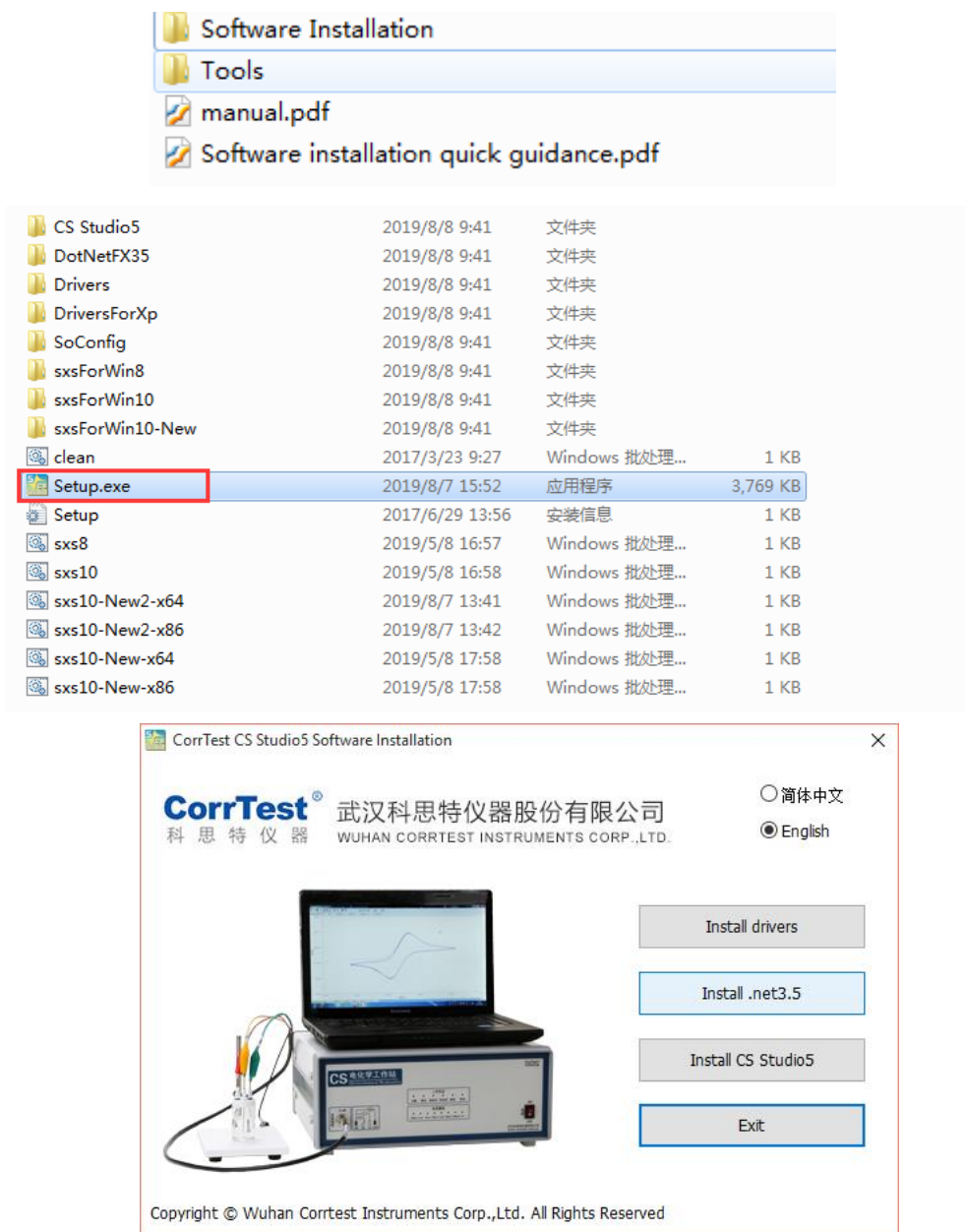
6. Run the software as administrator. Then the model and serial number will be shown. It means the instrument has been successfully connected.



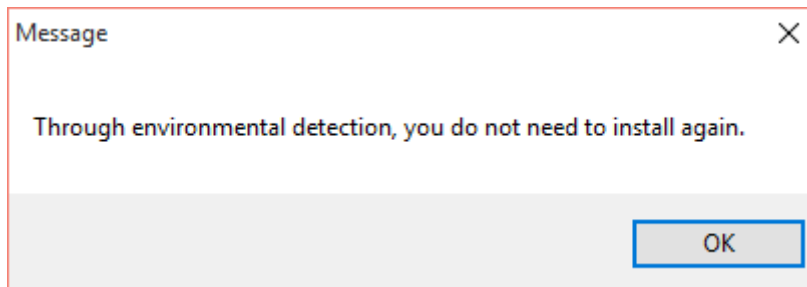
1.2.2 CS2350 Bipotentiostat(Ethernet) and CS multichannel potentiostat

1. 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.

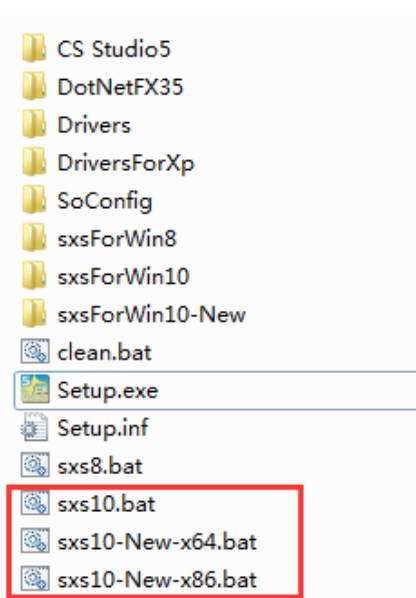


- (3) As it uses Ethernet communication, no need to install drivers. Firstly, install the .net 3.5. If your computer has already installed it, there will be a prompt as follows.



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

Notice: If your operating system is windows 10 and it appears error prompt when you follow above step, then you have to install .net 3.5 through below tools. Please try one by one till you success. Remember to “run as administrator”.

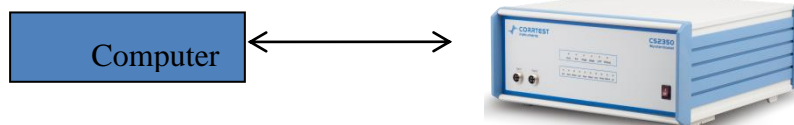


(4) Click install CS Studio5. Created a shortcut is on the desktop.

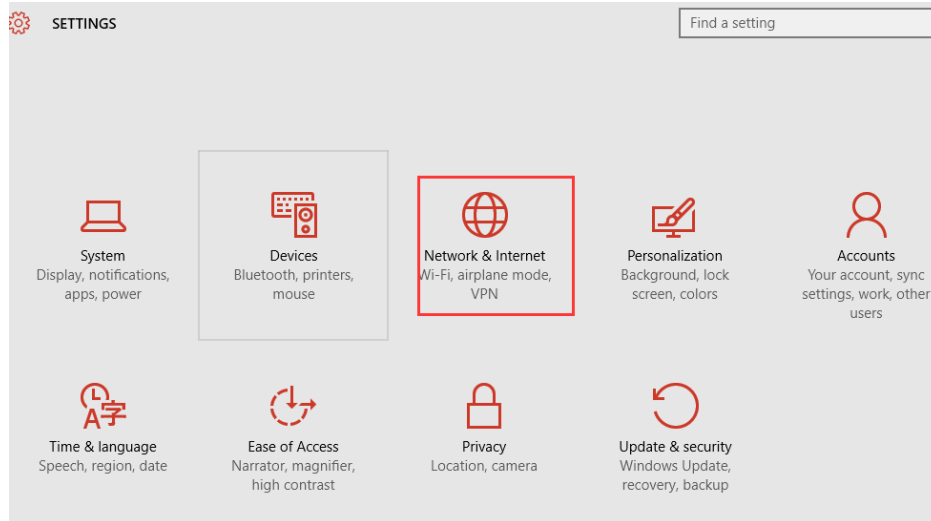


2. IP address configuration

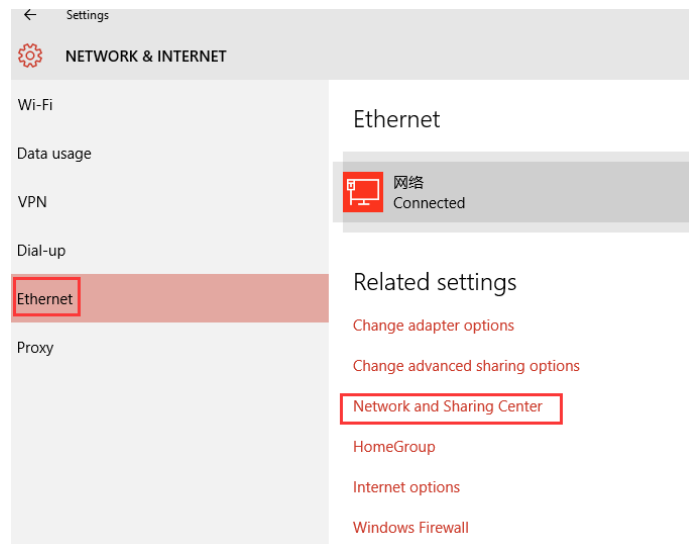
Connecting the instrument with computer by Ethernet cable, you should reset the IP address of the computer.



(1) Find the “Network and sharing center”



Then, Ethernet → Network and sharing center

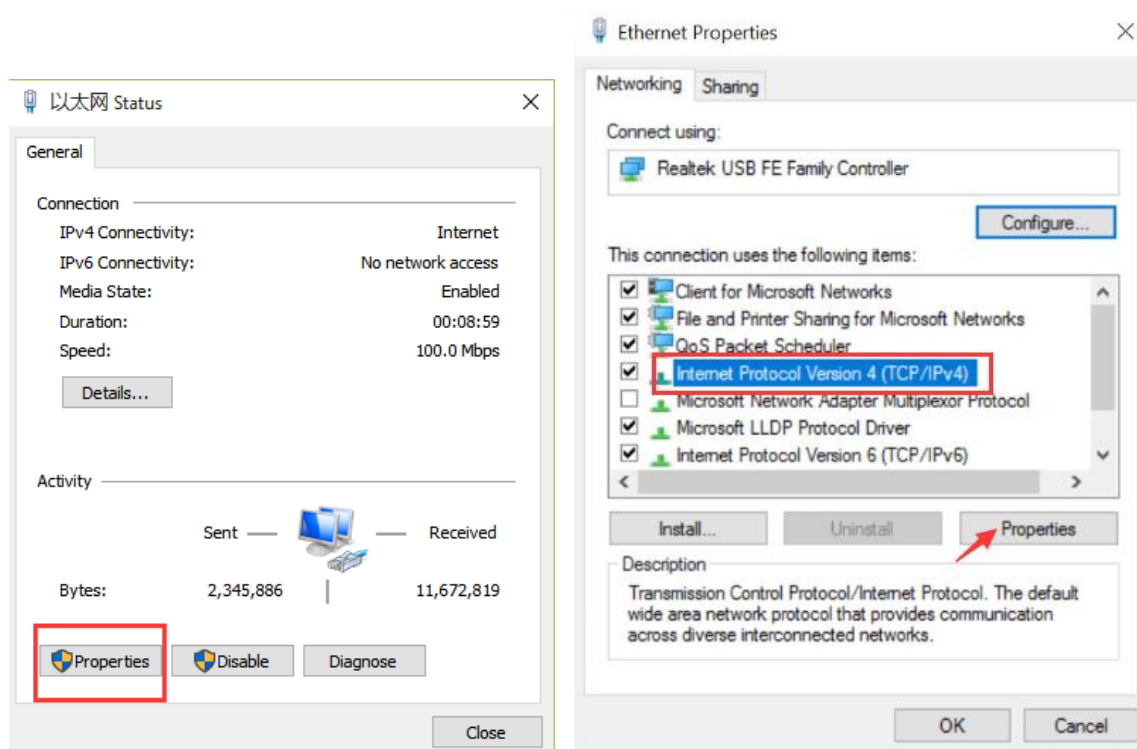


(Or  → Network and sharing center)

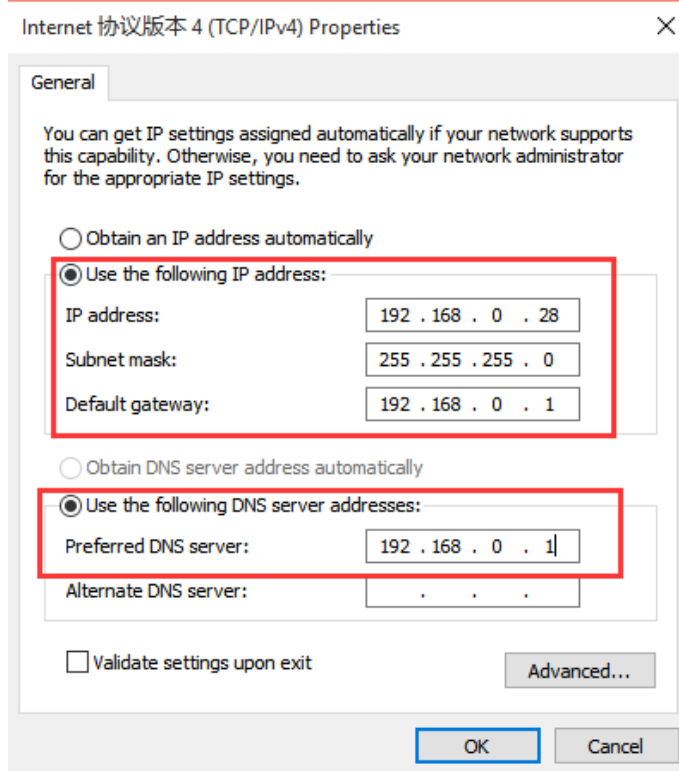
(2) Click “Ethernet” shown as below:



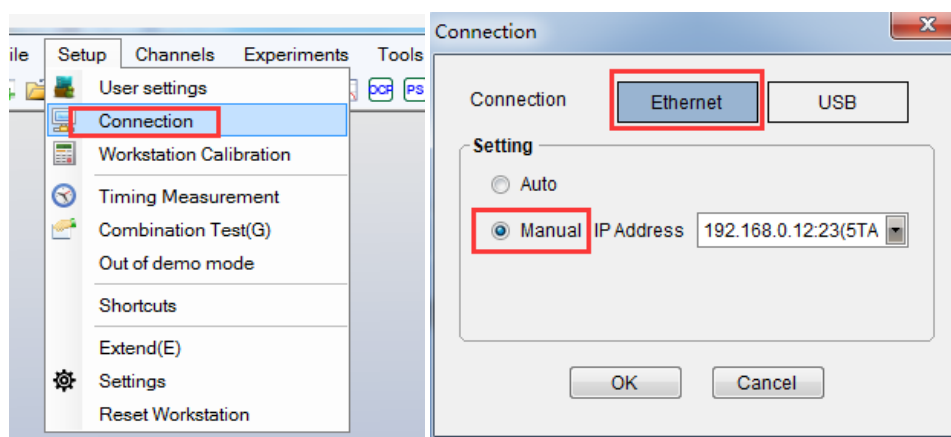
(3) Click “Properties”, then check “Internet Protocol version 4(TCP/IPv4)”



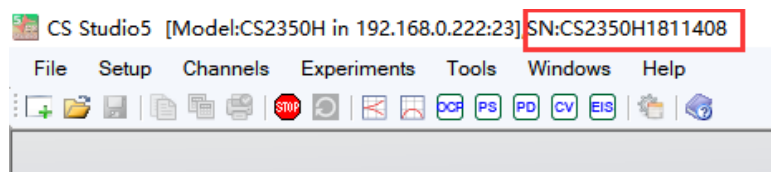
(4) Fill in the IP address exactly as below:



(5) Open CS Studio5 software, “Setup” → Connection→“Ethernet” →Manual



(5) When the bipotentiostat CS2350 is successfully connected with the computer, there will be model and serial number shown on the software interface, as is shown below.




2. Menu

There are key shortcuts for experiment techniques, such as “F2” for “Open Circuit Potential”, F4 for technique of “Potentiodynamic”.

There is a toolbar under the main menu, and it can achieve the same function as the main menu, and there will be a text message tip when you put the mouse on.

the “Experiments” will appear when you right-click the mouse on anywhere of the window. You can choose one technique to perform. Of course you can clicking main menu of “Experiments” and then click one technique..

The button  will be activated when a test is running. You can click it to stop the test. This button will gray out when you finish a test.

2.1 File

2.1.1 Open File

Open a “.cor” data file. You can view data and do analysis. .

2.1.2 New Project

Build a new project window. The original project window will not be closed or replaced.

2.1.3 Open Project

Open a project file. You can view the file and do data analysis.

2.1.4 Save Project

Save the project window file in project file format.

2.1.5 Save Project As

Save data file or project file as a new project file.

2.1.6 Close Project

Close an open project window. If no file is open, this menu is disabled.

2.1.7 Page Setup

Set the format for printing output .

2.1.8 Print

Output the graph of the open file to the printer.

2.1.9 Exit

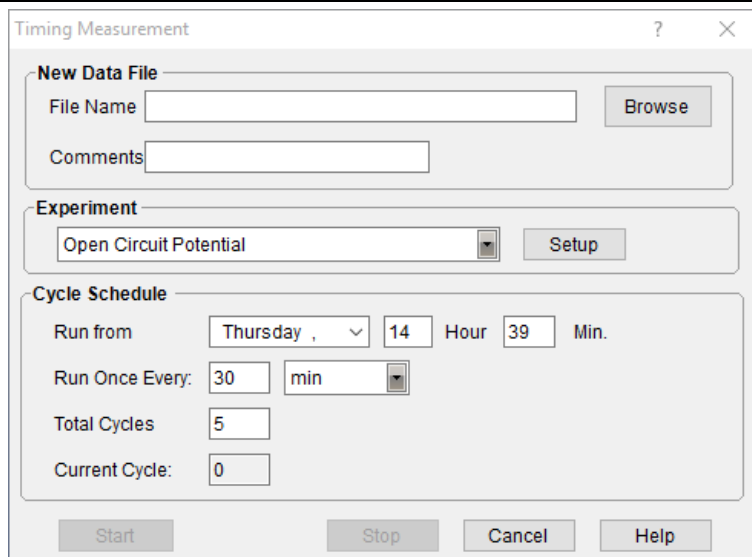
Exit the CS studio software. When a test is being performed, there will be a prompt.

2.2 Setup

2.2.1 Timing Measurement

You can do unattended experiments by timing measurement mode.

It achieves the unattended automatic measurement at a fixed interval that you set after the specified time. This mode facilitates the work of tracking the characteristics of a testing system as a function of time.



The dialog box is titled "Timing Measurement" and contains the following sections:

- New Data File:** Includes a "File Name" text field, a "Browse" button, and a "Comments" text field.
- Experiment:** Includes a dropdown menu showing "Open Circuit Potential" and a "Setup" button.
- Cycle Schedule:** Includes fields for "Run from" (Thursday, 14), "Hour" (39), "Min." (), "Run Once Every:" (30 min), "Total Cycles" (5), and "Current Cycle:" (0).

At the bottom are four buttons: "Start", "Stop", "Cancel", and "Help".

Start button is not activated until you enter a valid file name. All testing data files will be saved in the same directory that you specified.

File Name--For long-term timing measurement, the subsequent data files (abc_1.cor, abc_2.cor, abc_3.cor ...) will be automatically saved.

In the dialog box, you can specify the time when the measurement is started, the interval of measurements, and the total times of measurements.

The current cycle is the number of measurements that have been conducted.

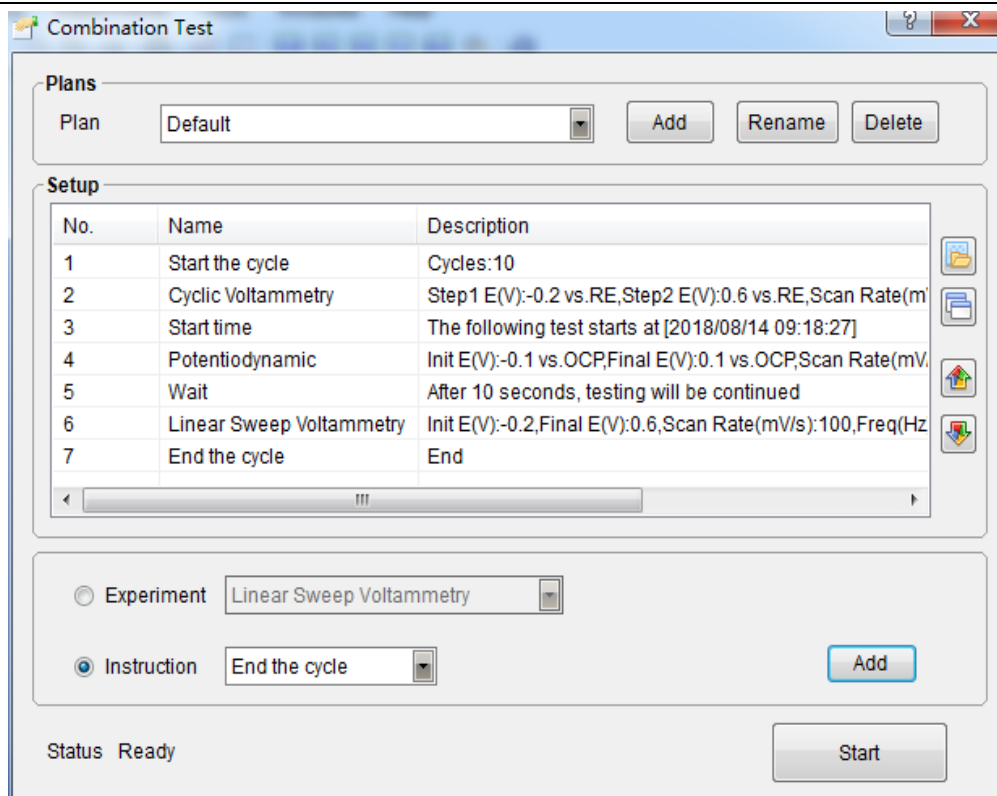
When you select an experiment for timing measurement, the parameters setting will be the same as last time when this experiment is performed. You can modify them and then they will be written in the software for timing measurement use.

For polarization experiments(eg. potentiodynamic, cyclic voltammetry, electrochemical impedance...), the instrument will automatically leave polarization state after each measurement is finished and the cell stays open circuit until the next measurement.

When the total times of measurement is reached, timing measurement window will automatically exit.

2.2.2 Combination Test

Combination test(also called "batch test") is helpful for the user to self-define the experiments. The user can conduct different experiments by adding them from the experiment drop-down box. For each experiment, the parameter setting and number of cycles can be set as you want. After the experiments and instruction are all set, click "Start", the instrument will run all the experiments one by one and save data automatically.



Plan- it shows the combination test plan which is performing at present. Rename is used to modify the plan's name, **Add** is to add a new plan of combination test. The Delete is to get rid of the combination test plan that you don't need.



There are 4 instructions: start the cycle, start time, wait, and end the cycle. If you add instruction "start the cycle", after some techniques and instructions, there must be a "end the cycle".

In the left picture, start the cycle, we entered 10, so it shows "cycles 10". The process from CV to LSV will be repeated for 10 times/cycles.

Start time– You should set a specific time when Potentiodynamic will start.

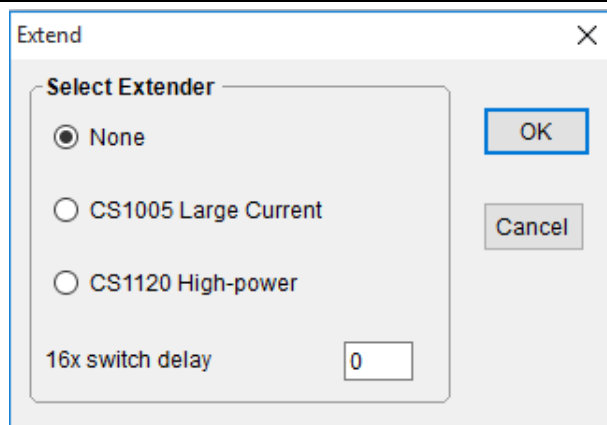
Wait – the delay time, it's a period. We set 10s. In the picture, it indicates that after 10s, the LSV will start to run.

For every technique you choose, every instruction you make, you should click Add.

The added experiments for combination test is shown here. You can click   to change the experiments order.

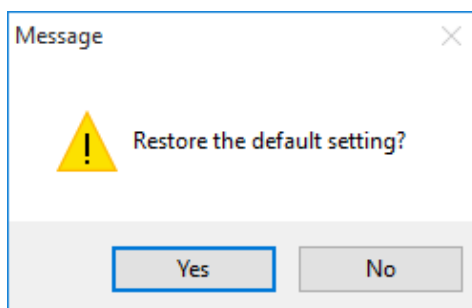
2.2.3 Extend

When CS electrochemical workstation is working alone, you don't need to use the function of "Extend", just check "none". When the normal CS electrochemical workstation CS350 is connected to CS1005 (current amplifier) or CS1120 (power amplifier), please check respectively.



2.2.4 Reset Workstation

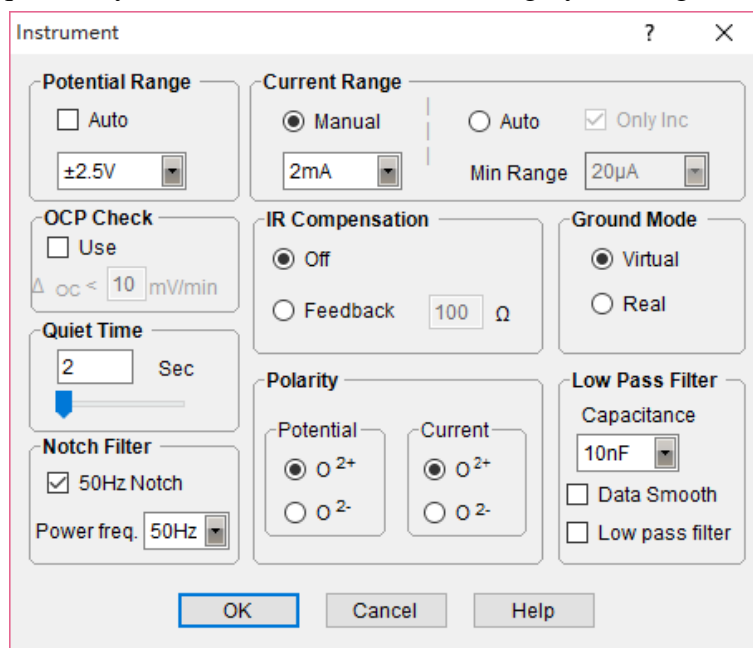
Click “Yes” to restore the factory default settings.



3. Experiment Setting

3.1 Pstat/Gstat(ECS)Setting

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



Potential Range

Potential range can be $\pm 2.5V$, $\pm 5V$, or $\pm 10V$. The default range is $\pm 2.5V$. The narrower the range is, the higher the input signal gain. Normally when the potential signal input is in the

range of $\pm 2.5V$, “ $\pm 2.5V$ ” range is OK. But if the potential of the tested system is over $\pm 2.5V$, you must choose the range to be $\pm 5V$, or $\pm 10V$.

Current Range

You can choose either “Manual” or “Auto”. If check Manual, the drop-down box is activated, and you can choose a suitable current range. If the current in the experiment is over 120% of the set range, then the software will automatically cut off the polarization of the potentiostat. “Auto” allows the instrument to select the suitable current range according to the polarization current.

“**Min Range**” - you can set a limitation for minimum current range to avoid possible extra noise in some high-resistance systems in case the current range is too small.

“**Only Inc**” means the current range will be switched only from lower range to higher range, just in this direction. This is particularly useful for CV technique.

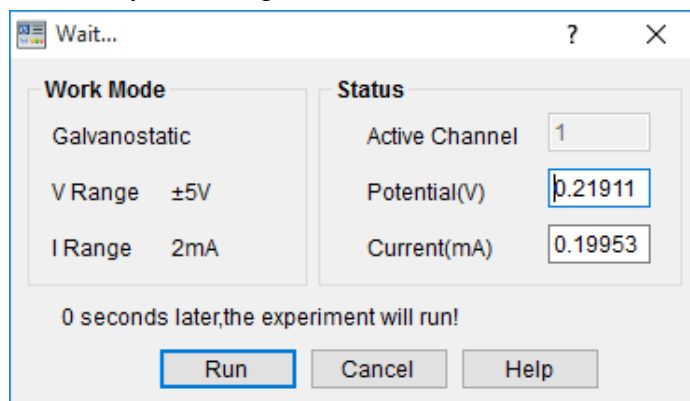
In the moment of current range switching, noise may be inevitable. Therefore, it is recommended to choose a fixed current range in fast measurements or when the data acquisition frequency is high.

OCP Check

If you check the radio button “Use”, the software will judge whether the open circuit potential is in the range that you set. If yes, the experiment will conduct automatically if you have set the data file save path.

Quiet Time

Enter a number or drag the slider, you can specify the duration of delay for scan. The maximum delay time is 1000s. Setting the quiet time can make the measuring current stable, especially when polarization doesn’t start from OCP. As you know, transient polarization may cause a large current, and the value will decrease as time goes by. Therefore, there should be a quiet time before formally recording data.



Before this window appear, the potentiostat is already in the state of polarization, but doesn’t start scan. If you think the polarization current is already stable, then you can click Run anytime to start testing. You can click cancel to quit the experiment.

When the countdown is completed, the scan will start automatically.

If you set “Auto” change current range, during this process, CS studio software will auto choose the suitable range according to the actual current. If the current range is set to be “manual”, once the current is overloaded, the software will give you a prompt to change a larger current range. If you choose “No”, then the software will control the instrument to change from polarization state to natural state.

IR Compensation

In high-resistance system, the solution resistance(R_s) is large between the working electrode and the tip of luggin capillary where the reference electrode is put, especially for concrete or

coated samples, so it must be compensated. R_s measurement can be done with method of Potential Stair-Step (VSTEP). Enter the R_s value in the feedback for IR compensation in the subsequent measurements.

Ground mode

There are two modes for the working electrode: virtual and real. The “virtual” mode is suitable for most stable test systems. As for electrochemical noise or galvanic corrosion measurement, you must choose “virtual” mode. Real mode is suitable for a system where the working electrode is connected to earth, such as the rebar in the concrete. For EIS test, you should choose real mode to increase the high-frequency response characteristic.

Polarity

When choose the normal “ O^{2+} ”, a more positive potential will produce a bigger oxidation force, meanwhile the generated current is positive. In a typical water environment(pH=0), when the potential is +1.23V(vs NHE), the oxygen will precipitate on the surface of the working electrode. If choosing the reverse “ O^{2-} ”, a more negative potential will produce a bigger oxidation force, the oxidation current value is negative. At this time, in a typical water environment (pH=0), when the potential is - 1.23V(vs NHE), oxygen will be precipitated on the surface of the WE.

Low Pass Filter

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

If all the filters are closed, then the power amplifier has the best frequency response characteristics. But for some high-resistance systems, oscillation may appear. If you use the virtual mode and choose a low capacitance, it is very likely for the instrument to occur oscillation even positive feedback. You should decrease the bandwidth of the amplifier, i.e., increase the capacitance in the low pass filter.

When increasing the capacitance, the response frequency bandwidth will decrease, which equals to low-pass filtering the signals. 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) or 0~1nF(real).

Data smooth

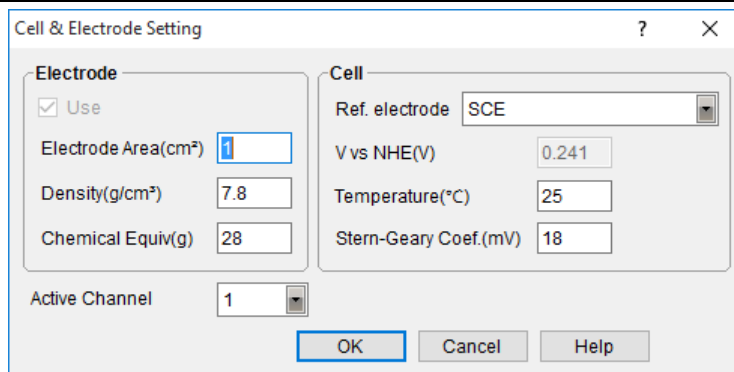
When choosing data smooth, the software will do real-time filtering of the data and automatically get rid of the burrs on the curves. Please note that when you do transient measurements, you don't need to use it because it can bring slight distortion for data.

Notch filter

If you check the notch filter and choose the frequency, the interference can be restrained when the experiment is being conducted.

3.2 Cell Setting

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.



Electrode parameters

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

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

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

Cell parameters

Reference electrode: in the drop box you can choose SCE, Ag/AgCl, Hg/HgO, Hg/HgSO₄, Cu/CuSO₄... You can also choose "Custom" if your RE is not in the list, then you should specify the value of "V vs. NHE (normal hydrogen electrode)".

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.

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

Active channel

For single-channel CS potentiostat, there is only 1 channel. For multi-channel potentiostat, you can set the cell information independently.

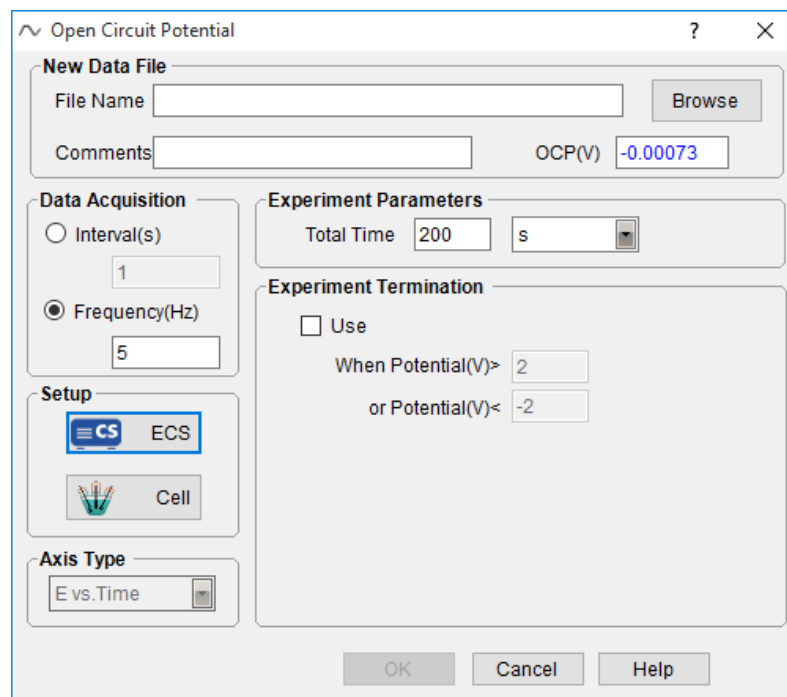
4. Stable Polarization

4.1 Open Circuit Potential

Experiments→Stable Polarization→Open Circuit Potential

This experiment aims at monitoring the open circuit potential (or free corrosion potential, i.e., the potential difference between WE and RE without any applied electric field) as a function of time. The experiment can be performed for a fixed duration or until a particular potential is reached.

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.

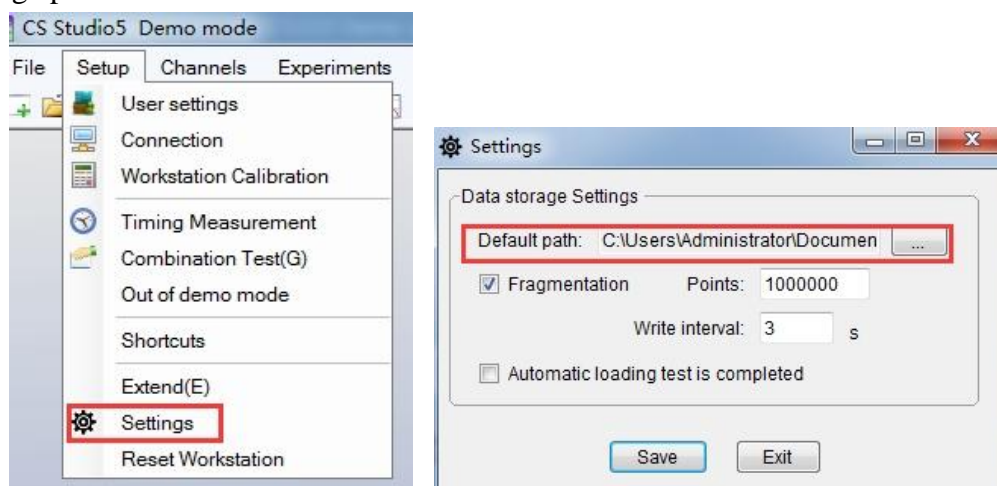


OCP (V) will display the current open circuit potential of the cell (update every second).

4.1.1 File Name

You're suggested to build up 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.

If you don't click browse and directly enter a name and confirm, then the default data storage path is as follows:



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 box 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.

4.1.2 Experiment

The Total Time decides the total duration of the experiment OCP. Unit is second, minute or hour.

4.1.3 Data Acquisition

Choose either “Interval” or “Frequency”.

Interval determines the time between each sampled data point. Frequency (Hz) specifies the data points sampled 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).

4.1.4 Experiment Termination

If the Use is checked, the experiment will be automatically terminated once the open circuit potential goes above the high value (2V in the above dialog box for instance) or below the low value (-2V).

4.1.5 Axis Type

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

4.1.6 Pstat/Gstat(ECS)

See 3.1Pstat/Gstat(ECS) Setting

4.1.7 Cell Setup

See Cell Setting 3.2.

Click OK to exit the parameter setting dialog box, and enter the “wait...” interface before testing. Meanwhile, CS Studio will save all the parameters that you set and remain the same the next time when you run this experiment.

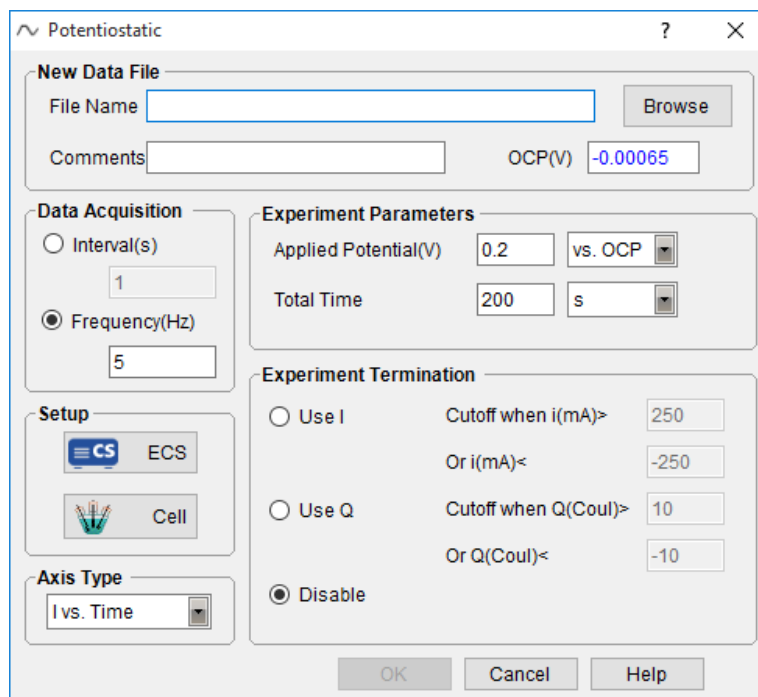
Click “Cancel” also to exit the dialog box, not conducting the experiment. All the set parameters will be lost.

Click Help to access to the on-line help information on the setup of this experiment.

4.2 Potentiostatic

Experiments→Stable Polarization→Potentiostatic

In this experiment, the potentiostat applies a constant polarization potential on the working electrode and monitor the polarization current as a function of time. The polarization duration (Total Time) can be set by the user, or you can also let the experiment be automatically terminated when the polarization current or quantity of electric charge reaches to a certain value (change from the polarization state to OCP state).



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

4.2.1 File Name

See 4.1.1 File Name.

4.2.2 Experiment Parameters

Applied Potential is the potential applied on the measured system. It can be potential “vs. OCP” or “vs. RE”.

For CS series potentiostat, choosing potential “vs. OCP”, then input of a positive value means anodic polarization, negative value means cathodic polarization. Then the actual potential applied on the WE is the algebraic sum of the input value and the current open circuit potential. For example, enter “0.2”, then the actual potential of the working electrode (vs. RE) is “0.2V+OCP”. If selecting “vs. RE”, then the polarization potential of the working electrode (vs. RE) is just 0.2V.

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

4.2.3 Experiment Termination

If the Use I box is checked, the experiment of potentiostatic will be automatically terminated once the polarization current goes above the high value(anodic current, 250mA in above dialog box for instance) or below the low value (cathodic current, -250mA in above dialog box for instance) .

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

If the Disable is checked, the above two experiment termination prerequisites are ineffective. The experiment will not be terminated until the total time is reached.

4.2.4 Data Acquisition

See 4.1.3 Data Acquisition.

4.2.5 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”.

4.2.6 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting

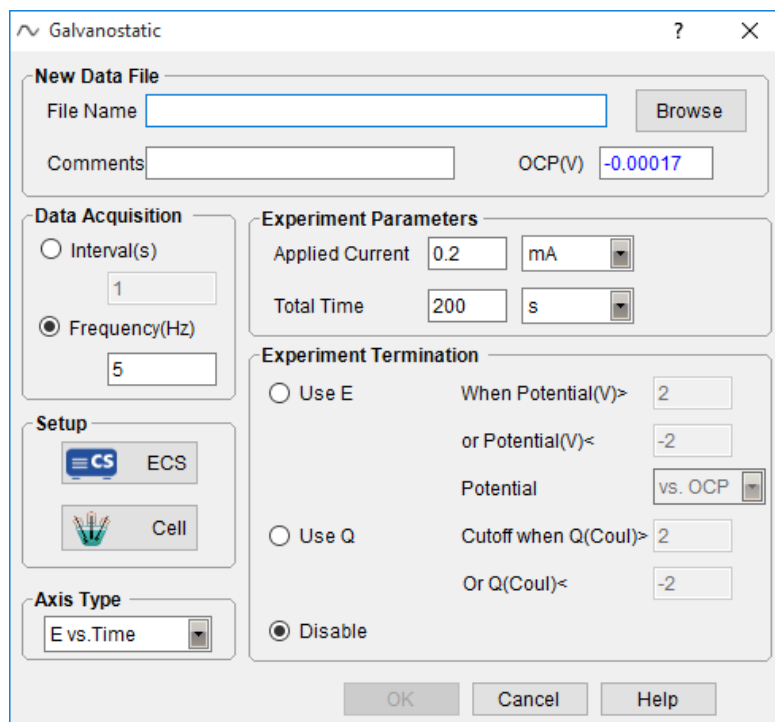
4.2.7 Cell Setting

See Cell Setting 3.2.

4.3 Galvanostatic

Experiments→Stable Polarization→Galvanostatic

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



The dialog box titled "Galvanostatic" contains the following sections:

- New Data File:** Includes a "File Name" text box, a "Browse" button, a "Comments" text box, and an "OCP(V)" field showing "-0.00017".
- Data Acquisition:** Features two radio buttons: "Interval(s)" with a value of "1" and "Frequency(Hz)" with a value of "5".
- Experiment Parameters:** Includes "Applied Current" set to "0.2" mA and "Total Time" set to "200" s.
- Experiment Termination:** Contains two radio buttons: "Use E" and "Use Q". Under "Use E", there are fields for "When Potential(V) >" (set to "2") and "or Potential(V) <" (set to "-2"), along with a "Potential" dropdown set to "vs. OCP". Under "Use Q", there are fields for "Cutoff when Q(Coul) >" (set to "2") and "Or Q(Coul) <" (set to "-2"). A "Disable" radio button is also present.
- Setup:** Includes buttons for "CS" (selected) and "ECS", and a "Cell" button with a cell icon.
- Axis Type:** A dropdown menu set to "E vs. Time".

At the bottom are "OK", "Cancel", and "Help" buttons.

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

4.3.1 File Name

See 4.1.1 File Name.

4.3.2 Experiment

Applied Current is the current applied on the measured system. Positive value means anodic polarization; negative value means cathodic polarization. This is the total current applied, not the current density. Units of μA , mA, A are available.

The Total Time determines the duration of the galvanostatic polarization process.

4.3.3 Experiment Termination

If the Use E box is checked, the experiment of galvanostatic will be automatically terminated once the polarization potential goes above the high value(2V in above dialog box for instance) or below the low value (-2V in above dialog box for instance) .

If Use Q is checked, the experiment of galvanostatic 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 above two experiment termination prerequisites are ineffective. The experiment will not be terminated until the total time is reached.

4.3.4 Data Acquisition

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

4.3.5 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”.

4.3.6 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting

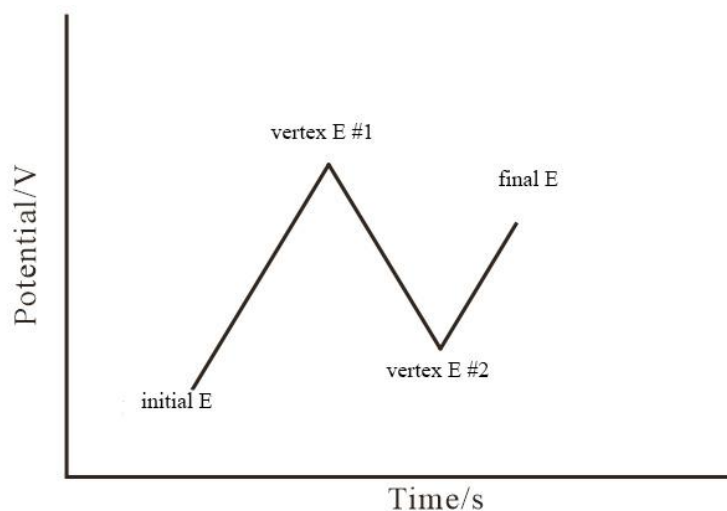
4.3.7 Cell Setting

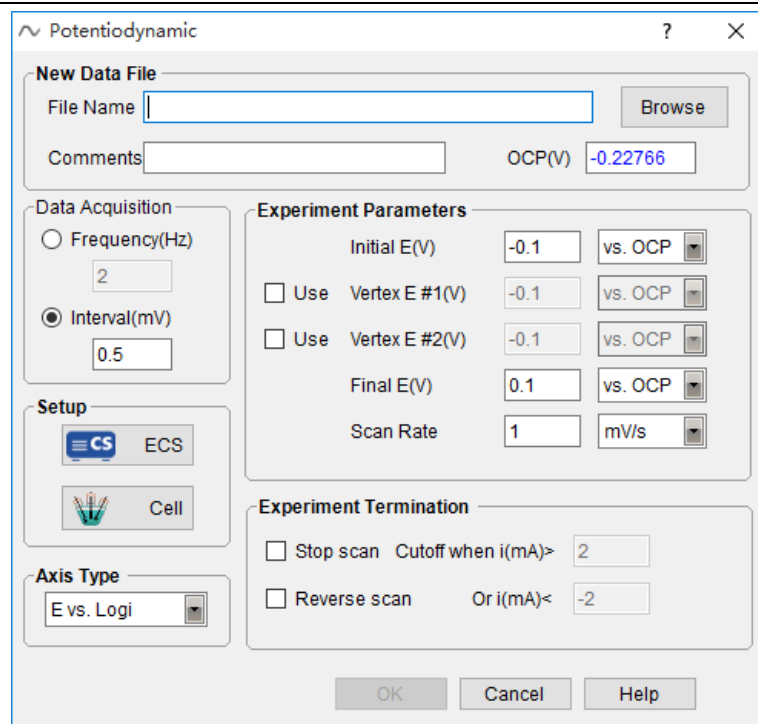
See Cell Setting 3.2.

4.4 Potentiodynamic

Experiments→Stable Polarization→Potentiodynamic

For technique of potentiodynamic, there are up to four individual polarization potential set points. The scan starts from the “initial E” and goes through “vertex E #1”, “vertex E #2”, and finally reaches “final E”. The “vertex E #1” and “vertex E #2” can be both chosen, partly chosen or neither chosen by the **Use** box. The scan can be stopped or reversed when current reaches to a certain value. The logarithm of current is recorded as a function of potential.





The screenshot shows the 'Potentiodynamic' window with the following sections:

- New Data File:** File Name (empty), Comments (empty), OCP(V) -0.22766, and a Browse button.
- Data Acquisition:** Radio buttons for Frequency(Hz) (set to 2) and Interval(mV) (set to 0.5, selected).
- Setup:** Buttons for CS, ECS, and Cell.
- Axis Type:** A dropdown menu showing 'E vs. Logi'.
- Experiment Parameters:**
 - Initial E(V): -0.1, vs. OCP (dropdown)
 - ☐ Use Vertex E #1(V): -0.1, vs. OCP (dropdown)
 - ☐ Use Vertex E #2(V): -0.1, vs. OCP (dropdown)
 - Final E(V): 0.1, vs. OCP (dropdown)
 - Scan Rate: 1, mV/s (dropdown)
- Experiment Termination:**
 - ☐ Stop scan Cutoff when i(mA) > 2
 - ☐ Reverse scan Or i(mA) < -2

Buttons at the bottom: OK, Cancel, Help.

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

4.4.1 File Name

See 4.1.1 File Name.

4.4.2 Experiment Parameters

If you check neither vertex E#1 nor vertex E#2, then the potential is scanned directly from Initial E towards Final E. For example, if you enter “-0.1” (vs. OCP) in the initial E, and “0.1” (vs. OCP) in the final E box, then the potential is actually scanned from cathodic polarization 100mV to anodic polarization 100mV. Of course when the polarization current density has already entered the range to terminate the experiment before the potential reaches 10mV, the scan will stop, and cut off the polarization state of the potentiostat. If potential is “vs. OCP”, then 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 potential. Scan time = scan amplitude/scan rate. Total measuring time = $\sum(|\text{amplitude of polarization potential of each segment}|/\text{scan rate})$

Experiment Termination

If check “Stop scan”, when final potential is reached or the polarization current density is higher than the maximum value (e.g. $2\text{mA}/\text{cm}^2$) or lower than the minimum set value (e.g. $-2\text{mA}/\text{cm}^2$), the experiment will be stopped automatically.

If check the “Reverse scan”, when polarization current reached the range that you set, the scan direction will be reversed, from current potential to initial potential. If the current density is lower than the minimum value you set during cathodic retrace scan, the scan will be automatically stopped.

If neither is checked, the experiment will be conducted according to the potential settings. Normally, to protect the working electrode from excessively high current, you can choose Stop scan and set a maximum anodic current.

4.4.3 Data Acquisition

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

4.4.4 Axis Type

In the experiment of potentiodynamic, you can choose “E vs. Logi”.

4.4.5 Pstat/Gstat(ECS)

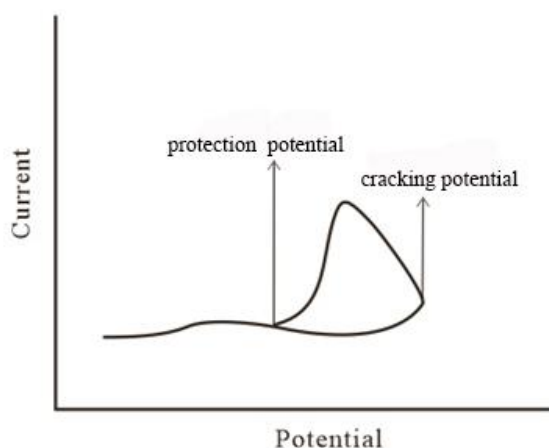
See 3.1 Pstat/Gstat(ECS) Setting

4.4.6 Cell Setting

See Cell Setting 3.2.

4.4.7 Passivation curve

In potentiodynamic test, sometimes we need to measure passivation curves of some metals such as chromium, nickel, cobalt and their alloys in certain medium. It will produce a layer of passivation film on the surface of these metals when their potential is relatively positive. At this moment, they are similar to noble metals in behavior, with slight passivation current flowing. In order to evaluate their anti-corrosion performance, it is necessary to obtain the cracking potential and protection potential. Therefore, the passivation curve is graphed.



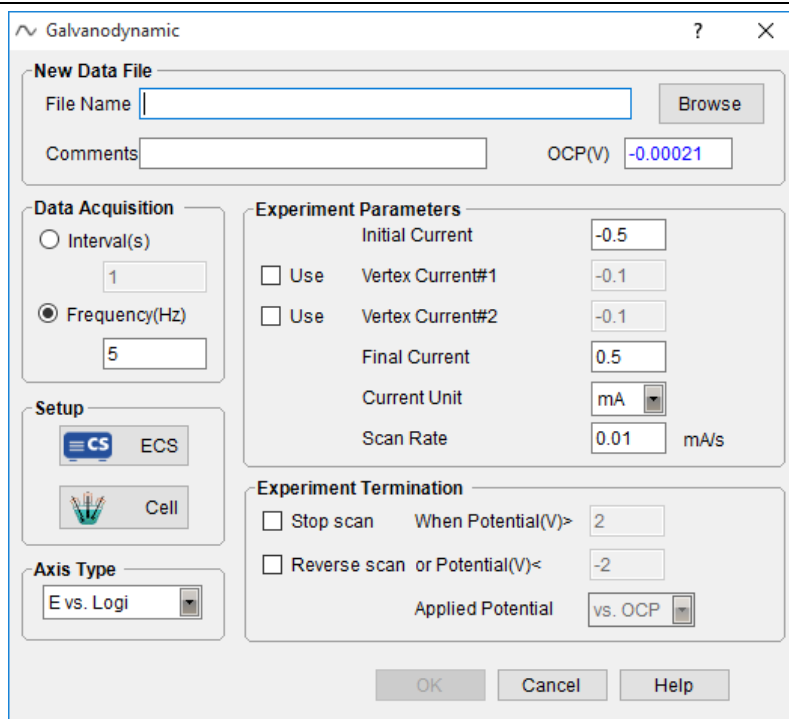
Typical passivation curve

When the polarization potential is scanned towards positive to a certain value, the passivation film will be cracked, then the polarization current will increase rapidly, this polarization potential is called cracking potential ϕ_b . When the current exceeds a certain value (eg. $100\mu\text{A}/\text{cm}^2$), the potential will immediately be scanned towards negative, there will be a hysteresis loop on the polarization curve. The intersection of the positive curve and the flyback curve is considered to be the protection potential of the metal in this medium ϕ_p .

4.5 Galvanodynamic

Experiments→Stable Polarization→Galvanodynamic

For technique of galvanodynamic, there are up to four individual polarization current set points. The scan starts from the “initial current” and goes through “vertex i #1”, “vertex i #2”, and finally reaches “final i”. The “vertex i #1” and “vertex i #2” can be both chosen, partly chosen or neither chosen by the Use box. The scan can be stopped or reversed when potential reaches a certain value.



The screenshot shows the 'Galvanodynamic' window with the following settings:

- New Data File:** File Name (empty), Comments (empty), OCP(V) -0.00021
- Data Acquisition:** Interval(s) 1, Frequency(Hz) 5 (selected)
- Setup:** CS ECS, Cell
- Axis Type:** E vs. Logi
- 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
- 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 every second).

4.5.1 File Name

See 4.1.1 File Name.

4.5.2 Experiment Parameters

If you check neither vertex i#1 nor vertex i#2, then the current is scanned directly from Initial i towards Final i. For example, if you enter “-100” (unit: μ A) in the initial i, and “100” in the final i box, then the current is actually scanned from cathodic polarization 0.1mA to anodic polarization 0.1mA. Of course when the polarization potential has already entered the range to terminate the experiment before current reaches 0.1mA, the scan will stop, and cut off the polarization state of the potentiostat.

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.

4.5.3 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 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.

4.5.4 Data Acquisition

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

4.5.5 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.

4.5.6 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting

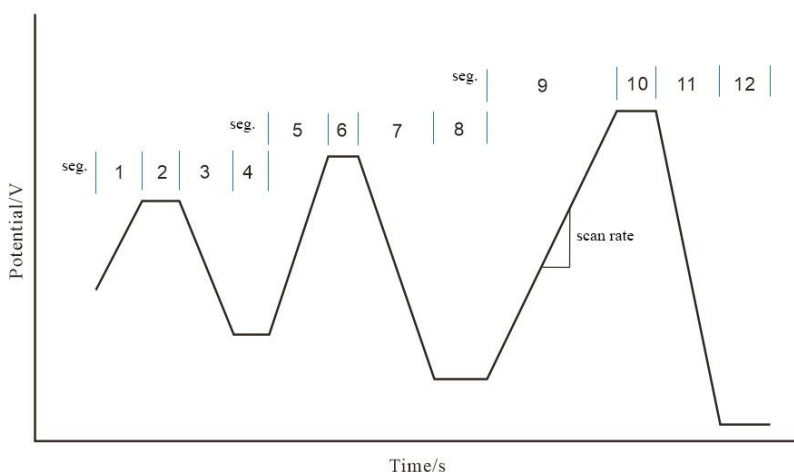
4.5.7 Cell Setting

See Cell Setting 3.2.

4.6 Potential Sweep-step

Experiments→Stable Polarization→Potential Sweep-step

In Potential Sweep-step, the instrument alternates between six potential sweeps and six potential steps, somewhat like an arbitrary waveform generator. The following diagram shows the potential waveform applied as a function of time. One can skip any segment by setting parameters sufficiently small, allowing enhanced flexibility for waveform control. Current is recorded as a function of time; for sweep segments, it can also be presented as a function of potential.



Potential Sweep-Step

New Data File

File Name Browse

Comments OCP(V)

Data Acquisition

☐ Interval(s)

☒ Frequency(Hz)

Setup

☒ CS ECS

☐ Cell

Axis Type

Segment	Init E(V)	Final E(V)	Scan Rate(V/s)	Step E(V)	Step Time(s)
Segment1	-0.1	0.1	0.05	0.1	10
Segment2				0.1	10
Segment3	-0.3	0.3	0.05	0.3	10
Segment4				0.3	10
Segment5	-0.5	0.5	0.05	0.5	10
Segment6				0.5	10
Segment7	-0.7	0.7	0.05	0.7	10
Segment8				0.7	10
Segment9	-0.9	0.9	0.05	0.9	10
Segment10				0.9	10
Segment11	-1.1	1.1	0.05	1.1	10
Segment12				1.1	10

Potential ☒ vs. OCP ☐ Quiet Time(s)

OK Cancel

Parameter setting dialog box

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	1E-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

4.6.1 Data Acquisition

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

4.6.2 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.

4.6.3 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

4.6.4 Cell Setting

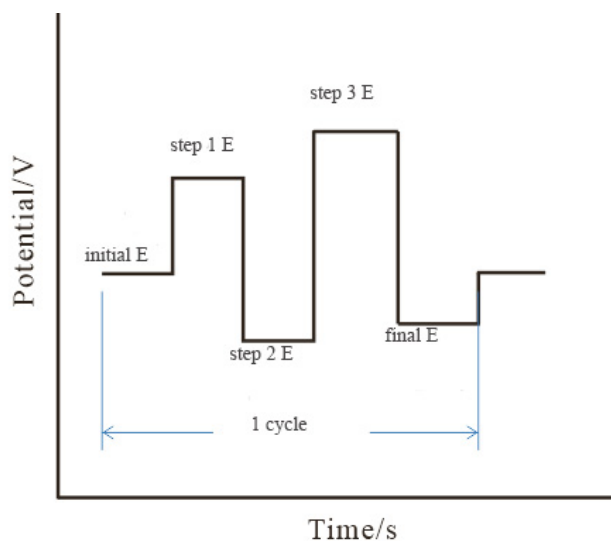
See Cell Setting 3.2.

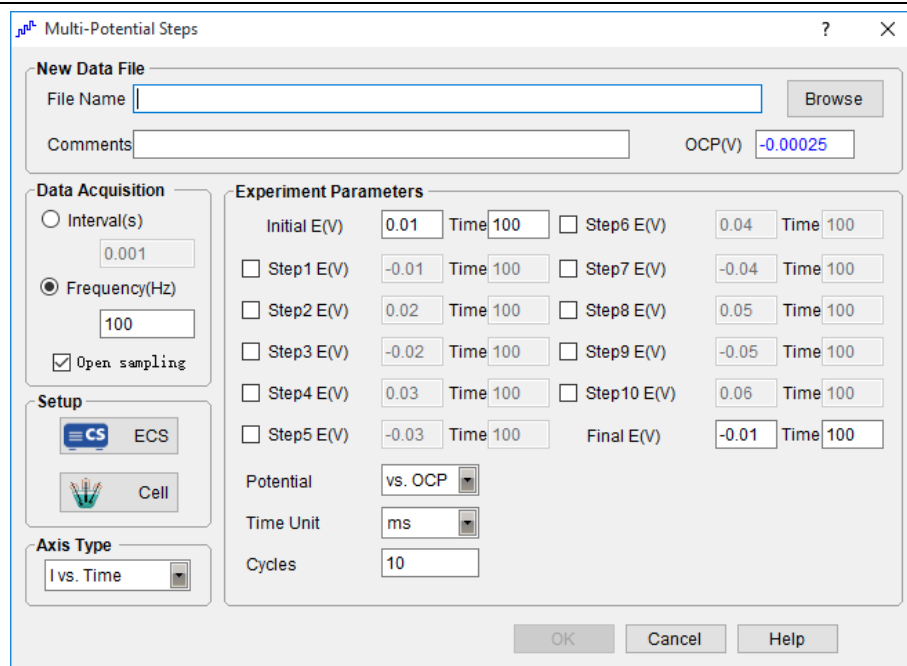
5. Transient Polarization

5.1 Multi-Potential Steps

Experiments→Transient Polarization→Multi-potential Steps

In the Multi-potential Steps technique, up to twelve potential steps can be applied and cycled. Current is recorded as a function of time.





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

5.1.1 File Name

See 4.1.1 File Name.

5.1.2 Experiment Parameters

The steps start from the Initial E, then to Step 1E, Step 2E, Step 3E,...towards Final E. If the time of a step is “0” or the box before it is unchecked, this segment will be skipped.

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

Cycles specifies how many times the potential is stepped between Initial E and Final E.

Time determines the duration of the step potential being held.

5.1.3 Data Acquisition

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

5.1.4 Axis Type

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

5.1.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting

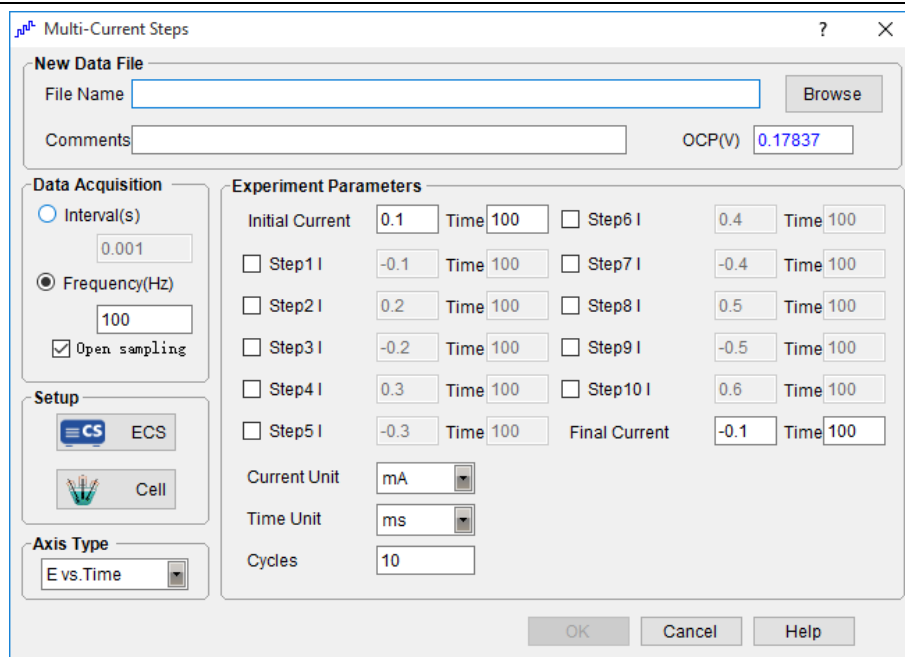
5.1.6 Cell Setting

See Cell Setting 3.2.

5.2 Multi-Current Steps

Experiments→Transient Polarization→Multi-Current Steps

In the Multi-Current Steps technique, up to twelve current steps can be applied and cycled. Potential is recorded as a function of time.



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

5.2.1 File Name

See 4.1.1 File Name.

5.2.2 Multi-Current Steps Parameters

The steps start from the Initial i , then to Step 1 i , Step 2 i , Step 3 i ,...towards Final i . If the time of a step is "0" or the box before it is not checked, this segment will be skipped.

Cycles specifies how many times the current is stepped between Initial i and Final i .

Time determines the duration of the step current being held.

5.2.3 Data Acquisition

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

5.2.4 Axis Type

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

5.2.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting

5.2.6 Cell Setting

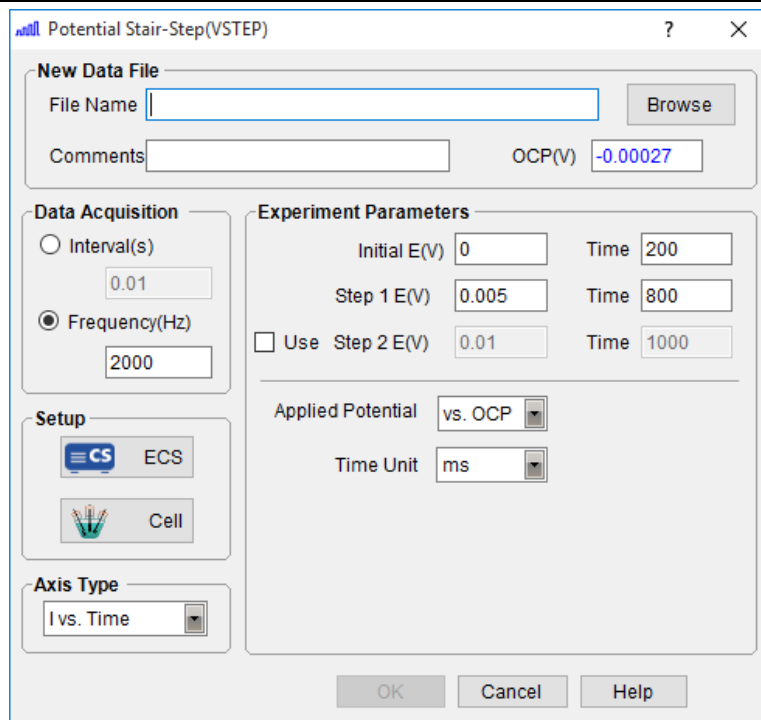
See Cell Setting 3.2.

5.3 Potential Stair-Step(VSTEP)

Experiment→Transient Polarization→Potential Stair-Step

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 box is checked, the mode of the stair step is Initial E→Step1 E→Step2 E to finish two segments of stair step measurement.



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

5.3.1 File Name

See 4.1.1 File Name.

5.3.2 Experiment Parameters

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

Time determines the holding time of a step potential.

5.3.3 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, 1~3KHz is recommended.

5.3.4 Axis Type

Axis Type is I vs. time.

5.3.5 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.

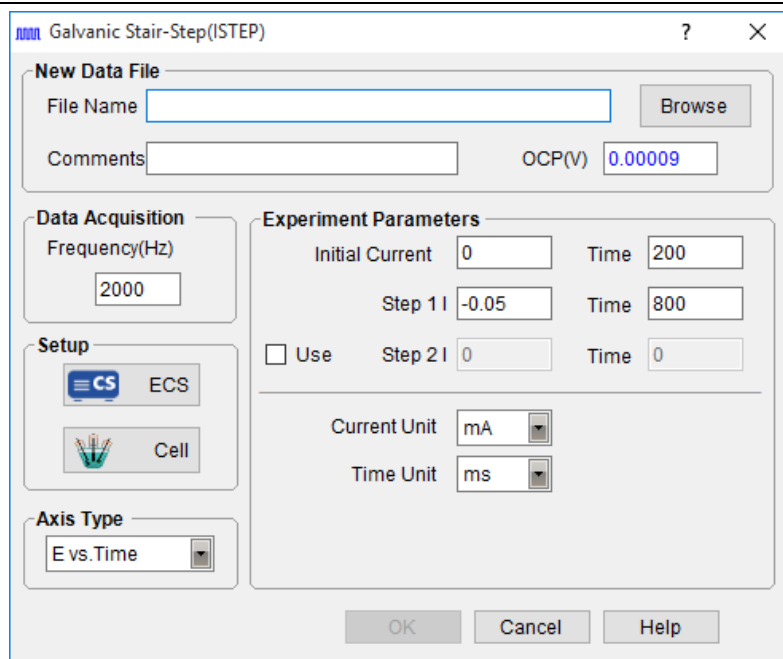
5.3.6 Cell Setting

See Cell Setting 3.2.

5.4 Galvanic Stair-Step(ISTEP)

Experiments→Transient Polarization→Galvanic Stair-Step

There are up to 3 individual current setpoints for galvanicStair-step. If the Use box is checked, the mode of the stair step is Initial current→Step 1 E→Step 2 E to finish two segments of stair step measurement.



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

5.4.1 File Name

See 4.1.1 File Name.

5.4.2 Scan Parameters

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

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

5.4.3 Data Acquisition

If **Frequency(Hz)** is chosen, the acquisition rate in points/second is specified. Owing to the fast process of step, the data acquisition rate is fast too. The frequency is normally set between 1~3KHz.

5.4.4 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.

5.4.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

5.4.6 Cell Setting

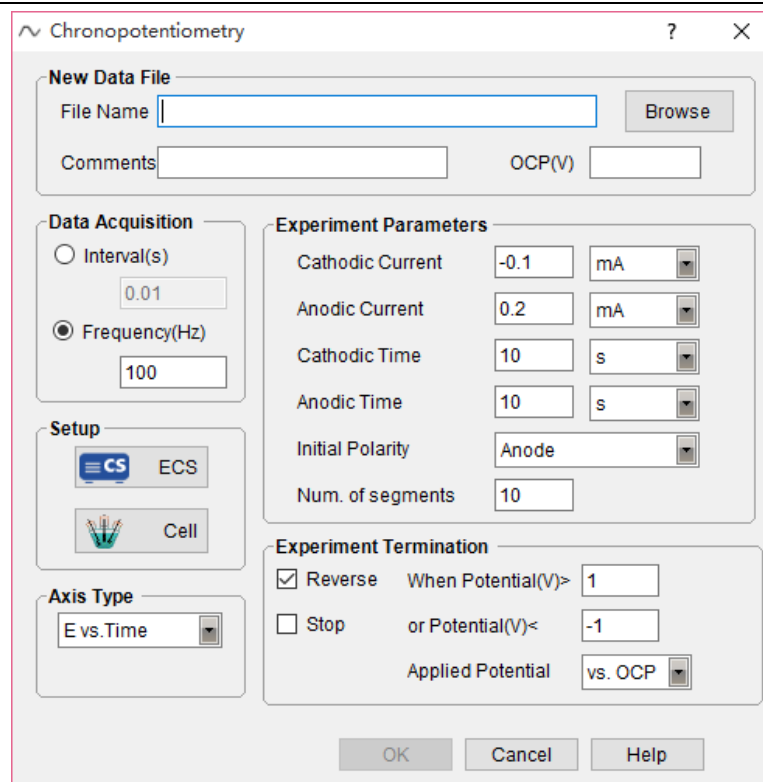
See Cell Setting 3.2.

6. Chrono Techniques

6.1 Chronopotentiometry

Experiments→Chrono Techniques→Chronopotentiometry

In Chronopotentiometry (CP), two current levels can be specified to pass through the working electrode, with the switching between the two dictated by time or potential. Potential is recorded as a function of time.



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

6.1.1 File Name

See 4.1.1 File Name.

6.1.2 Experiment Parameters

Cathodic /anodic current is applied on the working electrode during the test. You can choose the unit of the current.

Cathodic /anodic time is the duration of the applied cathodic /anodic current. Second, minute and hour can be selected.

Num. of segments specifies how many times the current is cycled between cathodic and anodic current. When the number of current polarity switches (segments) is reached, the experiment stops.

Parameters	Range	Description
Cathodic current	-2A~+2A	The cathodic current applied on the working electrode
Anodic current	-2A~+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 number of applied cathodic and anodic current

6.1.3 Current Polarity Switching

It's 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 polarity will be switched, proceeding the cathodic polarization. If the potential reaches -1V in less than 10s, anodic polarization is triggered.

6.1.4 Data Acquisition

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

6.1.5 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.

6.1.6 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

6.1.7 Cell Setting

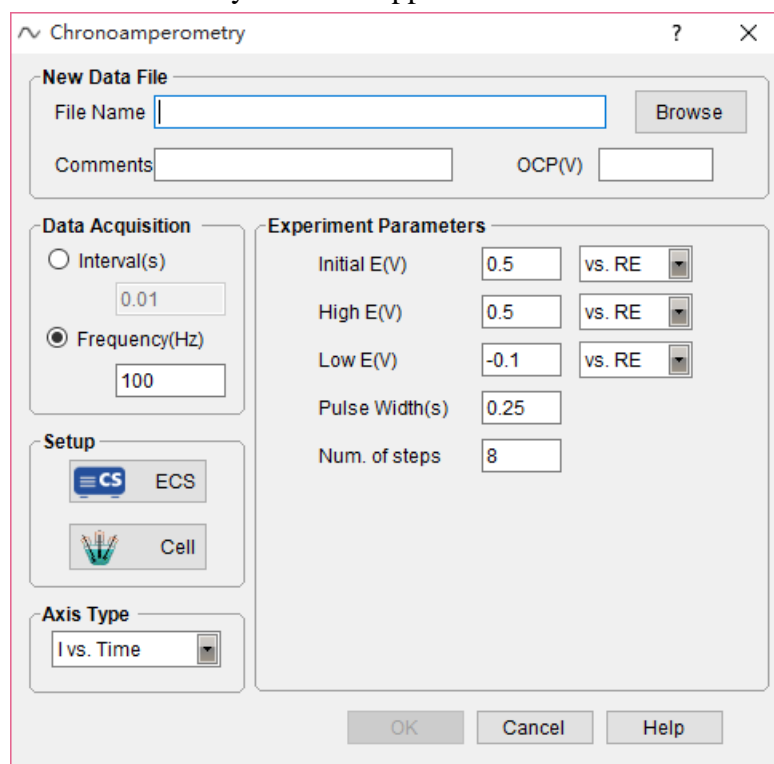
See Cell Setting 3.2.

6.2 Chronoamperometry

Experiments→Chrono Techniques→Chronoamperometry

Chronoamperometry method measures the current response as a function of time after applying a single or dual potential step on the working electrode. Electrodes of fixed area are often used in this method. This method is used to study the electrode process of coupling chemical reaction, especially the reaction mechanism of organic electrochemistry.

In Chronoamperometry (CA), the potential is stepped from Init. E to either High E or Low E depending on the Init. P/N and may then be stepped back.



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

6.2.1 File Name

See 4.1.1 File Name.

6.2.2 Parameters setting

The experiment starts at the Initial E, sweeps to High E, and then to Low E. The 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. If “vs.RE” is chosen, an exact potential is applied.

Pulse width specifies how long the potential is sustaining.

Number of Steps specifies how many potential cycles are formed between High E and Low E.

Parameters	Range	Description
Initial E (V)	-10~+10	Initial potential
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

6.2.3 Data Acquisition

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

6.2.4 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.

6.2.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

6.2.6 Cell Setting

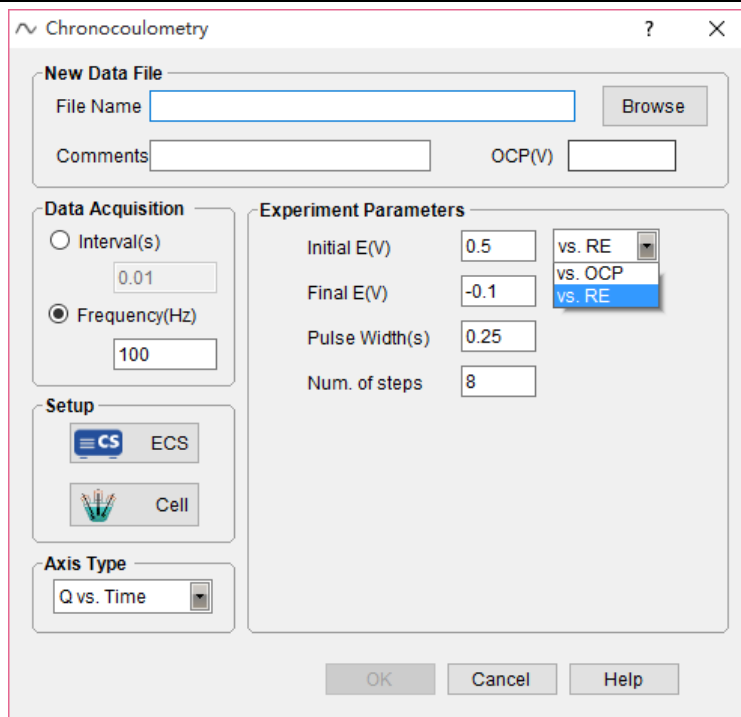
See Cell Setting 3.2.

6.3 Chronocoulometry

Experiments→Chrono Techniques→Chronocoulometry

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. It can study electrode process in all kinds of coupling reactions. It can also study the electroactive substance adsorption.

A fast-rising potential pulse is applied on the working electrode of an electrochemical cell. The current flowing through this electrode is measured and integrated, reporting coulombs as a function of time. Technique is also referred to as CC.



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

6.3.1 File Name

See 4.1.1 File Name.

6.3.2 Parameters setting

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)	0.001~10	Duration of the applied potential pulse
Number of steps	>0	Number of potential steps

The potential may be swept between up to 2 separate setpoints in this experiment. The experiment starts at the initial potential, and then to the final potential. 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” is chosen to select an exact potential to be applied.

Pulse width specifies how long the potential is sustaining.

Number of steps specifies how many times the potential is cycled between Initial E and Final E.

6.3.3 Data Acquisition

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

6.3.4 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.

6.3.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

6.3.6 Cell Setting

See Cell Setting 3.2.

7. Voltammetry

7.1 Cyclic Voltammetry

Experiments→Voltammetry→Cyclic Voltammetry

CV technique is used for the theoretical study of redox couples. Cyclic Voltammetry is a special LSV that performs a triangular wave scanning on the working electrode. The potential is linearly swept from Init E to High E (or Low E, depending on the Init P/N polarity parameter). The potential is then swept back in the reverse direction.

CV curve usually consists of two parts: 1) the lower reduction /cathode part where the reduction waveform is generated from reduction process of the oxidation state of the electroactive material, 2) and the upper oxidation/anode part where the oxidation waveform is generated from oxidation process of reduction products. CV technique can directly measure the ratio of anodic peak current/cathodic peak current and the difference between anodic peak potential and cathodic peak potential.

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

For reversible system, if the cathodic reduction products are stable, then $i_{pc}/i_{pa}=1$.

To judge the reversibility of electrode process, the following formulas are employed:

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

Where E_{pa} = anodic peak potential

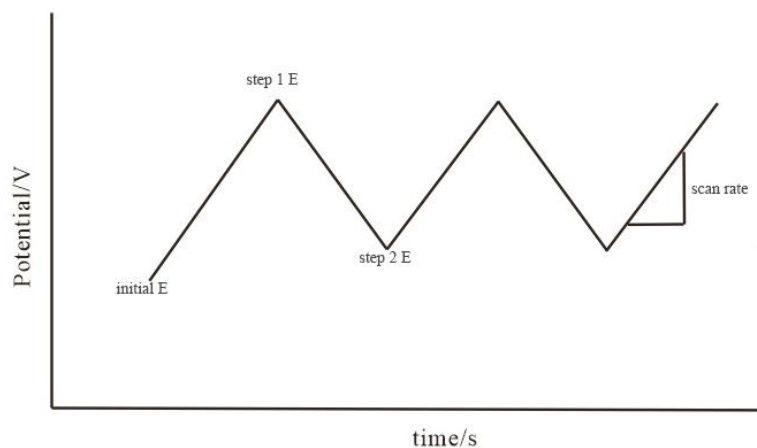
$$E_{pc} = E_{1/2} - \frac{28.25}{n}$$

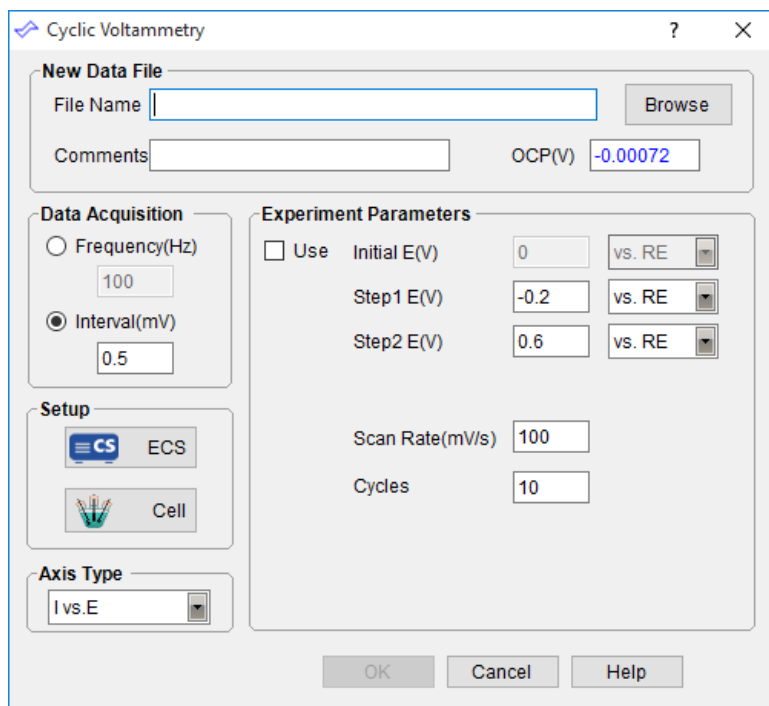
E_{pc} = cathodic peak potential.

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

Note: ΔE_p is related to the reversing potential during CV scan. If $n=1$, and the reversing potential is -100mV vs. E_{pc} , the ΔE_p will be 59mV. ΔE_p is also associated with the experiment environment, the value is in the range of 55~65mV($n=1$), we can judge it as a reversible process.

There are three individual setting points of potential. If use “initial E”, then the potential is scanned from “initial E” to “step 1 E”, to “step 2E”, and back to initial E, cyclically.





The dialog box is titled "Cyclic Voltammetry". It contains several sections:

- New Data File:** Includes a "File Name" input field with a "Browse" button, a "Comments" input field, and an "OCP(V)" input field showing "-0.00072".
- Data Acquisition:** Has two radio buttons: "Frequency(Hz)" (set to 100) and "Interval(mV)" (set to 0.5, which is selected).
- Setup:** Contains two buttons: "CS ECS" and "Cell".
- Axis Type:** A dropdown menu showing "I vs. E".
- Experiment Parameters:** Includes a "Use" checkbox, and three potential setpoints: "Initial E(V)" (0 vs. RE), "Step1 E(V)" (-0.2 vs. RE), and "Step2 E(V)" (0.6 vs. RE). It also has "Scan Rate(mV/s)" (100) and "Cycles" (10) input fields.

At the bottom are "OK", "Cancel", and "Help" buttons.

Parameters setting dialog box

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

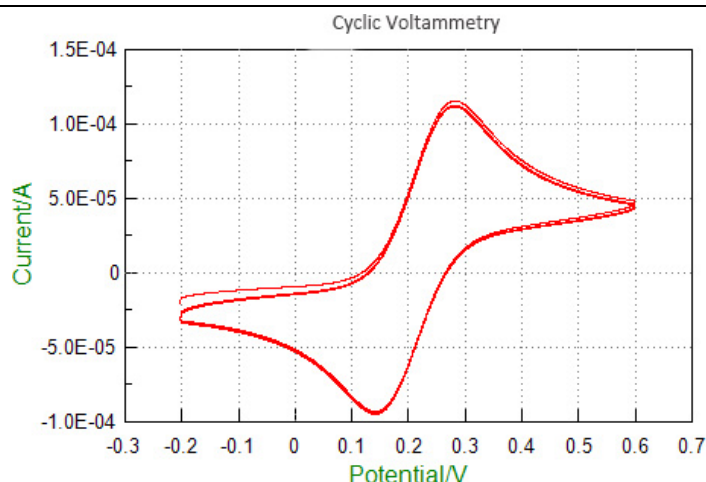
7.1.1 File Name

See 4.1.1 File Name.

7.1.2 Scan Parameters

Parameters	Range	Description
Initial E(V)	-10~+10	Initial potential of scan
Step 1E(V)	-10~+10	Initial potential of the scan(not checking "Use") or the first vertex potential
Step 2 E(V)	-10~+10	the second vertex potential of the scan
Scan rate(mV/s)	$10^{-3} \sim 10^7$	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	Sampling as per frequency, Either Interval or Frequency should be chosen.

The potential may be swept between up to 3 separate setpoints in this experiment. The experiment starts at the Initial E, sweeps to Step 1E, to Step 2 E, and then back to the Initial E. Check "Use" to turn on or turn off the Initial E setpoint.



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

7.1.3 Data Acquisition

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

7.1.4 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.

7.1.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

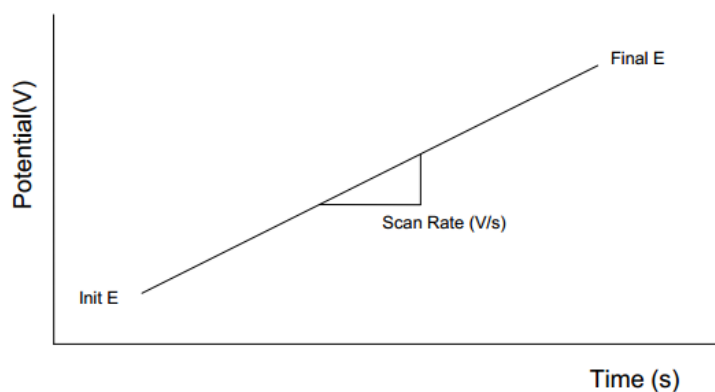
7.1.6 Cell Setting

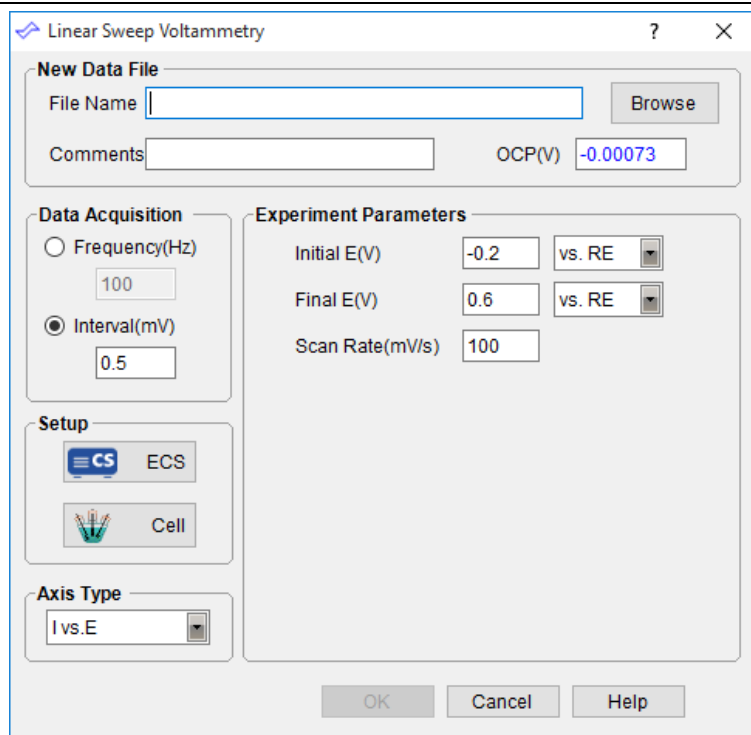
See Cell Setting 3.2.

7.2 Linear Sweep Voltammetry

Experiments→Voltammetry→Linear Sweep Voltammetry

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. Normally, the scan rate of the instrument can be from several mV to 1V per second.





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

7.2.1 File Name

See 4.1.1 File Name.

7.2.2 Scan 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)	$10^{-3} \sim 10^7$	The scan rate of the potential
Interval (mV)	> 0.001	Potential difference between two sampling points
Frequency (Hz)	0.01~1000	Sampling as per frequency, Either Interval or Frequency should be chosen

Up to 2 separate potentials can be set during the experiment. The scan starts at the Initial E, and to the Final E.

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, which has nothing to do with OCP.

7.2.3 Data Acquisition

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

7.2.4 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.

7.2.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

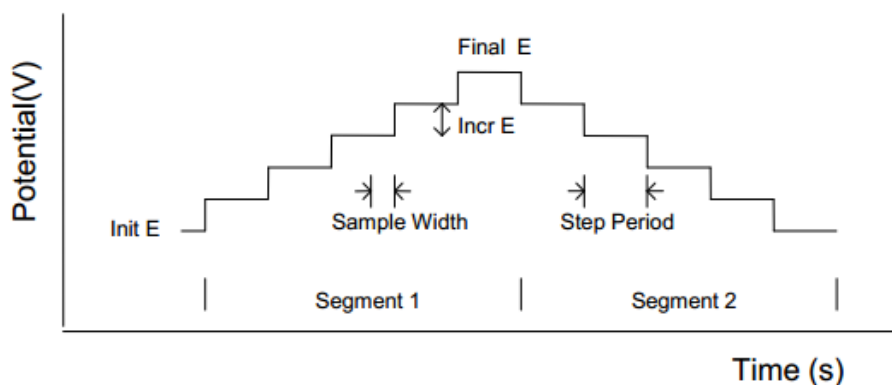
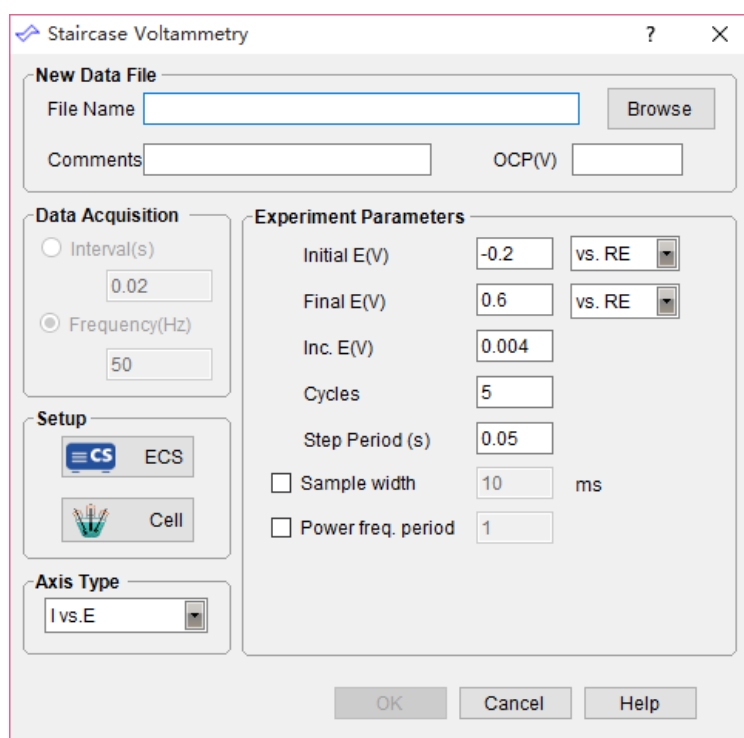
7.2.6 Cell Setting

See Cell Setting 3.2.

7.3 Staircase Voltammetry

Experiments→Voltammetry→Staircase Voltammetry

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. The following diagram shows the potential waveform applied as a function of time.

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

7.3.1 File Name

See 4.1.1 File Name.

7.3.2 Scan Parameter

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 numble of cyclic staircase waveform
Sample 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

Init E and Final E should be at least 0.01 V apart. If the sampling width is over half of the step period, there will be prompt from the software to adjust the sampling width within range. Data will be acquired at the end of each step. In general, potential is chosen to be vs. RE.

7.3.3 Data Acquisition

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

7.3.4 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.

7.3.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

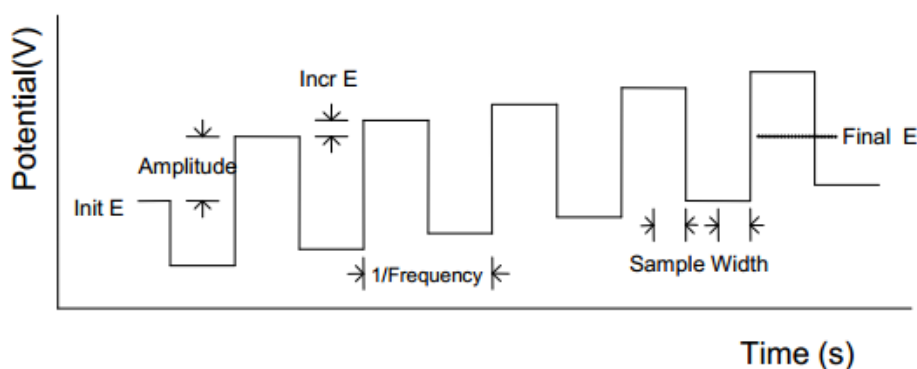
7.3.6 Cell Setting

See Cell Setting 3.2.

7.4 Square Wave Voltammetry

Experiments→Voltammetry→Square Wave Voltammetry

In Square Wave Voltammetry (SWV), the base potential is incremented from Init E towards Final E. A square wave potential is superimposed onto the base potential, which increments after each cycle of the square wave. Current is sampled at the second half 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

New Data File

File Name Browse

Comments OCP(V)

Data Acquisition

☐ Interval(s)

☒ Frequency(Hz)

Setup

☒ CS ECS

☐ Cell

Axis Type

Experiment Parameters

Initial E(V) vs. RE

Final E(V) vs. RE

Inc. E(V)

Amplitude(V)

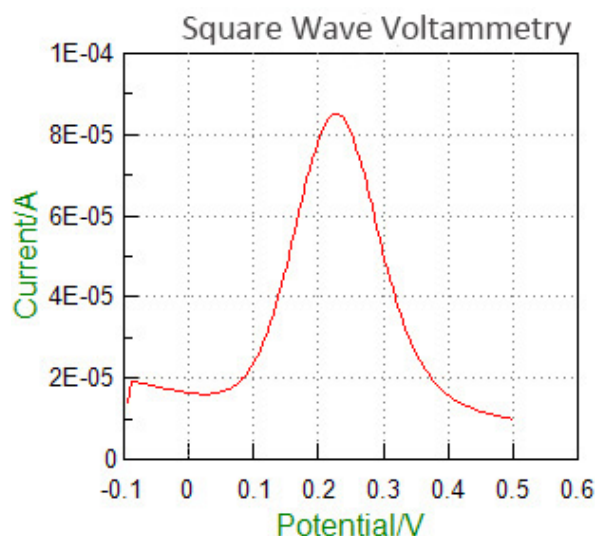
Frequency(Hz)

☐ Sample width ms

☐ Power freq. period

OK Cancel Help

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



SWV curve in $K_3Fe(CN)_6$ system

7.4.1 File Name

See 4.1.1 File Name

7.4.2 Scan 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 adjacent two square wave
Amplitude(V)	0.001~0.5	The amplitude of each square wave
Frequency(Hz)	1~100,000	Square wave output frequency

Init E and Final E should be at least 0.01V apart. “vs. RE” is usually chosen to specify the exact potential range.

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

Amplitude can be chosen from 0.001V to 0.5V.

7.4.3 Data Acquisition

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

7.4.4 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.

7.4.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

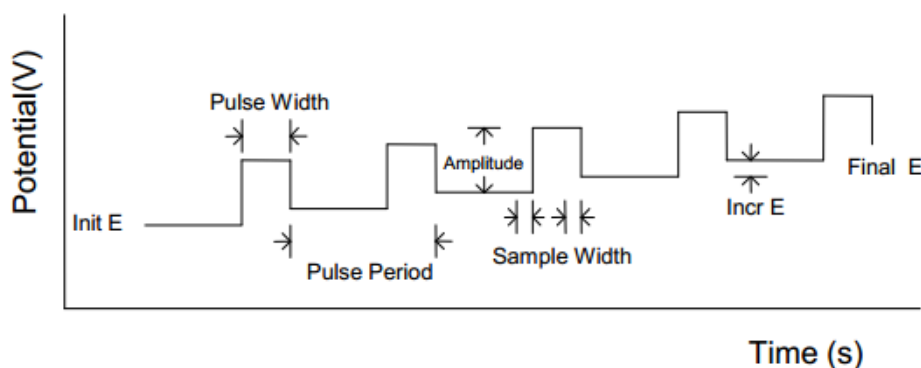
7.4.6 Cell Setting

See Cell Setting 3.2.

7.5 Differential Pulse Voltammetry

Experiments→Voltammetry→Differential Pulse Voltammetry

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.



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

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

Where, ΔE is the amplitude, A is the electrode area, t_m is the interval of pulse applying and current sampling. D is the diffusion coefficient of the measured material. From the equation, it can be seen that the peak current is related to pulse amplitude. But too large amplitude will influence the resolution. Generally speaking, 25~50mV in amplitude and 5mV/s in scan rate are suitable.

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

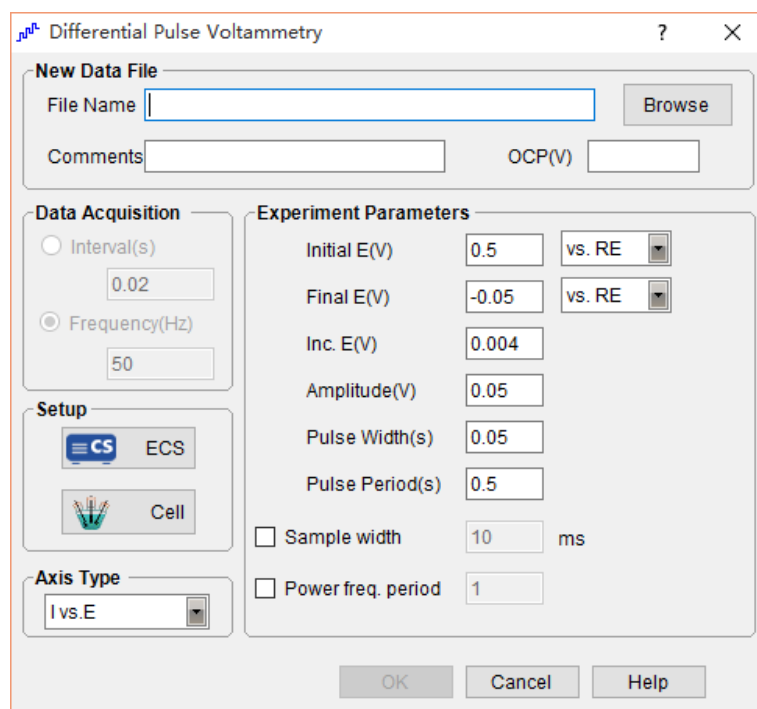
There is relationship between peak potential(E_p) of DPV curve and polarograph half-wave potential($E_{1/2}$) as follows:

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

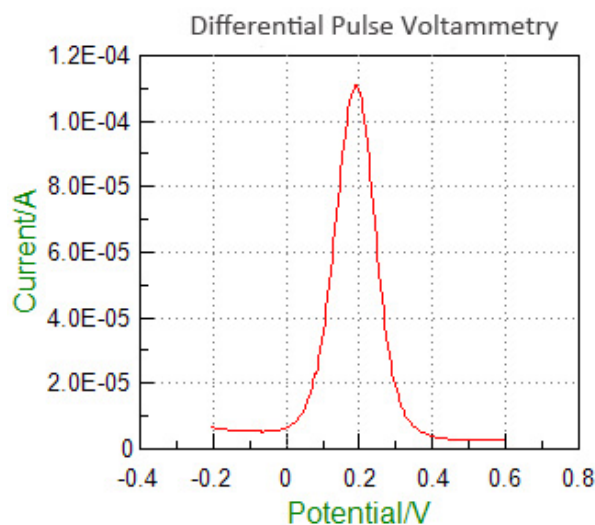
There is a useful parameter, the half-peak width($W_{1/2}$) when $I = I_p/2$. When the amplitude is relatively small,

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

Measuring the $W_{1/2}$ can be a supporting measure to calculate the number of transferred electron in reactions.



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



DPV curve in $K_3Fe(CN)_6$ system

7.5.1 File Name

See 4.1.1 File Name.

7.5.2 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 two pulses
Amplitude(V)	0.001~0.5	Potential pulse amplitude
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
Sample width(ms)	1~ half of pulse width	Data sampling width

7.5.3 Data Acquisition

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

7.5.4 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 any of the other formats.

7.5.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

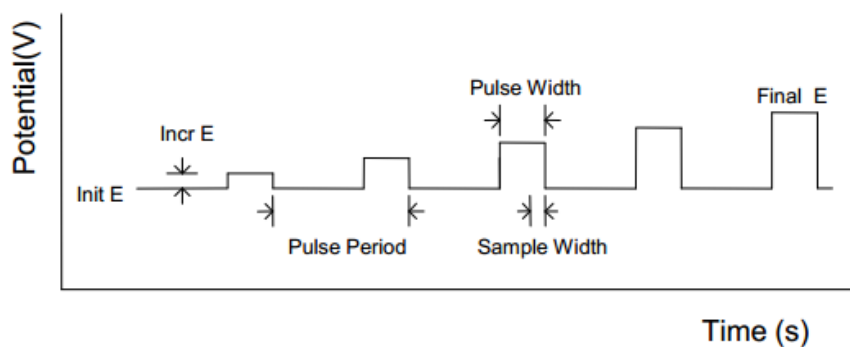
7.5.6 Cell Setting

See Cell Setting 3.2.

7.6 Normal Pulse Voltammetry

Experiments→Voltammetry→Normal Pulse Voltammetry

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 Faraday current flows.



Normal Pulse Voltammetry

New Data File

File Name

Comments OCP(V)

Data Acquisition

☐ Interval(s)

☒ Frequency(Hz)

Setup

☒ CS ECS

☐ Cell

Axis Type

☒ I vs. E

Experiment Parameters

Initial E(V) vs. RE

Final E(V) vs. RE

Inc. E(V)

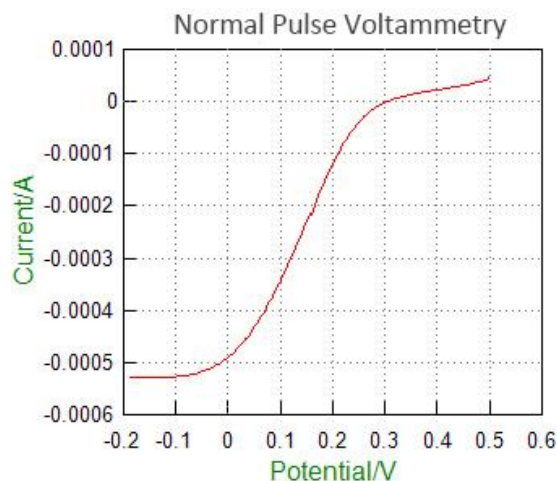
Pulse Width(s)

Pulse Period(s)

☐ Sample width ms

☐ Power freq. period

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



7.6.1 File Name

See 4.1.1 File Name.

7.6.2 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
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
Sample width(ms)	1~ half of pulse width	Data sampling width

7.6.3 Data Acquisition

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

7.6.4 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 any of the other formats.

7.6.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

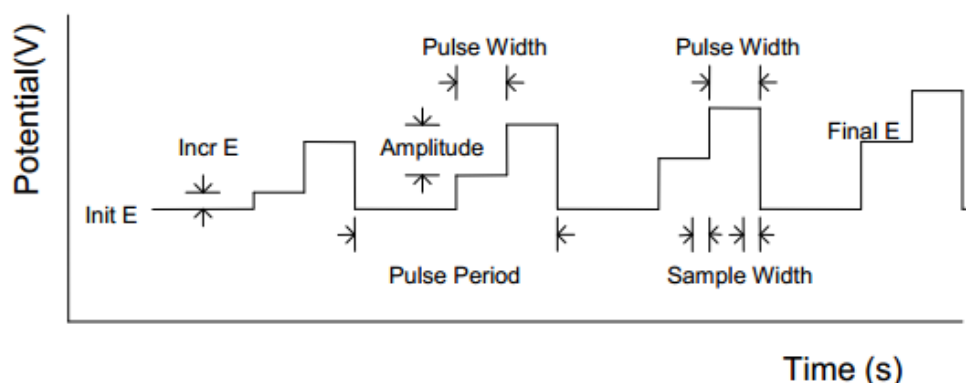
7.6.6 Cell Setting

See Cell Setting 3.2.

7.7 Differential Normal Pulse Voltammetry

Experiments→Voltammetry→Differential Normal Pulse Voltammetry

In DNPV, the base potential is held at Init 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

New Data File

File Name Browse

Comments OCP(V)

Data Acquisition

☐ Interval(s)

☒ Frequency(Hz)

Setup

☒ CS ECS

☐ Cell

Axis Type

Experiment Parameters

Initial E(V) vs. RE

Final E(V) vs. RE

Inc. E(V)

Amplitude(V)

1st Pulse Width(s)

2nd Pulse Width(s)

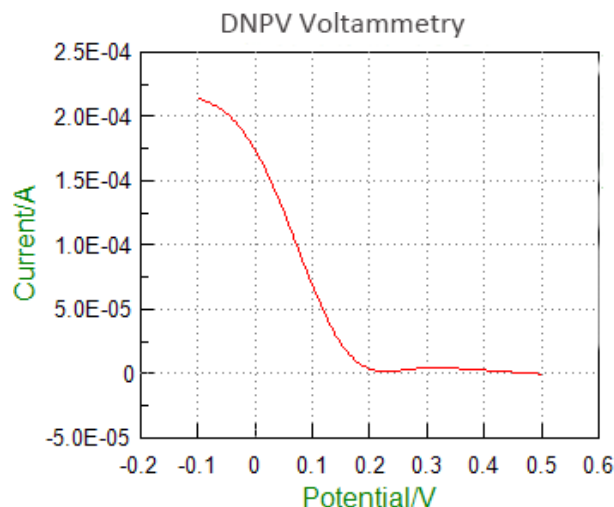
Pulse Period(s)

☐ Sample width ms

☐ Power freq. period

OK Cancel Help

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



7.7.1 File Name

See 4.1.1 File Name.

7.7.2 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
1 st pulse width(s)	0.001~0.02	First potential pulse width
2 nd pulse width(s)	0.001~0.02	Second potential pulse width
Pulse period(s)	0.05~50	Potential pulse period or dropping time
Sample width(ms)	1~half of pulse width	Data sampling width

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

7.7.3 Data Acquisition

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

7.7.4 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.

7.7.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

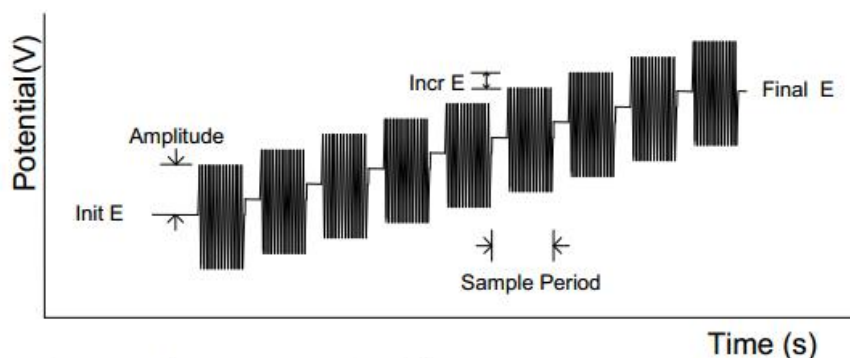
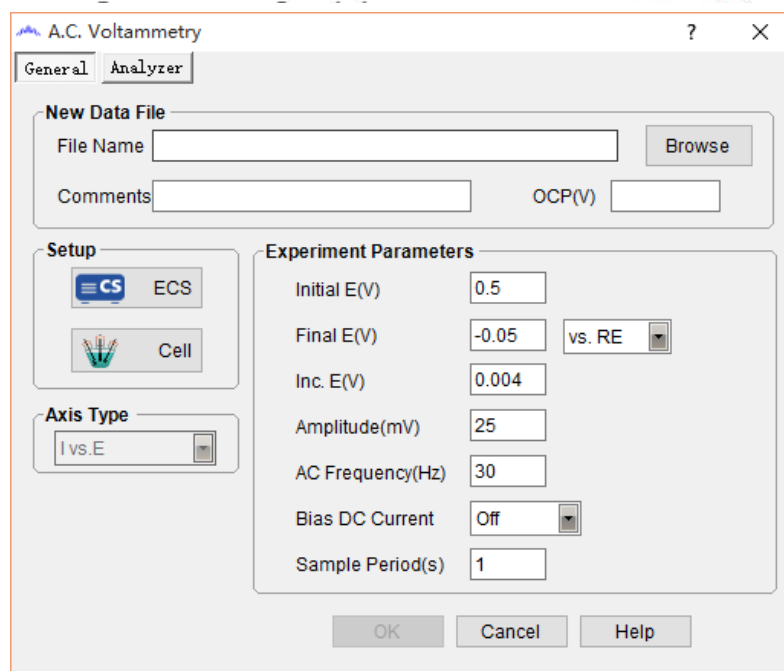
7.7.6 Cell Setting

See Cell Setting 3.2.

7.8 A.C. Voltammetry

Experiments→Voltammetry→A.C. Voltammetry

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

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

7.8.1 File Name

See 4.1.1 File Name.

7.8.2 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	Potential difference between adjacent waves
Amplitude(mV)	1~500	AC amplitude of each waveform
AC frequency(Hz)	0.1~10000	AC frequency

Bias DC	Off-range-On	Enable DC current bias during run
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.

When the AC frequency is 2Hz or lower, the sample period parameter should be at least 2 seconds.

Bias DC Current, check off or on, enables DC current bias during run.

7.8.3 Data Acquisition

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

7.8.4 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.

7.8.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

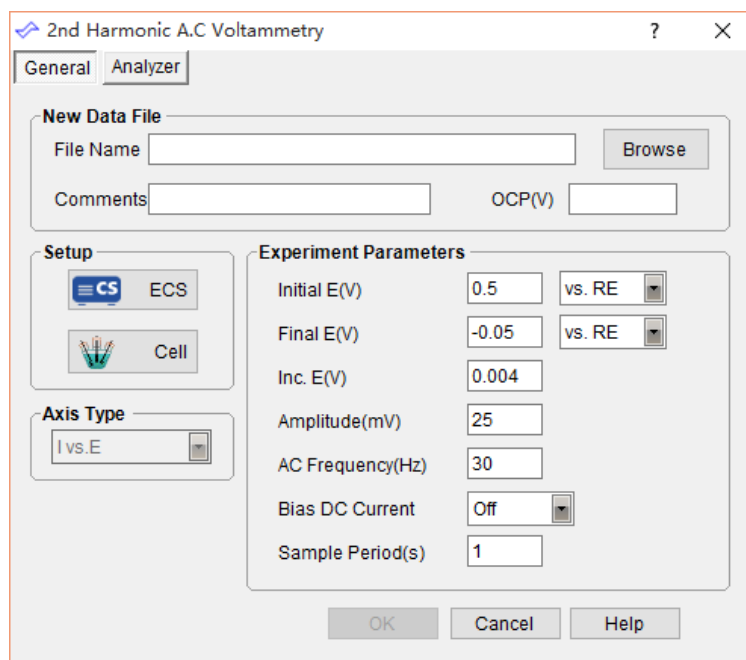
7.8.6 Cell Setting

See Cell Setting 3.2.

7.9 2nd Harmonic A.C. Voltammetry

Experiments→Voltammetry→2nd Harmonic A.C. Voltammetry

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.



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

7.9.1 File Name

See 4.1.1 File Name.

7.9.2 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	Potential difference between adjacent waves
Amplitude(mV)	1~500	AC amplitude of each waveform
AC frequency(Hz)	0.1~5000	AC frequency
Bias DC current	Off-range-On	Enable DC current bias during run
Sample period(s)	1~50	Data sampling period or dropping time

7.9.3 Data Acquisition

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

7.9.4 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.

7.9.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

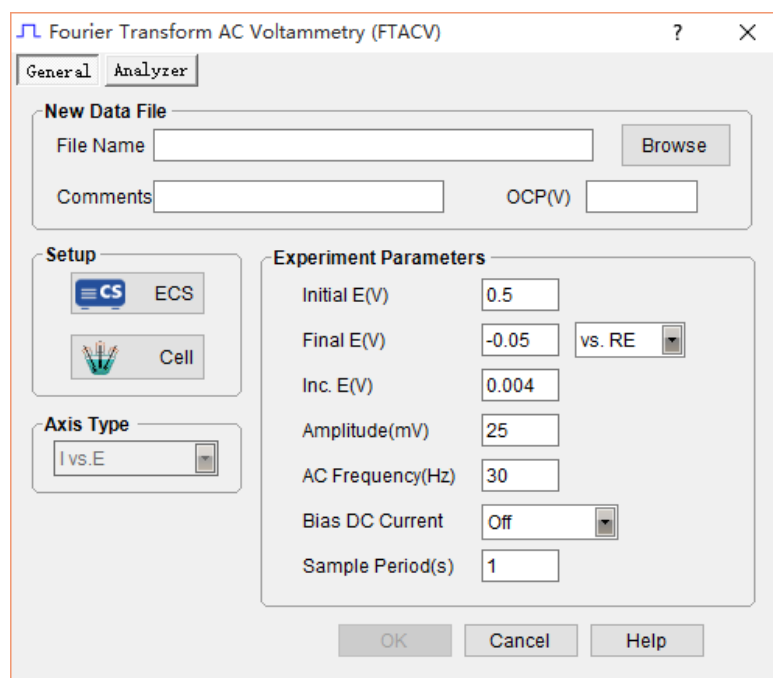
7.9.6 Cell Setting

See Cell Setting 3.2.

7.10 Fourier Transform AC Voltammetry (FTACV)

Experiments→Voltammetry→Fourier Transform AC Voltammetry

For FTACV, the way of testing, parameters setting and data acquisition are the same as ACV. The difference lies in post-processing of the data. After the test, the software will automatically do the Fourier conversion with the original data, meanwhile obtaining the 2nd, 3rd, 4th, 5th, and 6th harmonics ACV data.



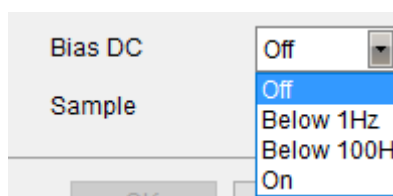
Parameter setting window for FTACV

7.10.1 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-range-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.



7.10.2 File Name

See 4.1.1 File Name.

7.10.3 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

7.10.4 Cell Setting

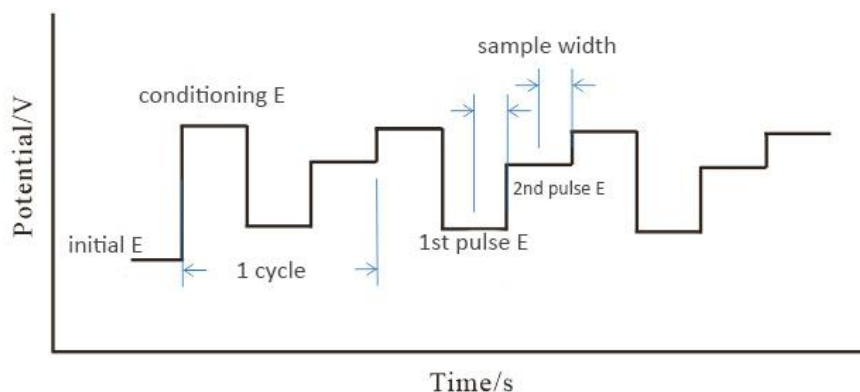
See Cell Setting 3.2.

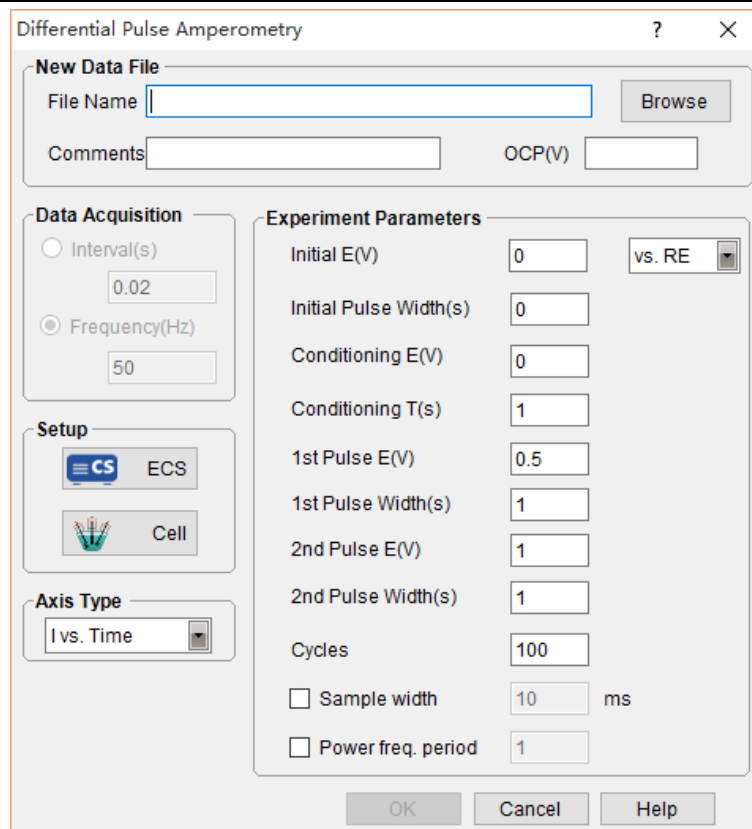
8. Amperometric

8.1 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.





Parameter setting window for DPA

8.1.1 Experiment parameters

Parameters	Range	Description
Initial E(V)	-10~10	initial potential
Initial pulse width (s)	≥ 0	The duration of the initial potential. No data acquisition
Conditioning E(V)	-10~10	The electrode conditioning potential
Time(s)	≥ 0	The duration of the conditioning potential. Current is not sampled.
1 st pulse potential(V)	-10~10	The 1 st pulse potential in each cycle.
1 st pulse width (s)	0.01~100	The duration of the 1 st pulse potential. Current is sampled.
2 nd pulse potential (V)	-10~10	The 2 nd pulse potential in each cycle.
2 nd pulse width (s)	0.01~100	The duration of the 2 nd pulse potential. Current is sampled.
Cycles	10~100,000	The total number of cycling.
Sample width(ms)	1~ half of pulse width	The sampling width of the 1 st and 2 nd pulse potential in each pulse.

8.1.2 File Name

See 4.1.1 File Name.

8.1.3 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

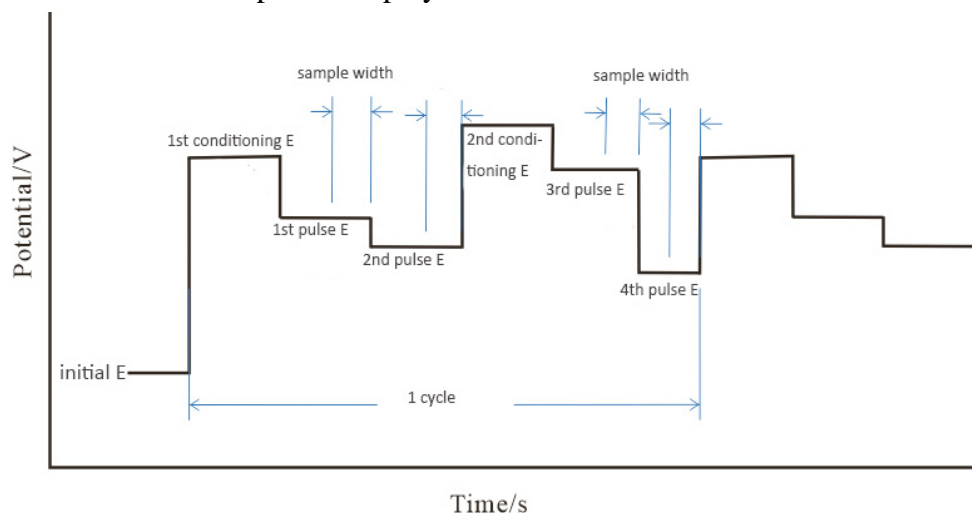
8.1.4 Cell Setting

See Cell Setting 3.2.

8.2 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.



?

×

Double Differential Pulse Amperometry

New Data File

File Name

Browse

Comments

OCP(V)

Data Acquisition

Interval(s)

0.02

Frequency(Hz)

50

Setup

CS ECS

Cell

Axis Type

I vs. Time

Experiment Parameters

Initial E(V)	0	Initial Pulse Width(s)	0	vs. RE
1st Conditioning E(V)	0	1st Conditioning T(s)	1	
1st Pulse E(V)	0.5	1st Pulse Width(s)	1	
2nd Pulse E(V)	1	2nd Pulse Width(s)	1	
2nd Conditioning E(V)	1.5	2nd Conditioning T(s)	1	
3rd Pulse E(V)	2	3rd Pulse Width(s)	1	
4th Pulse E(V)	2.5	4th Pulse Width(s)	1	
Cycles	100			
<input type="checkbox"/> Sample width	10	ms		
<input type="checkbox"/> Power freq. period	1			

OK

Cancel

Help

Parameter setting window for DDPA

8.2.1 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.
1 st Conditioning E(V)	-10~10	the 1 st cleaning potential
1 st Conditioning T(s)	≥ 0	The duration of the 1 st cleaning potential. Current is not sampled.
1 st pulse E (V)	-10~10	The 1 st pulse potential in each cycle
1 st pulse width(s)	0.01~100	The duration of the 1 st pulse potential. Current is sampled.
2 nd pulse E (V)	-10~10	The 2 nd pulse potential in each cycle
2 nd pulse width(s)	0.01~100	The duration of the 2 nd pulse potential in each cycle. Current is sampled.
2 nd Conditioning E(V)	-10~10	The 2 nd cleaning potential of the experiment
2 nd Conditioning T(s)	≥ 0	The duration of the 2 nd cleaning potential. In this process the current is not sampled
3 rd pulse E(V)	-10~10	the 3 rd pulse potential in each cycle
3 rd pulse width (s)	0.01~100	The duration of the 3 rd pulse potential in each cycle. Current is sampled.
4 th pulse E (V)	-10~10	The 4 th pulse potential in each cycle
4 th pulse width(s)	0.01~100	The duration of the 4 th pulse potential in each cycle. The current is sampled in this process.
Cycles	10-100,000	Total number of cycling
Sample width(ms)	1~half of pulse width	The sampling width of pulse potential 1,2,3,4.

8.2.2 File Name

See 4.1.1 File Name.

8.2.3 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

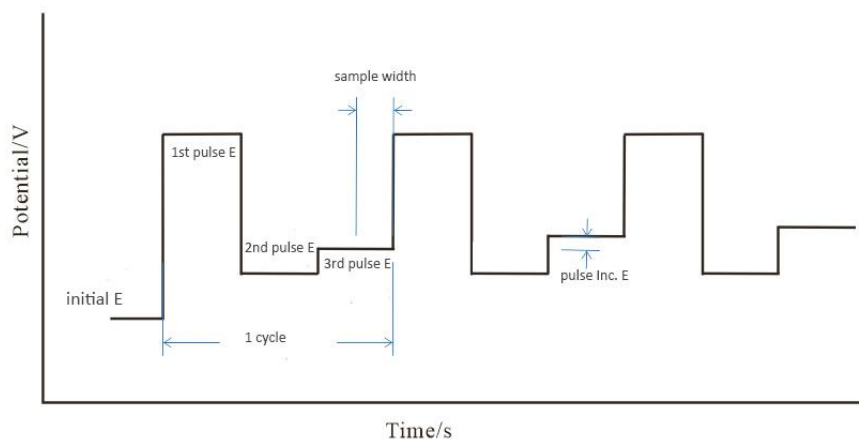
8.2.4 Cell Setting

See Cell Setting 3.2.

8.3 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.



8.3.1 Experiment parameters

Triple Pulse Amperometry

New Data File

File Name Browse

Comments OCP(V)

Data Acquisition

☐ Interval(s) 0.02

☒ Frequency(Hz) 50

Setup

☒ CS ECS

☐ Cell

Axis Type

☒ I vs. Time

Experiment Parameters

Initial E(V) 0 vs. RE

Initial Pulse Width(s) 0

1st Pulse E(V) 0.5

1st Pulse Width(s) 1

2nd Pulse E(V) 1

2nd Pulse Width(s) 1

3rd Pulse E(V) 1.5

3rd Pulse Width(s) 1

Pulse Inc. E(V) 0.004

Final E(V) 2

Cycles 100

☐ Sample width 10 ms

☐ Power freq. period 1

OK Cancel Help

Parameter setting window for TPA

Parameter	Range	Description
Initial E(V)	-10~10	The initial potential
Initial pulse width (s)	≥ 0	The duration of the initial potential. The current is not sampled.
Final E(V)	-10~10	The final potential
1 st pulse E(V)	-10~10	the 1 st pulse potential in each cycle
1 st pulse width(s)	≥ 0	The duration of the 1 st pulse potential in each cycle.
2 nd pulse E(V)	-10~10	The 2 nd pulse potential in each cycle
2 nd pulse width(s)	≥ 0	The duration of the 2 nd pulse potential in each cycle. The current is not sampled.

3 rd pulse E(V)	-10~10	the 3 rd pulse potential in each cycle
3 rd pulse width(s)	0.01~100	The duration of the 3 rd pulse potential in each cycle. The current is sampled.
Pulse inc. E(V)	0~0.02	Potential difference of the 3 rd pulse of adjacent cycles
Cycles	10-100,000	Total number of cycling
Sample width(ms)	1~ half of 3 rd pulse width	The sampling width of the 3 rd pulse potential in each cycle

8.3.2 File Name

See 4.1.1 File Name.

8.3.3 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

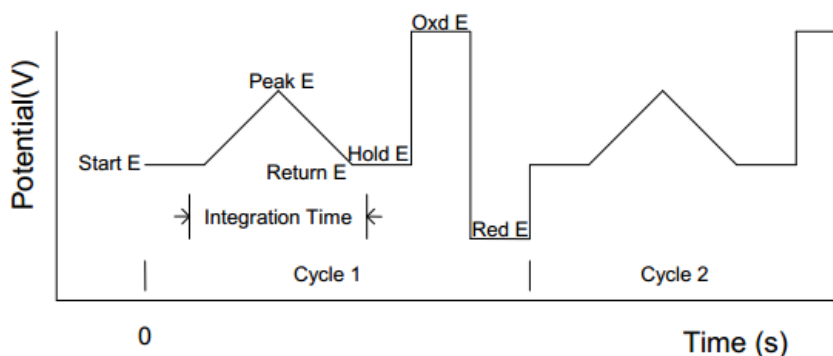
8.3.4 Cell Setting

See Cell Setting 3.2.

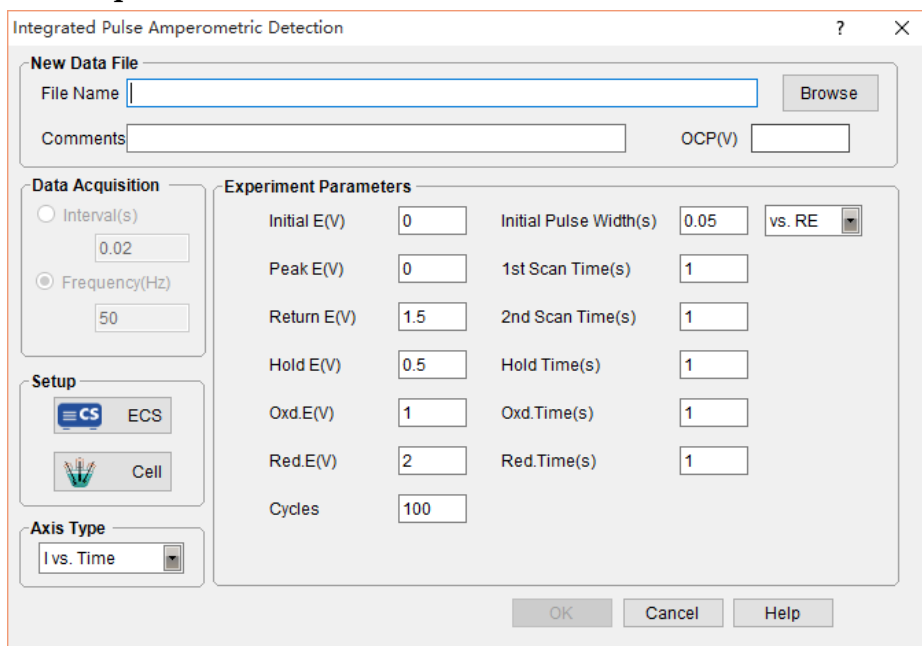
8.4 Integrated Pulse Amperometric Detection(IPAD)

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.



8.4.1 Experiment parameters



Parameter setting window for IPAD

Parameters	Range	Description
Initial E(V)	-5~5	The initial potential
Initial pulse width(s)	0.05~1	Duration of initial potential (current is sampled and integrated for the last 10ms)
Peak E(V)	-5~5	Peak potential
1 st scan time(s)	0.1~1	Scan time from Initial E to peak E; The current is sampled and integrated.
Return E(V)	-5~5	Return potential in each cycle
2 nd 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 of each cycle
Hold Time(s)	0.05~1	Duration of hold potential (current is sampled and integrated for the first 10ms)
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	Total number of cycling

8.4.2 File Name

See 4.1.1 File Name.

8.4.3 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

8.4.4 Cell Setting

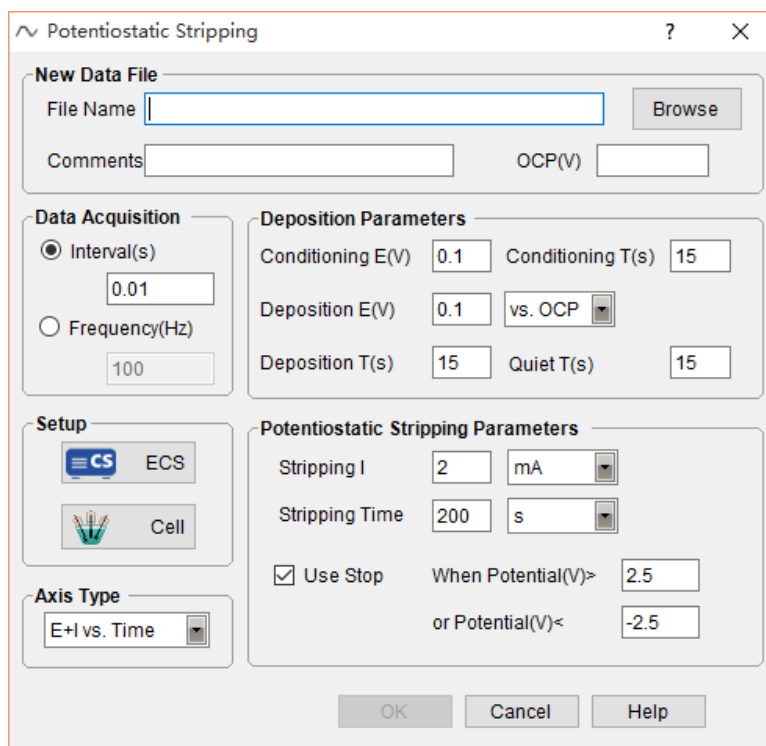
See Cell Setting 3.2.

9. Stripping Voltammetry

9.1 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. Potential is recorded as a function of time.



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

Parameters	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 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.
Deposition Time(s)	> 0	the time of potentiostatic stripping process

9.1.1 File Name

See 4.1.1 File Name.

9.1.2 Data Acquisition

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

9.1.3 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.

9.1.4 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

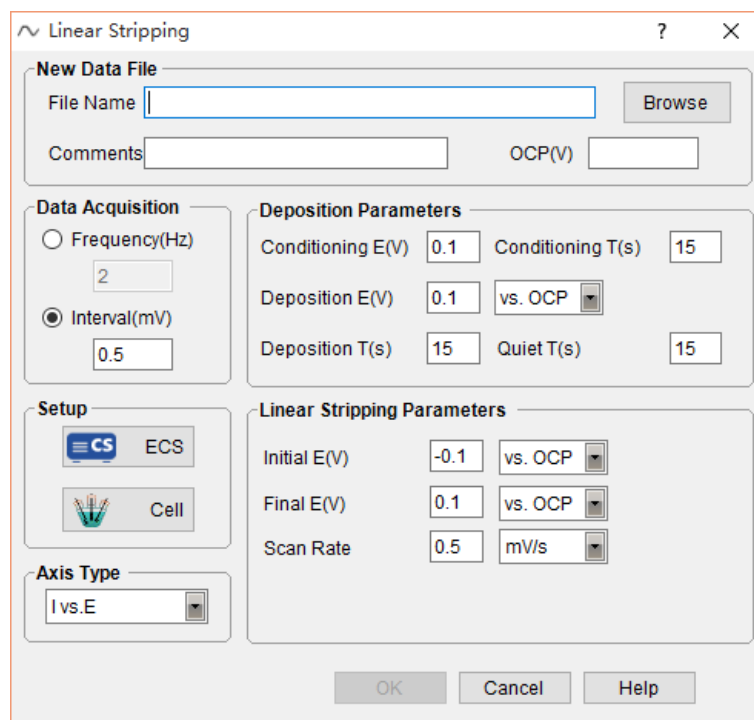
9.1.5 Cell Setting

See Cell Setting 3.2.

9.2 Linear Stripping Voltammetry

Experiments→Stripping Voltammetry→Linear Stripping

Voltammetry stripping 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 that progresses at a defined scan rate.



The screenshot shows the 'Linear Stripping' dialog box with the following settings:

- New Data File:** File Name (empty), Comments (empty), OCP(V) (empty), Browse button.
- Data Acquisition:** Frequency(Hz) (radio button, value 2), Interval(mV) (radio button, value 0.5).
- Deposition Parameters:** Conditioning E(V) (0.1), Conditioning T(s) (15), Deposition E(V) (0.1), vs. OCP (dropdown), Deposition T(s) (15), Quiet T(s) (15).
- Setup:** CS (selected), ECS, Cell.
- Axis Type:** I vs. E (dropdown).
- Linear Stripping Parameters:** Initial E(V) (-0.1), vs. OCP (dropdown), Final E(V) (0.1), vs. OCP (dropdown), Scan Rate (0.5), mV/s (dropdown).
- Buttons: OK, Cancel, Help.

OCP will display the current open circuit potential of the cell (update every 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
Scan Rate(mV/s)	0.01~1000	Scan rate in stripping process

9.2.1 File Name

See 4.1.1 File Name.

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

9.2.3 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.

9.2.4 Data Acquisition

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

9.2.5 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.

9.2.6 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat (ECS) Setting.

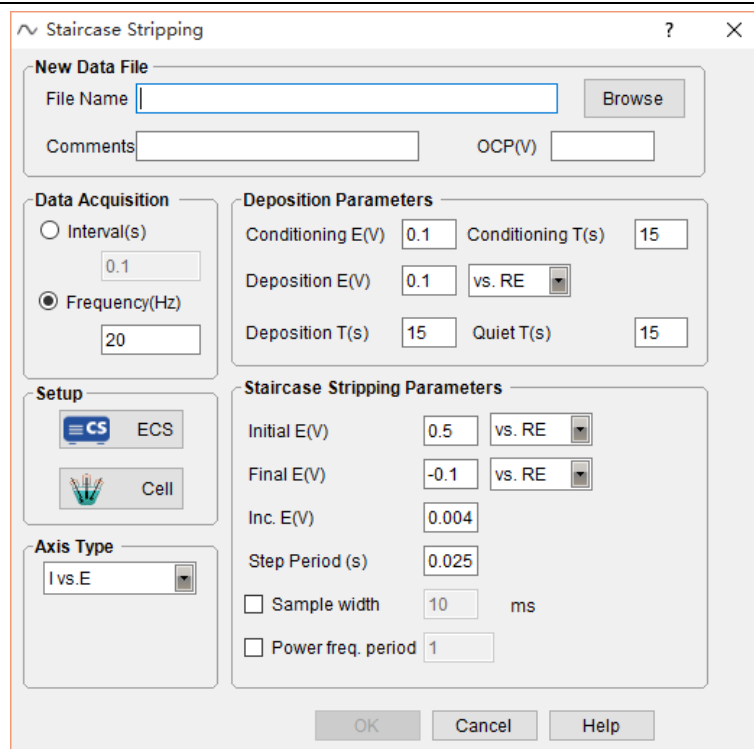
9.2.7 Cell Setting

See Cell Setting 3.2.

9.3 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 that progresses at a defined increment. It is similar to linear stripping. Staircase stripping is considered to be a derivative of linear sweep stripping.



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

9.3.1 File Name

See 4.1.1 File Name.

9.3.2 Staircase Stripping 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 determines how long the potential will be held at this step. After deposition, the experiment can be quiet for some time.

9.3.3 Data Acquisition

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

9.3.4 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.

9.3.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

9.3.6 Cell Setting

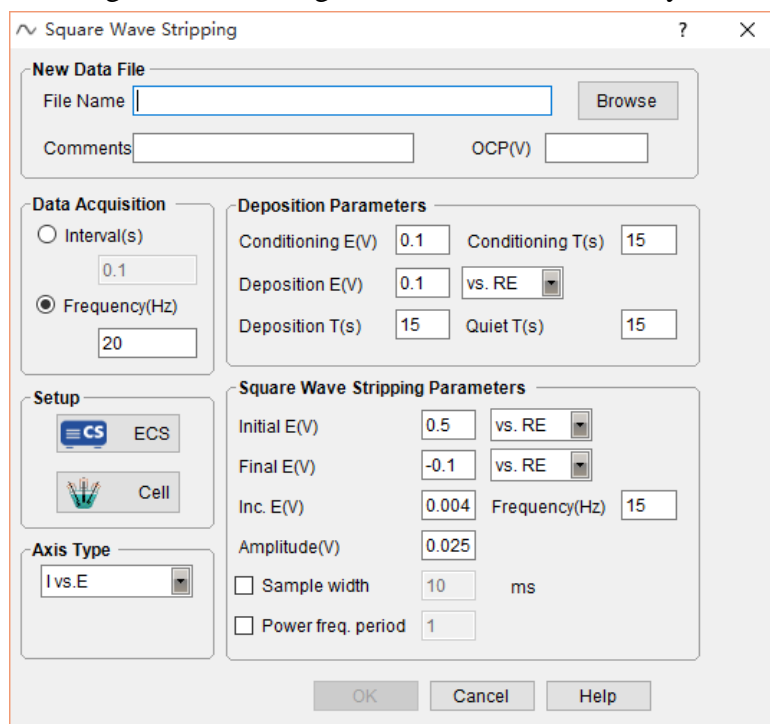
See Cell Setting 3.2.

9.4 Squarewave stripping Voltammetry

Experiments→Stripping Voltammetry→Square Wave Stripping

In square wave stripping voltammetry, the potential applied on the working electrode is linearly varied in the mode of square-wave in stripping process. The stripping process applies the technique of substantial differential, and the potential applied on the working electrode is in the mode of a symmetric square wave being superimposed on a base step potential. High

sensitivity and fast scanning are its advantages, which reduces the analysis time.



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

9.4.1 File Name

See 4.1.1 File Name.

9.4.2 Deposition Parameters

Conditioning E: Before deposition, the conditioning potential is applied on working electrode to remove impurities. working electrode surface state is automatically updated.

Conditioning T: the duration of conditioning potential.

Deposition E: 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: the duration of deposition potential.

Quiet time: Stop stirring, the potential is not applied on the working electrode.

9.4.3 Square wave stripping Parameters

Initial E: the minimum potential for stripping process to begin.

Final E: final potential is generally higher than the oxidation potential of analyte ions.

Inc.E: the incremental potential of each step.

Amplitude: Square wave amplitude

The 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. For example, “0.1V vs.OCP” means applying a potential 0.1V above the open circuit potential. “vs.RE” means selecting an exact potential.

9.4.4 Data Acquisition

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

9.4.5 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.

9.4.6 Pstat/Gstat(ECS)

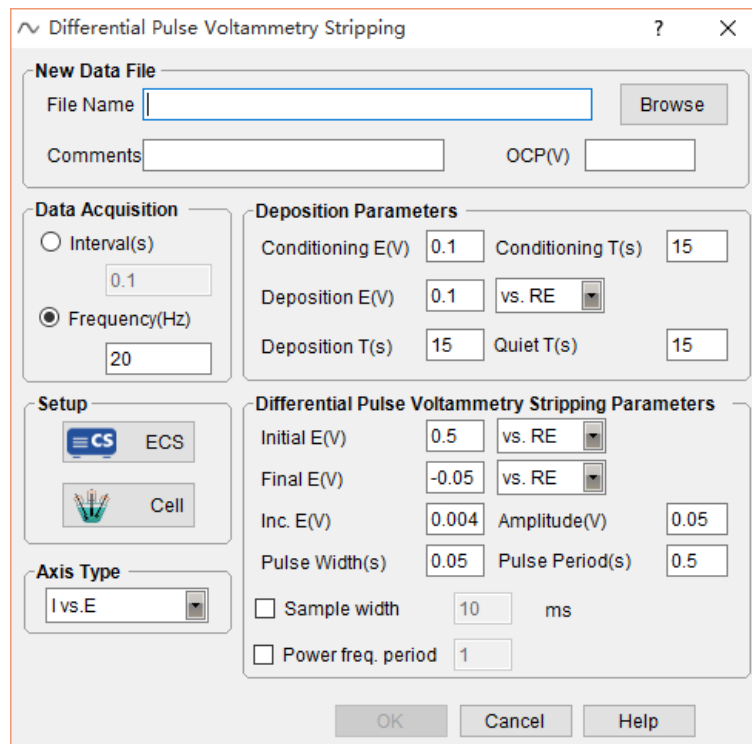
See 3.1 Pstat/Gstat(ECS) Setting.

9.4.7 Cell Setting

See Cell Setting 3.2.

9.5 Differential Pulse Stripping Voltammetry

Experiments→Stripping Voltammetry→Differential Pulse Voltammetry Stripping



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

9.5.1 File Name

See 4.1.1 File Name.

9.5.2 Data Acquisition

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

9.5.3 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.

9.5.4 Pstat/Gstat(ECS)

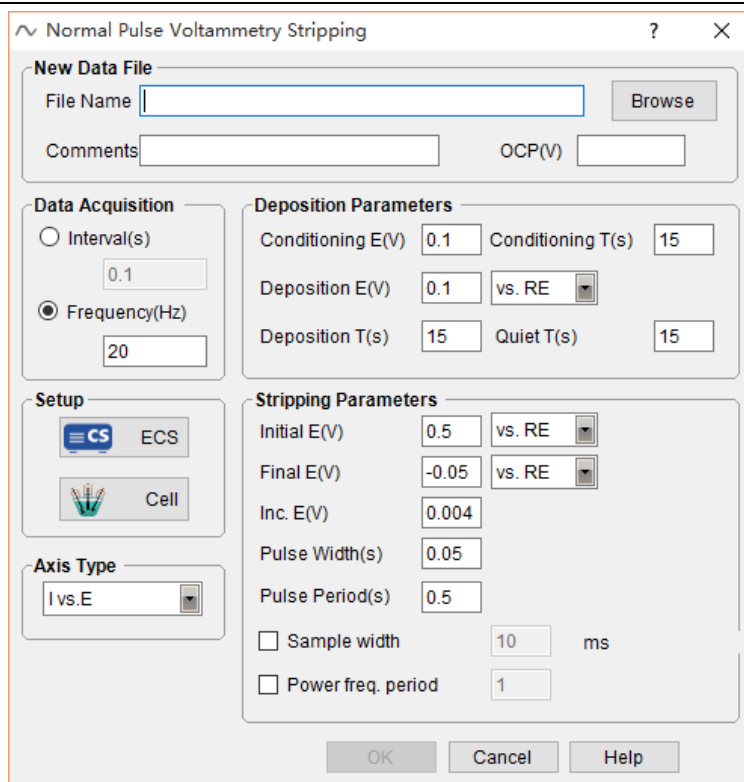
See 3.1 Pstat/Gstat(ECS) Setting.

9.5.5 Cell Setting

See Cell Setting 3.2.

9.6 Normal Pulse Stripping Voltammetry

Experiments→Stripping Voltammetry→Normal Pulse Voltammetry Stripping



Normal Pulse Voltammetry Stripping

New Data File

File Name: Browse

Comments: OCP(V):

Data Acquisition

☐ Interval(s)

☒ Frequency(Hz)

Deposition Parameters

Conditioning E(V): Conditioning T(s):

Deposition E(V): vs. RE

Deposition T(s): Quiet T(s):

Setup

☒ CS ECS

☐ Cell

Axis Type

Stripping Parameters

Initial E(V): vs. RE

Final E(V): vs. RE

Inc. E(V):

Pulse Width(s):

Pulse Period(s):

☐ Sample width ms

☐ Power freq. period

OK Cancel Help

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

9.6.1 File Name

See 4.1.1 File Name.

9.6.2 Data Acquisition

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

9.6.3 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.

9.6.4 Pstat/Gstat(ECS)

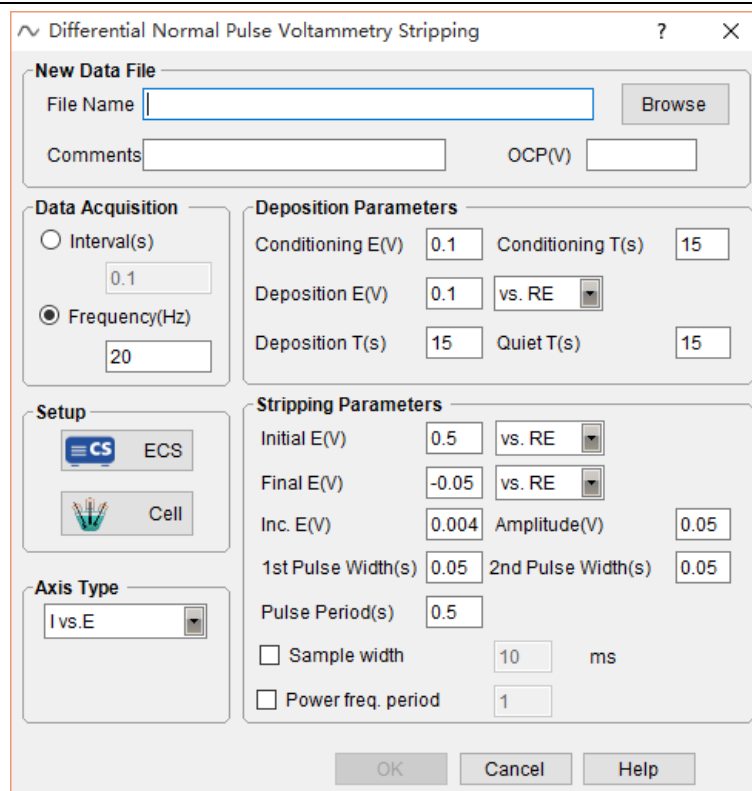
See 3.1 Pstat/Gstat(ECS) Setting.

9.6.5 Cell Setting

See Cell Setting 3.2.

9.7 Differential Normal Pulse Stripping Voltammetry

Experiments→Stripping Voltammetry→Differential Normal Pulse Voltammetry Stripping



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

9.7.1 File Name

See 4.1.1 File Name.

Data Acquisition

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

9.7.2 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.

9.7.3 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

9.7.4 Cell Setting

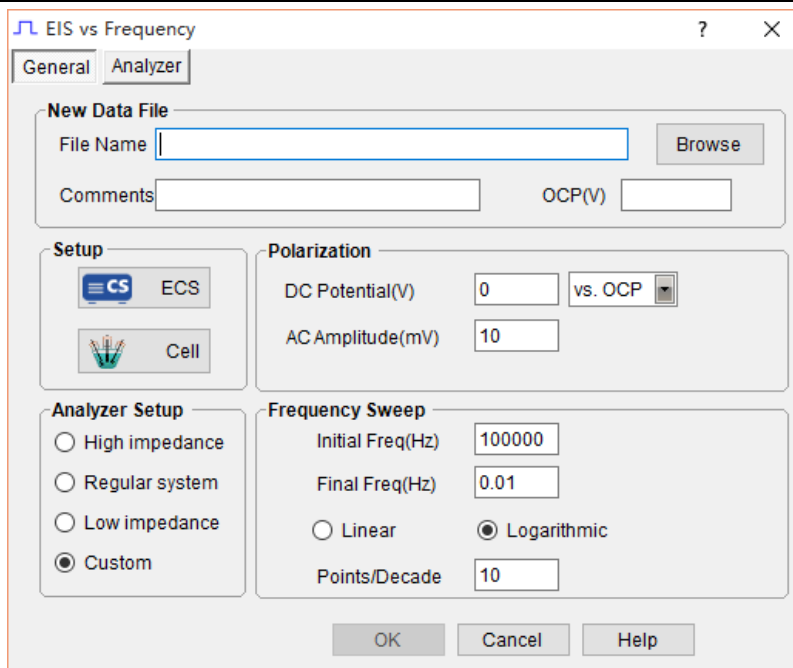
See Cell Setting 3.2.

10. Impedance(EIS)

10.1 EIS vs. Frequency(IMP)

Experiments→Impedance→EIS vs. Frequency

In EIS vs. Frequency technique, it measures the impedance spectroscopy of the electrochemical system in difference frequency. Nyquist and Bode plot is obtained.



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

10.1.1 File Name

The user should enter a file name to save data before starting the test. At the first time, when You input a name and click OK, you will see the default data storage path on the top of the testing window. Or you can click the Browse, and choose the storage path as you want. This is particularly useful if you forget the file names that you already use.

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”.

10.1.2 Polarization

DC potential: the DC polarization potential of the working electrode during impedance test. If the test needs to be conducted under open circuit potential, the user should enter “0” and select “vs. OCP” here. At this moment, the potentiostat will automatically give an output of OCP+ DC potential on the working electrode. For example, if you need to do the impedance test under 50mV DC potential of anodic polarization, you can enter “0.05”.

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 potentiostat will polarize the working electrode to be -0.5V.

AC amplitude is the amplitude of the electrochemical impedance excitation signals. For example, $E=0.012\sin(\omega t)V$ means AC signal amplitude is 12mV. Under high frequency, the actual polarization amplitude of the working electrode may be lower than this value due to rate limitation of the amplifier and high-frequency transmission loss of the conducting wires.

10.1.3 Frequency Sweep

The user should choose the mode of frequency sweep. Frequency sweep starts from the initial frequency to the final frequency, and the mode can be both linear and logarithmic.

If you choose linear mode, the measured points will be evenly distributed between the initial frequency and final frequency. For example, if the frequency range is from “1kHz to 1Hz”, and you set “10” measured points, the frequencies will be “1Hz, 99.9Hz, 2×99.9Hz ...” Generally speaking, this mode is not usually selected unless for special requirements.

If you choose logarithmic, the sampling data points will be evenly distributed in frequency logarithmic axis (Bode plot). It is particularly useful when frequency range is between 2 to 5 orders of magnitude. For example, if the frequency range is from 100kHz to 0.01Hz, and you set 10 points/10 decade, then the measured points will be evenly distributed between initial and final frequency, 70 points in total. The users usually choose this mode.

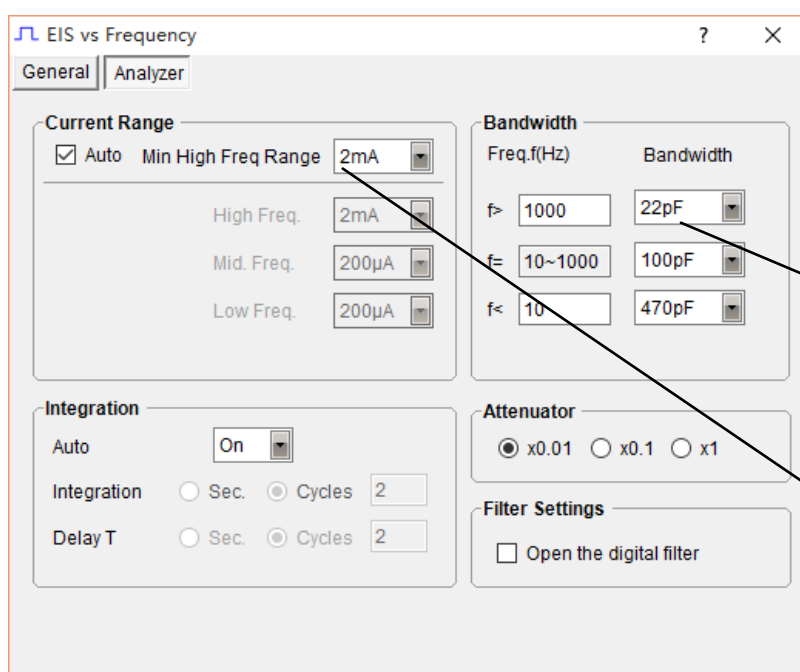
10.1.4 Pstat/Gstat(ECS)

For regular electrochemical impedance system, in ground mode the “real” mode is recommended. The bandwidth of filter can be 2.2pF~1μ F.

10.1.5 Cell Setting

See Cell Setting 3.2.

10.1.6 Analyzer



For stable system, you can select “off”. For high impedance system (e.g. coating), you can choose 22~100pF to reduce the noise of the plot. But there may be a small additional capacitor ring in the high impedance region of the spectroscopy.

For low impedance system, you can choose 2mA. For high impedance system, you can choose 20μA~200μA. If the range is not properly set, noise may appear on the EIS plot.

Current range

The user can set current range automatically/manually. If select “auto”, you need to set a minimum current range in high frequency. In the above dialog for example, when the measuring frequency is over 1000Hz, the auto current range will be no lower than 2mA.

The high frequency is defined by the user. In the above picture, $f > 1000\text{Hz}$ is high frequency region, $f < 10\text{Hz}$ is low frequency region, and $10\text{Hz} \sim 1000\text{Hz}$ is middle frequency region.

If auto current range cannot meet the need, then manual setting is recommended. For example, in above picture, under manual setting, the current range is 2mA ($f > 1000\text{Hz}$), 200μA ($f < 10\text{Hz}$ and $f = 10\text{Hz} \sim 1000\text{Hz}$)

To improve measurement accuracy, the setting for current range should be varied. The user should select suitable current range according to frequency band. In general, 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 bent points on the curve. By observing signal amplitude of the waveform, the user can judge if the current range is suitable.

Bandwidth

The higher the selected capacitance value is, the narrower the bandwidth of the potentiostat 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.

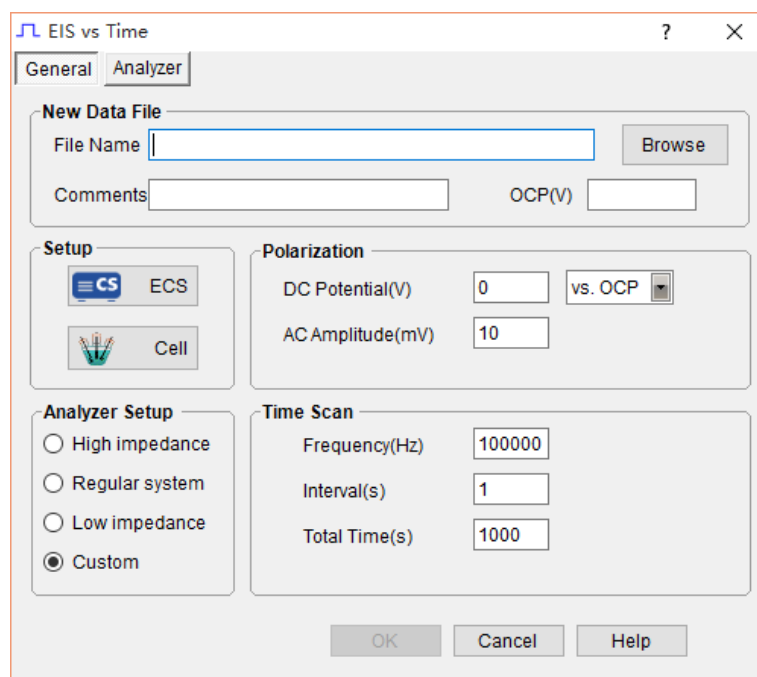
10.1.7 The impedance spectroscopy analyzing

Impedance data file (.z60) is fully compatible with Zview software which is the tool to analyze impedance spectroscopy and draw graphics. After data acquisition in impedance test, you can click “Tools” → “EIS Analysis” or directly click Zview icon  to analyze data.

10.2 EIS vs Time (IMPT)

Experiments → Impedance → EIS vs. Time (IMPT)

IMPT measures the impedance characteristics of the electrochemical system as a function of time at a fixed frequency. It tracks the dynamic processes of some systems, such as conductivity.



The screenshot shows the 'EIS vs Time' dialog box with the 'Analyzer' tab selected. The 'New Data File' section includes a 'File Name' input field, a 'Browse' button, a 'Comments' input field, and an 'OCP(V)' input field. The 'Setup' section has two sub-sections: 'ECS' (with a button) and 'Cell' (with a button). The 'Polarization' section includes 'DC Potential(V)' (set to 0) and 'AC Amplitude(mV)' (set to 10), both with dropdown menus. The 'Analyzer Setup' section has four radio buttons: 'High impedance', 'Regular system', 'Low impedance', and 'Custom' (which is selected). The 'Time Scan' section includes 'Frequency(Hz)' (set to 100000), 'Interval(s)' (set to 1), and 'Total Time(s)' (set to 1000). At the bottom are 'OK', 'Cancel', and 'Help' buttons.

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

10.2.1 File Name

See 10.1.1 File Name.

10.2.2 Polarization

DC potential is the DC polarization potential of the working electrode during impedance test. If the test needs to proceed under open circuit potential (OCP), then you can enter “0” and select “vs. OCP”. At this moment the potentiostat will automatically give an output of the sum of OCP and the DC potential to the working electrode. If you do the impedance test at anodic polarization 50mV DC potential, you can enter “0.05” here.

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”. The potentiostat will polarize the working electrode to be “-0.5V”, instead of “-0.5+OCP”.

AC amplitude is the amplitude of the electrochemical impedance excitation signals. For example, $E = 0.012 \sin(\omega t)$ V means AC signal amplitude is 12mV. At high frequency, the actual polarization amplitude of the working electrode may be lower than this value due to rate limitation of the amplifier and high-frequency transmission loss of the conducting wires.

10.2.3 Time Scan

In Impedance~ Time scan, frequency of sine wave is constant. It measures the impedance of some electrochemical systems at a frequency point as a function of time.

Interval - interval for measurement at each frequency point.

Total time- the total time of measurement.

10.2.4 Pstat/Gstat(ECS)

Click this button, and open the window for instrument setting. You can choose the instrument model, set the switching way of current range, signal gain/loss, ground mode, filter bandwidth, digital smoothing, quiet time (scan delay). For regular electrochemical impedance measurement system, real ground mode is recommended, and 2.2pF~1μF is OK for filter bandwidth.

10.2.5 Cell Setting

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.

10.3 EIS vs Potential(IMPE)

Experiments→Impedance→EIS vs. Potential

This method is used to measure impedance characteristics at different DC polarization potential. The potential is stepped from initial potential to final potential. It can obtain Mott-Schottky (M-S) plot which has been widely used to study the semiconductor characteristics of passivation film on the metal. It can determine the carrier type, concentration and the flat band potential of the semiconductor passivation film.

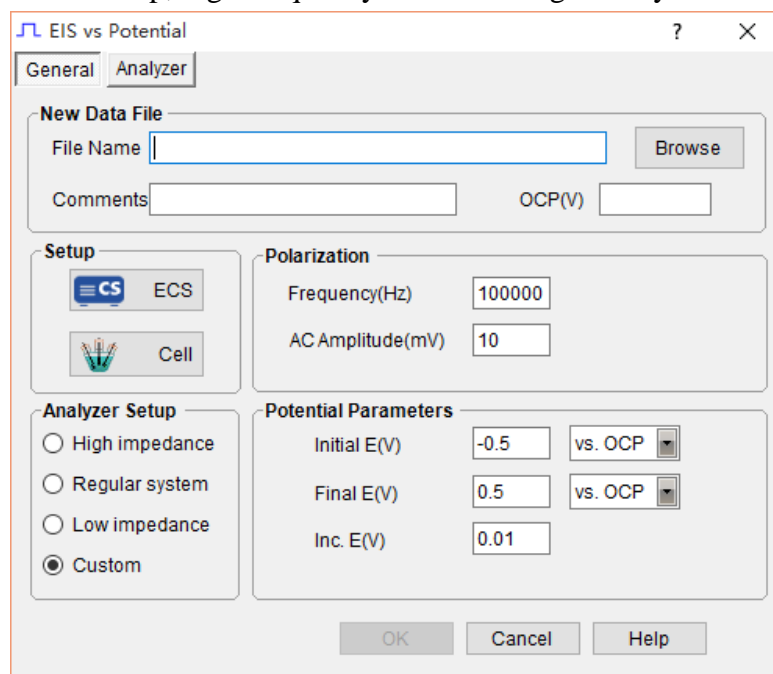
When the passivation film is in contact with the solution and the space charge of the semiconductor passivation film is in the state of depletion, for the space charge capacitance (C_{sc}) and the measured voltage (V_m), there is the following linear relationship:

$$C_{sc}^{-2} = \frac{2}{eN_d\epsilon\epsilon_0A^2} \left(V_m - V_{fb} - \frac{kT}{e} \right) \quad \text{n-type semiconductor} \quad (1)$$

$$C_{sc}^{-2} = \frac{-2}{eN_a\epsilon\epsilon_0A^2} \left(V_m - V_{fb} + \frac{kT}{e} \right) \quad \text{p-type semiconductor} \quad (2)$$

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 Boltzman constant, T is absolute temperature, e is the quantity of electric charge.

Passivation film is of a double layer structure. Because the composition and crystal structure are different for the inner and outer layer of the passivation film, semiconductor type is also different. Therefore, two space charge layers are formed inside the passivation film, that is, the space charge layer on solution/passivation film interface, and the inner layer /outer layer interface pn junction capacitance. Because pn and passivation film capacitance are small, in the impedance~potential sweep, high-frequency sine wave is generally used for measurement.



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

10.3.1 File Name

See 10.1.1 File Name.

10.3.2 EIS Parameters

Frequency and AC Amplitude specify the frequency and amplitude of sine wave during the impedance measurement.

10.3.3 Potential Parameters

Initial E is the initial DC level of the working electrode in impedance ~ potential sweep.

Final E is the final potential in impedance ~ potential sweep.

Inc. E is the potential increment. Potential is increased with the form of steps.

10.3.4 Pstat/Gstat(ECS)

Click on this button, and open the window for instrument setting. You can choose the instrument model, set the switching way of current range, signal gain/loss, ground mode, filter

bandwidth, digital smoothing, quiet time (scan delay). For regular electrochemical impedance measurement system, real ground mode is recommended, and 10pF~100pF is OK for filter bandwidth.

10.3.5 Cell Setting

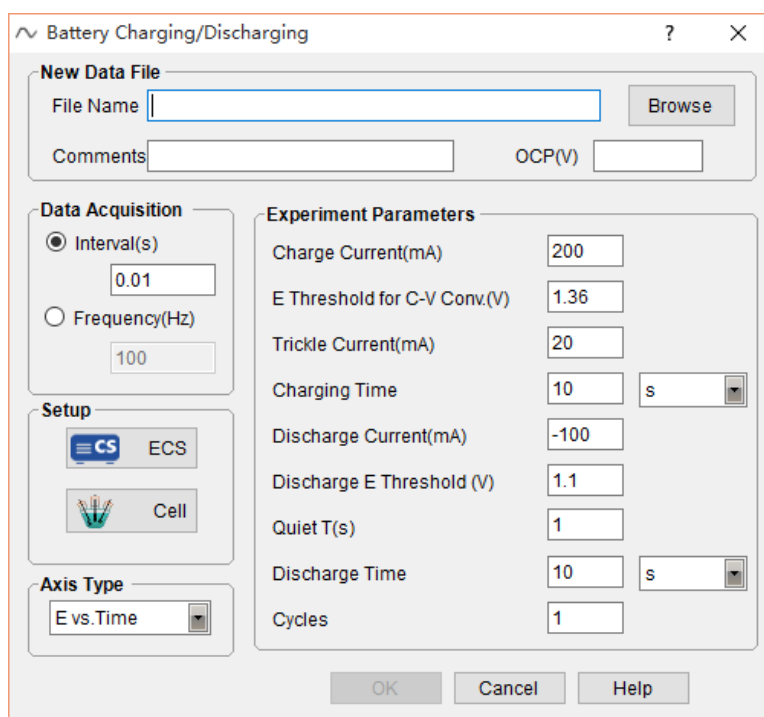
You can enter related information of one or more working electrode(s) and electrolytic cell(s), eg. surface area, material, and temperature... The electrode area, density and chemical equivalent will affect the results of experiment and fitting. Temperature or type of RE will not affect the original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

11. Charging/Discharging

11.1 Battery Charging/Discharging

Experiments→Charging/Discharging→Battery Charging/Discharging

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



11.1.1 File Name

See 4.1.1 File Name.

11.1.2 Experiment parameters

Charge current--According to different connecting ways of the electrodes, the sign of charge current will be different. Connect the working electrode to anode, and the reference & counter electrodes to the cathode, if the open circuit potential is positive, then a positive value entering means charging process. .

E-Threshold for C-V Conv. is the critical 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 critical 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.

Discharge current--Connect the working electrode to anode, and the reference & counter

electrode are connected to cathode, if the OCP is a positive value, then it means discharging if you enter a negative value here.

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

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

Charge/ Discharge time--When the charge/discharge time is reached, even the specified threshold voltage hasn't been reached yet, the charge / discharge process will stop, and turn to discharge/charge. You can select second, minute or hour.

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.

11.1.3 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

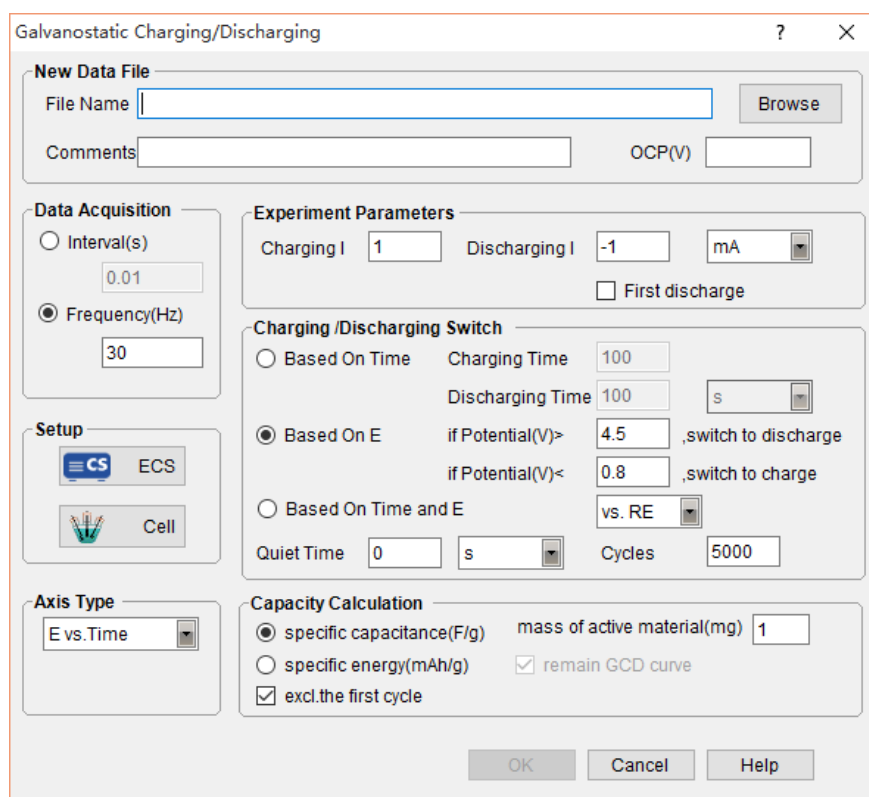
11.1.4 Cell Setting

See Cell Setting 3.2.

11.2 Galvanostatic Charging/Discharging(GCD)

Experiments→Charging/Discharging→Galvanostatic Charging/Discharging

It measure cyclic charge-discharge characteristics of the electrode materials, such as secondary battery or supercapacitor electrode material, under a constant current. It tests the cycle lifetime of the electrode material.



11.2.1 File Name

See 4.1.1 File Name.

11.2.2 Charge/Discharge Current

Charging I- if the anode is connected to the working electrode, entering a positive value means charge.

Discharging I- if the anode is connected to the working electrode, entering a negative value means discharge.

11.2.3 Condition for switch of Charging/Discharging

Based on Time

Charging/discharging time-- it specifies the duration of the process of charge /discharge. Charging process will be stopped and turn to discharge if the duration reaches the set value, and vice versa. You can select “seconds”, “minute” and “hour.”

Based on E

When the potential (V) $< E_{ch}$ (vs.RE) set by the user, it means the material has fully discharged, the instrument will switch to the charging state. If the potential during constant current charging process is higher than E_{dis} (vs.RE), it means the material charging process has finished, and a cycle is completed, and will go to the discharge state.

Based on Time and E

Either condition is met, the charge/discharge process 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.

Capacity calculation

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 discharging(charging) time, ΔV is discharging(charging) potential difference, m is the mass of electrode active materials(note: m cannot be 0, otherwise the software will give an error prompt.)

Through many times of cyclic measurement, we can evaluate the lifespan of the capacitors. By symmetry of the charging and discharging curve, we can judge whether capacitor charging and discharge, and the electrochemical reactions are reversible or not.

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

$$\eta = \frac{C_{dis}}{C_{ch}} \times 100\% \quad , \quad \eta = \frac{\Delta t_{dis}}{\Delta t_{ch}} \times 100\%$$

Where, C_{ch} , C_{dis} is the charging capacitance and discharging capacitance, respectively. Δt_{ch} , Δt_{dis} is charging time and discharging time, respectively, they are displayed on the software.

Excl. the first cycle—Normally error is relatively big for the data of the first cycle. You can check it to not save the data of the first cycle.

11.2.4 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

11.2.5 Cell Setting

See Cell Setting 3.2.

12. Bipotentiostat



12.1 Hydrogen Diffusion Test (HDT)

Experiments→Bipotentiostat→Hydrogen diffusion Test

CS2350 bipotentiostat can do hydrogen diffusion test.

Hydrogen Diffusion Test(HDT) requires a set of H-cell which consists of two cells connected in serial. For each cell, there is a set of reference & counter electrode, and they share a working electrode which is a thin metal plate clipped in the middle of the two cells. (See the right picture).



On the hydrogen-charging surface of the working electrode, the square wave cathodic current is applied. By alternatively changing the current value, the atoms will diffuse into the metal and gradually reach the other side (detection surface) of the working electrode. By measuring the amplitude of the current waveform and the delay time, the hydrogen diffusion rate and diffusion coefficient can be calculated.

Connect the double electrolytic cells in the way as shown below, add 0.1mol/L NaOH solution into the anodic cell (right cell). Connect the electrode cable to the main channel on the front panel, and the cathodic cell to the slave channel. Firstly, set the anodic polarization potential of the main channel to be 0.2V vs. Hg/HgO, then start the polarization. The anodic current will decline dramatically at the beginning, then slowly remain a stable value, i.e. the anodic residual current which is generated by the residual hydrogen inner the steel plate or the impurities that can be oxidized in solution of the diffusion surface. When the residual current is lower than the set value, the user can add experimental medium (such as dilute hydrochloric acid) into the cathodic cell, and then start galvanostatic polarization of the slave channel. The initial current is the peak current, e.g. 10mA (see the figure). At this moment hydrogen ions on cathodic surface of cathodic cell will be reduced to hydrogen atoms, some of which will permeate into the metal disc and arrive on anodic surface of the anodic cell, then these arrived hydrogen atoms will be oxidized into ions under anodic polarization in the main channel, forming oxidation current.

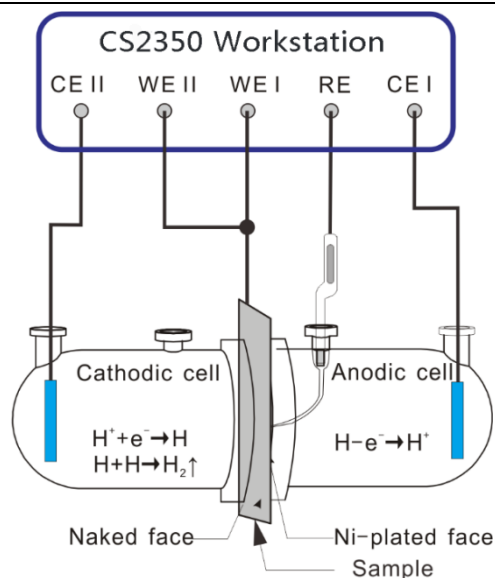
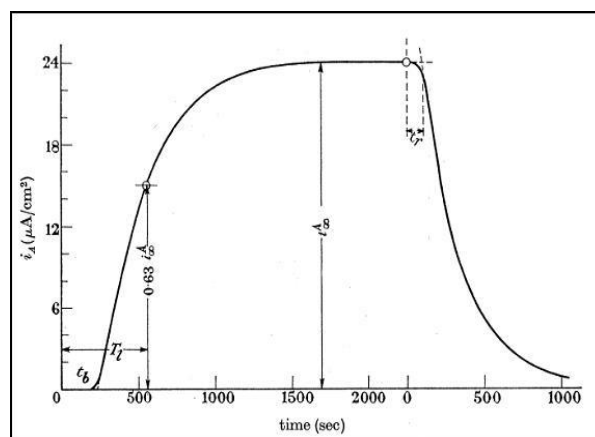
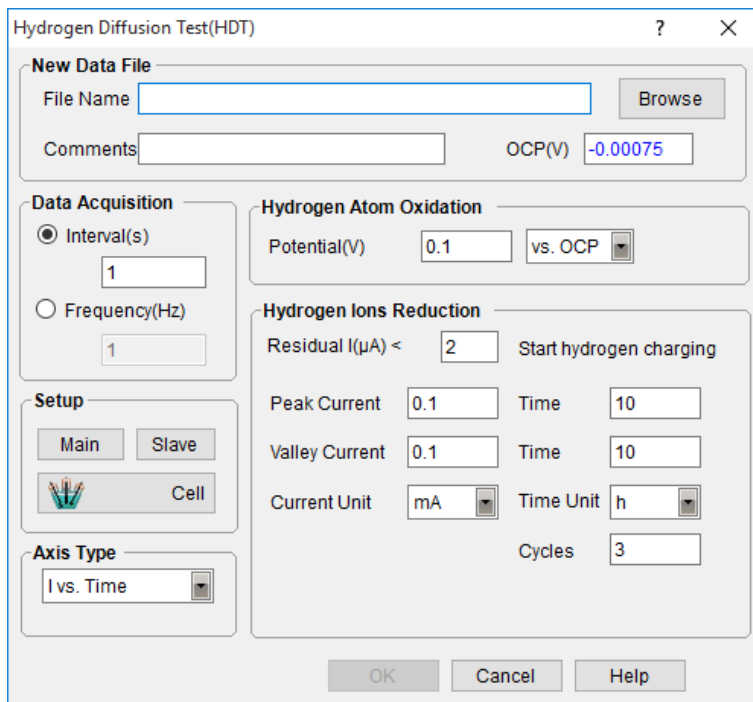


Diagram for Hydrogen diffusion cells



Current vs time curve in hydrogen diffusion test

Because hydrogen atoms diffusion rate is limited, current at the hydrogen detecting side delays, taking the form that anodic current increases (rising edge) or decreases (falling edge) gradually with time. According to the delay time of the hydrogen detecting current and its value, we can calculate the hydrogen concentration and diffusion rate in the metal, and further, we also can evaluate some inhibitors' effect on hydrogen diffusion.



12.1.1 File Name

See 4.1.1 File Name.

12.1.2 Hydrogen Atoms Oxidation (main channel)

Potential (V)—it is the polarization potential applied on the working electrode at the hydrogen current detection side. This potential should make the working electrode (metal disk) in anodic polarization. That is, a positive value should be entered to allow hydrogen atoms to be oxidized to ions.

12.1.3 Hydrogen Ions Reduction (slave channel)

Please set peak current and valley current of the square wave of hydrogen charging current as well as time. Hydrogen charging current can only be the cathodic direction so that the hydrogen ions are reduced to be atoms and pass through the working electrode (metal disk in the middle). Number of cycles of hydrogen charging current is the number of square wave.

Residual current—With the potentiostatic polarization going on, residual hydrogen current in the metal will gradually decrease. When it is lower than the set residual current, the software will start galvanostatic polarization for hydrogen charging.

At the beginning, the main channel will firstly start potentiostatic polarization, letting the hydrogen atoms in the metal fully diffuse onto the oxidation surface and be oxidized. It takes a relatively long time. Normally when the residual current is lower than $1\sim 2\mu\text{A}/\text{cm}^2$ (threshold of residual current), it's considered that hydrogen atoms in the metal are totally oxidized. Once the oxidation current is lower than the threshold value, the slave channel will start galvanostatic hydrogen charging. Hydrogen charging current varies between the peak current and the valley current. In general, 10~20 minutes later (depends 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.

12.1.4 Data Acquisition

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

12.1.5 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.

12.1.6 Main/Slave settings

For bipotentiostat, the “main channel” and “slave channel” settings can be same or different. Please choose “real” in ground mode. .

12.1.7 Cell Setting

See Cell Setting 3.2.

12.2 Rotating ring-disk Electrode (RRDE)

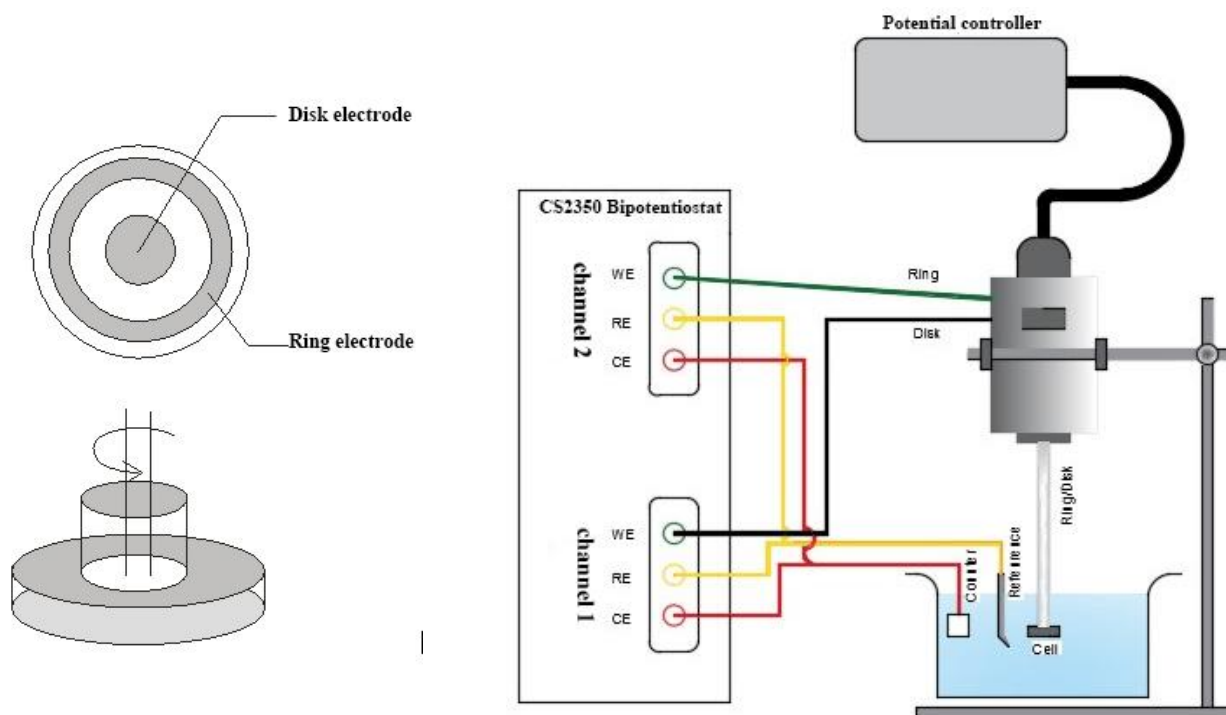
Experiments→Bipotentiostat→Rotating ring-disk electrode

CS2350 bipotentiostat can conduct rotating ring-disk electrode.

Compared with stationary electrodes, the rotating disk electrode is more stable in terms of concentration polarization. It has better polarization curve stability; and can measure rapid electrochemical reactions. Therefore, measuring the polarization curve of the rotating disk electrode has wide applications, especially in diffusion coefficient measurement, electron gain & loss in reactions, the reactant concentration, leveling effect of electroplating additives, and the kinetic parameters of electrode reactions, etc. With the help of ring electrode, it can also detect reaction intermediate products on the disk electrode.

In the following picture, disk working electrode (DW) and ring working electrode (RW) are two independent WE in concentric circle. DW and RW should be controlled at different polarization potential to ensure that electrochemical reaction product on DW can arrive in ring electrode for further redox reactions and be detected.

RRDE setup should be connected to the bipotentiostat with main channel (channel 1) and the slave channel (channel 2). The slave channel controls the potential difference between DW and RW.



The main channel applies the common three-electrode mode: CE clamp connects to the counter electrode; RE clamp connects to the reference electrode; and WE clamp connects to

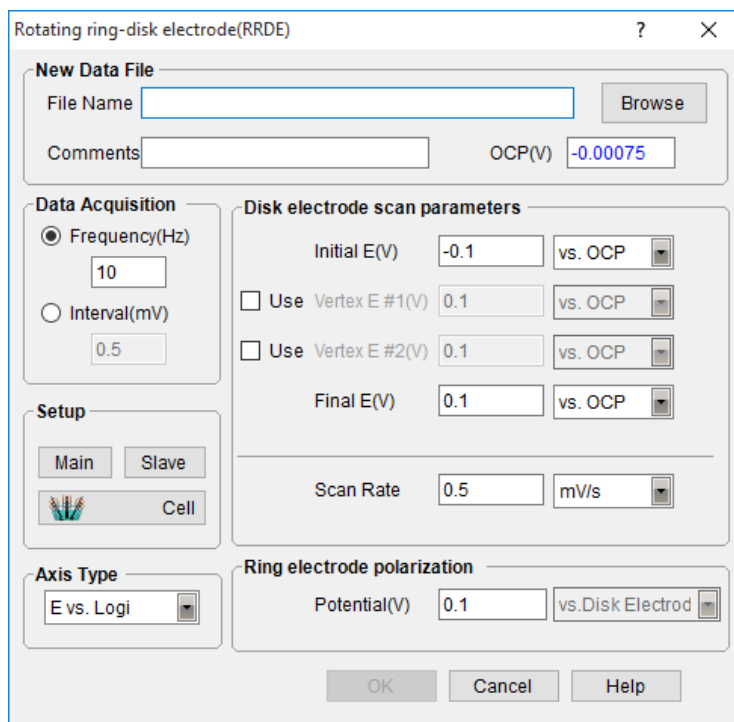
the disk electrode.

The slave channel also applies three-electrode potentiostatic mode: WE clamp connects to the ring electrode, CE clamp connects to the counter electrode, and RE clamp connects to the reference electrode. That is, RE clamp and CE clamp of each channel connects to a common reference electrode and counter electrode.

The intermediate product generated during disk electrode polarization further will be oxidized or reduced on the ring electrode due to the potential difference between the ring-disk electrode. Current on the ring electrode is measured and displayed by slave channel potentiostat.

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

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



parameters setting for rotating ring-disk electrode test

12.2.1 File Name

See 4.1.1 File Name.

12.2.2 Disk electrode scan parameters

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

12.2.3 Ring electrode polarization

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

12.2.4 Data Acquisition

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

12.2.5 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.

12.2.6 Main/Slave settings

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

12.2.7 Cell Setting

See Cell Setting 3.2.

13. Misc. Techniques

13.1 Electrochemical Noise (EN)

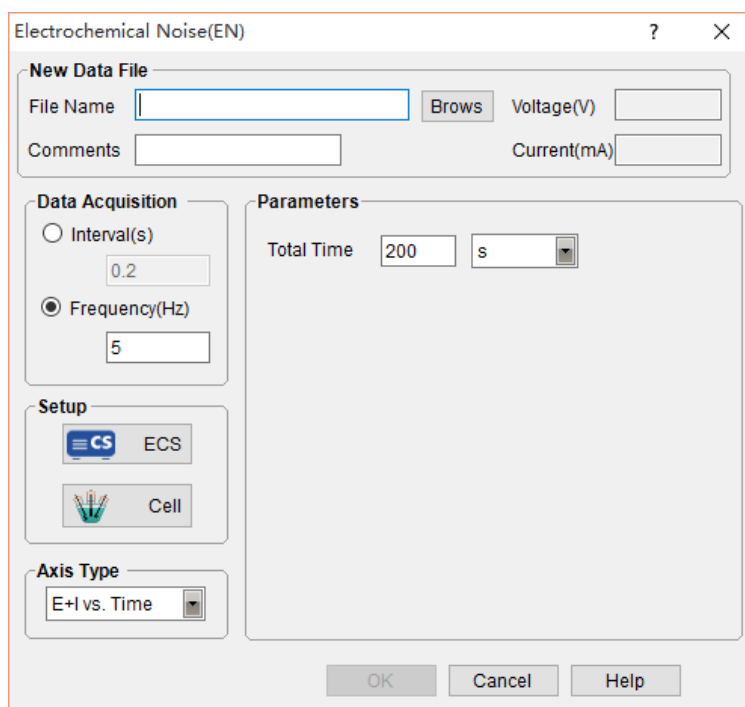
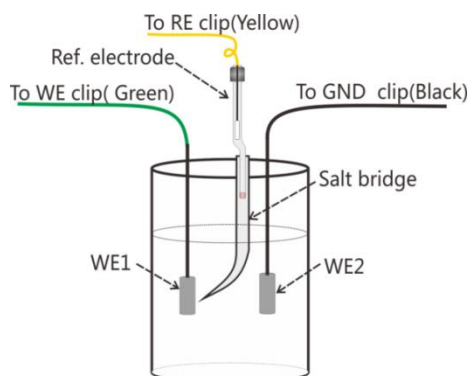
Experiments→Misc.Techniques→Electrochemical Noise

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 duration can be set.

For CS series electrochemical workstation, the noise signals (or galvanic current) measurement is different from other methods in that it doesn't need to be in the state of polarization. In the noise/galvanic current measurement, the working (galvanic) electrode I is connected to the green clamp of the electrode cable, and working (galvanic) electrode II is connected to the black clamp, and the reference electrode is connected to the yellow clamp. (See the picture on the right.)

Run the CS Studio software, select electrochemical noise measurement, on the software dialog box, it will appear coupling potential and galvanic current. If the current value is positive, it means the working /galvanic electrode I is anode and the working (galvanic) II is cathode. The current flows from electrode I to electrode II.

During measurement, the potentiostat will automatically switch current range according to the current.



13.1.1 File Name

See 4.1.1 File Name.

13.1.2 Data Acquisition

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

13.1.3 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.

13.1.4 Pstat/Gstat(ECS)

Please pay special attention that you should choose “**virtual**” for the ground mode.

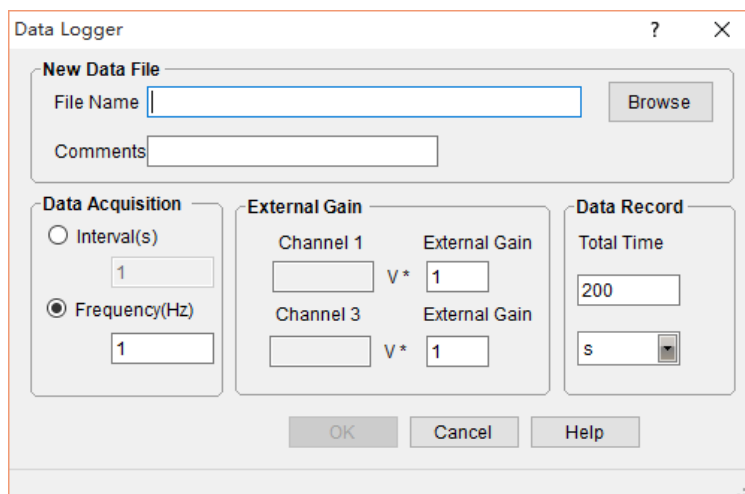
13.1.5 Cell Setting

See Cell Setting 3.2.

13.2 Data Logger

Experiments→Misc.Techniques→Data Logger

The data logger is used to synchronously record external signals. A maximum of six external signals can be recorded simultaneously. This method is completely independent from other electrochemical tests. That is, there is no interaction between potentiostat’s work and external signal recording.



13.2.1 File Name

See 4.1.1 File Name.

13.2.2 Data Acquisition

Interval -- it specifies the time it takes to acquire one sampling point.

Frequency -- it specifies sampling rate.

13.2.3 Sampling Data

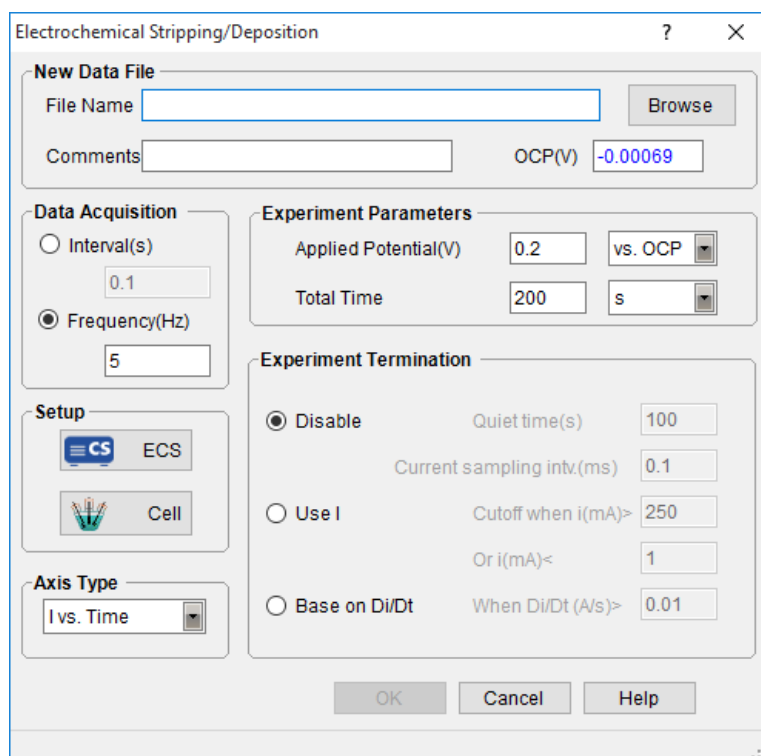
External gain -- amplification of external signals. For example, if the external signal is expected to amplify five times, then enter “5” here.

All external signals are recorded in the form of potential. The user must convert the potential value to magnitude of the original signals. Please note that external gain cannot be lower than zero.

13.3 Electrochemical Stripping/Deposition

Experiments→Misc.Techniques→Electrochemical Stripping/Deposition

A constant polarization potential is applied on the working electrode, and monitor the polarization current as a function of time. The polarization total time can be specified by the user, and it can also be set as that when the polarization current achieves a certain value, test is automatically terminated.



13.3.1 File Name

See 4.1.1 File Name.

13.3.2 Deposition Parameters

Applied potential (V)—it is 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. By clicking on the drop-down box, users can choose the applying way of polarization potential.

Total time— you can specify the duration of potentiostatic polarization; time unit can be “second”, “minute” or “hour”.

13.3.3 Experiment Termination

If you select “Use I” 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 maximum value (anodic current) or lower than the specified minimum value (cathodic current).

If you choose “Based on Di/Dt”, the program will automatically terminate potentiostatic polarization test once the Di/Dt is higher than the set value.

If you choose “Disable”, neither of the two conditions to terminate the test works.

13.3.4 Data Acquisition

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

13.3.5 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.

13.3.6 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

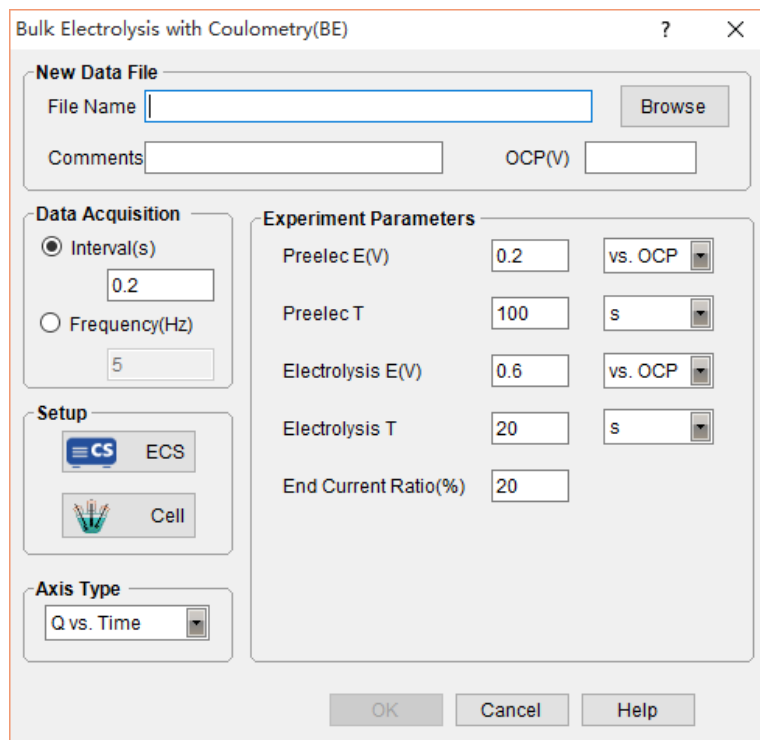
13.3.7 Cell Setting

See Cell Setting 3.2.

13.4 Bulk Electrolysis with Coulometry (BE)

Experiments→Misc.Techniques→Bulk Electrolysis with Coulometry

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



13.4.1 File Name

See 4.1.1 File Name.

13.4.2 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.

13.4.3 Data Acquisition

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

13.4.4 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.

13.4.5 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

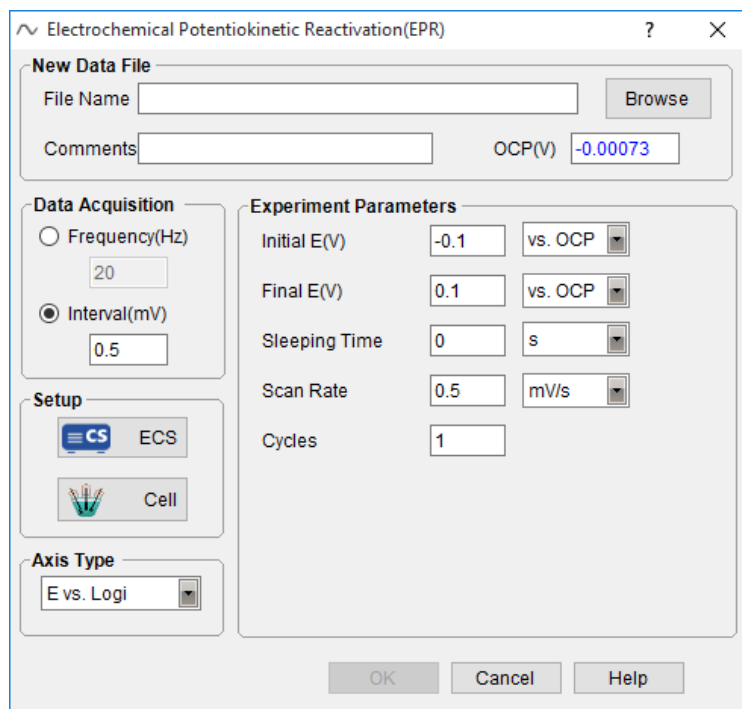
13.4.6 Cell Setting

See Cell Setting 3.2.

13.5 Electrochemical Potentiokinetic Reactivation(EPR)

Experiments→Misc.Techniques→Electrochemical Potentiokinetic Reactivation

This technique can be applied to evaluate susceptibility to intergranular corrosion. It can be determined by I_a/I_r (activation peak current/reactivation peak current). It can also be obtained by the ratio Q_a/Q_r . When the experiment is finished, the measured data can be analyzed and obtain the value of I_r , I_a , Q_r , and Q_a through “EPR index calculation” of voltammetric analyzing & fitting.



13.5.1 File Name

See 4.1.1 File Name.

13.5.2 Parameters setting

Initial E/Final E/Scan Rate: please refer to the parameter setting in technique Potentiodynamic.

Sleeping Time: the time staying at final potential.

Cycles: The number of cycles can be set. A complete cycle is finished scanning from the initial E to final E.

13.5.3 Pstat/Gstat(ECS)

See 3.1 Pstat/Gstat(ECS) Setting.

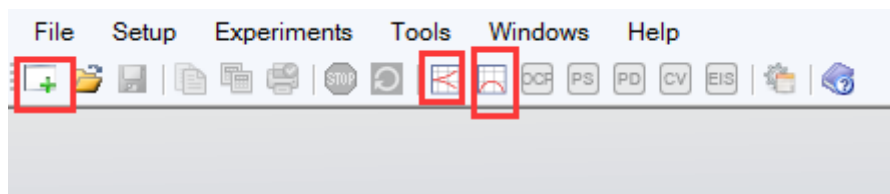
13.5.4 Cell Setting

See Cell Setting 3.2.

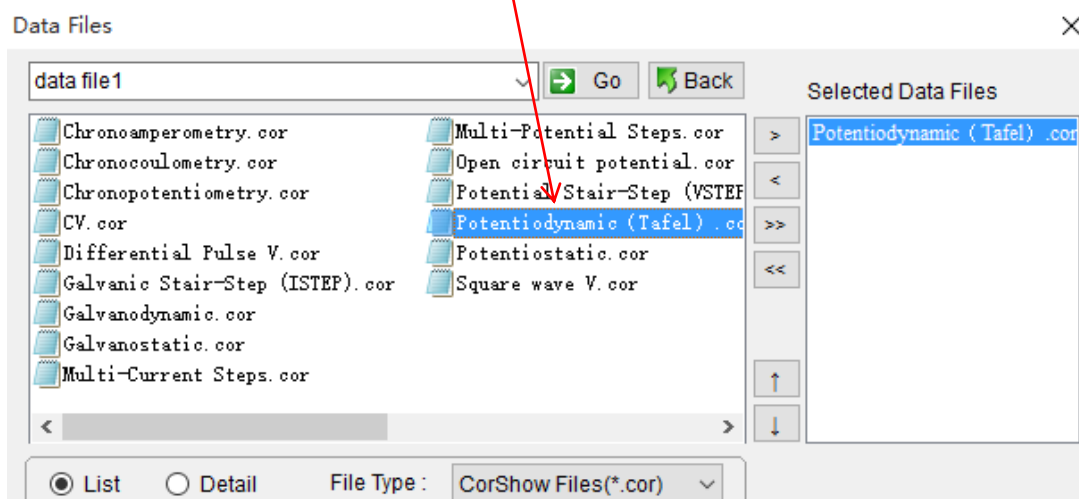
14. Graph Display

14.1 “.cor” Data file Graphing

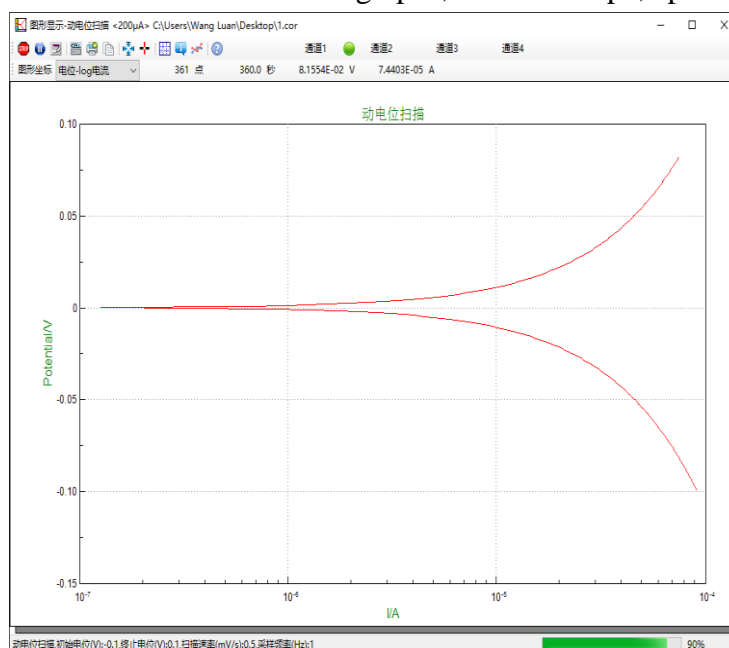
Except for EIS, all the other experiments (such as potentiostatic/galvanostatic polarization, CV, LSV, DPV, NPV...), the data file is suffixed with “.cor”.



Double-click to import a data file



For all the techniques based on constant potential, constant current, galvanic current, the window displays real-time data in the form of graphs, and can “stop”, “pause”, or “reverse”.

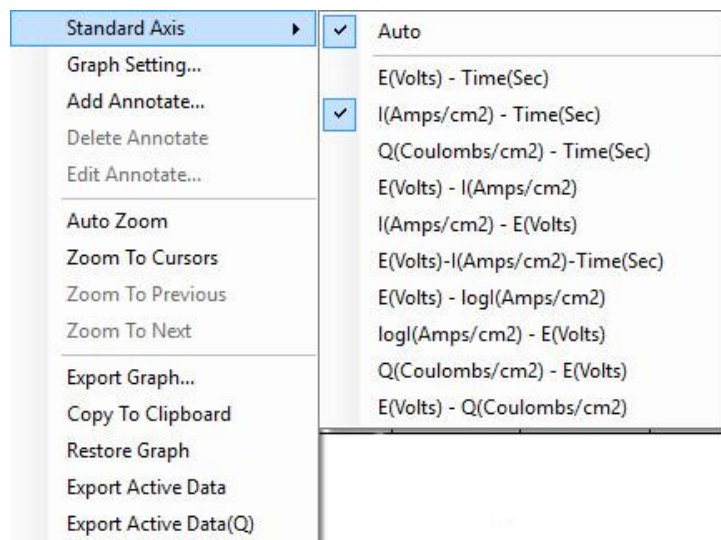


dynamic graph display window

The file name is shown at the top of the window. The techniques such as potentiostatic, potentiodynamic, parameters such as the scan rate, measuring time, working status, total data amount, etc , and test completion percentage will be shown at the bottom.

CS Studio will automatically find the best beginning and end point in the coordinate and refresh the graph in real time.

14.1.1 Coordinate



E vs. time- the abscissa is time in “second”; the Y- axis is potential of the electrode.

I vs. time- the abscissa is time in “second”; the Y- axis is current.

E vs. I- the abscissa is current; the Y- axis is the potential of the electrode.

I vs. E- the abscissa is the potential of the electrode ; the Y- axis is current.

E vs. LogI- the abscissa is the logarithm of the absolute current; the Y- axis is the potential of electrode.

E+I vs. time- The abscissa is time, and the Y- axis is electrode’s potential and polarization (galvanic) current.


Q vs. Time - the abscissa is time and the Y- axis is the integral quantity of electric charges.

14.1.2 Zoom In


If you want to zoom in a local position, you can left-press the mouse button on the target area, and drag it to the lower- right side, and then release the button. The selected graph will be immediately zoomed in and fill up the entire window. The graph will not be updated, but CS studio is still scanning and acquiring data signals. If you want to go back to the previous state , please just double click the mouse anywhere on the graph or click “zoom out”.

14.1.3 Buttons


Stop

Click  to stop the ongoing test.

Pause/Start

Click  to pause the test, re-click to resume the testing.

Reverse

Click  button then the scan direction will be reversed. It is only used in potentiodynamic

and cyclic voltammetry test. A single click will let the scan direction reverse, and the scan rate keeps unchanged. Click again, then the direction will be returned to the original.


Polar off

Click  then you can change the state of the electrode polarization anytime.

Print

Click , then the real-time graph in the window will be output to the printer immediately.


Copy

Click  then the real-time graph in the window can be copied and pasted.

Auto zoom

Click  then the real-time graph will zoom in and fill up the entire graph window.

Data reader

It shows the real-time data, from left to right they are: data points, time(s), potential(V), current(A). If you want to know the value of a certain point, you can click the  icon and move the mouse cursor on that specific point on the graph. The value will be displayed immediately. For example, if you set coordinate to be “E-T”, then the text will be the time and potential; and if you select “E-I”, then the text will be current density and potential.

Show Grid

Click , the coordinate grids will be shown, click it again not to show the grids.

Show Parameters

Click  then the testing parameters can be shown, click it again not to display.

Show Mark

Click  button to display the mark. Click it again to cancel display.


Help

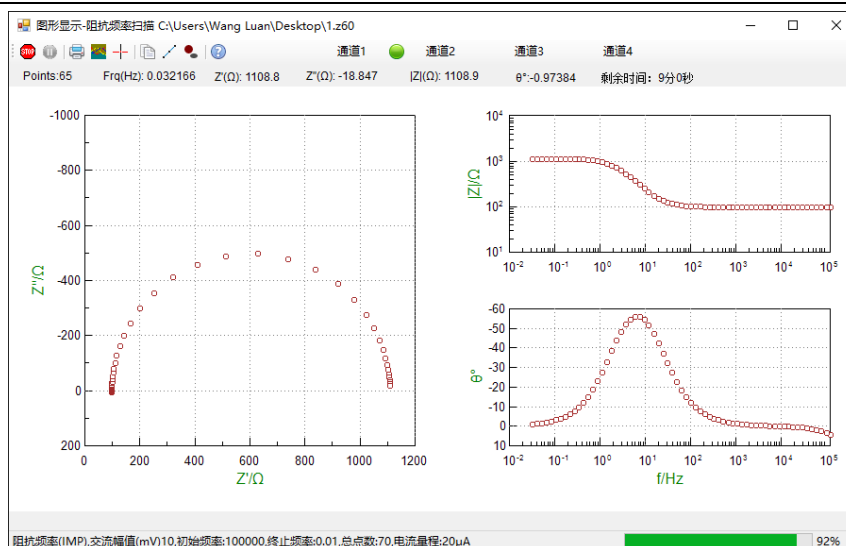
Click  to get help info. of the test at present.

14.2“.z60” Impedance Data

CS studio will display the real-time impedance data. The real part, the imaginary part, the impedance modular, phase angle and frequency will be displayed. The measuring data will be automatically saved .

Data reader

If you want to know the value of a certain data point on the graph, you can click  and move the cursor to the graph area, then the data will be displayed immediately. You can read the real part, imaginary part, frequency, impedance modular and phase angle of a data point in “Nyquist” or “Bode” plot, as shown in below.




EIS vs. Frequency testing window

Zoom in

If you want to zoom in a local position, you can left-press the mouse button on the target area, and drag it to the lower- right side, and then release the button. The selected graph will be immediately zoomed in and fill up the entire window. The graph will not be updated, but CS Studio is still scanning and acquiring data signals. If you want to go back to the previous state, please just double click the mouse anywhere on the graph or click “zoom out”.

Note: Due to the large amount of data during the test, you’d better use the zoom in function after the measurement.

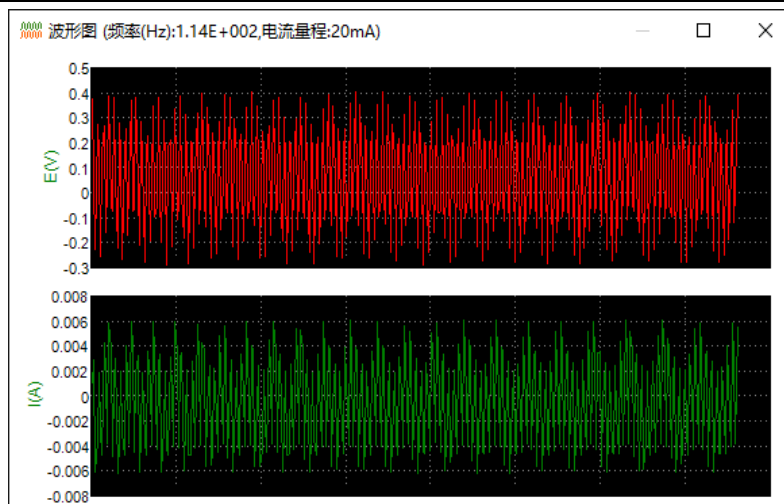
Stop

Click  button to stop the testing and change from polarization status to natural status.

Waveform

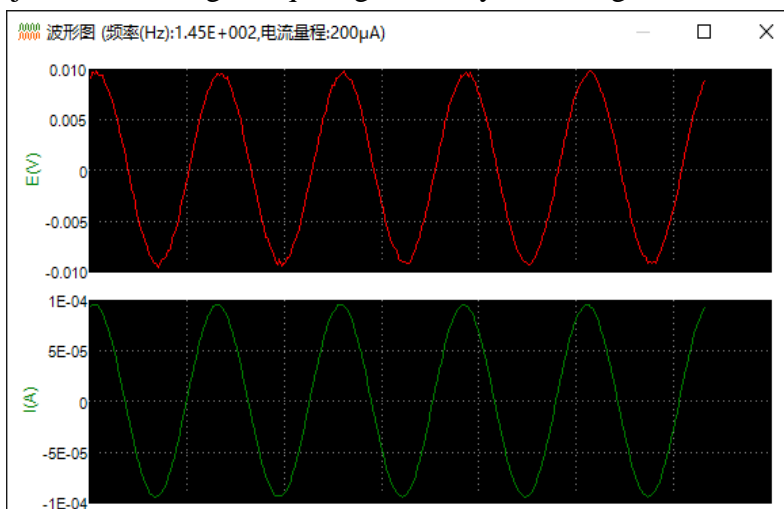
The waveform window shows the acquired potential and current waveform during EIS test, and guide the user to choose the suitable “Min. High Freq. range” and “Bandwidth” in the analyzer setting. If the noise is big, you should probably increase capacitance of the bandwidth filter, and prevent measuring system oscillation.

For EIS test of high-impedance system, if you don’t open the bandwidth response capacitor in analyzer setting, oscillation may happen, as shown in below. In this picture, you can’t see sine signals, and the amplitude is not 10mV, meaning there is oscillation in the testing system.



(close bandwidth capacitor) acquired potential / current waveform(oscillation appears)

Choose the bandwidth capacitance to be “22pF” in analyzer setting, then you can see the normal sine wave signals, suggesting that the instrument can response to the applied sine wave signals, and works properly. As shown in below picture, the amplitude of the potential signals is 10mV, in accordance with the amplitude of the applied signals. Meanwhile, the current signal is around 100 μ A, matching the selected current range 200 μ A. If the current amplitude is too big or too small, there will be relatively big error in the measured impedance spectroscopy. You should re-adjust the min. high freq. range in analyzer setting.



(selecting 22pF capacitor) acquired potential/current waveform(normal sine wave signals)

If just current signals noise is big, the cause may be high input impedance of the reference electrode loop (eg. high-impedance coating). You should increase the capacitance of the bandwidth filter to improve the stability.

15. Tools

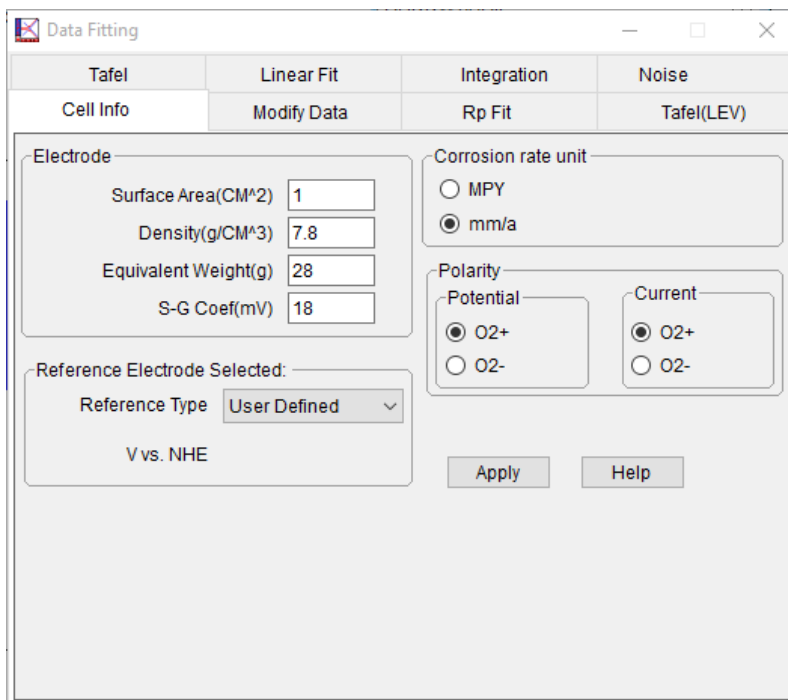
15.1Data Export

This command is to export the data file of the active window, and save as data file suffixed with “.cor”. The data format is “.csp” if you choose “save project as”.

15.2Data fitting

There are: tafel fitting, linear fit, integration, Noise, cell information, modify data, R_p fit,

Least square method etc.



Data Fitting

15.2.1 Modify Data

This is used to change the original data for data / graph offset and flipping. After modification, all data is changed. During switch, there will be a prompt to ask if you want to save the data.

If you want to do subtraction, you only need to enter a negative value in Addition. If you want to do division, you just need to change the corresponding relationship.

15.2.2 Cell info.

See Cell Setting 3.2.

Electrode area is the area of the working electrode. If it is 1, the current density will be the same as the measured current in value.

CS studio employs material density or the chemical equivalent for corrosion rate calculation. Chemical equivalent= atomic weight/the number of electrons transferred in the reaction. For example, for reaction $\text{Fe}-2\text{e} \rightarrow \text{Fe}^{2+}$, the number of transferred electrons is 2, then the chemical equivalent is $55.8/2=27.9$.

If such values are not entered, then the software only calculate the polarization resistance R_p or the Tafel slope, and cannot calculate corrosion rate.

“Polarity” determines how the positive/negative potential/current is interpreted. When choose the normal “ O^{2+} ”, a more positive potential will produce a bigger oxidation driving force, meanwhile the generated current is positive. If you choose “ O^{2-} ”, a more negative potential will produce a bigger oxidation driving force, the oxidation current value is negative.

15.2.3 R_p fitting

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

If the data range is set to be “auto”, CS Studio 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 adesired data range, or directly enter a max. and min.potential.

Fitting results:

R_p (Ohms/cm²):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/cm²): 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(E_p & b_c) cannot be obtained directly in linear polarization area, CS studio program assume it to be 0.12V/dec, thus for Stern Geary coefficient:

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

Normally, assign the B to be 18mV(it can also be set in cell info.), then,

$$I_{corr} \text{ (mA/cm}^2\text{)} = \frac{18\text{mV}}{R_p}$$

Corrosion rate is calculated according:

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

$\text{mm/a} = \text{MPY} \div 39.37(\text{mil/mm})$.

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

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

15.2.4 Tafel fitting

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

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

If fit B_a , then $i = i_0 \times [10^{(E-E_0)/B_a}]$ can be simplified as: $\lg i = E/B_a + \lg i_0 - E_0/B_a$. Then it becomes a standard linear equation. i_0 and B_a can be calculated.

Using the same method, you can calculate B_c . If fit the B_a and B_c respectively, then we can calculate E_0 and i_0 more accurately.

Auto fitting

By auto fitting, the software will automatically find the data in range of 200mV around open circuit potential, and then do the anodic and cathodic fitting respectively, obtaining two equations and the intersection of the two lines. The more accurate i_0 and E_0 will be obtained, then we can calculate the corrosion rate.

15.2.5 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:

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

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 studio software will automatically find the OCP, then choosing 250mV range for anodic and cathodic part. 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. You can also enter max. and min. value to directly specify the range.

15.2.6 Linear fit

There are six types of fitting we provide, but the latter five methods are based on the first type, i.e., according to linear equation: $y = a + bx$.

Linear fit principle

The linear fitting is based on the least square method.

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

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

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

Expand the equation:

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

Other linear fittings

Take the function: $i = i_0 \times 10^{E/B}$ for an example:

Firstly you should judge the sign of the i ; it can be either all positive or all negative. Convert the equation to be $\lg i = \lg i_0 + E/B$. Assume $\lg i = y$, $\lg i_0 = a$, $1/B = b$, then it's

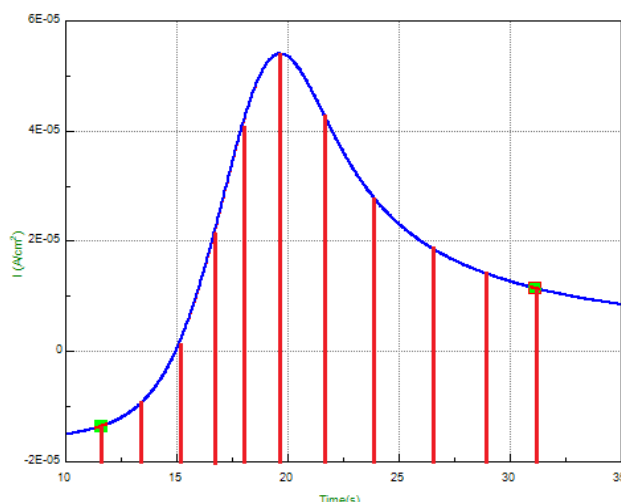
simplified to be a standard linear equation. Find the value of $\lg i_0$ and $1/B$, then calculate the i_0 and B indirectly. The value of i_0 is determined by the sign of i .

15.2.7 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)

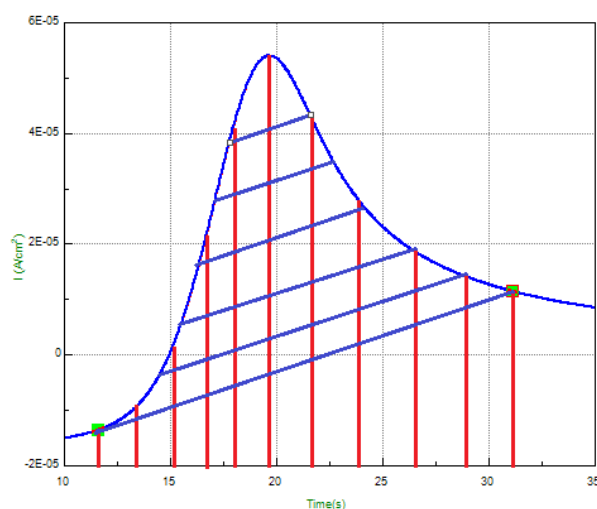
Trapezoidal integration means to calculate the area of the trapezoid constituted by two adjacent points, that is, to do trapezoidal integration for every data point on the I-T graph. The current value is the bottoms, and the time difference (Δt) is the height (see the picture as below). The sum of each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



Q integration area diagram

Q (with background)

If the Q is with background, then we should find the area between two points and the connection line of them. As shown in below picture, the area of the grid is to be obtained. It equals to the difference between the area constituted by points collection and the area of the lines.



Q integration(background) area

15.2.8 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 drift.

I_RMS represents the RMS value of the current noise after removing the background drift.

The formula is as follows:

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

Where, n is the number of data 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, influence of filter and ambient noise etc. The validity of results depends entirely on the user's judgment.

15.3 Voltammetry Analysis

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

15.3.1 Cyclic Voltammetry

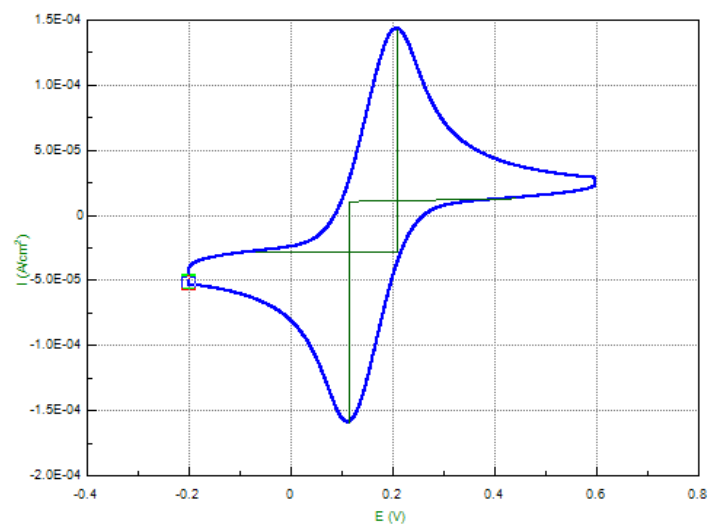
CV graph Display

In the data file, there is mark of cycle, so it can display each cycle. If the number of cycles is more than 2, then there is a radio button "Show". Check it, you can adjust the graph display, from which cycle to which cycle, as you wish.

Cycles: ☒ Show From To Cycle


Auto

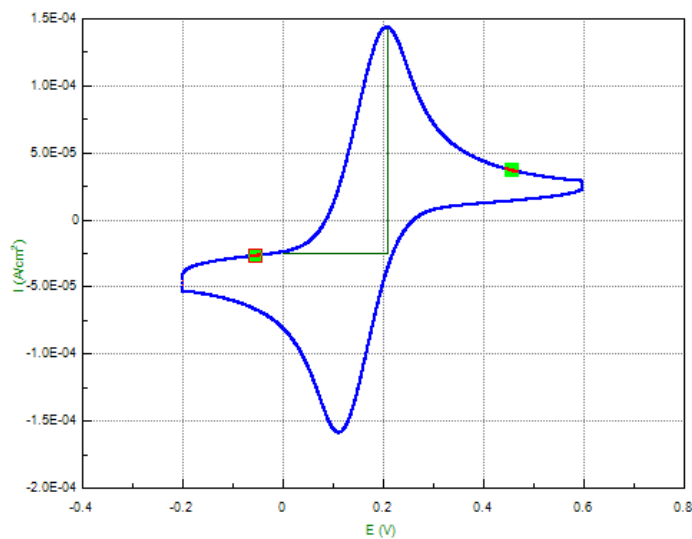
The program provides a method to find the peak: divide the data points cycle by cycle, then find the peak and valley of each cycle, and find a baseline which parallels to the X axis most, obtaining the peak height and half-peak area. You can also find the peak and baseline manually.



CV auto analysis


Anodic peak between cursors

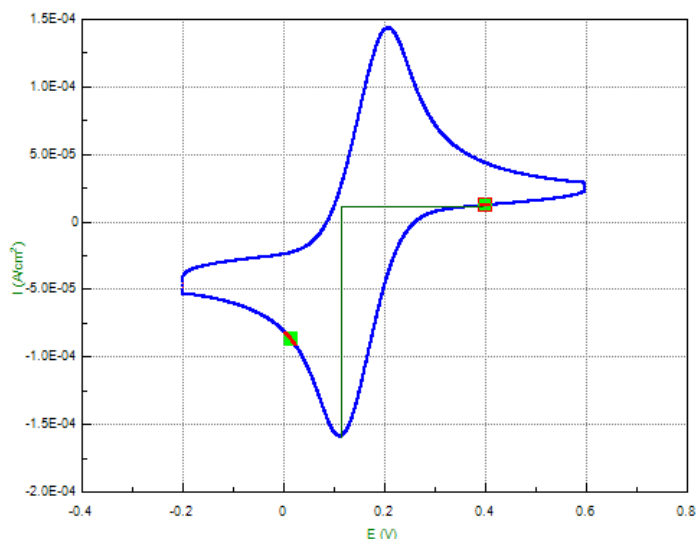
By swapping cursor , you can locate the beginning and end position for the anodic peak. The software will make the scan direction as baseline, and find the highest point as the peak. The peak height and half-peak area can be calculated.



Anodic peak interface between cursors

Cathodic peak between cursors

Through swapping cursor , you 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 vs. E.

Capacitance calculation

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

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

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

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

The result is shown like this:

Segment 2:

Area = 1.6438E-05 W

$\Delta E = E_2 - E_1 = 0.79803 \text{ V}$

Scan rate = 0.05 V/s

$C = 0.00020598 \text{ F}$

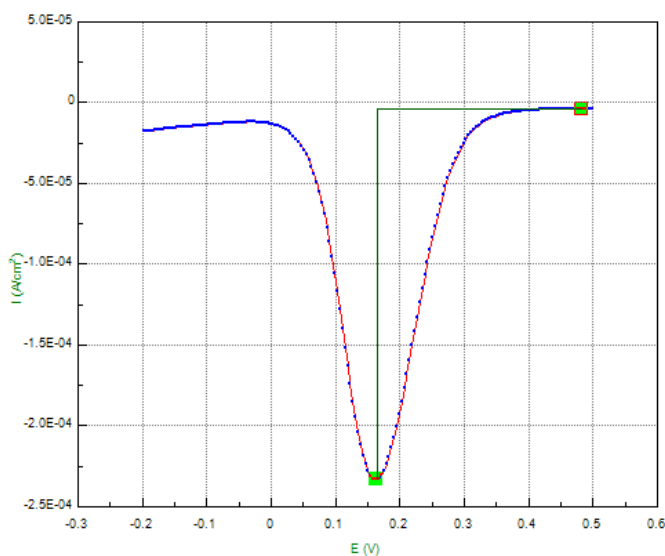
15.3.2 Differential Pulse Voltammetry (DPV)

It provides two methods: Auto and Peak between cursors.

Two methods are supplied for DPV: auto and peak value between the cursors.

Auto

The software 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 between cursors

Because there will be error or what you obtain is not what you want by auto method, we supply manual method. By swapping the cursors to determine the beginning and ending points, the software will then find the peak height and half-peak area based on the baseline and highest point.

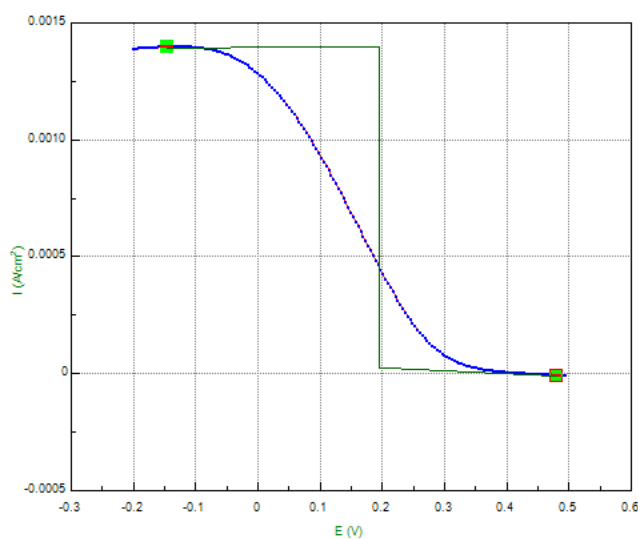
In voltammetric analysis, in order to show the height line, the coordinate must be I-E.

15.3.3 Normal Pulse Voltammetry(NPV)

It supplies two methods: Auto and Peak between the cursors.

Auto

Firstly you should find the median current, and then make the line that most parallels to X-axis as the baseline, then calculate the height.



NPV curve in $K_3Fe(CN)_6$ system

Peak between the 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.

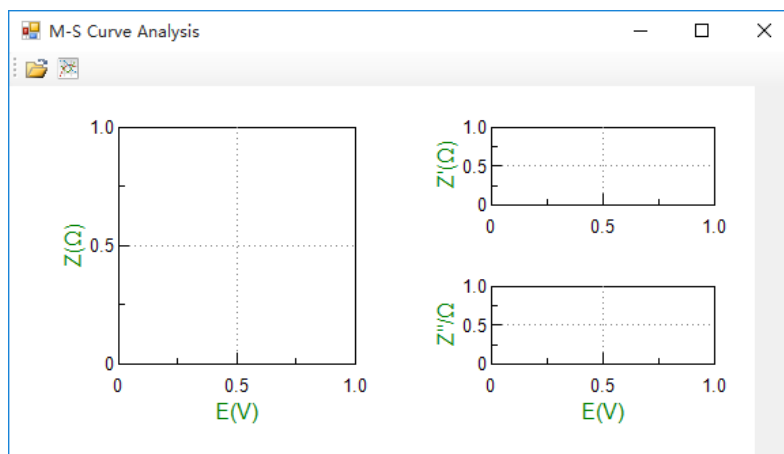
15.3.4EPR

See 13.5.


15.4M-Scurve analysis

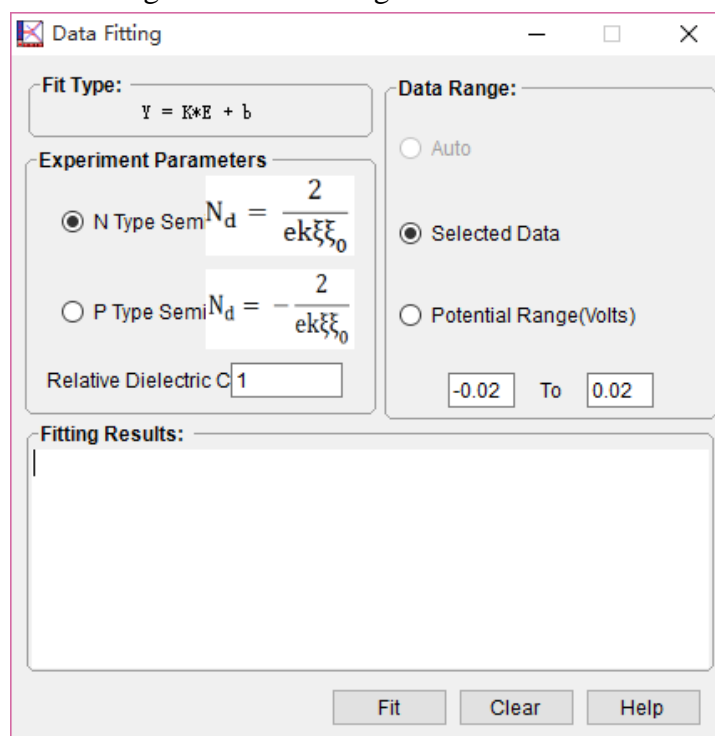
“Tools ” → M-S curve analysis

The generated EIS data file (.z60) is compatible to ZView software, but ZView cannot do Mott-Schottky analysis. After data acquisition, you should click “Tools”→M-S curve analysis to open the M-S curve analysis. Click  to import a data file, click  to open M-S curve fitting interface.



M-S curve analysis interface

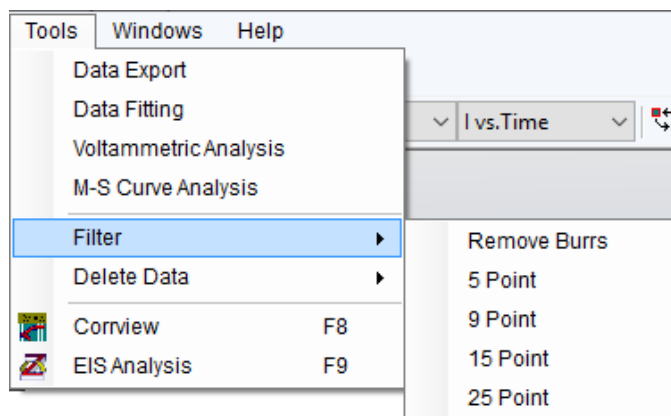
Click  to get the following M-S curve fitting interface:



The figure shows the 'Data Fitting' window. It contains several sections:

- Fit Type:** $y = K \cdot E + b$
- Experiment Parameters:**
 - ☒ N Type Semi $N_d = \frac{2}{ek\xi_0}$
 - ☐ P Type Semi $N_d = -\frac{2}{ek\xi_0}$
 - Relative Dielectric C: 1
- Data Range:**
 - ☐ Auto
 - ☒ Selected Data
 - ☐ Potential Range(Volts)
 - 0.02 To 0.02
- Fitting Results:** (Empty text area)
- Buttons:** Fit, Clear, Help

15.5 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.

15.6 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

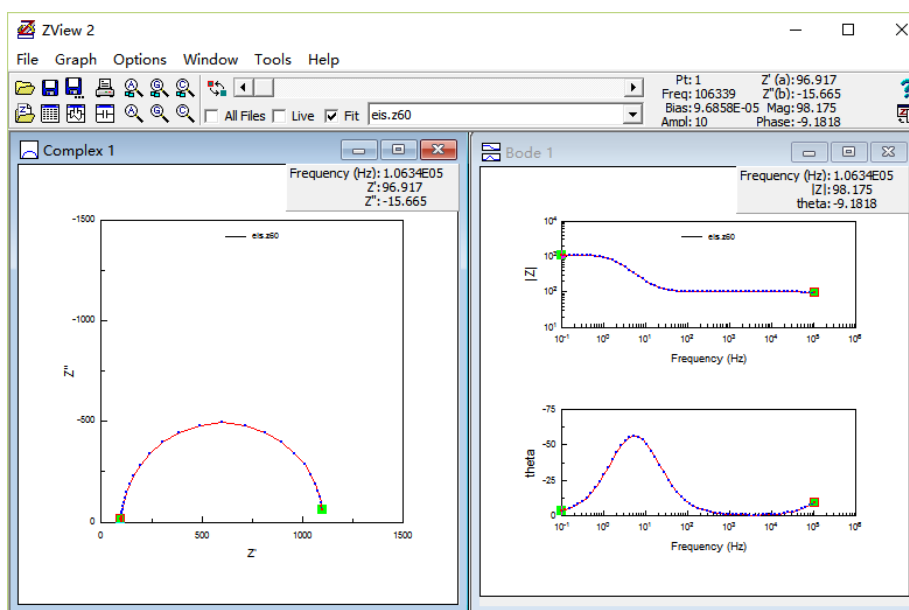
You can use this command to delete all data points between two cursors. After the data segment is deleted, the source file will be unchanged. The data after modification can also be saved via “Tools” → “Data Export”.

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”.

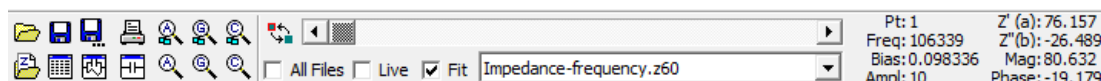
15.7EIS Analysis

ZView is a powerful EIS analysis and graphing software. It can do various electrochemical parameters computing, and do smoothing and digital filtering to the original potential and current data. It can also compensate solution resistance by software. ZView interface is clear, and the data, graphs can be easily printed and saved, and output to Word in vector mode.




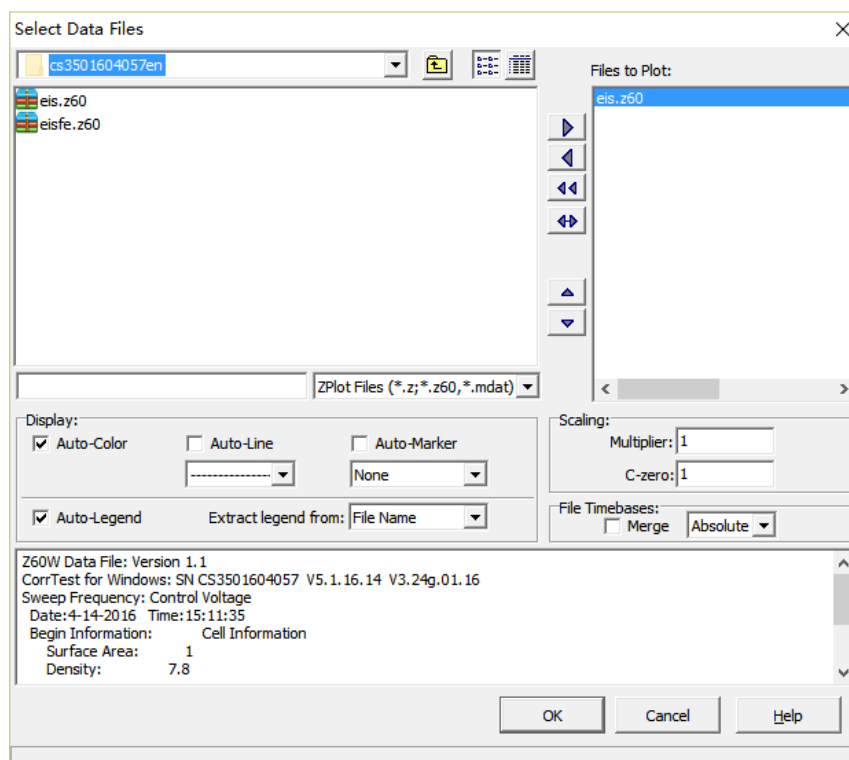
ZView impedance analysis interface

Toolbar is the shortcut keys of the menu. If you locate the mouse cursor on the icon, there will be explanation of the icon.



15.7.1 Open data files

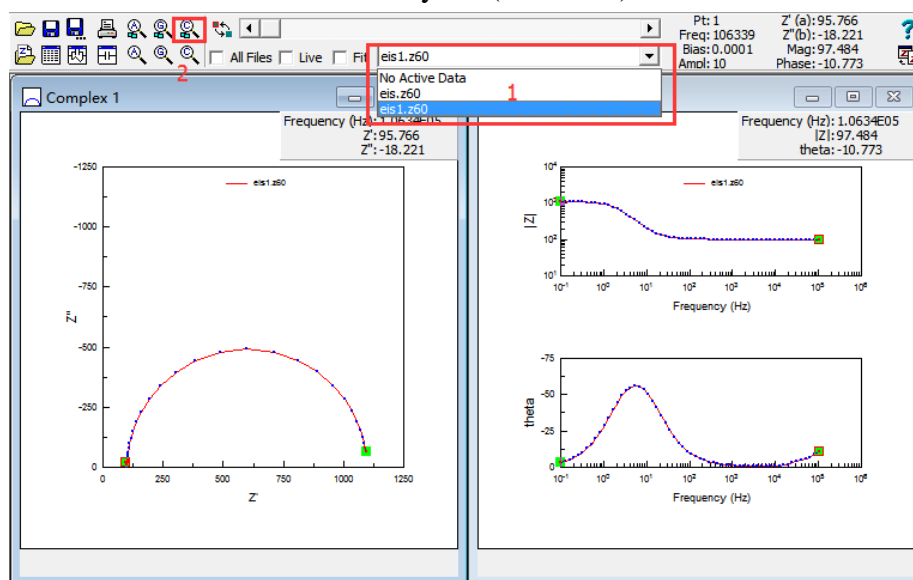
Click “File”→“Data Files”(or directly )to import the EIS data file, as shown in below:



ZView data import window

Activate data

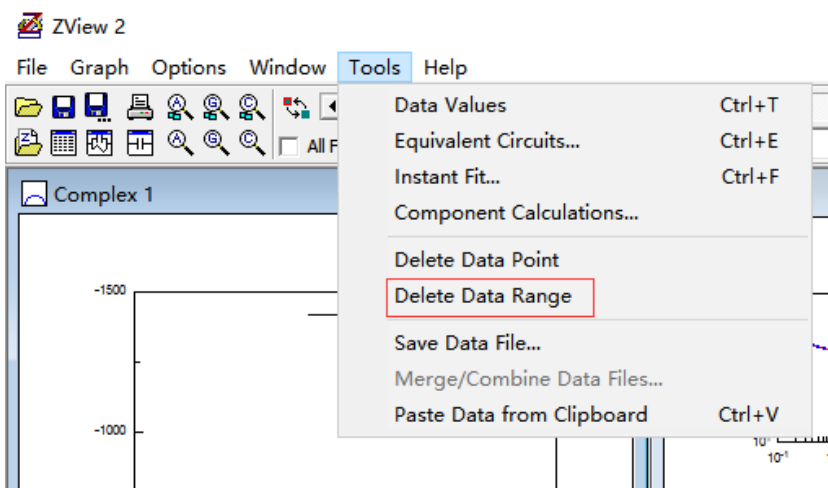
Choose the data file which is to be analyzed (marked 1).



ZView: choose the active data file

Delete data range

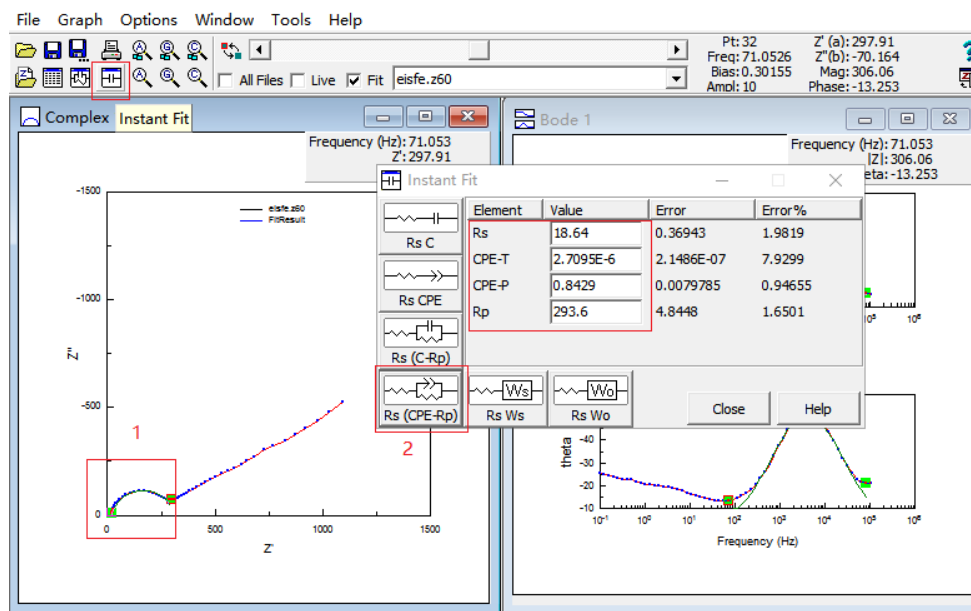
Select the unwanted data range (the part cannot be fitted by ZView) by the mouse cursor, and then delete them through Tools →Delete Data Range.




ZView : delete data range

15.7.2 Instant fit

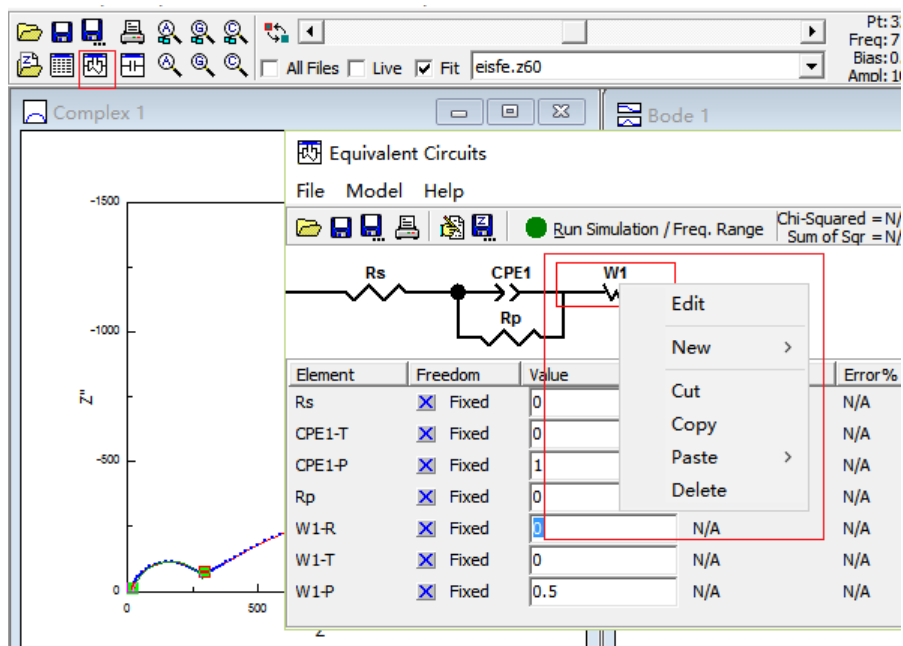
Instant fit is to obtain the initial value, a preparation for the formal fitting afterwards.



- (1) Choose the element one by one for instant fitting individually.
- (2) Click  for instant fitting.
- (3) Choose the suitable equivalent element(eg. the one marked 2), and obtain the initial value of the equivalent circuit.

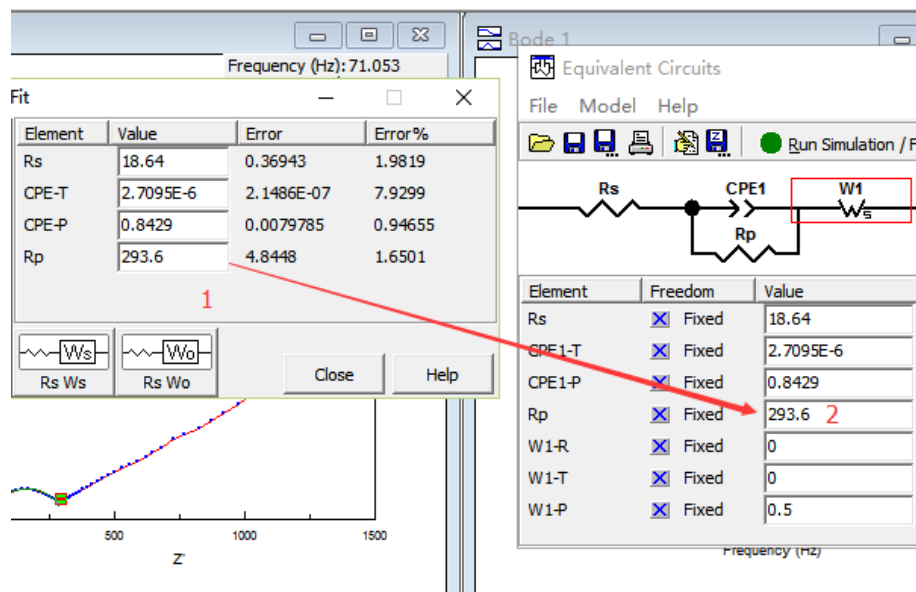
15.7.3 Complex circuit fitting

Build the suitable equivalent circuit based on the instant fit(see the below picture as an example). It depends on the actual testing system.



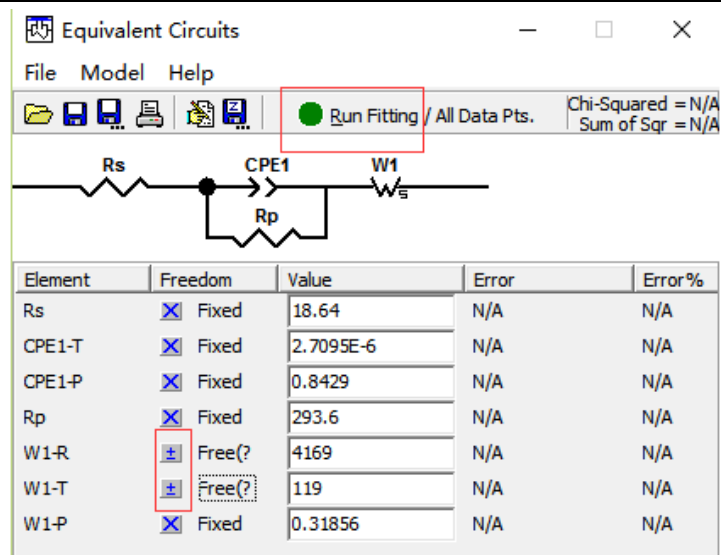
Choose the suitable equivalent circuit from ZView for formal fitting

Drag the data in place "1" to place "2", as shown below:



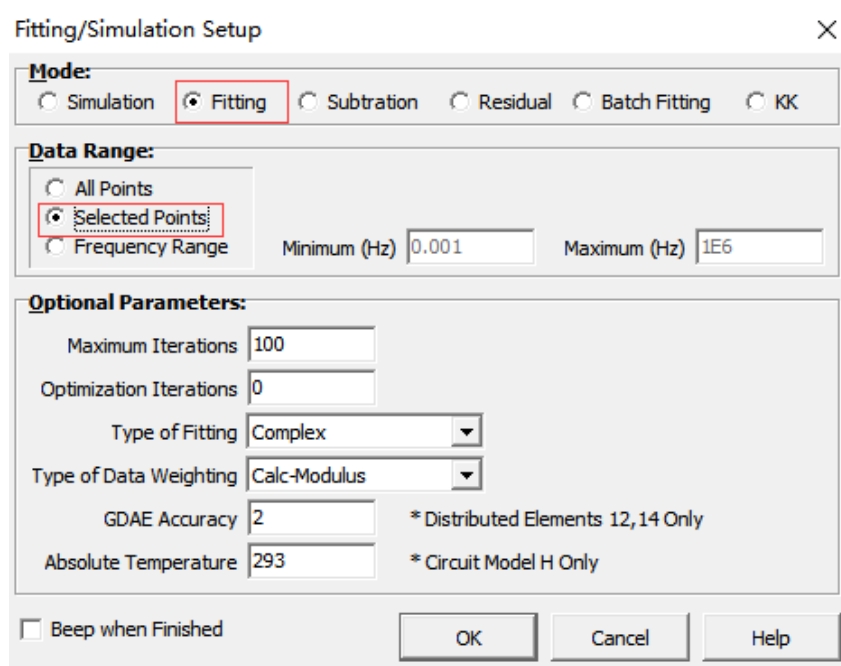
Drag the data from the instant fit window to the initial value entering box

Change "fixed" to "free", shown in the following picture:



Data fitting based on equivalent circuit

And change the mode from “Simulation” to “Fitting”



The 'Fitting/Simulation Setup' dialog box is shown with the 'Fitting' mode selected. The 'Data Range' section has 'Selected Points' selected. The 'Optional Parameters' section shows various settings for the fitting process.


Mode:
☐ Simulation ☒ Fitting ☐ Subtraction ☐ Residual ☐ Batch Fitting ☐ KK

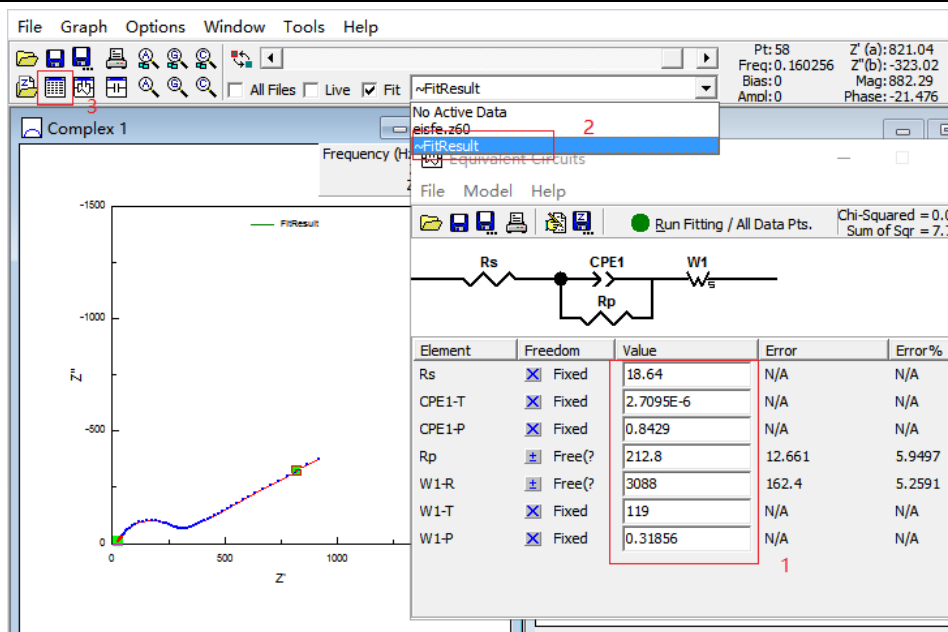
Data Range:
☐ All Points ☒ Selected Points ☐ Frequency Range
 Minimum (Hz) 0.001 Maximum (Hz) 1E6

Optional Parameters:
 Maximum Iterations 100
 Optimization Iterations 0
 Type of Fitting Complex
 Type of Data Weighting Calc-Modulus
 GDAE Accuracy 2 * Distributed Elements 12, 14 Only
 Absolute Temperature 293 * Circuit Model H Only

☐ Beep when Finished [OK] [Cancel] [Help]

Parameters setting dialog box

The place marked with “1” are the fitting results. If you want to re-graph for the results, choose “fit result” in place “2”, and click  to show the data. After copying them to the clipboard, they can be copied to Excel or Origin software.



Fitting results and fitting curve

16. Windows

This option is used to manage all current project subforms.

Cascade

All project subforms are displayed in the form of Cascade

Tile

All project subforms are displayed in the form of Tile

Arrange

All project subforms are rearranged.

Close all

Close all project subforms.

17. Help

Index and search: manual

Language: English and Chinese optional

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

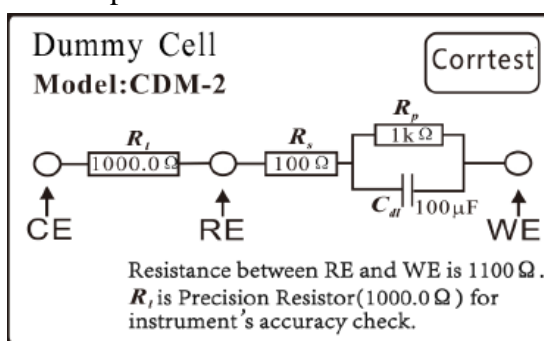
Check for update: click to update the software to the latest version

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

18. FAQs

18.1 Instrument Commissioning

The instrument should be put in dry, clean and corrosive-gas-free environment. During usage, the power supply of both the potentiostat and PC must be connected to the ground well.



Dummy cell

If there is malfunction or something abnormal, please use the dummy cell to check following the steps as below:

- 1) connect the green clamp to WE, the yellow clamp to RE, and the red one to CE. Based on the principles of the potentiostat, when change the applied potential, the output current should always obey the Ohm law: $I = E / R$
- 2) Start the CS Studio, and do the potentiodynamic experiment: apply potential 0~1V , then for each data point, the $E=IR$ should be obeyed. If it is, it means the instrument is well-functioning.
- 3) If the slant ratio or the value of potential/current is completely wrong, please check whether the crocodile clamp is broken, or whether there is poor connection between terminals on the dummy cell (you can use the multi-meter to measure the resistance between two terminals.). If these possible causes are ruled out, then it is deemed to be broken. The user should contact us (the manufacturer) for repair;

4) If the result is correct using dummy cell, obvious malfunction still appears when measuring the real system, please check carefully of the following: ①The actual test system/design of the experiment ②Environmental interference ③Reference Electrode ④GND wire

18.2 How to understand 3-electrode system

3-electrode system: the potentiostat measures and controls the potential difference between WE and RE. Current flow from the WE to CE. CS series potentiostat works with three electrodes immersed in a conductive electrolyte.

Working Electrode (WE): a sample being tested.

Reference Electrode (RE): an electrode with a constant electrochemical potential.

WE and RE constitute measuring circuit. There is no current flow on RE.

Counter Electrode (CE): a current-carrying electrode that completes the cell circuit.

WE and CE constitute polarization circuit.

2-electrode system: there is no individual RE involved in the experiment in 2-electrode system. When using the CS potentiostat/galvanostat for 2-electrode system testing, the CE can be used as RE to provide reference potential. During the measurements, you simply need to connect the RE&CE clamp to an electrode.

18.3 What may cause potential overload?

- (1) Max. potential difference between the RE and WE is higher than 10V
- (2) WE is unconnected.
- (3) Low impedance system (fuel cell, battery) in galvanostat mode.
- (4) Compliance voltage is over than 21V.
- (5) Broken RE or poor RE connection.
- (6) High-impedance system.

18.4 How to reduce the noise in electrochemical experiment?

1. Make sure the solution in salt bridge is conductive, and that the tip of the RE is down in the agar and connected well with the working solution. To make sure the microporous ceramic is well soaked, so as to reduce the RE impedance.

2. Open the filter to improve system stability.

3. Give a serial capacitor (100nF) between the RE and CE if the noise resulted from the solution resistance is unavoidable.

4. For corrosion test, add a 1 μ F capacitor between WE and machine shell of the potentiostat.

5. For impedance test, make a parallel connection of a Pt wire and RE. Dip one end of the Pt wire into solution and connect the other end to RE output port by a 100nF capacitor.

6. All of the equipment in the experiment incl. the PC must be connected to the ground using individual ground wire. If there is no suitable ground wire, you can use a thick copper wire to connect the PC with a nearby metal conductive water tap.

7. Shut down all the possible environmental interference source, such as high-power power supply, computer monitor, stirrer, and fluorescence light etc.

8. Use the Faraday cage, and connect it to the ground.

19. Service & Contact us

We are always dedicated to providing professional and comprehensive technical support to our customers from various research fields. Based on their different research focus, we supply the most suitable instrument, even the customized one if it's required. Good pre- and after-sales service distinguishes us from our rivals, and is the base that we win a reputation among clients.

Corrtest is equipped with a technical team with profound electrochemical background and abundant experience, which enables us to provide responsive & helpful technical support along with products supply. Service includes: installation guidance, theoretical explanation in electrochemistry, experimental scheme making, instrument use explanation, data analysis and treatment, users' training etc.

Warranty period of the instrument is 3 years. We will provide lifelong repair service for instruments that we sell, and supply upgraded software for the same model. The loss is on us in case of product damage during transportation.

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Website: www.corrtest.com.cn

www.kstinstruments.com



www.csechem.com





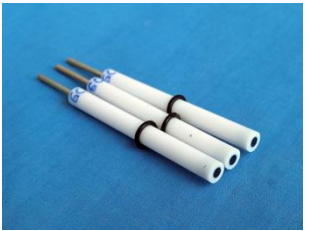



20. Appendix

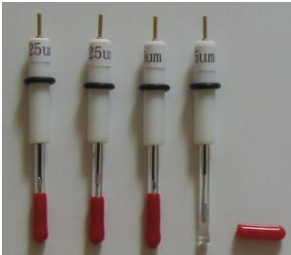
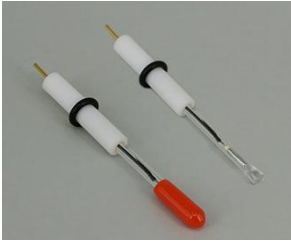




Accessories






Appendix







Electrochemical Accessories

Part #	Product	Picture	Specification
CS900	Saturated Calomel Electrode		model-212(straight), model-232(bent) model-217 (double salt bridge) Saturated KCl solution
CS901	Ag/AgCl reference electrode		Ø4mm/Ø6mm Saturated KCl solution
CS9001	Non-aqueous Ag/Ag ⁺ reference electrode		Ø4mm/Ø6mm
CS902	Hg/HgO reference electrode		suitable for alkaline/base solution
CS903	Mercury/Mercurous sulfate electrode		suitable in acid solution
CS904	Cu/CuSO ₄ electrode		Saturated CuSO ₄ solution
CS910	Platinum conductivity electrode		
CS911	Platinum plate electrode size can be customized		99.95%, 10x10x0.1mm,10x10x0.2mm, 20x20x0.1mm,20x20x0.2mm, 20x20x0.3mm etc.

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		Ø2mm
			Ø3mm
			Ø4mm/Ø5mm
			Ø6mm
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

CS925	Palladium working electrode		Ø2mm/ Ø3mm
CS926	Pt micro electrode		10µm/25µm
CS927	Gold micro electrode		12.5µm/25µm
CS928	Glass cell + Teflon cap		Glass cell: 10ml Diameter of the three holes: φ6.35mm, φ6.35mm, φ6mm
CS930	Glass electrolytic Cell, 4 ports Not include the electrodes in the photo.		150ml
			250ml
			500ml
			1000ml
CS931	Jacketed glass cell not sealed		50ml
			100ml
			150ml
CS931-S	Jacketed glass cell (Sealed)		50ml
			100ml
			150ml

CS932-1	H- cells		250ml/piece
CS932-2	H- cells (not sealed) Not include electrodes in the pic.		Volume:10~500mL(each cell, the volume can be customized) 50ml is easy to make. PTFE caps The two cells are separated by ion membrane which is prepared by user.
CS932-s	H- cells (sealed) The holes on the caps are tailored according to three electrodes you insert Not include electrodes in the pic.		Sealing system 50~250mL(each cell) 50ml is easy to make. PTFE caps The two cells are separated by ion membrane which is prepared by user.
CS933	Optoelectrochemical cell (material quartz) Not include electrode in the pic		30*30*30mm
			35*15*45mm
			40*40*40mm
			50*50*50mm
CS9330	Spectroelectrochemical cell		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 Not include the electrodes in the picture		10mL Working area is 1cm ²
CS935	Seal electrolytic cell The holes on the Teflon lid are tailored according to three electrodes you insert		50mL
			100mL
			150mL
			250mL
CS936	Flat corrosion cell kit -single		Single-deck working area is 1cm ² including: Ag/AgCl reference electrode counter electrode: Pt mesh*1 (20*20mm)
	Flat corrosion cell kit -double jacketed		Double-deck: working area is 1cm ² including: Ag/AgCl reference electrode *1 counter electrode: Pt mesh *1 (20*20mm)
CS940	Cell stand 1		Base material: carbon steel. Not included the cell and electrodes
CS941	Simple Cell Stand		Base material: PTFE provide 2*30ml electrolytic cup (free)

CS942	Electrode Polishing Kit		<p>Alpha alumina powder 0.05 μm, 0.3 μm, 1 μm 10g for each</p> <p>1 piece of Mastertex pad and a Microcloth polishing pad ($\varnothing 200\text{mm}$);</p> <p>Carbimet disks (4000#, $\varnothing 200\text{mm}$);</p> <p>2 pieces of glass plates</p>
CS945	Electrode clamp		<p>Disassemble;</p> <p>Pt mesh or Pt plate electrode of any size can be put onto the clamp</p>

Wuhan Corrtest Instruments Corp., Ltd.

**Rm 501, Dingye Hall B, International Enterprise Center,
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<http://www.corrtest.com.cn>