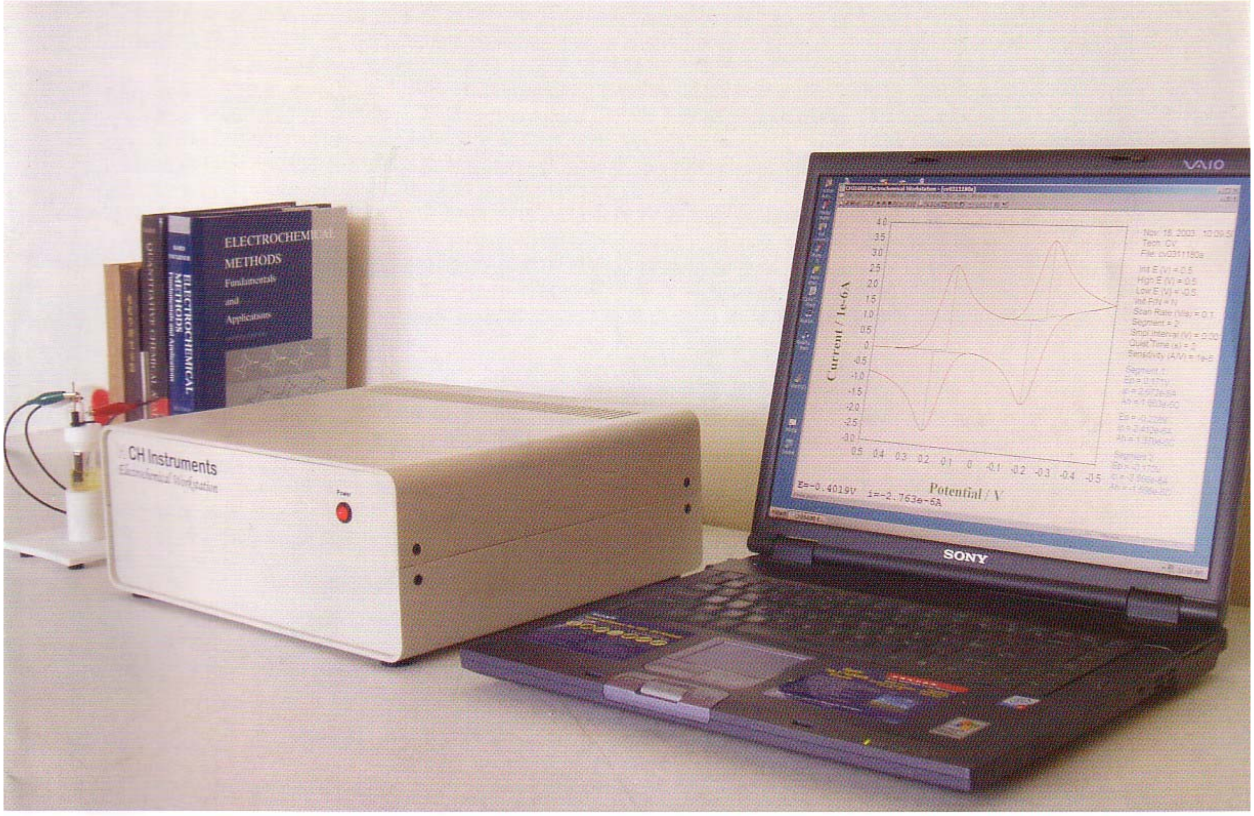
Electrochemical Instrumentation



CH Instruments

Overview

CH Instruments was established in 1994. Our first instrument series, the Model 600 series electrochemical analyzer/workstation, was introduced at the end of 1994. Since then, new products have been added to provide a full line of electrochemical instrumentation:

Model 400A Series Time-Resolved Electrochemical Quartz Crystal Microbalance (EQCM): for electro-deposition, adsorption, and chemical and biological sensor studies.

Model 600D Series Potentiostat/Galvanostat: for general purpose electrochemical measurements, such as kinetic measurements, electroanalysis, fundamental research, corrosion, and battery studies.

Model 700D Series Bipotentiostat: for rotating ring-disk electrodes (RRDE) and other cases where dual channel measurements are essential.

Model 800C Series Electrochemical Detector: for either single or dual channel electrochemical detection of flow cell, capillary electrophoresis and liquid chromatography, for chemical and biological sensors, and conventional electroanalysis.

Model 920C Scanning Electrochemical Microscope (SECM): for electrode surface, corrosion, biological samples, solid dissolution, liquid/liquid interfaces and membranes studies.

Model 1000A Series Multi-potentiostat: 8-channel potentiostat for array electrode characterization and sensor studies. It can be used for eight independent cells or for eight working electrodes in a same solution.

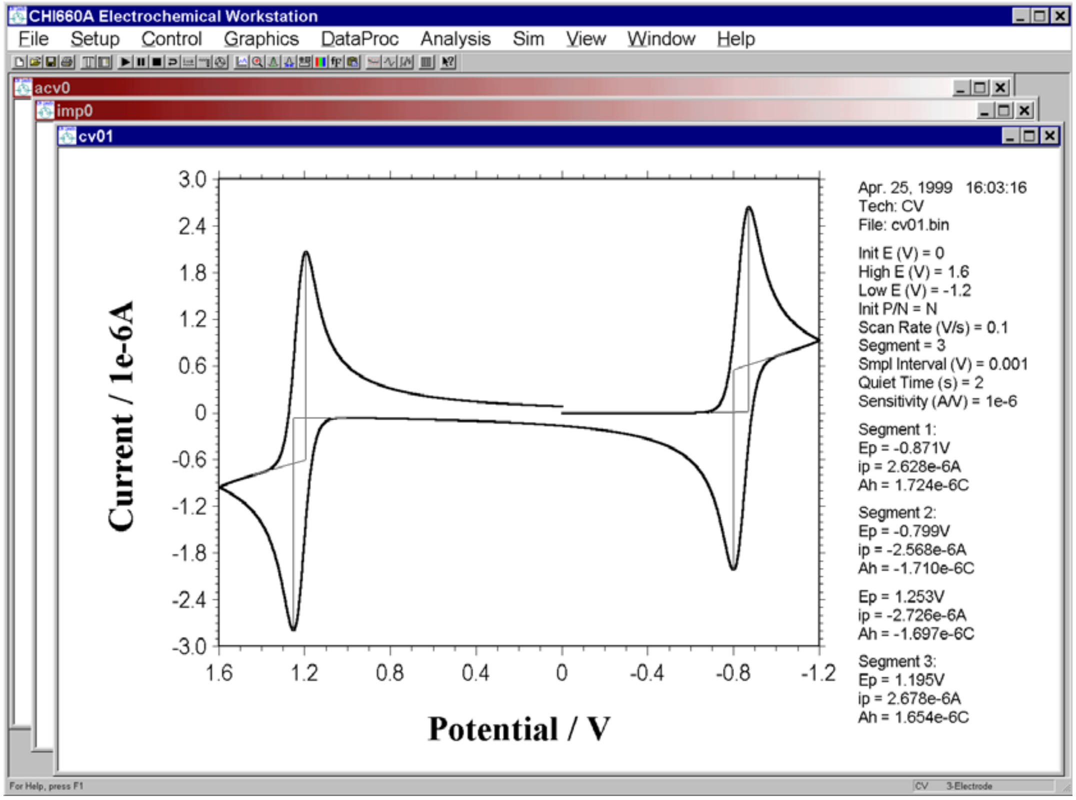
Model 1100A Power Potentiostat/Galvanostat: for applications involving higher current and compliance voltage.

Model 1200A Handheld Potentiostat/Bipotentiostat: for electroanalysis, sensor studies, and field applications.

Model 1550A Pico Liter Solution Dispenser: for making high density and high accuracy solution arrays.

All models are controlled by an external PC under the Windows 95/98/NT/Me/2000/XP environment. The instruments are easy to install and use. No plug-in card or other hardware is required on the PC side.

These instruments provide a rich repertoire of electrochemical techniques. Most well-established electrochemical techniques can be readily employed, including potential sweep, step, pulse, alternating current, stripping, and various other techniques. For each instrument series, we provide various models to suit different needs and budgets. Our instruments offer superior performance at competitive prices, and are ideal for both research and teaching purposes.



Apr. 25, 1999 16:03:16
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Model 400A Time-Resolved Electrochemical Quartz Crystal Microbalance

The quartz crystal microbalance (QCM) is a variant of acoustic wave microsensors that are capable of ultrasensitive mass measurements. Under favorable conditions, a typical QCM can measure a mass change of 0.1-1 ng/cm^2. QCM oscillates in a mechanically resonant shear mode under the influence of a high frequency AC electric field which is applied across the thickness of the crystal. Figure 1b shows an edge view of a QCM crystal that is undergoing the shear distortion from the oscillation. The central portions of the top and bottom sides of the crystal are coated with a typically disk-shaped thin film of gold or other metals. The mass sensitivity of the QCM originates from the relationship between the oscillation frequency on the total mass of the crystal and the adlayers of materials residing at the metal-coated crystals, given by the Sauerbrey equation below:

$$\Delta f = -2f_0^2\ \Delta m / [A\ \mathrm{sqrt}(\mu\rho)]$$

where f_0 is the resonant frequency of the fundamental mode of the crystal, A is the area of the gold disk coated onto the crystal, ρ is the density of the crystal (= 2.684 g/cm^3), and μ is the shear modulus of quartz (= 2.947×10^{11} $g/cm\cdot s^2$). Using a crystal with a 7.995-MHz fundamental frequency (as used in our measurements) as an example, a net change of 1 Hz corresponds to 1.34 ng of materials adsorbed or desorbed onto the crystal surface of an area of 0.196 cm^2.

QCM and the combination of QCM with electrochemistry (EQCM) have been widely employed for the determination of metals deposited onto the crystal, studies of ion-transport processes in polymer films, biosensor development, and investigations of the kinetics of adsorption/desorption of adsorbate molecules. In EQCM experiments, the measurements of the various electrochemical parameters, such as potential, current and charge at the working electrode, and the acquisition of the corresponding frequency change, can be conducted simultaneously with the experimental setup shown in Figure 1a. For any model in the CHI400A series, the application of a specific potential waveform (e.g., triangular potential waveform for cyclic voltammetric experiments), as well as subsequent current measurements and the frequency counting, was carried out with a potentiostat/frequency counter, in turn controlled by a computer.

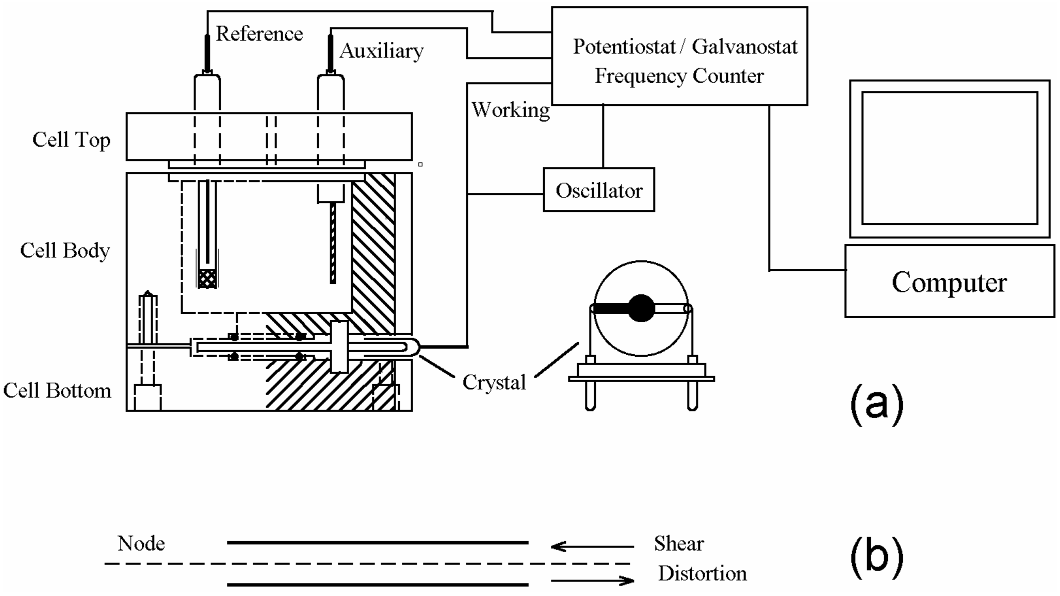


Figure 1. Schematic representation of a typical EQCM instrument. (a) The quartz crystal has a fundamental frequency of 7.995 MHz and is coated with thin gold films on both sides. The gold disk deposited on the top side of the crystal is in contact with the electrolyte solution and used as the working electrode. The top view of the gold-coated crystal is also shown. (b) Edge view of QCM crystal showing shear deformation. The disk thickness and shear deformation have been exaggerated for clarity.

The CHI400A series contains a quartz crystal oscillator, frequency counter, fast digital function generator, high-resolution and high-speed data acquisition circuitry, potentiostat, and a galvanostat (Model 440A only). The

QCM is integrated with potentiostat and galvanostat, making the EQCM study simple and convenient. Instead of measuring the frequency directly, the CHI400A series uses time-resolved mode. The frequency signal of the QCM is subtracted from a standard reference frequency. The difference is then measured by a reciprocal technique, which greatly reduces the time needed to sample the QCM signal and gives much better time resolution of the QCM signal. With the direct counting method, a 1 Hz QCM resolution requires 1 second of sampling time, and a 0.1 Hz resolution requires 10 seconds of sampling time. The time-resolved mode allows the QCM signal to be measured in milliseconds with much better resolution.

The potential control range of the instrument is ±10 V and the current range is ±250 mA. Besides QCM and EQCM measurements, the instrument can also be used for general-purpose electrochemical applications, which are integrated. The instrument is very sensitive and very fast, capable of measuring current down to the picoampere level. The scan rate in cyclic voltammetry can be up to 100 V/s with a 0.1 mV potential increment or 2000 V/s with a 2 mV potential increment.

Figure 2 shows the voltammogram of underpotential and bulk depositions of Pb from a 0.1 M $HClO_4$ solution containing 1 mM Pb^{2+}, and the corresponding frequency changes have been plotted as a function of the applied potential. In Figure 2a, the cathodic peaks at –0.28 V and at ca. –0.59 V have been assigned to the underpotential deposition of monolayer Pb and the bulk deposition of multlayers of Pb, respectively, whereas the anodic peaks at –0.41 V and at –0.28 V are attributable to the stripping of the deposited Pb. The frequency-potential diagram (Figure 2b) displays the frequency decrease due to the deposition of monolayer Pb (about 25 Hz or 33.5 ng between –0.28 V and –0.59 V) and the more drastic frequency decrease arising from bulk Pb deposition (a net change of 425 Hz or 573.8 ng at ca. –0.5 V).

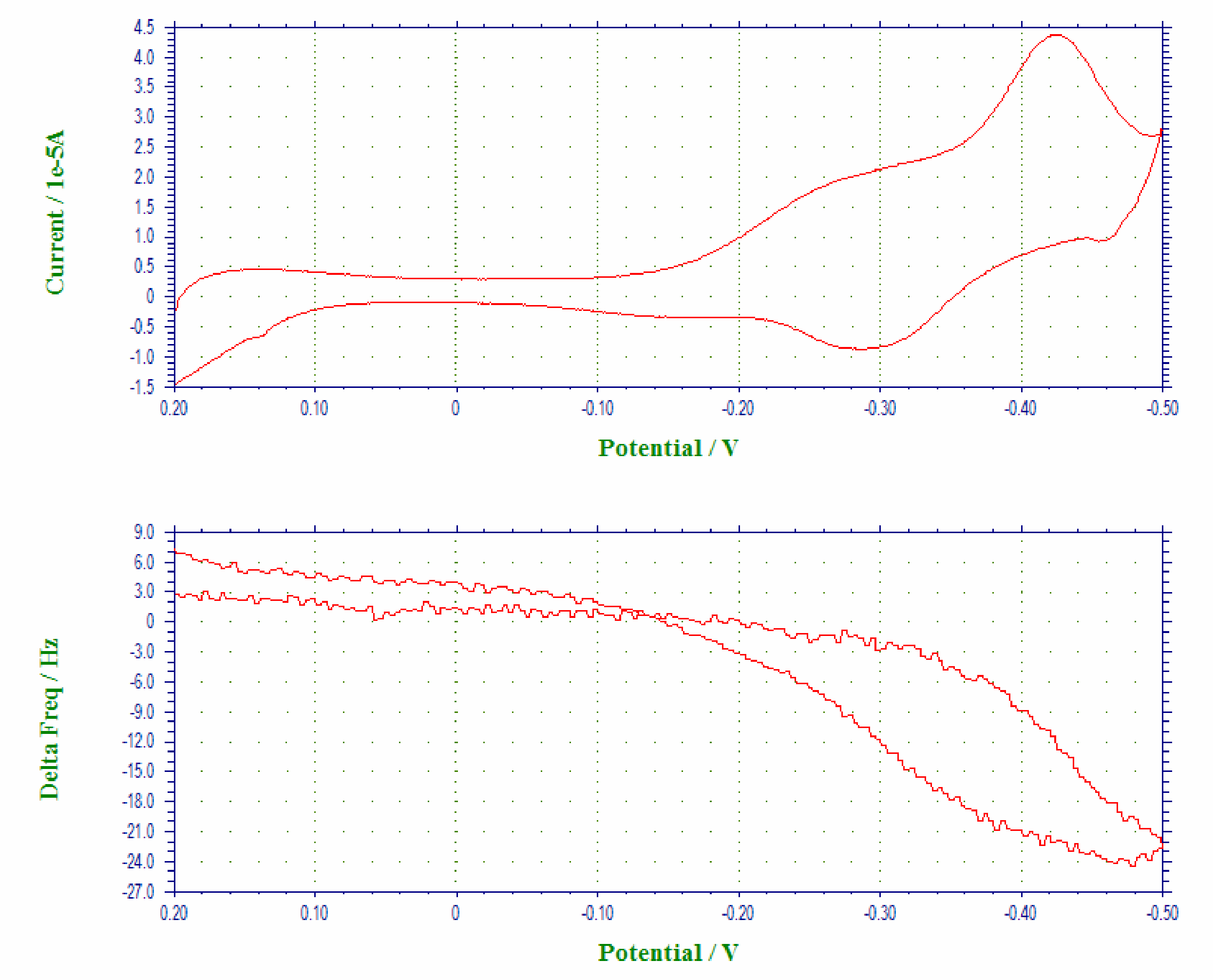


Figure 2. Voltammogram and QCM data of Pb underpotential deposition. Scan rate = 0.05 V/s.

Figure 3 depicts the voltammogram of the oxidation of pyrrole to form polypyrrole film at the gold-coated crystal and the corresponding frequency change. Five scan segments between the lower limit of –1.0 V and the upper limit of 1.0 V were conducted in this experiment. As clearly shown in Figure 3a, pyrrole monomer can be oxidized to its radical at ca. 0.65 V. When this occurred, a thin polypyrrole film was formed, resulting in a decrease of the fundamental frequency of the quartz crystal (Figure 3b). During the first potential cycle, the net frequency change was found to be 1150 Hz. The frequency ceased to change, as the potential became insufficiently positive for the synthesis of polypyrrole film. The subsequent potential cycles displayed in Figure 3 demonstrate the continuous growth of polypyrrole film and the further frequency decrease or mass increase at the crystal. A fast scan rate (0.1 V/s) was employed.

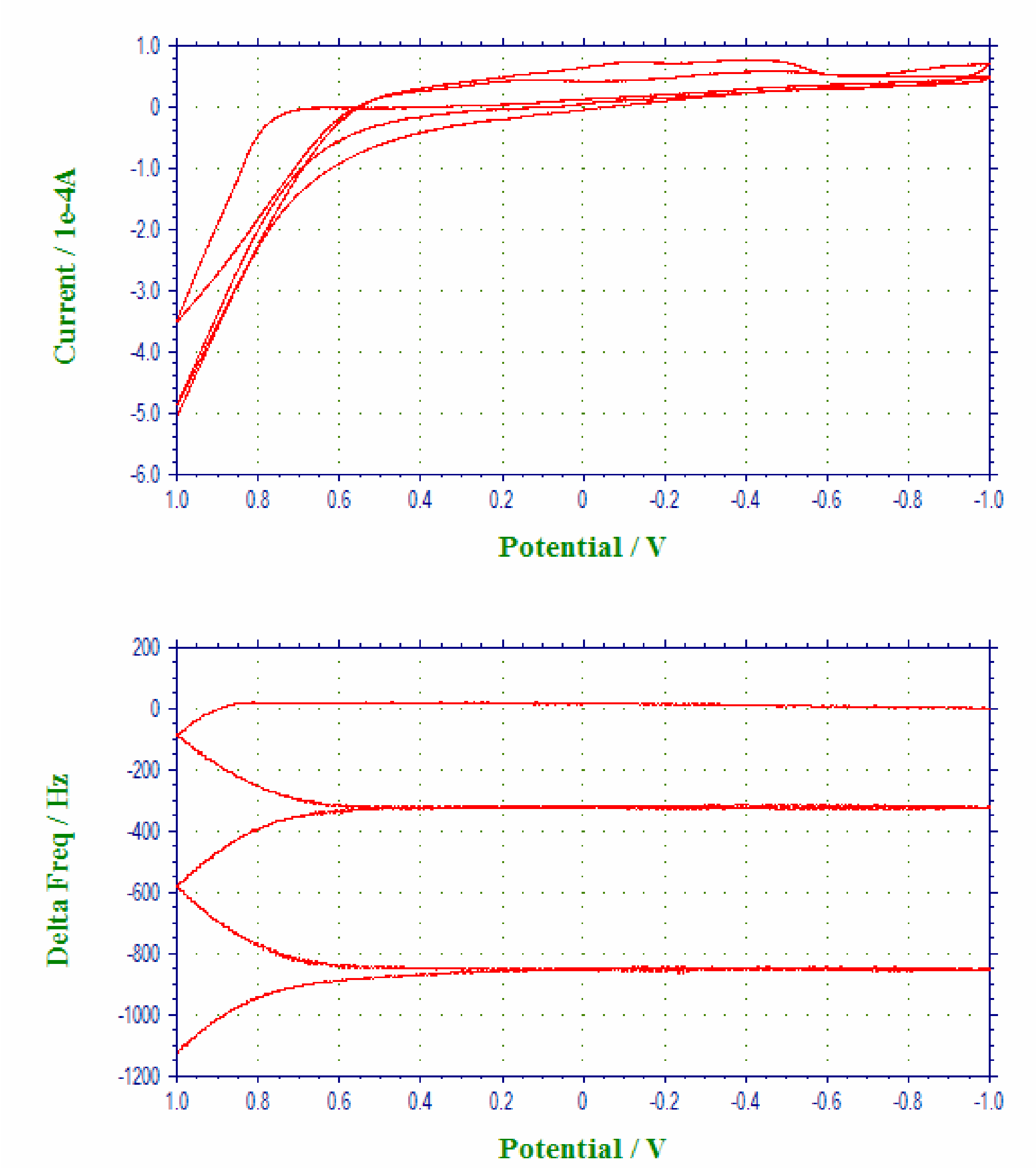


Figure 3. Voltammogram and QCM data of oxidation of pyrrole to form polypyrrole film. Scan rate 0.1 V/s.

The instrument can also be used for regular QCM. Figure 4 shows the QCM data of flow cell detection. The total frequency change is less than 8 Hz. The long term drift and noise levels are extremely low.

The model 400A series is our upgrade to the model 400 series. The redesigned instrument contains a new processor (about 50 times faster than the 400) and FLASH memory (allowing instrument updates to be distributed by e-mail instead of the shipment of an EPROM chip).

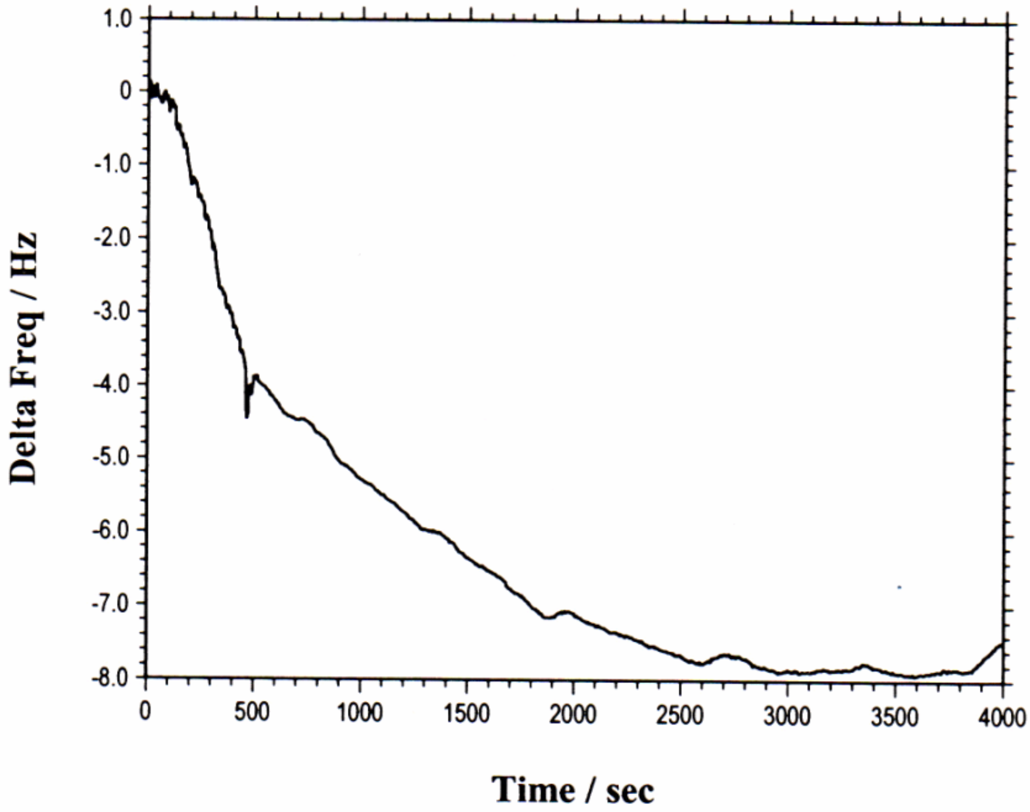


Figure 4. A typical flow injection-QCM experiment. As soon as the sample is injected, the QCM starts recording the frequency change (t = 0). The pump is stopped at 460 s (where a small glitch on the curve can be seen). The reaction is completed about 40 min after sample injection. The total monitoring time is over 1 hr. A net change of 8 Hz is monitored. After 40 min or so, the frequency becomes very stable again (for at least more than 20 min, the frequency drift is much less than 1 Hz).

The 400A series has a serial port (default) and a USB for data communication with the PC. You can select either serial port or USB (but not both) by changing the jumper setting on the board.

A 16-bit highly stable bias circuitry is added for current or potential bias. This allows wider dynamic range is ac measurements. It can also be used to re-zero the dc current output.

The EQCM cell consists of three round Teflon pieces (Figure 1a). The total height is 37 mm with a diameter of 35 mm. The top piece is the cell top to hold reference and counter electrodes. There are also two 2 mm holes for manual purging. The center piece is the solution cell, and the bottom piece is for mounting purposes. Four screws are used to tighten the O-ring seal between the bottom center piece. The quartz crystal is located between the center and bottom pieces. The diameter of the quartz crystal is 13.7 mm. The gold electrode diameter is 5.1 mm.

Specifications

Potentiostat
Galvanostat (Model 440A)
Potential range: -10 to 10V
Potentiostat rise time: < 2 us
Compliance voltage: ±12 V
3- or 4-electrode configuration
Current range: 250 mA
Reference electrode input impedance: 1×10^{12} ohm
Sensitivity scale: 1×10^{-12} - 0.1 A/V in 34 ranges
Input bias current: < 50 pA
Current measurement resolution: < 0.01 pA
Minimum potential increment in CV: 100 µV
Data acquisition: 16 bit @ 200 kHz
Frequency resolution: < 0.1 Hz
QCM maximum sampling rate: 1 kHz
Automatic and manual iR compensation
CV and LSV scan rate: 0.000001 to 2000 V/s
Potential increment during scan: 0.1 mV @ 100 V/s
CA and CC pulse width: 0.0001 to 1000 sec
CA and CC Steps: 320
DPV and NPV pulse width: 0.0001 to 10 sec
SWV frequency: 1 to 100 kHz
ACV frequency: 1 to 10 kHz
SHACV frequency: 1 to 5 kHz
Automatic potential and current zeroing
Low-pass signal filters, automatic and manual setting
RDE rotation control output: 0 - 10 V (430 and up)
Cell control: purge, stir, knock
Data length: 128K – 4096K selectable
Dimension: 12.5"(W) × 11"(D) × 4.75"(H)
Oscillator Box (external):
    4.75"(L) × 2.6" (W) × 1.55" (H)
Weight: 15 Lb.

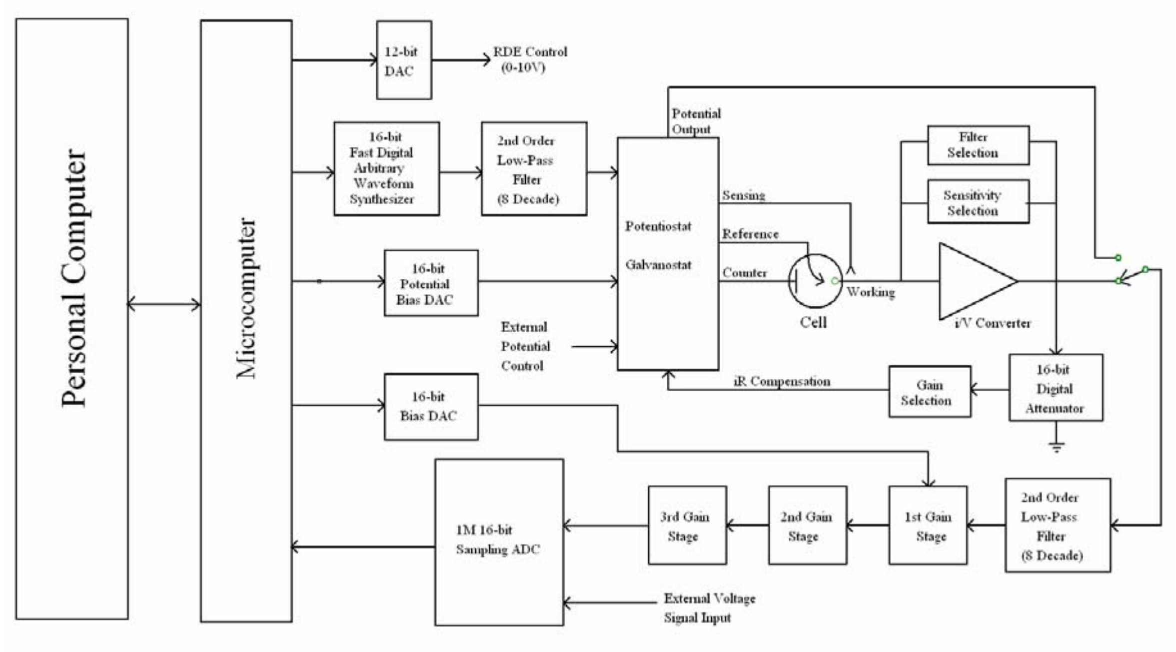
Differences of 400A Series Models

Functions	*400A*	*410A*	*420A*	*430A*	*440A*
Cyclic Voltammetry (CV)	●	●	●	●	●
Linear Sweep Voltammetry (LSV) [&]	●	●	●	●	●
Staircase Voltammetry (SCV) [#,&]				●	●
Tafel Plot (TAFEL)				●	●
Chronoamperometry (CA)	●		●	●	●
Chronocoulometry (CC)	●		●	●	●
Differential Pulse Voltammetry (DPV) [#,&]		●	●	●	●
Normal Pulse Voltammetry (NPV) [#,&]		●	●	●	●
Differential Normal Pulse Voltammetry (DPNV)[#,&]					●
Square Wave Voltammetry (SWV) [&]			●	●	●
AC Voltammetry (ACV) [#,&,$]				●	●
2nd Harmonic AC Voltammetry (SHACV) [#,&,$]				●	●
Amperometric I-t Curve (I-t)				●	●
Differential Pulse Amperometry (DPA)					●
Double Differential Pulse Amperometry (DDPA)					●
Triple Pulse Amperometry (TPA)					●
Bulk Electrolysis with Coulometry (BE)	●		●	●	●
Hydrodynamic Modulation Voltammetry (HMV)					●
Sweep-Step Functions (SSF)					●
Multi-Potential Steps (STEP)					●
Chronopotentiometry (CP)					●
Chronopotentiometry with Current Ramp (CPCR)					●
Potentiometric Stripping Analysis (PSA)					●
Open Circuit Potential - Time (OCPT)	●	●	●	●	●
Quartz Crystal Microbalance (QCM)	●	●	●	●	●
Galvanostat					●
RDE control (0-10V output)				●	●
Full version of CV simulator				●	●
Limited version of CV simulator	●	●	●		
iR Compensation	●	●	●	●	●

#: Corresponding polarographic mode can be performed.
&: Corresponding stripping mode can be performed.
$: Phase selective data are available.

Model 600D Series
Electrochemical Analyzer / Workstation

The Model 600D series is designed for general purpose electrochemical measurements. The figure below shows the block diagram of the instrument. The system contains a fast digital function generator, high speed data acquisition circuitry, potentiostat, and a galvanostat (available only in select models). The potential control range is ±10 V and the current range is ±250 mA. The instrument is capable of measuring current down to tens of picoamperes. The steady state current of a 10 μm disk electrode can be readily measured without external adapters. With the CHI200B Picoamp Booster and Faraday Cage (fully automatic and compatible with the CHI600D series), currents down to 1 pA can be measured. These instruments are very fast. The function generator can update at a 10 MHz rate, and the maximum sampling rate is 1 MHz at 16-bit resolution. The instrument provides very wide dynamic range on experimental time scales. For instance, the scan rate in cyclic voltammetry can be up to 1000 V/s with a 0.1 mV potential increment or 5000 V/s with a 1 mV potential increment. The potentiostat/galvanostat uses a 4-electrode configuration, allowing it to be used for liquid/liquid interface measurements and eliminating the effect of contacting resistance of connectors and relays for high current measurements. Multiple data acquisition systems allow an external input signal (such as spectroscopy signals to be recorded simultaneously with electrochemical data). The instrument will also automatically re-zero both potential and current, so that periodic re-calibration of the instrument can be avoided.



The 600D series is the upgrade to our very popular 600/600A/600B/600C series. The instrument utilizes FLASH memory, allowing instrument updates to be distributed by e-mail instead of the shipment of an EPROM chip.

The 600D series has a serial port (default) and a USB for data communication with the PC. You can select either serial port or USB (but not both) by changing the jumper setting on the board.

The 600D series also includes a true integrator for chronocoulometry.

A 16-bit highly stable bias circuitry is used for current or potential bias. This allows wider dynamic range in ac measurements. It can also be used for re-zero the dc current output.

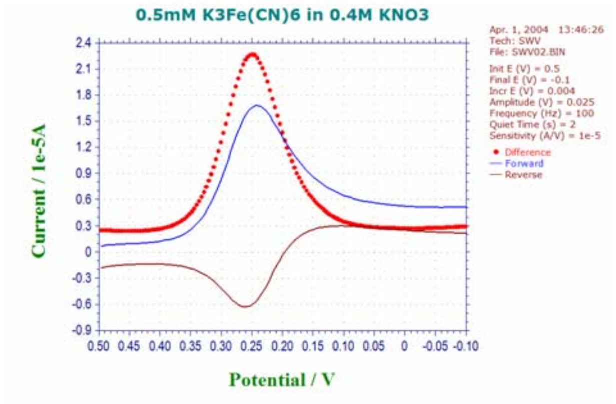
The model 600D series can be upgraded to a bipotentiostat. The model 700D series will be an add-on board to the 600D series. It will therefore be identical to the 600D series when used for single channel measurements. When it is used as a bipotentiostat, the second channel can be controlled at an independent constant potential to scan or step at the same potential as the first channel, or to scan with a constant potential difference with the first channel. The second channel is available for many voltammetric and amperometric techniques.

The instrument also provides various electrochemical techniques, Windows-based software, and integrated digital CV simulator, impedance simulation and fitting program. These features provide powerful tools for both electrochemical mechanistic studies and trace analysis.

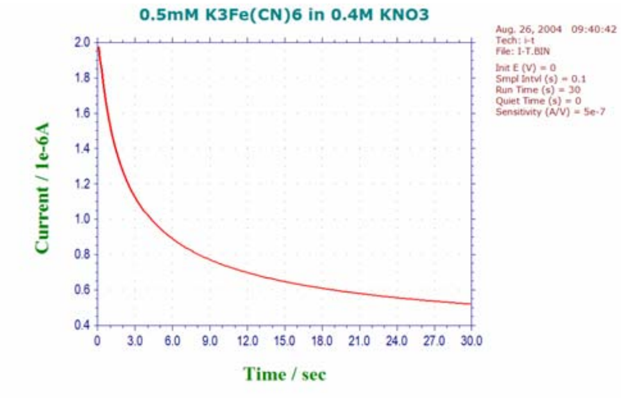
We provide several different models in the 600D series. The following table compares the different models. Other than what is listed, the specifications and features of these models are identical. Models 600D and 610D are basic units for mechanistic study and electrochemical analysis, respectively. They are also great for teaching purposes. Models 602D and 604D are for corrosion studies. Models 620D and 630D are comprehensive electrochemical analyzers. Models 650D and 660D are advanced electrochemical workstations.

Specifications

Potentiostat
Galvanostat (Model 660D)
Potential range: -10 to 10 V
Potentiostat rise time: < 1 us
Compliance voltage: ±12 V
3- or 4-electrode configuration
Current range: 250 mA
Reference electrode input impedance: 1×10^{12} ohm
Sensitivity scale: 1×10^{-12} - 0.1 A/V in 12 ranges
Input bias current: < 50 pA
Current measurement resolution: < 0.01 pA
Minimum potential increment in CV: 100 µV
Potential update rate: 10 MHz
Fast data acquisition: 16 bit @ 1 MHz
External signal recording channel
Automatic and manual iR compensation
Flash memory for quick software update
Serial port or USB selectable for data communication
CV and LSV scan rate: 0.000001 to 5000 V/s
Potential increment during scan: 0.1 mV @ 1000 V/s
CA and CC pulse width: 0.0001 to 1000 sec
CA and CC Steps: 320
True integrator for CC
DPV and NPV pulse width: 0.001 to 10 sec
SWV frequency: 1 to 100 kHz
ACV frequency: 0.1 to 10 kHz
SHACV frequency: 0.1 to 5 kHz
IMP frequency: 0.00001 to 100 kHz
Automatic potential and current zeroing
Potential, current low-pass filters, covering 8-decade frequency range, Automatic and manual setting
RDE rotation control voltage output: 0 - 10 V (Model 630D and up)
Cell control: purge, stir, knock
Maximum data length: 128K-8192K selectable
Dimension: 12.5"(W) × 11"(D) × 4.75"(H)
Weight: 15 Lb.



Square wave voltammogram.

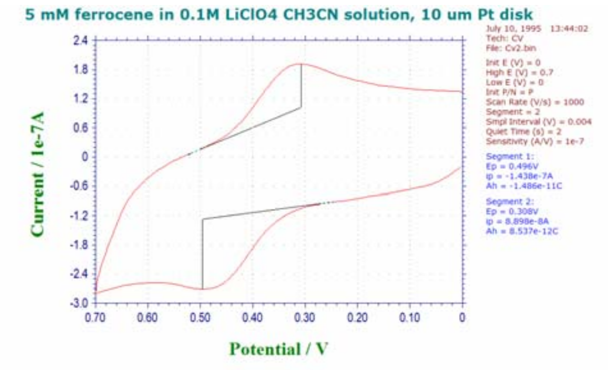


Amperometric i-t Curve.

Differences of 600D Series Models

Functions	***600D***	***602D***	***604D***	***610D***	***620D***	***630D***	***650D***	***660D***
Cyclic Voltammetry (CV)	●	●	●	●	●	●	●	●
Linear Sweep Voltammetry (LSV) [&]	●	●	●	●	●	●	●	●
Staircase Voltammetry (SCV) [#,&]						●	●	●
Tafel Plot (TAFEL)		●	●			●	●	●
Chronoamperometry (CA)	●	●	●		●	●	●	●
Chronocoulometry (CC)	●	●	●		●	●	●	●
Differential Pulse Voltammetry (DPV) [#,&]				●	●	●	●	●
Normal Pulse Voltammetry (NPV) [#,&]				●	●	●	●	●
Differential Normal Pulse Voltammetry (DPNV)[#,&]								●
Square Wave Voltammetry (SWV) [&]					●	●	●	●
AC Voltammetry (ACV) [#,&,$]						●	●	●
2nd Harmonic AC Voltammetry (SHACV) [#,&,$]						●	●	●
Amperometric i-t Curve (i-t)						●	●	●
Differential Pulse Amperometry (DPA)								●
Double Differential Pulse Amperometry (DDPA)								●
Triple Pulse Amperometry (TPA)								●
Integrated Pulse Amperometric Detection (IPAD)								●
Bulk Electrolysis with Coulometry (BE)	●	●	●		●	●	●	●
Hydrodynamic Modulation Voltammetry (HMV)							●	●
Sweep-Step Functions (SSF)							●	●
Multi-Potential Steps (STEP)							●	●
AC Impedance (IMP)			●				●	●
Impedance - Time (IMPT)			●				●	●
Impedance - Potential (IMPE)			●				●	●
Chronopotentiometry (CP)								●
Chronopotentiometry with Current Ramp (CPCR)								●
Multi-Current Steps (ISTEP)								●
Potentiometric Stripping Analysis (PSA)								●
Electrochemical Noise Measurement (ECN)								●
Open Circuit Potential - Time (OCPT)	●	●	●	●	●	●	●	●
Galvanostat								●
RDE control (0-10V output)						●	●	●
Full version of CV simulator						●	●	●
Limited version of CV simulator	●	●	●	●	●			
Impedance Simulation and fitting			●				●	●
iR Compensation	●	●	●	●	●	●	●	●
External Potential Input	●	●	●	●	●	●	●	●
Auxiliary Signal Measurement Channel	●	●	●	●	●	●	●	●

#: Corresponding polarographic mode can be performed.
&: Corresponding stripping mode can be performed.
$: Phase selective data are available.



July 10, 1995 13:44:02
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Quiet Time (s) = 2
Sensitivity (A/V) = 1e-7

Segment 1:
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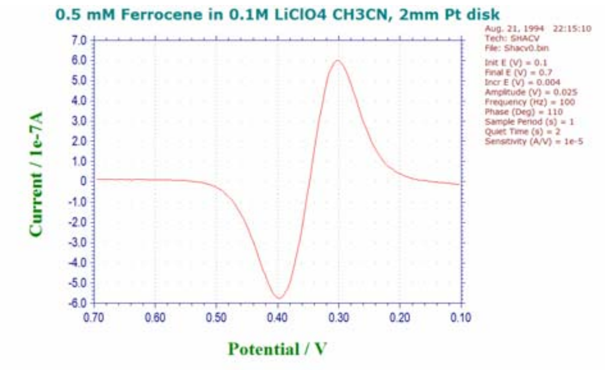
Ah = -1.486e-11C

Segment 2:
Ep = 0.308V
ip = 8.898e-8A
Ah = 8.537e-12C

Cyclic voltammogram at 1000V/s.



Aug. 21, 1994 22:15:10
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Sample Period (s) = 1
Quiet Time (s) = 2
Sensitivity (A/V) = 1e-5

Phase selective second harmonic AC voltammogram.

Model 700D Series Bipotentiostat

The Model 700D series are computerized general purpose potentiostat / bipotentiostat / galvanostat instruments. A typical application involves a rotating ring-disk electrode (RRDE), but these systems can also be used for other applications where dual channel measurements are essential, such as dual channel electrochemical detection. The system contains a fast digital function generator, high speed data acquisition circuitry, (bi)potentiostat, and a galvanostat (only available in select models). The potential control range is ±10 V and the current range is ±250 mA. The instrument is capable of measuring current down to tens of picoamperes. The steady state current of a 10 μm disk electrode can be readily measured without external adapters. With the CHI200B Picoamp Booster and Faraday Cage (fully automatic and compatible with the CHI700D series), currents down to 1 pA can be measured (primary current channel only). These instruments are very fast. The function generator can update at a 10 MHz rate, and the maximum sampling rate is 1 MHz at 16-bit resolution. The instrument provides a very wide dynamic range on experimental time scales. For instance, the scan rate in cyclic voltammetry can be up to 1000 V/s with a 0.1 mV potential increment or 5000 V/s with a 1 mV potential increment. The potentiostat / galvanostat uses a 4-electrode configuration, allowing it to be used for liquid/liquid interface measurements and eliminating the effect of contacting resistance of connectors and relays for high current measurements. Multiple data acquisition systems allow an external input signal (such as spectroscopy signals to be recorded simultaneously with electrochemical data). The instrument will also automatically re-zero both potential and current, so that periodic re-calibration of the instrument can be avoided.

The 700D series shares many common features with the 600D series. When used as a single channel potentiostat, the instrument is identical to the model 600D series. The bipotentiostat is realized by adding the second channel potential control and current measurement board to the model 600D series. There are also two filter stages, three extra gain stages, and a channel selection circuitry on the board. When it is used as a bipotentiostat, the second channel can be controlled at an independent constant potential, to scan or step at the same potential as the first channel. In case of CV, it can also scan with a constant potential difference with the first channel. Techniques available for the second channel include CV, LSV, SCV, CA, DPV, NPV, SWV, and i-t.

The 700D series is the upgrade to our very popular 700/700A/700B/700C series. The instrument utilizes FLASH memory, allowing instrument updates to be distributed by e-mail instead of the shipment of an EPROM chip.

The 700D series has a serial port (default) and a USB for data communication with the PC. You can select either serial port or USB (but not both) by changing the jumper setting on the board.

The 700D series also has a true integrator for chronocoulometry.

A 16-bit highly stable bias circuitry is used for current or potential bias. This allows wider dynamic range is ac measurements. It can also be used for re-zero the dc current output.

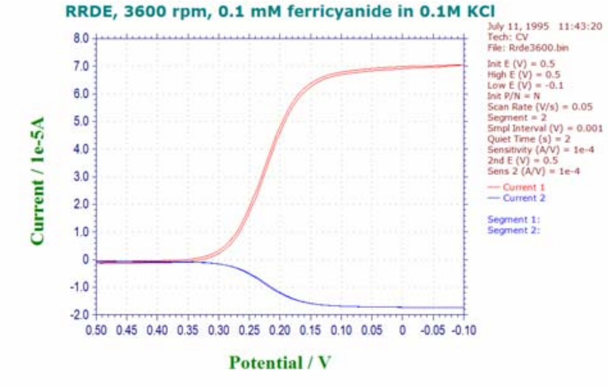
When used as a single channel potentiostat, the instrument is identical to the model 600D series. The bipotentiostat is realized by adding the 2nd channel potential control and current measurement board. When it is used as bipotentiostat, the 2nd channel can be controlled at a independent constant potential, to scan or step at the same potential as the first channel, and to scan with a constant potential difference with the first channel.

The instrument also provides various electrochemical techniques, Windows-based software, and integrated digital CV simulator, impedance simulation and fitting program. These features provide powerful tools for both electrochemical mechanistic studies and trace analysis.

We provide several different models in the 700D series. The following table compares the different models. Other than what is listed, the specifications and features of these models are identical. Models 700D and 710D are basic units for mechanistic study and electrochemical analysis, respectively. Models 720D and 730D are comprehensive electrochemical analyzers. Model 750D and 760D are advanced electrochemical workstations.

Specifications

Potentiostat
Bipotentiostat
Galvanostat
Potentiostat rise time: < 1 µs
Potential range: ±10 V for both channels
Compliance voltage: ±12 V
Current: 0.25 A if single channel, or 0.25 A total for two channels
Input impedance of reference electrode: 10^{12} ohm
Sensitivity scale: 1×10^{-12} - 0.1 A/V in 12 ranges
Input bias current: < 50 pA
Current measurement resolution: < 0.01 pA
Minimum potential increment in CV: 100 µV
Potential update rate: 10 MHz
Fast data acquisition: 16 bit @ 1 MHz
External voltage signal recording channel
External potential input
Automatic and manual iR compensation
CV and LSV scan rate: 0.000001 to 5000 V/s
Potential increment during scan: 0.1 mV @ 1000 V/s
CA and CC pulse width: 0.0001 to 1000 sec
CA and CC Steps: 320
True integrator for CC
DPV and NPV pulse width: 0.001 to 10 sec
SWV frequency: 1 to 100 kHz
ACV frequency: 0.1 to 10 kHz
SHACV frequency: 0.1 to 5 kHz
IMP frequency: 0.00001 to 100 kHz
Automatic potential and current zeroing
Potential, current low-pass filters, covering 8-decade frequency range, Automatic and manual setting
RDE rotation control voltage output: 0 - 10 V
Cell control: purge, stir, knock
Flash memory for quick software update
Serial port or USB selectable for data communication
Maximum data length: 128K-4096K selectable
Dimension: 12.5”(W) × 11”(D) × 4.75”(H)
Weight: 15 Lb.



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Init P/N = N
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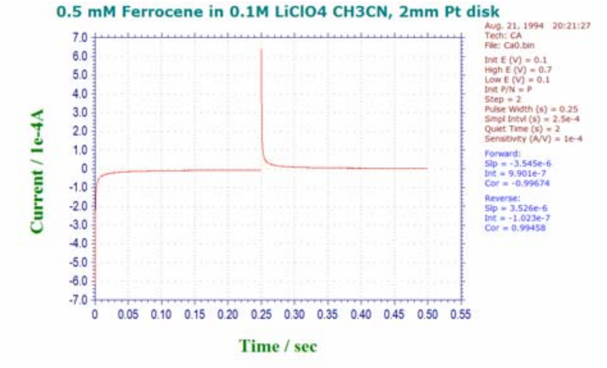
Smpl Interval (V) = 0.001
Quiet Time (s) = 2
Sensitivity (A/V) = 1e-4
2nd E (V) = 0.5
Sens 2 (A/V) = 1e-4
Segment 1:
Segment 2:

Voltammogram at rotating ring-disk electrode.



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Low E (V) = 0.1
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Step = 2
Pulse Width (s) = 0.25
Smpl Intvl (s) = 2.5e-4
Quiet Time (s) = 2
Sensitivity (A/V) = 1e-4
Forward:
Slp = -3.545e-6
Int = 9.901e-7
Cor = -0.99674
Reverse:
Slp = 3.526e-6
Int = -1.023e-7
Cor = 0.99458

Chronoamperometric data.

Differences of 700D Series Models

Functions	***700D***	***710D***	***720D***	***730D***	***750D***	***760D***
Cyclic Voltammetry (CV)*	●	●	●	●	●	●
Linear Sweep Voltammetry (LSV) [&,*]	●	●	●	●	●	●
Staircase Voltammetry (SCV) [#,&,*]				●	●	●
Tafel Plot (TAFEL)				●	●	●
Chronoamperometry (CA)*	●		●	●	●	●
Chronocoulometry (CC)	●		●	●	●	●
Differential Pulse Voltammetry (DPV) [#,&,*]		●	●	●	●	●
Normal Pulse Voltammetry (NPV) [#,&,*]		●	●	●	●	●
Differential Normal Pulse Voltammetry (DPNV)[#,&]						●
Square Wave Voltammetry (SWV) [&,*]			●	●	●	●
AC Voltammetry (ACV) [#,&,$]				●	●	●
2nd Harmonic AC Voltammetry (SHACV) [#,&,$]				●	●	●
Amperometric i-t Curve (i-t)*				●	●	●
Differential Pulse Amperometry (DPA)						●
Double Differential Pulse Amperometry (DDPA)						●
Triple Pulse Amperometry (TPA)						●
Integrated Pulse Amperometric Detection (IPAD)						●
Bulk Electrolysis with Coulometry (BE)	●		●	●	●	●
Hydrodynamic Modulation Voltammetry (HMV)					●	●
Sweep-Step Functions (SSF)					●	●
Multi-Potential Steps (STEP)					●	●
AC Impedance (IMP)					●	●
Impedance - Time (IMPT)					●	●
Impedance - Potential (IMPE)					●	●
Chronopotentiometry (CP)						●
Chronopotentiometry with Current Ramp (CPCR)						●
Multi-Current Steps (ISTEP)						●
Potentiometric Stripping Analysis (PSA)						●
Electrochemical Noise Measurement (ECN)						●
Open Circuit Potential - Time (OCPT)	●	●	●	●	●	●
Galvanostat						●
RDE control (0-10V output)				●	●	●
Full version of CV simulator				●	●	●
Limited version of CV simulator	●	●	●			
Impedance Simulation and Fitting					●	●
iR Compensation	●	●	●	●	●	●
External Potential Input	●	●	●	●	●	●
Auxiliary Signal Measurement Channel	●	●	●	●	●	●

#: Corresponding polarographic mode can be performed.
&: Corresponding stripping mode can be performed.
$: Phase selective data are available.
*: Second channel (bipotentiostat mode) can be performed.

Model 800C Series Electrochemical Detector

The Model 800C series is designed for electrochemical detection. This instrument can be used for monitoring the current passing through a flow cell in liquid chromatography/electrochemistry and in-flow injection analysis, as well as other electroanalytical applications. Each instrument contains a digital function generator, a data acquisition system, and a potentiostat / bipotentiostat / Galvanostat. The potential control range is ±10 V and the current range is ±10 mA. These instruments are capable of measuring currents down to picoamperes. This series is designed for analytical purposes that require high sensitivity and low noise levels. It has a maximum sampling rate of 1M Hz at 16-bit. The circuitry has very low electrical noise. The instrument allows an external input signal (such as spectroscopy signals) to be recorded simultaneously with electrochemical data. When it is used for amperometric detection, three decades of current scales are plotted during the experiment to display signals of various magnitudes clearly. This model has superior ease of use compared with analog instruments, as well as data storage and analysis capabilities, without the need for recorder/baseline adjustments. It also provides a much larger current dynamic range, so that separate runs for large and weak signals can be avoided.

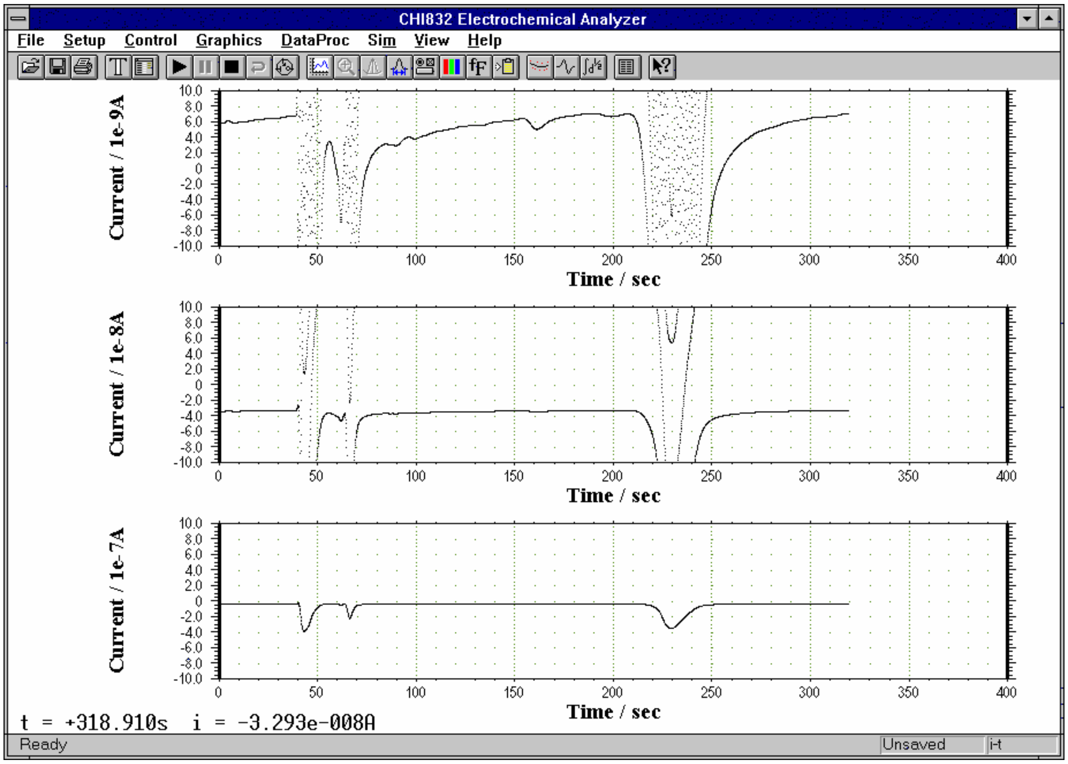
The Model 8×0C is for single channel measurements, and the Model 8×2C contains a bipotentiostat and is for dual channel measurements. As a bipotentiostat, it is well suited to rotating ring-disk electrodes applications. It can also be used for other applications where dual channel measurements are essential. Dual channel measurements are available for CV, LSV, CA, DPV, NPV, SWV, and amperometric i-t curves. The 2nd channel can be controlled at a independent constant potential, to scan or step at the same potential as the first channel, and to CV scan with a constant potential difference with the first channel.

The model 800C series is our upgrade to the model 800/800A/800B series. The instrument utilizes FLASH memory, allowing instrument updates to be distributed by e-mail instead of the shipment of an EPROM chip.

The 800C series has a serial port (default) and a USB for data communication with the PC. You can select either serial port or USB (but not both) by changing the jumper setting on the board.

The 800C series also has a true integrator for chronocoulometry.

We provide several different models in the 800C series. The following table compares the different models. Other than what is listed, the specifications and features of these models are identical. Models 800C/802C and 810C/812C are mainly for flow cell detection. Models 820C/822C cannot be used for flow cell detection, but are intended for voltammetry applications. Models 830C/832C are comprehensive electrochemical analyzers that can be used for electrochemical detection, voltammetry, and other applications. Models 840C/842C and 850C/852C are more advanced models with a galvanostat.



t = +318.910s i = -3.293e-008A

Real time data display for flow cell detection.

Specifications

Potentiostat
Bipotentiostat
Galvanostat (840C/842C/850C/852C)
Potential range: ±10 V
Compliance voltage: ±12 V
Current range: 0 to ±0.01 A
3- or 4-electrode configuration
Input impedance of reference electrode: 10^{12} ohm
Sensitivity scale: 1×10^{-12} - 0.001 A/V in 10 ranges
Input bias current: < 5 pA
Current measurement resolution: < 0.01 pA
Fast data acquisition: 16 bit @ 1M Hz
External voltage signal recording channel
External potential input
Automatic and manual iR compensation
Potential and current analog output
CV and LSV scan rate: 1×10^{-6} to 500 V/s
CC and CA pulse width: 0.0001 to 1000 sec
True integrator for CC
DPV and NPV pulse width: 0.001 to 10 sec
SWV frequency: 1 to 100 kHz
ACV frequency: 0.1 to 10 kHz
SHACV frequency: 0.1 to 5 kHz
Dual channel measurements for CV, LSV, CA, DPV, NPV, SWV, i-t
Cell control: purge, stir, knock
Automatic potential and current zeroing
Current low-pass filters, covering 8-decade frequency range, Automatic and manual setting
RDE control output: 0-10V (corresponding to 0-10000rpm)
Flash memory for quick software update
Serial port or USB port selectable for data communication
Maximum data length: 128K - 8192K selectable
Dimension: 12.5”(W) × 11”(D) × 4.75”(H)
Weight: 15 Lb.

Differences of 800C Series Models

Functions	*800C/802C*	*810C/812C*	*820C/822C*	*830C/832C*	*840C/842C*	*850C/852C*
Cyclic Voltammetry (CV)*	●	●	●	●	●	●
Linear Sweep Voltammetry (LSV) [&,*]	●	●	●	●	●	●
Staircase Voltammetry (SCV) [#,&,*]						●
Tafel Plot (TAFEL)						●
Chronoamperometry (CA)*				●	●	●
Chronocoulometry (CC)				●	●	●
Differential Pulse Voltammetry (DPV) [#,&,*]			●	●	●	●
Normal Pulse Voltammetry (NPV) [#,&,*]			●	●	●	●
Differential Normal Pulse Voltammetry (DPNV)[#,&]						●
Square Wave Voltammetry (SWV) [&,*]			●	●	●	●
AC Voltammetry (ACV) [#,&,$]						●
2nd Harmonic AC Voltammetry (SHACV) [#,&,$]						●
Amperometric i-t Curve (i-t)*	●	●		●	●	●
Differential Pulse Amperometry (DPA)		●		●	●	●
Double Differential Pulse Amperometry (DDPA)		●		●	●	●
Triple Pulse Amperometry (TPA)		●		●	●	●
Integrated Pulse Amperometric Detection (IPAD)						●
Bulk Electrolysis with Coulometry (BE)			●	●	●	●
Hydrodynamic Modulation Voltammetry (HMV)						●
Sweep-Step Functions (SSF)					●	●
Multi-Potential Steps (STEP)					●	●
Chronopotentiometry (CP)					●	●
Chronopotentiometry with Current Ramp (CPCR)					●	●
Multi-Current Steps (ISTEP)					●	●
Potentiometric Stripping Analysis (PSA)				●	●	●
Electrochemical Noise Measurement (ECN)						●
Open Circuit Potential - Time	●	●	●	●	●	●
Galvanostat					●	●
RDE control (0-10V output)					●	●
Full version of CV simulator				●	●	●
Limited version of CV simulator	●	●	●			
iR Compensation	●	●	●	●	●	●
External Potential Input	●	●	●	●	●	●
Auxiliary Signal Measurement Channel	●	●	●	●	●	●

#: Corresponding polarographic mode can be performed.
&: Corresponding stripping mode can be performed.
*: Second channel (bipotentiostat mode) can be performed.

Model 920C
Scanning Electrochemical Microscope

The scanning electrochemical microscope (SECM) was introduced in 1989[1] as an instrument that could examine chemistry at high resolution near interfaces. By detecting reactions that occur at a small electrode (the tip) as it is scanned in close proximity to a surface, the SECM can be employed to obtain chemical reactivity images of surfaces and quantitative measurements of reaction rates. Numerous studies with the SECM have now been reported from a number of laboratories all over the world, and the instrument has been used for a wide range of applications, including studies of corrosion, biological systems (e.g., enzymes, skin, leaves), membranes, and liquid/liquid interfaces.[2] Trapping and electrochemical detection of single molecules with the SECM has also been reported.

The CHI920C Scanning Electrochemical Microscope consists of a digital function generator, a bipotentiostat, high resolution data acquisition circuitry, a three dimensional nanopositioner, and a sample and cell holder. Diagrams for the SECM and cell/sample holder are shown below. The three dimensional nanopositioner has a spatial resolution down to nanometers but it allows a maximum traveling distance of 50 millimeters. The potential control range of the bipotentiostat is ± 10 V and the current range is ± 250 mA. The instrument is capable of measuring current down to sub-picoamperes.

In addition to SECM imaging, three other modes of operation are available for scanning probe applications: Surface Patterned Conditioning, Probe Scan Curve, and Probe Approach Curve. Surface Patterned Conditioning allows user to edit a pattern for surface conditioning by controlling the tip at two different potentials and durations. The Probe Scan Curve mode allows the probe to move in the X, Y, or Z direction while the probe and substrate potentials are controlled and currents are measured. The probe can be stopped when the current reaches a specified level. This is particularly useful in searching for an object on the surface and determining approach curves. The Probe Approach Curve mode allows the probe to approach the surface of the substrate. It is also very useful in distinguishing the surface process, using PID control. The step size is automatically adjusted to allow fast surface approach, without letting the probe touching the surface.

The CHI920C is designed for scanning electrochemical microscopy, but many conventional electrochemical techniques are also integrated for convenience, such as CV, LSV, CA, CC, DPV, NPV, SWV, ACV, SHACV, i-t, DPA, DDPA, TPA, SSF, STEP, IMP, IMPE, IMPT, and CP. When it is used as a bipotentiostat, the second channel can be controlled at an independent constant potential, to scan or step at the same potential as the first channel, or to scan with a constant potential difference with the first channel. The second channel works with CV, LSV, CA, DPV, NPV, DNPV, SWV, and i-t.

The CHI920C SECM is an upgrade from the CHI900B/CHI910B SECM. The stepper motor positioner now has a resolution of 4 nanometers with 50 mm travel distance. CHI920C will be the stepper motor positioner with a combination of closed loop 3-dimensional piezo positioner. The closed-loop piezo control allows improved linearity and reduced hysteresis of the piezo devices.

The other improvements for the CHI920C over the CHI900B/910B include faster data acquisition (1M Hz 16-bit), higher current (250mA), faster CV (1000V/s at 0.1 mV potential increment), and ac impedance measurements.

1. A. J. Bard, F.-R. F. Fan, J. Kwak, and O. Lev, *Anal. Chem*. **61**, 132 (1989); U.S. Patent No. 5,202,004 (April 13, 1993).
2. A. J. Bard, F.-R. Fan, M. V. Mirkin, in *Electroanalytical Chemistry,* A. J . Bard, Ed., Marcel Dekker, New York, 1994, Vol. 18, pp 243-373.

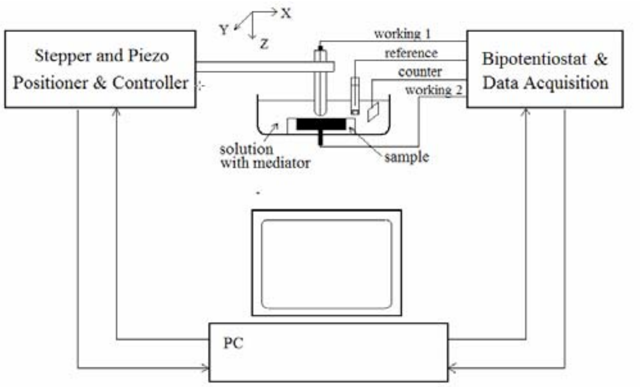
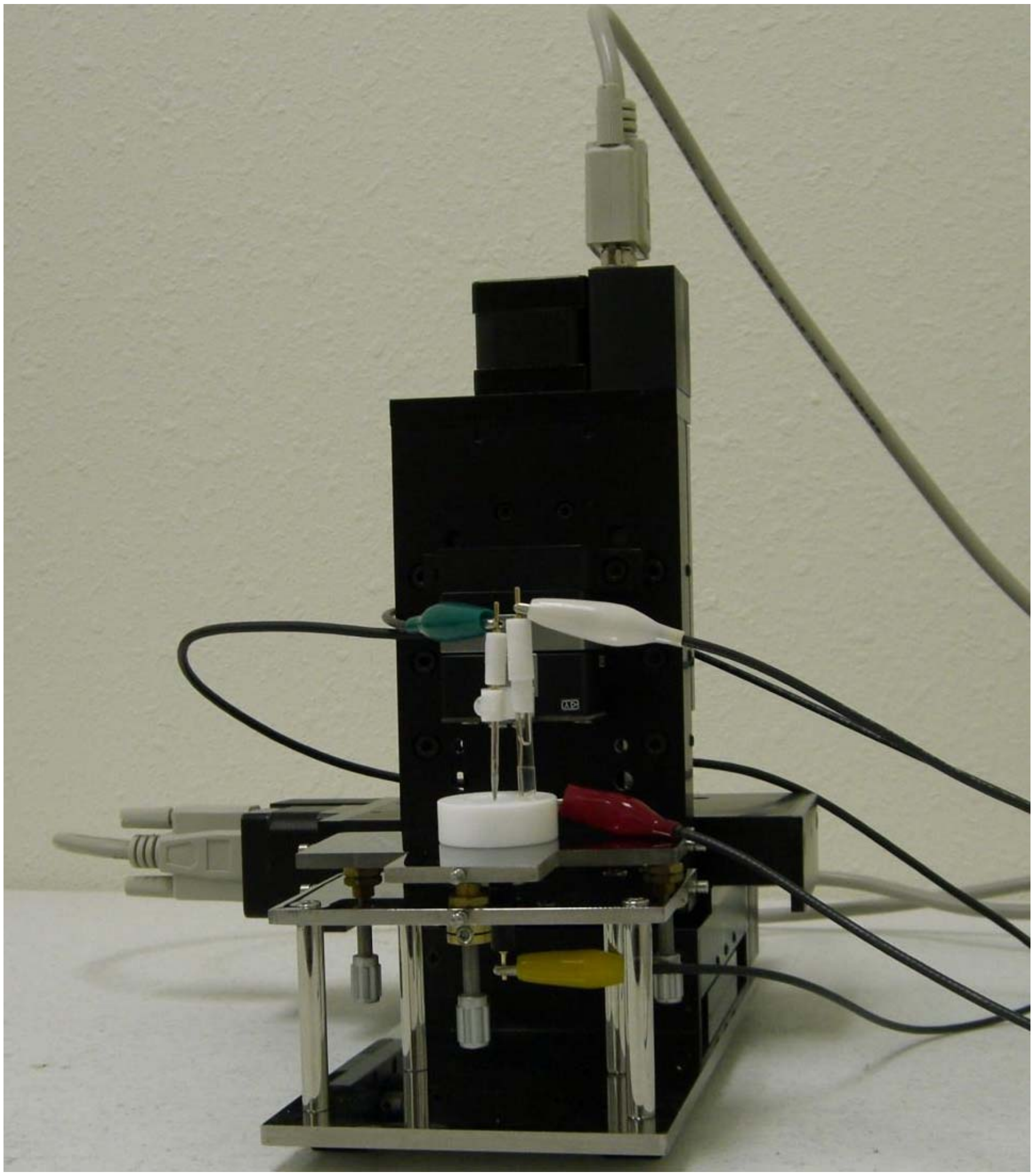
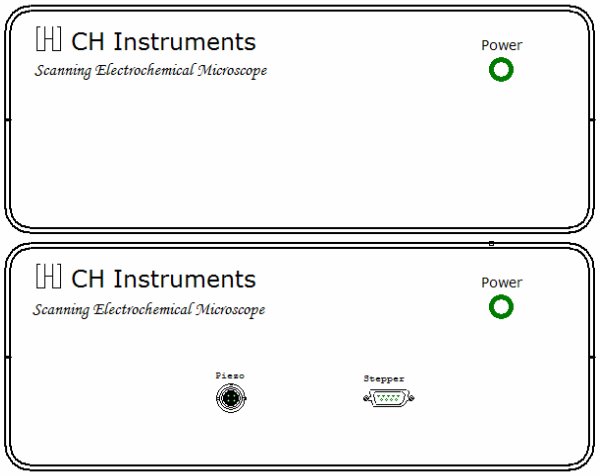


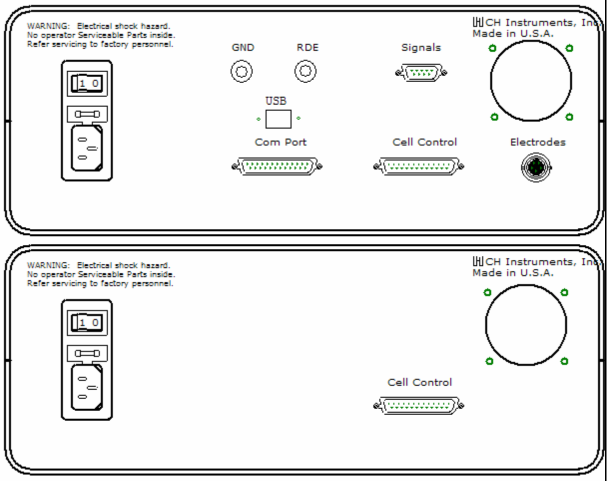
Diagram of Scanning Electrochemical Microscope



Cell/Sample Holder



Bipotentiostat (top) and Motor Controller Front View



Bipotentiostat (top) and Motor Controller Rear View

CHI920C SECM Specifications

Nanopositioner:

X, Y, Z resolution: 1.6 nm with Piezo positioner, closed loop control
4 nm with stepper motor positioner
X, Y, Z total distance: 5 cm

Bipotentiostat:

Probe Potential: ± 10 V
Substrate Potential: ± 10 V
Compliance Voltage: ± 12 V
3- or 4-electrode configuration
Reference electrode input impedance: 1e12 ohm
Current Sensitivity: 10^{-12} A/V to 10^{-1} A/V
Maximum Current: ± 250 mA
External signal recording channel
ADC Resolution: 16-bit @ 1 M Hz

Galvanostat:

Current range: ± 250 mA

Experimental Parameters:

CV and LSV scan rate: 0.000001 to 10,000 V/s
Potential increment during scan: 0.1 mV @1000 V/s
CC and CA pulse width: 0.0001 to 1000 sec
True integrator for CC
DPV and NPV pulse width: 0.001 to 10 sec
SWV frequency: 1 to 100 kHz
ACV frequency: 0.1 to 10 kHz
SHACV frequency: 0.1 to 5 kHz
IMP frequency: 0.00001 to 100 kHz
Automatic potential and current zeroing
Automatic and manual iR compensation
Current low-pass filters, covering 8-decade frequency range, Automatic and manual setting
RDE control output: 0-10 V (corresponding to 0-10000 rpm)
Flash memory for quick software update
Serial port or USB port selectable for data communication

Other Features:

Real Time Absolute and Relative Distance Display
Real Time Probe and Substrate Current Display
Dual channel measurements for CV, LSV, CA, DPV, NPV, SWV, i-t
Cell control: purge, stir, knock
Automatic potential and current zeroing
Current low-pass filters, covering 8-decade frequency range, Automatic and manual setting
RDE control output: 0-10 V (corresponding to 0-10000 rpm)
Flash memory for quick software update
Serial port or USB port selectable for data communication
Digital CV simulator, user defined mechanisms
Impedance simulator and fitting program

Techniques

Scanning Probe Techniques

- SECM Imaging (SECM) : constant height, constant current, potentiometric modes
- Probe Approach Curves (PAC)
- Probe Scan Curve (PSC) : amperometric, potentiometric and constant current modes
- Surface Patterned Conditioning (SPC)

Sweep Techniques

- Cyclic Voltammetry (CV)
- Linear Sweep Voltammetry (LSV)
- Tafel Plot (TAFEL)

Step and Pulse Techniques

- Staircase Voltammetry (SCV)
- Chronoamperometry (CA)
- Chronocoulometry (CC)
- Differential Pulse Voltammetry (DPV)
- Normal Pulse Voltammetry (NPV)
- Differential Normal Pulse Voltammetry (DNPV)
- Square Wave Voltammetry (SWV)

AC Techniques

- AC Voltammetry (ACV)
- Second Harmonic AC Voltammetry (SHACV)
- AC Impedance (IMP)
- Impedance versus Potential (IMPE)
- Impedance versus Time (IMPT)

Galvanostatic Techniques

- Chronopotentiometry (CP)
- Chronopotentiometry with Current Ramp (CPCR)
- Multi-Current Steps (ISTEP)
- Potentiometric Stripping Analysis (PSA)

Other Techniques

- Amperometric i-t Curve (i-t)
- Differential Pulse Amperometry (DPA)
- Double Differential Pulse Amperometry (DDPA)
- Triple Pulse Amperometry (TPA)
- Integrated Pulse Amperometric Detection (IPAD)
- Bulk Electrolysis with Coulometry (BE)
- Hydrodynamic Modulation Voltammetry (HMV)
- Sweep-Step Functions (SSF)
- Multi-Potential Steps (STEP)
- Electrochemical Noise Measurements (ECN)
- Open Circuit Potential - Time (OCPT)
- Various Stripping Voltammetry
- Potentiometry

Applications

- Electrode surface studies
- Corrosion
- Biological samples
- Solid dissolution
- Liquid/liquid interfaces
- Membranes

Principles and Applications of SECM

I. Operational Principles of SECM

As in other types of scanning probe microscopes, SECM is based on the movement of a very small electrode (the tip) near the surface of a conductive or insulating substrate.[1] In amperometric SECM experiments, the tip is usually a conventional ultramicroelectrode (UME) fabricated as a conductive disk of metal or carbon in an insulating sheath of glass or polymer. Potentiometric SECM experiments with ion-selective tips are also possible.[2]

In amperometric experiments, the tip current is perturbed by the presence of the substrate. When the tip is far (i.e. greater than several tip diameters) from the substrate, as shown in Fig. 1A, the steady-state current, $i_{T,\infty}$, is given by

$$i_{T,\infty} = 4nFDCa$$

where F is Faraday's constant, n is the number of electrons transferred in the tip reaction ($O + ne \rightarrow R$), D is the diffusion coefficient of species O, C is the concentration, and a is the tip radius. When the tip is moved toward the surface of an insulating substrate, the tip current, i_T, decreases because the insulating sheath of the tip blocks diffusion of O to the tip from the bulk solution. The closer the tip gets to the substrate, the smaller i_T becomes (Fig 1B). On the other hand, with a conductive substrate, species R can be oxidized back to O. This produces an additional flux of O to the tip and hence an increase in i_T (Fig. 1C). In this case, the smaller the value of d, the larger i_T will be, with $i_T \rightarrow \infty$ as $d \rightarrow 0$, assuming the oxidation of R on the substrate is diffusion-limited. These simple principles form the basis for the feedback mode of SECM operation.

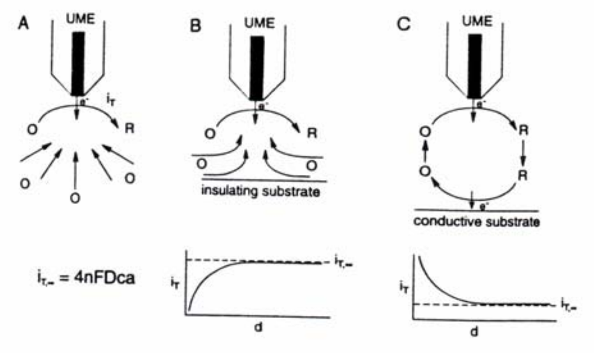


Figure 1. Operating principles of SECM. (A). With UME far from the substrate, diffusion of O leads to a steady-state current, $i_{T,\infty}$; (B). With the UME placed near an insulating substrate, hindered diffusion of O leads to $i_T < i_{T,\infty}$; (C). with UME near a conductive substrate, positive feedback of O leads to $i_T > i_{T,\infty}$.

When the tip is rastered in the x-y plane above the substrate, the tip current variation represents changes in topography or conductivity (or reactivity). One can separate topographic effects from conductivity effects by noting that over an insulator i_T is always less than $i_{T,\infty}$, while over a conductor i_T is always greater than $i_{T,\infty}$.

In the feedback mode of the SECM operation as stated above, the overall redox process is essentially confined to the thin layer between the tip and the substrate. In the substrate-generation/tip-collection (SG/TC) mode (when the substrate is a generator and the tip is a collector), the tip travels within a thin diffusion layer generated by the substrate electrode.[1b,3] There are some shortcomings which limit the applicability of the SG/TC mode if the substrate is large: (1). the process at a large substrate is always non-steady state; (2). a large substrate current may cause significant iR-drop; and (3). the collection efficiency, i.e., the ratio of the tip current to the substrate current, is low. The tip-generation/substrate-collection (TG/SC) mode is advisable for kinetic measurements, while SG/TC can be used for monitoring enzymatic reactions, corrosion, and other heterogeneous processes at the substrate surface.

II. Applications

A. Imaging and positioning

A three-dimensional SECM image is obtained by scanning the tip in the x-y plane and monitoring the tip

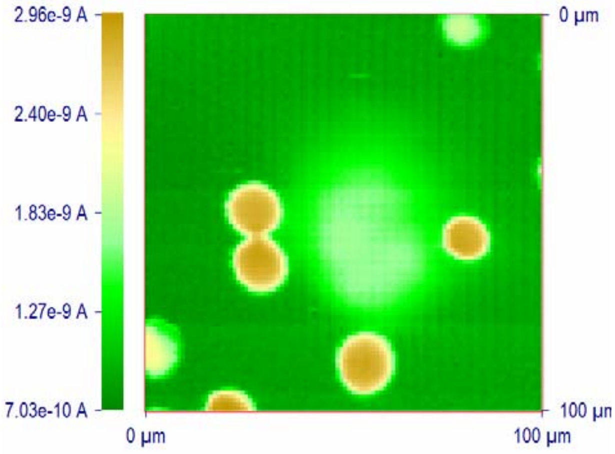


Figure 2. SECM image of a polycarbonate filtration membrane with a 2-µm-diameter Pt disk UME in $Fe(CN)_6^{4-}$ solution. Average pore diameter is ca. 10 µm.

current, i_T, as a function of tip location. A particular advantage of SECM in imaging applications, compared to other types of scanning probe microscopy, is that the response observed can be interpreted based on fairly rigorous theory, and hence the measured current can be employed to estimate the tip-substrate distance. Moreover, SECM can be used to image the surfaces of different types of substrates, both conductors and insulators, immersed in solutions. The resolution attainable with SECM depends upon the tip radius. For example, Fig. 2 shows one SECM image of a filtration membrane obtained with a 2-µm-diameter Pt disk tip in $Fe(CN)_6^{4-}$ solution. Average pore diameter is ca. 10 µm. An image demonstrating the local activity of an enzymatic reaction on a filtration membrane is shown in Fig. 9 as described below.

B. Studies of heterogeneous electron transfer reactions

SECM has been employed in heterogeneous kinetic studies on various metal, carbon and semiconductor substrates.[4] In this application, the x-y scanning feature of SECM is usually not used. In this mode, SECM has many features of UME and thin layer electrochemistry with a number of advantages. For example, the characteristic flux to an UME spaced a distance, d, from a conductive substrate is of the order of DC/d, independent of the tip radius, a, when $d < a$. Thus, very high fluxes and thus high currents can be obtained. For example, the measurement of the very fast kinetics of the oxidation of ferrocene at a Pt UME has been carried out.[4e] Five steady-state voltammograms obtained at different distances are shown in Fig. 3, along with the theoretical curves calculated with the values of the kinetic parameters extracted from the quartile potentials. The heterogeneous rate constant, k^o, obtained (3.7 ± 0.6 cm/sec) remains constant within the range of experimental error, while the mass-transfer rate increases with a decrease in d.

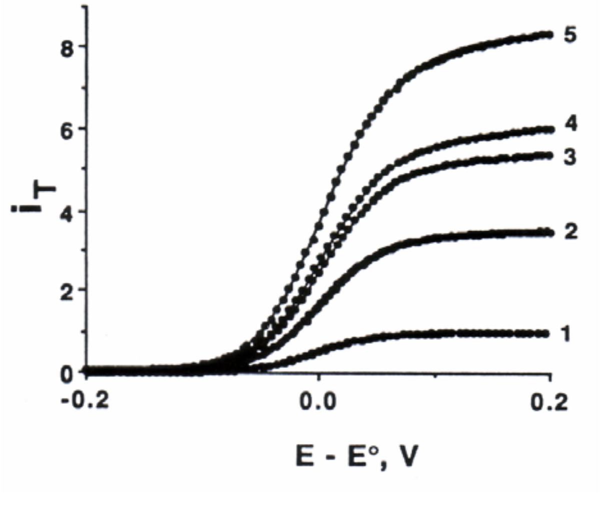


Figure 3. Tip steady-state voltammograms for the oxidation of 5.8 mM ferrocene in 0.52 M $TBABF_4$ in MeCN at a 1.1-µm-radius Pt tip. Solid lines are theoretical curves and solid circles are experimental data. Tip-substrate separation decreases from 1 to 5 ($d/a = \infty$, 0.27, 0.17, 0.14, and 0.1). (Reprinted with permission from Ref. 4e, copyright 1993, American Chemical Society.)

C. Studies of homogeneous chemical reactions

As mentioned above, the TG/SC (with small tip and substrate) mode of SECM, in the same manner as the rotating ring disk electrode (RRDE), is particularly suitable for the studies of homogeneous chemical kinetics.[1b,5] The SECM approach has the advantage that different substrates can be examined easily, i.e., without the need to construct rather difficult to fabricate RRDEs, and higher interelectrode fluxes are available without the need to rotate the electrode or otherwise cause convection in the solution. Moreover, in the TG/SC mode, the collection efficiency in the absence of perturbing homogeneous chemical reaction is near 100%, compared to significantly lower values in practical RRDEs. Finally, although transient SECM measurements are possible, most applications have involved steady-state currents, which are easier to measure and are not perturbed by factors like double-layer charging and also allow for signal averaging. For example, the reductive coupling of both dimethylfumarate (DF) and fumaronitrile (FN) in N,N-dimethyl formamide has been studied with the TG/SC mode.[5a] Fig. 4 shows tip and substrate steady-state voltammograms for the TG/SC regime. Comparable values of both of the plateau currents indicated that the mass

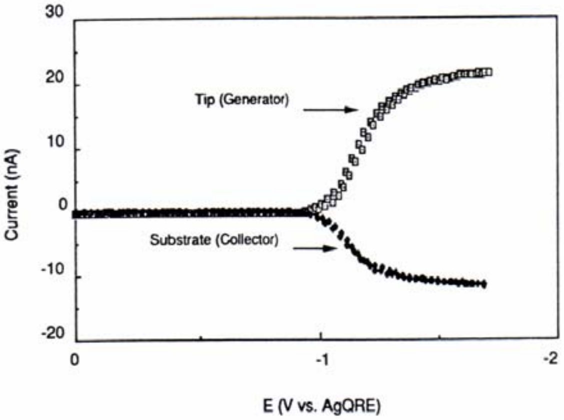


Figure 4. SECM voltammograms for FN (28.2 mM) reduction in TG/SC mode. d = 1.8 µm. E_T was scanned at 100 mV/sec with $E_S = 0.0$ V vs AgQRE. (Reprinted with permission from Ref. 5a, copyright 1992, American Chemical Society.)

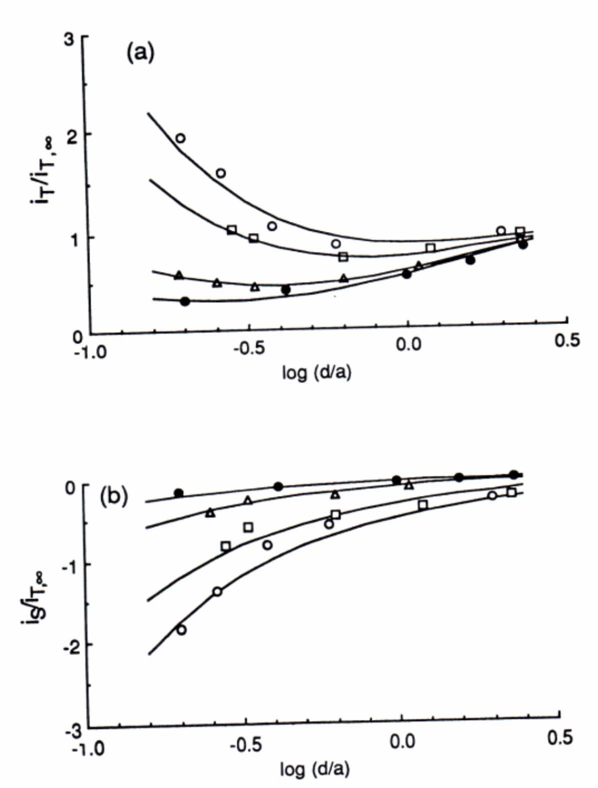


Figure 5. Normalized tip (generation, A) and substrate (collection, B) current-distance behavior for FN reduction. FN concentration: (open circle) 1.50 mM, (open square) 4.12 mM, (open triangle) 28.2 mM, and (filled circle) 121 mM. a = 5 μm, substrate radius is 50 μm. The solid lines represent the best theoretical fit for each set of data. (Reprinted with permission from Ref. 5a, copyright 1992, American Chemical Society.)

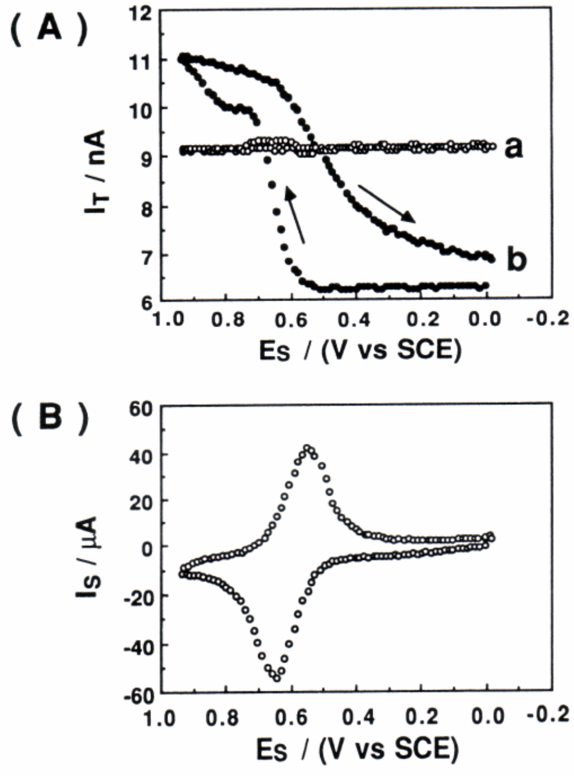


Figure 6. T/S CVs (A) curve a, d = 500 μm, and substrate CV (B) on Nafion/Os(bpy)$_3^{3+/2+}$ electrode in $K_3Fe(CN)_6/Na_2SO_4$, scan rate = 50 mV/sec, E_T = -0.4 V vs. SCE. (Reprinted with permission from Ref. 6a, copyright 1990, American Chemical Society.)

transfer rate was sufficiently fast to study the rapid homogeneous reaction. From the approach curves of both tip and substrate currents (Fig. 5) obtained at various FN concentrations, a rate constant k_c = 2.0 (± 0.4) x 10^5 $M^{-1}s^{-1}$ was determined for the dimerization reactions.

D. Characterization of thin films and membranes

SECM is also a useful technique for studying thin films on interfaces. Both mediated and direct electrochemical measurements in thin films or membranes can be carried out. For example, polyelectrolytes, electronically conductive polymers, passivation films on metals and dissolution processes have been investigated by SECM.[6] A unique type of cyclic voltammetry, called tip-substrate cyclic voltammetry (T/S CV), has been used to investigate the electrochemical behavior of an Os(bpy)$_3^{2+}$-incorporated Nafion film.[6a] T/S CV involves monitoring the tip current vs. the substrate potential (E_S) while the tip potential (E_T) is maintained at a given value and the tip is held near the substrate. The substrate CV (i_S vs. E_S) of an Os(bpy)$_3^{2+}$-incorporated Nafion film covering a Pt disk electrode in $Fe(CN)_6^{3-}$ solution only shows a wave for the Os(bpy)$_3^{2+/3+}$ couple (Fig. 6B), indicating the permselectivity of the Nafion coating. Fig. 6A shows the corresponding T/S CV curves. When the tip is far from the substrate, i_T is essentially independent of E_S. When the tip is close to the substrate (d = 10 μm), either negative or positive feedback effects are observed, depending on the oxidation state of the Os(bpy)$_3^{2+/3+}$ couple in the Nafion. When E_S is swept positive of the Os(bpy)$_3^{2+/3+}$ redox wave, a positive feedback effect is observed due to the regeneration of $Fe(CN)_6^{3-}$ in the solution gap region because of the oxidation of $Fe(CN)_6^{4-}$ by Os(bpy)$_3^{3+}$ at the solution-film interface. When E_S is negative of the redox wave, the film shows negative feedback behavior, since the

$Os(bpy)_3^{2+}$ formed is unable to oxidize tip-generated $Fe(CN)_6^{4-}$ back to $Fe(CN)_6^{3-}$.

E. Liquid-liquid interfaces

One of the most promising applications of SECM is the study of charge transport at the interface between two immiscible electrolyte solution (ITIES).[7] Unlike conventional techniques, SECM allows for the studies of both ion and electron transfer at the interface. For example, uphill electron transfer, in which an electron is transferred uphill from a redox couple with a higher standard reduction potential in one phase to another redox couple having a lower standard reduction potential in a second immiscible phase has been demonstrated using the system TCNQ (in 1,2-dichloroethane (DCE))/ferrocyanide (in water).[7c] Fig. 7 shows the approach curve obtained as the UME approaches the interface when the system contains supporting electrolytes with no partitioning ions such as tetraphenylarsonium ($TPAs^+$). However, the reverse electron flow for the same redox reaction can be induced by employing $TPAs^+$ as a potential-determining ion as shown in Fig. 8. The driving force for this reverse electron transfer is the imposition of an interfacial potential difference by the presence in solution of $TPAs^+$ in both phases ($\Delta_o^w\varphi$ = -364 mV). Note that the detection of reverse electron flow in this case could not be done using the method commonly used for studies of the ITIES, e.g., cyclic voltammetry.

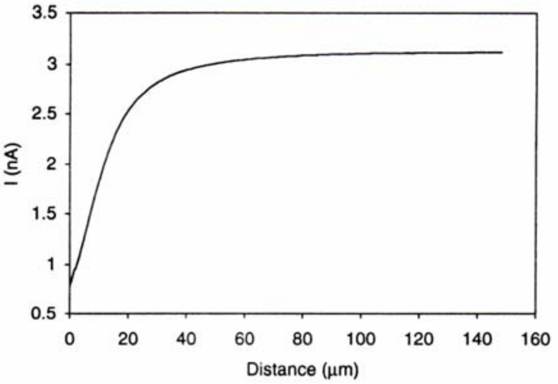


Figure 7. Approach curve for the system: 10 mM TCNQ and 1 mM TPAsTPB in DCE // 1 mM $Fe(CN)_6^{3-}$ and 0.1 M LiCl in H_2O, showing the absence of electron transfer across the liquid/liquid interface. A 25-µm-diameter Pt microelectrode was used to generate $Fe(CN)_6^{4-}$ at the electrode tip from the $Fe(CN)_6^{3-}$. Tip potential, -0.4 V vs Ag/AgCl. (Reprinted with permission from Ref. 7c, copyright 1995, American Chemical Society.)

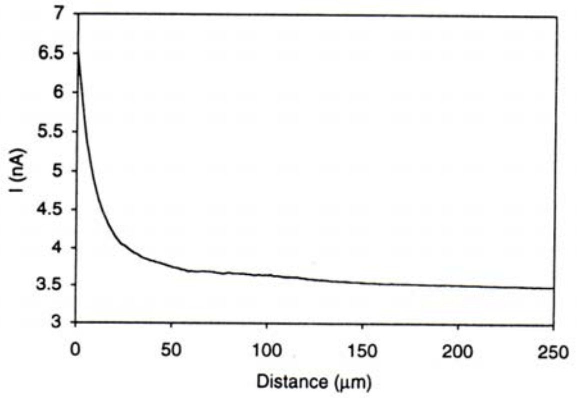


Figure 8. Approach curve for the system: 10 mM TCNQ and 1 mM TPAsTPB in DCE // 1 mM $Fe(CN)_6^{3-}$, 0.1 M LiCl and 1 mM TPAsCl in H_2O, showing reverse electron transfer driven by phase transfer catalyst $TPAs^+$. Tip potential, -0.4 V vs Ag/AgCl. (Reprinted with permission from Ref. 7c, copyright 1995, American Chemical Society.)

Since the ITIES is not polarizable in the presence of $TPAs^+$ in both phases, any attempt to impose externally a potential across the interface with electrodes in two phases would result in interfacial ion transfer and a current flow. The SECM approach does not suffer form this interference. Charge transfer processes across the ITIES with or without membranes have also been studied.

F. Probing patterned biological systems

SECM has been actively employed to probe artificially or naturally patterned biological systems.[8] Both amperometric and potentiometric techniques with ion-selective tips can be used. A direct test of the SECM's ability to image an enzymatic reaction over a localized surface region[8a] is shown in Fig. 9. Glucose oxidase (GO) hydrogel was filled inside small, well-defined pores of polycarbonate filtration membranes. The buffered assay solution contained a high concentration of D-glucose as well as two redox mediators, methyl viologen dication (MV^{2+}) and neutral hydroquinone (H_2Q). Fig. 9a shows an image obtained with a tip potential of -0.95 V vs. a silver quasi reference electrode (AgQRE) where MV^{2+} was reduced to $MV^{+\cdot}$. Since $MV^{+\cdot}$ does not react with reduced GO at the hydrogel-filled region, a negative feedback current was obtained. However, with the tip potential changed to 0.82 V, where hydroquinone was oxidized to p-benzoquinone by reduced GO, an increased tip current was observed (Fig. 9b). This positive feedback current over the hydrogel region indicates a significant catalytic feedback of the hydroquinone and provides a direct image of the local enzymatic reaction.

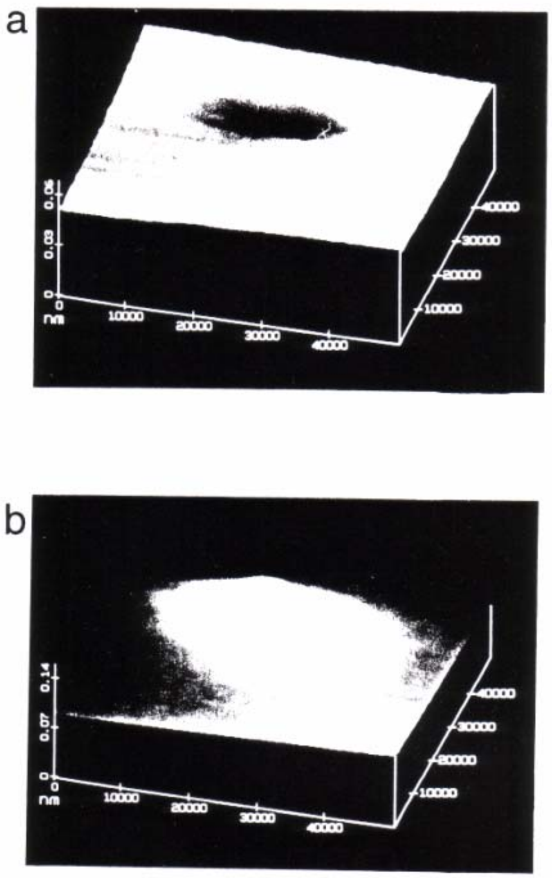


Figure 9. SECM images (50 µm x 50 µm) of a single GO hydrogel-filled pore on the surface of a treated membrane. Images were taken with a carbon microelectrode tip (a = 4.0 µm). (a). Negative feedback with MV^{2+} mediator at tip potential -0.95 V vs AgQRE. (b). Positive feedback with hydroquinone mediator at tip potential +0.82 V vs AgQRE in 0.1 M phosphate-perchlorate buffer (pH 7.0) containing 100 mM D-glucose, 50 µM hydroquinone and 0.1 mM $MVCl_2$. Lightest image regions depict the greatest tip current. (Reprinted with permission from Ref. 8a, copyright 1993, American Chemical Society.)

G. Fabrication

The SECM can be used to fabricate microstructures on surfaces by deposition of metal or other solids or by etching of the substrate.[9] Two different approaches have been used, the direct mode[9a,b] and the feedback mode[9c]. Typically, in the direct mode, the tip, held in close proximity to the substrate, acts as a working electrode (in deposition reactions) or as the counterelectrode (in etching processes). The feedback mode of fabrication utilizes the same arrangement as in SECM imaging.

The tip reaction is selected to generate a species that reacts at the substrate to promote the desired reaction, i.e., deposition or etching. For example, a strong oxidant, like Br_2, generated at the tip can etch the area of the substrate, e.g., GaAs, directly beneath the tip.[9d] The mediator reactant is chosen to be one that reacts completely and rapidly at the substrate, thus confining the reaction to a small area on the substrate and producing features of area near that of the tip. Small tip size and close tip-substrate spacing are required for high resolution.

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Model 1000A Series Multi-Potentiostat

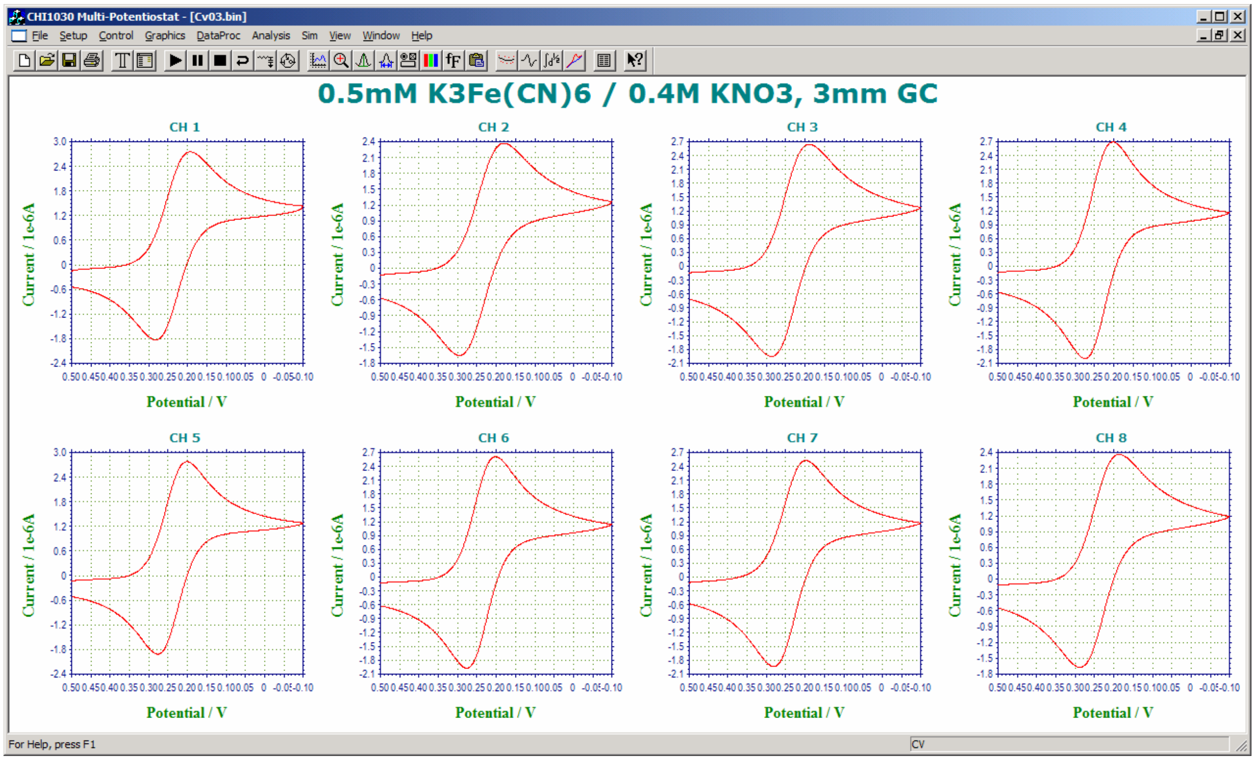
The model 1000A series is a computerized 8 channel potentiostat. The system contains a digital function generator, a multiplexed data acquisition circuitry, a multi-potentiostat can work with eight independent cells, or eight working electrodes in the same solution with a common reference electrode and a common counter electrode. The potential control range is ±10 V for the all channels. All channels can be set at independent potential, or the identical potential as the primary channel, so that they can sweep or step potentials together with the primary channel. Each electrode can be individually controlled, including on/off control, potential and sensitivity settings. The current range is ±10 mA. The instrument is capable of measuring current down to picoamperes.

The model 1000A series is an upgraded version from the model 1000 series. The new design allows eight independent cells, simultaneous or sequential measurements, much faster data acquisition speed (1M Hz @16-bit), lower in noise, and easier software update using FLASH memory.

Besides the commonly used cyclic voltammetry and amperometric i-t measurements, many other electrochemical techniques are available in the 1000A series. All eight channels can be used for various electrochemical techniques, except open circuit potential measurements. The parameters for all the channels should be set before running experiments. You can not alter the parameter setting during experiments. During run, you can alter display mode between single data set display and multi-set data display (either parallel or overlay plots). After a run, you can choose data sets of any channels as parallel plots or overlay plots.

The instrument is controlled by an external PC under the Windows 95/98/NT/Me/2000/XP operating systems using USB or serial port. The instruments are easy to install and use. No plug-in card or other hardware is required on the PC side. The commands, parameters, and options are in terminology that most chemists are familiar with. The toolbar allows quick access to the most commonly used commands. The systematic and complete help system provides context-sensitive help.

The instrument provides many powerful functions, such as file handling, experimental control, graphics, data analyses, and digital simulation. Some of the unique features include macro command, working electrode conditioning, color, legend and font selection, data interpolation, visual baseline correction, data point removal, visual data point modification, signal averaging, Fourier spectrum, and equations relating to electrochemical techniques. The maximum data length is 128K – 4096K points (selectable) if real-time data transfer is allowed. The software is 32-bit version and has a multi-document interface.



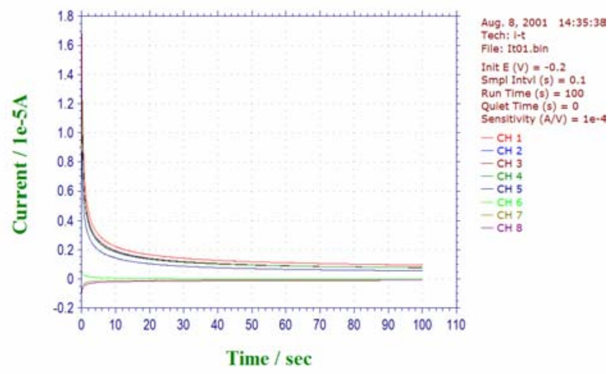
Differences of 1000A Series Models

Functions	***1000A***	***1010A***	***1020A***	***1030A***
Cyclic Voltammetry (CV)	●	●	●	●
Linear Sweep Voltammetry (LSV) &	●	●	●	●
Chronoamperometry (CA)				●
Chronocoulometry (CC)				●
Differential Pulse Voltammetry (DPV) &			●	●
Normal Pulse Voltammetry (NPV) &			●	●
Square Wave Voltammetry (SWV) &			●	●
Amperometric i-t Curve (i-t)	●	●		●
Differential Pulse Amperometry (DPA)		●		●
Triple Pulse Amperometry (TPA)		●		●
Sweep-Step Functions (SSF)				●
Multi-Potential Steps (STEP)				●
Open Circuit Potential - Time (OCPT)	●	●	●	●
Full version of CV simulator				●
Limited version of CV simulator	●	●	●	

&: Corresponding stripping mode can be performed.

Specifications

8-Channel potentiostat
(8 independent cells or a multi-working electrode cell)
Potential range (all channels): ±10 V
Compliance voltage: ±12 V
Current range (each channel): 10 mA
Reference electrode input impedance: 1×10^{12} ohm
Sensitivity scale: 1×10^{-9} - 0.001 A/V in 7 ranges
Input bias current: < 50 pA
Current measurement resolution: < 1 pA
Data acquisition: 16 bit @ 1M Hz maximum
CV and LSV scan rate: 0.000001 to 5000 V/s
CA and CC pulse width: 0.0001 to 1000 s
CA and CC Steps: 320
DPV and NPV pulse width: 0.001 to 10 s
SWV frequency: 1 to 100K Hz
Current low-pass filters
Current analog output
Cell control: purge, stir, knock
Maximum data length: 128000 points each channel
Chassis dimension: 12.5”(W) × 11”(D) × 4.75”(H)



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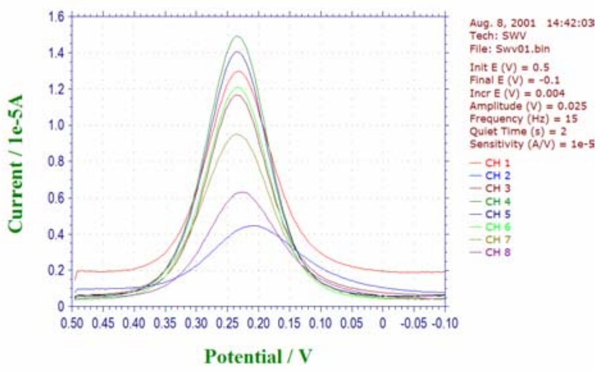
Overlay plot of 8 channel i-t Curve with different potential setting for each channel



Aug. 8, 2001 14:42:03
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Final E (V) = -0.1
Incr E (V) = 0.004
Amplitude (V) = 0.025
Frequency (Hz) = 15
Quiet Time (s) = 2
Sensitivity (A/V) = 1e-5

Overlay plot of 8 channel SWV with all eight channel potential scanned simultanousely

Model 1100A Series
Power Potentiostat / Galvanostat

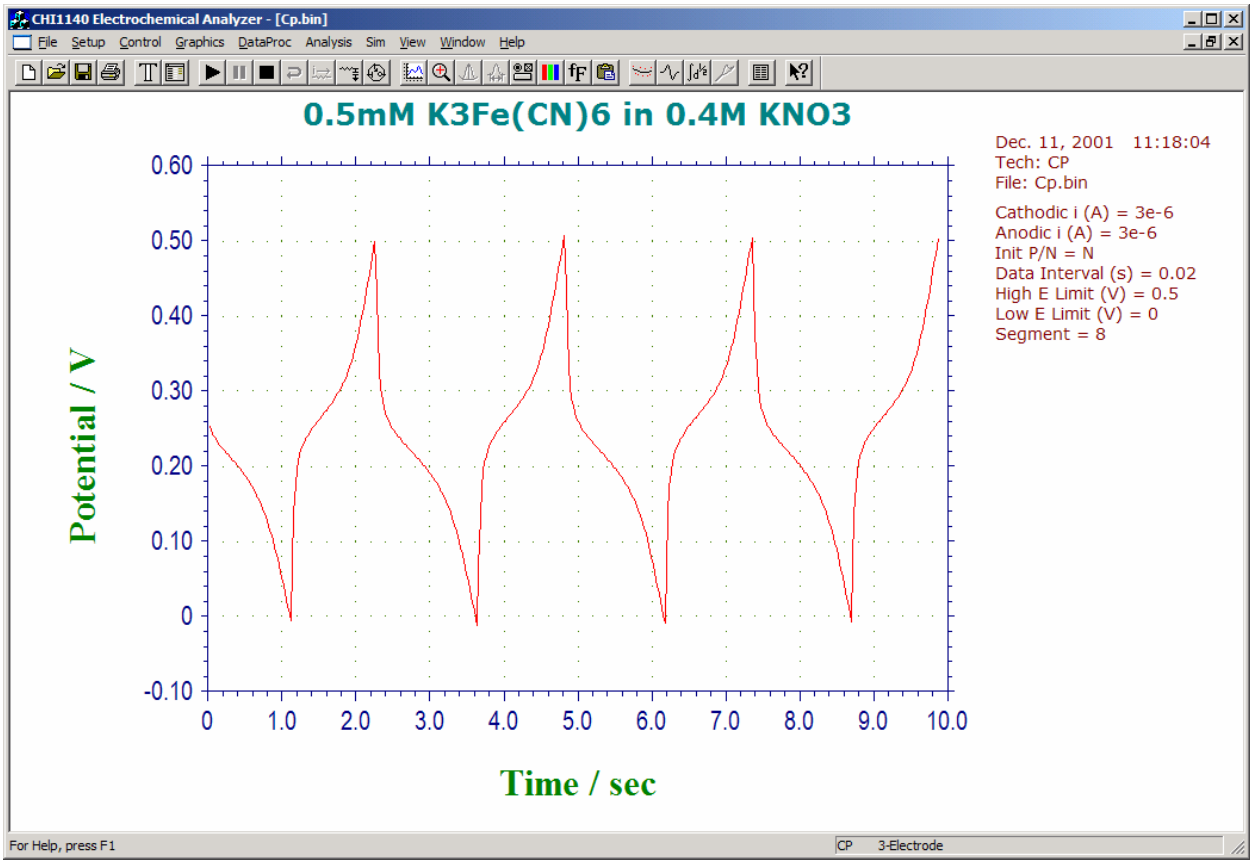
The Model 1100A series power potentiostat/galvanostat is designed for electrochemical applications that require relatively large current and high compliance voltage, such as battery, corrosion, electrolysis, and electroplating. The current range is ± 2 A. The compliance voltage is ± 26 V. The instrument contains a digital function generator, a data acquisition system, filters for the current signals, iR compensation circuitry, a potentiostat, and a galvanostat (Model 1140A). The potential control range is ± 10 V. The 1100 series is capable of measuring current down to tens of picoamperes. The steady state current of a 10 µm disk electrode can be readily measured without external adapters. The instrument is reasonably fast. For instance, the scan rate in cyclic voltammetry can be up to 1000 V/s. Multiple data acquisition systems allow an external input signal (such as spectroscopy signals to be recorded simultaneously with electrochemical data).

The model 1100A series is the upgrade from the model 1100 series. The redesigned instrument contains a new processor (about 50 times faster than the 1100) and FLASH memory (allowing instrument updates to be distributed by e-mail instead of the shipment of an EPROM chip). The maximum sampling rate is 200 KHz.

The 1100A series has a serial port (default) and a USB for data communication with the PC. You can select either serial port or USB (but not both) by changing the jumper setting on the board.

A 16-bit highly stable bias circuitry is added for current or potential bias. This allows wider dynamic range is ac measurements. It can also be used to re-zero the dc current output.

There are some other improvements. New techniques, such as AV Voltammetry (ACV), Second Harmonic AC Voltammetry (SHACV), Multi-Current Steps (ISTEP) have been added to the model 1100A series. ISTEP allows cycling through 12 current steps. Multi-Potential Steps (STEP) also allows cycling through 12 potential steps (cf. 6 steps in model 1100 series).



Dec. 11, 2001 11:18:04
Tech: CP
File: Cp.bin

Cathodic i (A) = 3e-6
Anodic i (A) = 3e-6
Init P/N = N
Data Interval (s) = 0.02
High E Limit (V) = 0.5
Low E Limit (V) = 0
Segment = 8

Chronopotentiometric measurement

Specifications

Potentiostat
Galvanostat (Model 1140A)
Potential range: -10 to 10 V
Potentiostat rise time: < 2 µs
Compliance voltage: ± 26 V
3- or 4-electrode configuration
Current range: ± 2 A
Reference electrode input impedance: 1×10^{12} ohm
Sensitivity scale: 1×10^{-12} - 0.1 A/V in 34 ranges
Input bias current: < 100 pA
Current measurement resolution: < 1 pA
Potential update rate: 1 MHz
Data acquisition: 16 bit @ 200 kHz
External voltage signal recording channel
External potential input
Automatic and manual iR compensation
Potential and current analog output
RDE control voltage output: 0-10V (1130 and up)
CV and LSV scan rate: 0.000001 to 2000 V/s
Minimum potential increment during scan: 0.1 mV
CA and CC pulse width: 0.001 to 1000 s
CA and CC Steps: 320
DPV and NPV pulse width: 0.001 to 10 s
SWV frequency: 1 to 10 kHz
Automatic potential and current zeroing
Signal low-pass filters, covering 8-decade frequency range, Automatic and manual setting
Potential and current analog output
Cell control: purge, stir, knock
Automatic potential and current zeroing
Current low-pass filters, covering 8-decade frequency range, Automatic and manual setting
Flash memory for quick software update
Serial port or USB selectable for data communication
Maximum data length: 128K-4096K selectable
Chassis dimension: 12.5”(W) × 11”(D) × 4.75”(H)
Weight: 18 Lb.

Differences of 1100A Series Models

Functions	*1100A*	*1110A*	*1120A*	*1130A*	*1140A*
Cyclic Voltammetry (CV)	●	●	●	●	●
Linear Sweep Voltammetry (LSV)[&]	●	●	●	●	●
Staircase Voltammetry (SCV)[#,&]				●	●
Tafel Plot (TAFEL)				●	●
Chronoamperometry (CA)	●		●	●	●
Chronocoulometry (CC)	●		●	●	●
Differential Pulse Voltammetry (DPV)[#,&]		●	●	●	●
Normal Pulse Voltammetry (NPV)[#,&]		●	●	●	●
Differential Normal Pulse Voltammetry (DPNV)[#,&]					●
Square Wave Voltammetry (SWV)[&]			●	●	●
AC Voltammetry (ACV)[#,&,$]				●	●
2nd Harmonic AC Voltammetry (SHACV)[#,&,$]				●	●
Amperometric i-t Curve (i-t)				●	●
Differential Pulse Amperometry (DPA)					●
Double Differential Pulse Amperometry (DDPA)					●
Triple Pulse Amperometry (TPA)					●
Bulk Electrolysis with Coulometry (BE)	●		●	●	●
Sweep-Step Functions (SSF)					●
Multi-Potential Steps (STEP)					●
Chronopotentiometry (CP)					●
Chronopotentiometry with Current Ramp (CPCR)					●
Multi-Current Steps (ISTEP)					●
Potentiometric Stripping Analysis (PSA)					●
Open Circuit Potential - Time (OCPT)	●	●	●	●	●
Galvanostat					●
RDE control (0-10V output)					
Full version of CV simulator				●	●
Limited version of CV simulator	●	●	●		
iR Compensation	●	●	●	●	●
External Potential Input	●	●	●	●	●
Auxiliary Signal Measurement Channel	●	●	●	●	●

#: Corresponding polarographic mode can be performed.
&: Corresponding stripping mode can be performed.

Model 1200A Series Hand-held Potentiostat / Bipotentiostat

The Model 1200A series is a computerized hand-held potentiostat/bipotentiostat. The instrument consists of a digital function generator, a data acquisition system, and a potentiostat/bipotentiostat. The potential range is ± 2.4 V. The current range is ± 2 mA. This series is capable of measuring current down to 100 pA. The steady state current of a 10 µm disk electrode can be readily measured. The size of the instrument is 7” (L) × 4.5” (W) × 1” (H). The instrument is powered by the USB port of a PC computer, without need of an external wall transformer or batteries. It is therefore more compact and convenient. The instrument can be used for electroanalysis and sensor studies. Due to its small size, light weight, and low cost, it is particularly useful for field applications and teaching laboratories.

Compared with the previous Model 1200 series, the new design allow ±7.5 V compliance voltage, which ensures the working potential range ±2.4 V for most of the electrochemical systems. It also uses dual 16-bit DAC and 16-bit ADC for improved resolution and accuracy.

The instrument provides many powerful functions, such as file handling, experimental control, graphics, data analysis, and digital simulation. Some of the unique features include macro command, working electrode conditioning, color, legend and font selection, data interpolation, visual baseline correction, data point removal, visual data point modification, signal averaging, Fourier spectrum, and equations relating to electrochemical techniques.

The CHI1200A series provides various instrument models to meet different applications and budget., and is available in potentiostat (CHI1200A, 1210A, 1220A, and 1230A) and bipotentiostat versions (CHI1202A, 1212A, 1222A, and 1232A).

Specifications

Potentiostat / bipotentiostat
Maximum potential range: ± 2.4 V
Compliance voltage: ± 7.5 V
Current range: ± 2 mA
Reference electrode input impedance: 1×10^{12} ohm
Sensitivity scale: 1×10^{-10} - 0.001 A/V in 8 ranges
Input bias current: < 100 pA
Current measurement resolution: < 5 pA
Data acquisition: 16 bit @ 10 kHz
CV and LSV scan rate: 0.000001 to 10 V/s
CA and CC pulse width: 0.001 to 1000 s
CA and CC Steps: 1 - 320
DPV and NPV pulse width: 0.001 to 10 s
SWV frequency: 1 to 5000 Hz
Low pass filter for current measurements
Maximum data length: 128K-4096K selectable
Power: UPS port of a PC
Chassis dimension: 7” (W) × 4.5” (D) × 1” (H)

Differences of 1200A Series Models

Functions	*1200A /1202A*	*1205A /1206A*	*1207A /1208A*	*1210A /1212A*	*1220A /1222A*	*1230A /1232A*
Cyclic Voltammetry (CV)*	●	●	●	●	●	●
Linear Sweep Voltammetry (LSV) $^{\&,*}$	●	●	●	●	●	●
Chronoamperometry (CA)*	●				●	●
Chronocoulometry (CC)	●				●	●
Differential Pulse Voltammetry (DPV) $^{\&,*}$				●	●	●
Normal Pulse Voltammetry (NPV) $^{\&,*}$				●	●	●
Differential Normal Pulse Voltammetry (DPNV) $^{\&,*}$						●
Square Wave Voltammetry (SWV) $^{\&,*}$					●	●
Amperometric i-t Curve (i-t)*		●	●			●
Differential Pulse Amperometry (DPA)			●			●
Double Differential Pulse Amperometry (DDPA)			●			●
Triple Pulse Amperometry (TPA)			●			●
Open Circuit Potential - Time (OCPT)	●	●	●	●	●	●
Full version of CV simulator						●
Limited version of CV simulator	●	●	●	●	●	

&: Corresponding stripping mode can be performed.
*: Second channel (bipotentiostat mode) can be performed.

CHI1550A Solution Dispenser

The CHI1550A solution dispenser is designed for making high density and high accuracy solution arrays. Solution arrays are widely used in chemical, biological and medical applications. The solution dispenser consists of a high resolution three dimensional positioner, a piezoelectric jetting device, and a sample platform. The diagram is shown in Figure 1.1.

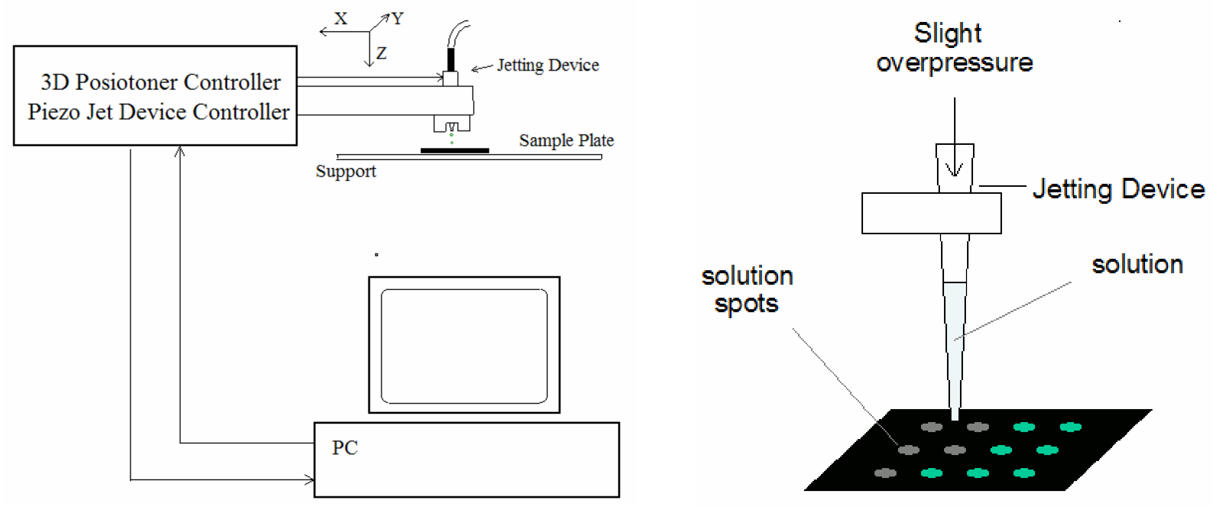


Figure 1. Diagram of the solution dispenser

The three dimensional positioner can travel 50 mm distance for all three axes with 0.1 micrometer resolution. This allows high precision patterning. This is particularly important when multiple solution components need to be dispensed overlapped.

The jetting device can dispense single drop of fluids. Typical fluids successfully jetted in this device have viscosity less than 40 centipoise and surface tension in the range of 0.02-0.07 N/m. Fluids with properties outside these limits can be jetted if changes to the properties can be achieved with solvents or changes in temperature. With a default 60 micron orifice size, the jetting device can produce drops ranging from 100-200 picoliters in volume depending on the operating parameters and fluids.

The CHI1550A solution dispenser control software is very user-friendly for creating binary, ternary and quadruple arrays of spots containing mixtures of solutions. Instead of using a manually created look-up table for solution dispensing patterns, the software will assist the pattern creation. The software can also provide commonly used patterns as default for binary, ternary and quadruple arrays. The positioner can memorize certain critical positions, such as solution loading point and first dispense point. This will help the jetting device to go to these positions easily and quickly.

The array pattern can be examined graphically. During dispensing process, the array pattern will also be displays as the dispensing progresses.

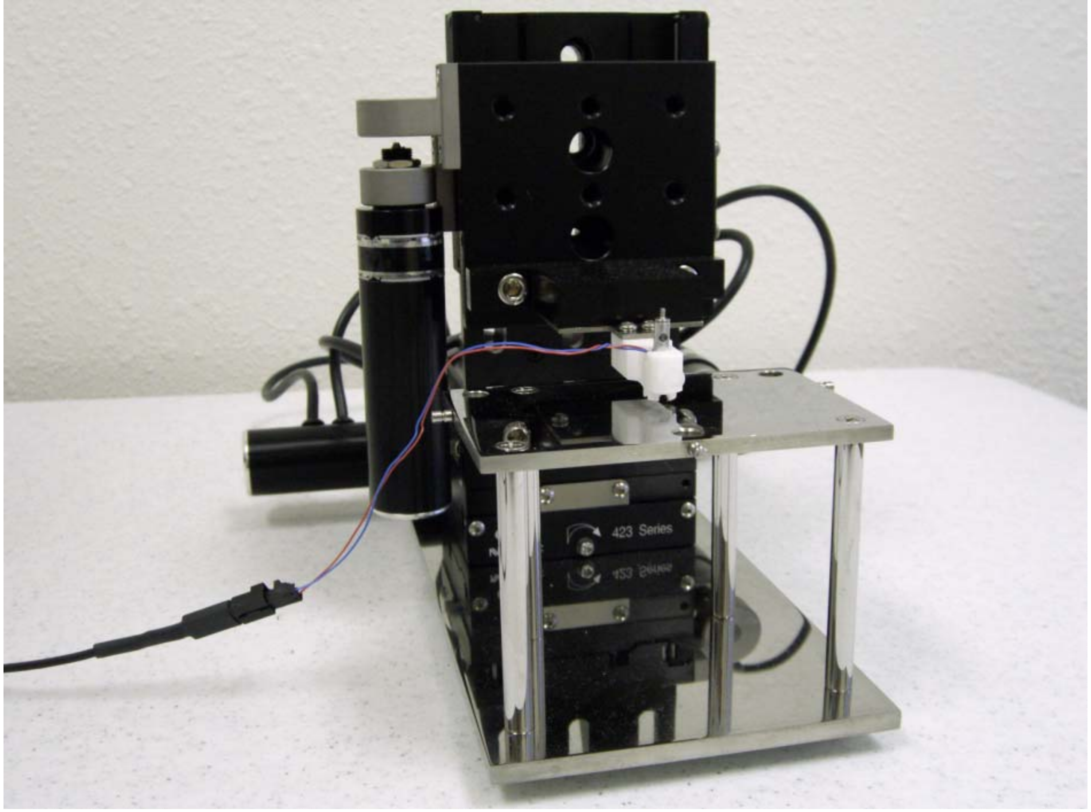


Figure 3. Micropositioner and sample stand

System requirements

Operating System: PC with Microsoft Windows 95 / 98 / NT /Me/ 2000 / XP
Communication: RS-232 serial port or USB

Hardware Specifications

Micropositioner:	**Jetting Device:**
Three high resolution stepper motors • Maximum range of motion: 25 mm • Motor resolution: 100 nm • Stall Load: 50 N • Maximum Speed: 4 mm / sec ***Three Translation Stages*** • Maximum range of motion: 25 mm • Angular deviation: < 200 microrad • Load capacity: 156 N • Load capacity (vertical): 67 N	Orifice side of the jetting device: 60 micron Droplet size: 100-200 picoliters Control voltage: 0-150V A protective holder for the jetting device

CHI200(B) Picoamp Booster and Faraday Cage

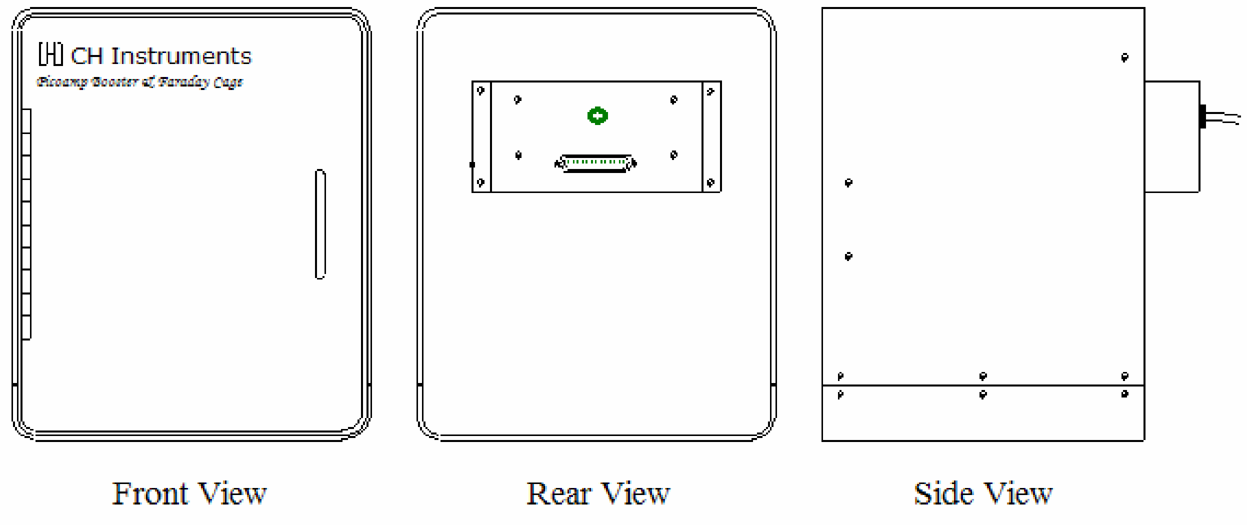
With the CHI200(B) Picoamp Booster and Faraday Cage, current down to a few picoamperes can be readily measured. The CHI200 is compatible with the Model 600/A, 700/A series of instruments, while the CHI200B is compatible with Model 600B/C and 700B/C series. When used with 700/A/B/C series bipotentiostat, the Picoamp Booster will affect the primary channel only.

The internal sensitivity of the 600C series is the same as the Picoamp Booster (1×10^{-12} A/V). However, the bias current of the 600B/C series input can be as high as 50 pA. The Picoamp Booster has lower bias current, and it also brings the preamplifier close to the electrode hence resulting in lower noise. The Faraday Cage also makes it possible to make relatively fast measurements of small currents.

When the Picoamp Booster is connected and the sensitivity scale is at or below 1×10^{-8} A/V, the Picoamp Booster will be enabled. Otherwise, it will be disabled. The instruments automatically sense whether a Picoamp Booster is connected. The enable/disable switching is also automatic.

The Picoamp Booster will be disabled for techniques using automatic sensitivity switching, such as Tafel plots, bulk electrolysis (BE), and ac impedance (IMP). It is not necessary to disconnect the Picoamp Booster to run those techniques. However, for galvanostatic techniques, such as chronopotentiometry (CP) and potentiometric stripping analysis (PSA), the Picoamp Booster must be disconnected.

Besides weak signal measurements, the Faraday cage is useful for eliminating electrical interference, especially line frequency noise. If the electrochemical cell is picking up electrical noise from the environment, the additional use of Faraday cage is strongly recommended.

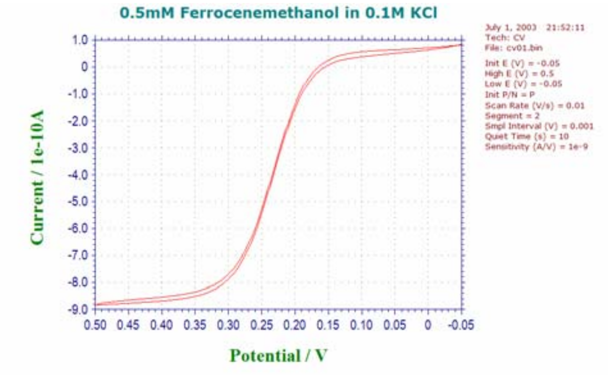


Front View

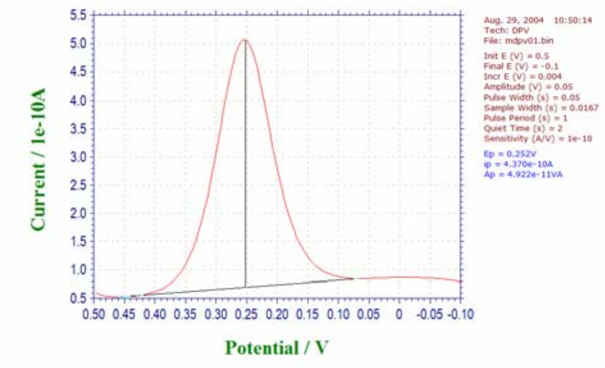
Rear View

Side View

Dimension: 9.6”(W) × 8.8”(D) × 11.8”(H)   Weight: 13 Lb.



Cyclic voltammogram at an ultramicroelectrode.



Differential pulse voltammogram at an ultramicroelectrode.

Model 680 Amp Booster

With the CHI680 Amp Booster, the current can be measured up to 2 A. The CHI680 is compatible with Model 600, 600A, 600B, and 600C series of instruments. You can stack the CHI600/A/B/C and the CHI680 together.

With the Amp Booster connected, the cell control signals such as purge, knock and stir are disabled.

The Amp Booster will also allow low current measurements. The current down to 10 pA can be measured. It is comparable with the CHI600/A/B/C alone. You may need to use the Faraday Cage to eliminate line frequency noise when the scan rate is above 50 mV/s.

The frequency response of the Amp Booster is somewhat lower than that of the CHI600/A/B/C instruments. For high speed experiments, the Amp Booster should be disconnected.

Dimension: 12.5”(W) × 11”(D) × 4.75”(H)
Weight: 18 Lb.

CHI682 Liquid/Liquid Interface Adapter

Liquid/liquid interface study is very important in understanding the charge transfer, chemical sensor, drug release, solvent extraction, and others. Liquid/liquid interface study usually involves two reference electrodes and two auxiliary electrodes. The modified potentiostat controls the potential difference of the two reference electrodes in two phases, while measuring the current passing through two auxiliary electrodes. The CHI682 Liquid/Liquid Interface Adapter is compatible with our model 700A series. It is fully automatic and integrates seamlessly. Although it does not have galvanostat and bipotentiostat functions, most other electrochemical techniques can be used.

Please notice that for model 400, 600A, 600B, 600C, 700B, 700C, 800B, 900B, 1100 and 1100A series, a 4-electrode configuration will allow liquid/liquid interface measurement to be made directly without using CHI682 Liquid/Liquid Interface Adapter.

CHI684 Multiplexer

CHI684 is a multi-channel multiplexer for the model 400/A, 600A/B/C, 700A/B/C, 800B, 900B and 1100A series. The multiplexer switches four lines (working, sensing, reference, and counter for a single potentiostat, second working, reference and counter for a bipotentiostat). You can have maximum 64 cells, but only one cell can be connected at a time.

The multiplexer is controlled from the "Multiplexer" command under the Control menu. You can select any channel and run experiments in a sequence of the selected channels. The files will automatically be saved after each run. You can also set a prompt before each channel run.

It is allowed to set arbitrary channels immediately. An experiment can then be run for that particular channel.

Two Macro commands are available for the multiplexer. One is "mch:##". It allows the user to choose an individual channel. The other macro command is "mchn". This is used in a For...Next loop to select the channel according to the For...Next loop counter.

The minimum number of channels for the CHI684 are 8. The channel increment is 8. The maximum number of channels are 64.

Highlights

User Interface

- ***32-bit Windows application***
- ***Multi-Document Interface***
- ***toolbar:*** quick access to frequently used commands
- ***status bar:*** technique and command prompt
- ***pull-down menus***
- ***WYSIWYG graphics***
- ***comprehensive and context sensitive help***

File Management

- ***reopen saved data files***
- ***save data file***
- ***delete files***
- ***list data file***
- ***convert to text files:*** for exporting data to other software, such as spreadsheets
- ***text file format***
- ***print present data***
- ***print multiple data files***
- ***print setup***

Setup

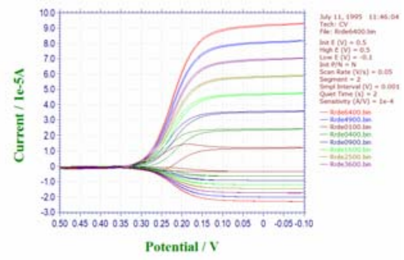
- ***technique:*** a large repertoire of electrochemical techniques
- ***experimental parameters:*** extremely wide dynamic range
- ***system setup:*** choice of communication port, line frequency, choice polarity of potential and current axis
- ***hardware test:*** digital and analog circuitry diagnostic test

Instrument Control

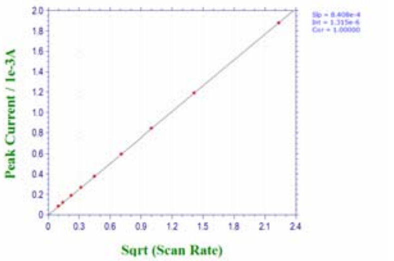
- ***run experiment:*** real time data display in most cases
- ***pause/resume during run***
- ***stop running experiment***
- ***reverse scan direction during run:*** for cyclic voltammetry
- ***repetitive runs:*** automatic data save, signal averaging, delay or prompt between runs, up to 999 runs
- ***run status:*** stir, purge, iR compensation, smooth after run, RDE and SMDE control status
- ***macro commands:*** edit, save, read, and execute a series of commands
- ***open circuit potential measurement***
- ***iR compensation:*** automatic and manual compensation, solution resistance, double layer capacitance and stability test
- ***analog filter setting:*** automatic or manual setting of potential, i/V converter, and signal filters
- ***cell control:*** purge, stir, cell on, SMDE drop collection, and pre-run drop knock
- ***step functions:*** initial and two step potentials, duration of steps and number of steps, particularly useful for electrode treatment
- ***working electrode conditioning before running experiment:*** programmable 3 steps
- ***rotating disk electrode:*** rotation speed, on/off control during deposition, quiescent time, run, and between runs
- ***stripping mode:*** enable/disable, deposition potential and time, stir and purge conditions

Graphic Display

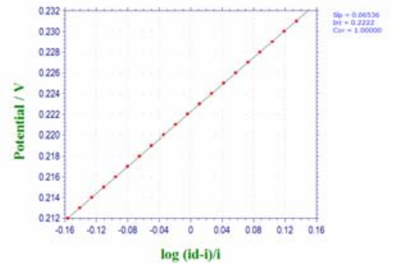
- ***present data plot***
- ***3D surface plot:*** front, rear, side, top and bottom view
- ***overlay plots:*** several sets of data overlaid for comparison
- ***add data to overlay:*** adding data files to overlay plot
- ***parallel plots:*** several sets of data plotted side by side
- ***add data to parallel:*** adding data files to parallel plot
- ***zoom in/out:*** visually selected zoom area
- ***manual results:*** visually selected baseline
- ***peak definition:*** shape, width, and report options
- ***Special Plots:*** x-y, i_p-v, i_p-$v^{1/2}$, E_p-log v, semilog plots, linear polarization resistance plot
- ***graph options:*** video or printer options, axis, parameters, baseline, results, grids, axis inversion, axis freeze, axis titles, data sets, XY scales, current density option, reference electrode, header, and notes



Overlay plots.



Automatic $i_p \sim v^{1/2}$ plot.



Automatic semilog plot.

Highlights

- ***color and legend:*** background, axis, grid, curves, legend size, thickness, and display intervals
- ***font:*** font, style, size and color for axis labels, axis titles, header, parameters, and results
- ***copy to clipboard:*** for pasting the data plot to word processors

Data Processing

- ***smoothing:*** 5-49 point least square and Fourier transform
- ***derivatives:*** 1st - 5th order, 5-49 point least square
- ***integration***
- ***convolution:*** semi-derivative and semi-integral
- ***interpolation:*** 2× - 64× data interpolation
- ***baseline correction:*** visually selected baseline, slope and dc level compensation
- ***baseline fitting and subtraction:*** selectable fitting function, polynomial order and potential range for best fitting and baseline subtraction; particularly useful for trace analysis
- ***data point removing***
- ***data point modifying:*** visual data point modification
- ***background subtraction:*** difference of two sets of data
- ***signal averaging***
- ***mathematical operations:*** both X and Y data array
- ***Fourier spectrum***

Analysis

- ***calibration curve:*** calculation and plot
- ***standard addition:*** calculation and plot
- ***data file report:*** analytical report from existing data files
- ***time dependence report***
- ***corrosion rate calculation***

CV Digital Simulator

- ***fast implicit finite difference algorithm***
- ***reaction mechanisms:*** 10 predefined mechanisms (low end models); or any combination involving electron transfer, first- and second-order chemical reactions (high end models)
- ***system:*** diffusive or adsorptive
- ***maximum equations:*** 12
- ***maximum species:*** 9
- ***simulation parameters:*** standard redox potentials, rate of electron transfer, transfer coefficient, concentration, diffusion coefficient, forward and reverse chemical reaction rate constants, temperature, electrode area, and experimental parameters
- ***simultaneous display of voltammogram and concentration profiles***
- ***automatic search and determine over-determined equilibrium constants***
- ***dimensionless current***
- ***equilibrium data***

Impedance Simulator and Fitting Program

- ***visual entry of equivalent circuitry***
- ***automatic equivalent circuit parameters fitting***

View

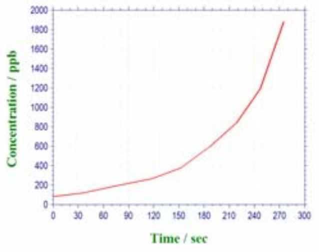
- ***data information:*** date, time, filename, data source, instrument model, data processing performed, header and notes
- ***data listing:*** data information and numerical data array
- ***equations:*** general equations and equations relating to various electrochemical techniques
- ***SECM probe status:*** probe position and current display
- ***clock***
- ***toolbar***
- ***status bar***

Help

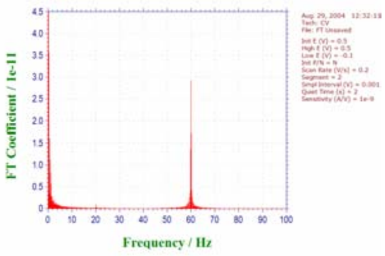
- ***context sensitive help***
- ***help topics***
- ***about the application***

System requirements

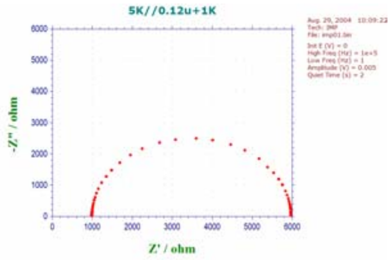
- ***operating system:*** Microsoft Windows 95 / 98 / NT / Me / 2000 / XP
- ***serial communication port or USB port***



Concentration-time dependence plot.

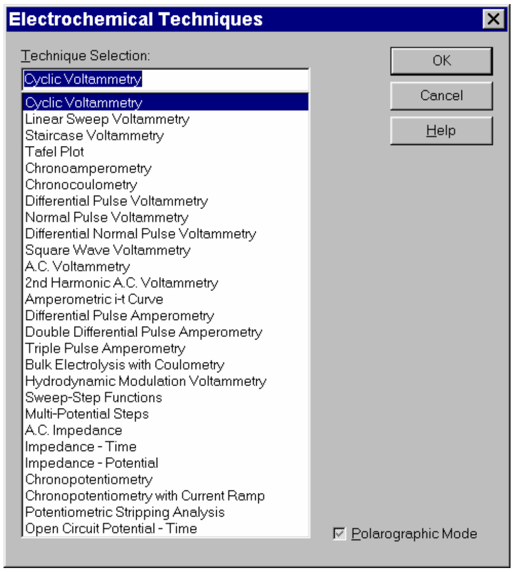


Fourier spectrum.



Nyquist plot of impedance data.

Highlights

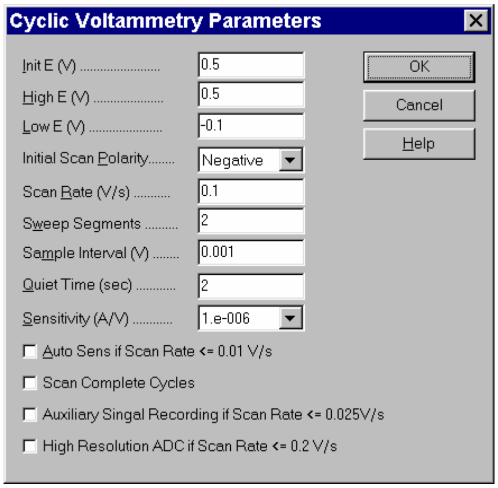


Technique Selection: Cyclic Voltammetry

- Cyclic Voltammetry
- Linear Sweep Voltammetry
- Staircase Voltammetry
- Tafel Plot
- Chronoamperometry
- Chronocoulometry
- Differential Pulse Voltammetry
- Normal Pulse Voltammetry
- Differential Normal Pulse Voltammetry
- Square Wave Voltammetry
- A.C. Voltammetry
- 2nd Harmonic A.C. Voltammetry
- Amperometric i-t Curve
- Differential Pulse Amperometry
- Double Differential Pulse Amperometry
- Triple Pulse Amperometry
- Bulk Electrolysis with Coulometry
- Hydrodynamic Modulation Voltammetry
- Sweep-Step Functions
- Multi-Potential Steps
- A.C. Impedance
- Impedance - Time
- Impedance - Potential
- Chronopotentiometry
- Chronopotentiometry with Current Ramp
- Potentiometric Stripping Analysis
- Open Circuit Potential - Time

☑ Polarographic Mode

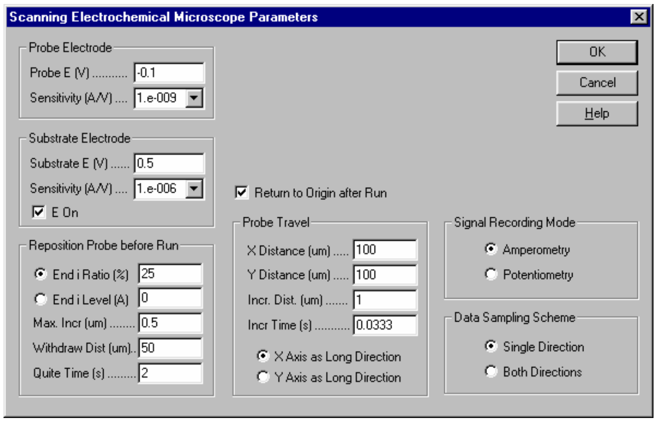
A large repertoire of electrochemical techniques.



Init E (V) 0.5
High E (V) 0.5
Low E (V) .... -0.1
Initial Scan Polarity........ Negative
Scan Rate (V/s) 0.1
Sweep Segments 2
Sample Interval (V) 0.001
Quiet Time (sec) 2
Sensitivity (A/V) 1.e-006

☐ Auto Sens if Scan Rate <= 0.01 V/s
☐ Scan Complete Cycles
☐ Auxiliary Singal Recording if Scan Rate <= 0.025V/s
☐ High Resolution ADC if Scan Rate <= 0.2 V/s

Experimental parameter dialog box for Cyclic Voltammetry.



Probe Electrode
Probe E (V) .... -0.1
Sensitivity (A/V) 1.e-009

Substrate Electrode
Substrate E (V) 0.5
Sensitivity (A/V) 1.e-006
☑ E On

Reposition Probe before Run
● End i Ratio (%) 25
○ End i Level (A) 0
Max. Incr (um) 0.5
Withdraw Dist (um).. 50
Quite Time (s) 2

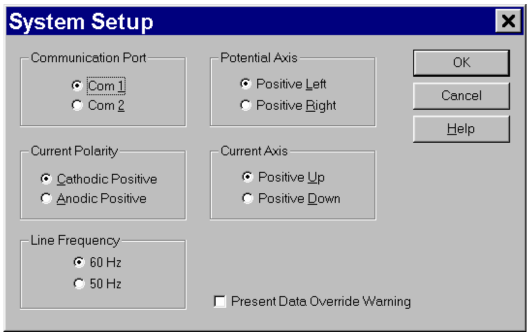
☑ Return to Origin after Run

Probe Travel
X Distance (um) 100
Y Distance (um) 100
Incr. Dist. (um) 1
Incr Time (s) 0.0333
● X Axis as Long Direction
○ Y Axis as Long Direction

Signal Recording Mode
● Amperometry
○ Potentiometry

Data Sampling Scheme
● Single Direction
○ Both Directions

Experimental parameter dialog box for SECM.



Communication Port
● Com 1
○ Com 2

Potential Axis
● Positive Left
○ Positive Right

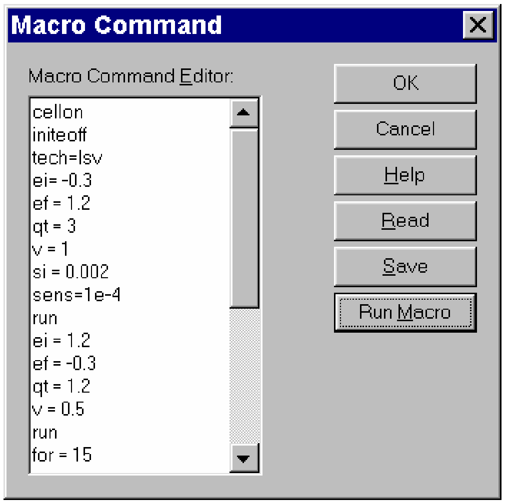
Current Polarity
● Cathodic Positive
○ Anodic Positive

Current Axis
● Positive Up
○ Positive Down

Line Frequency
● 60 Hz
○ 50 Hz

☐ Present Data Override Warning

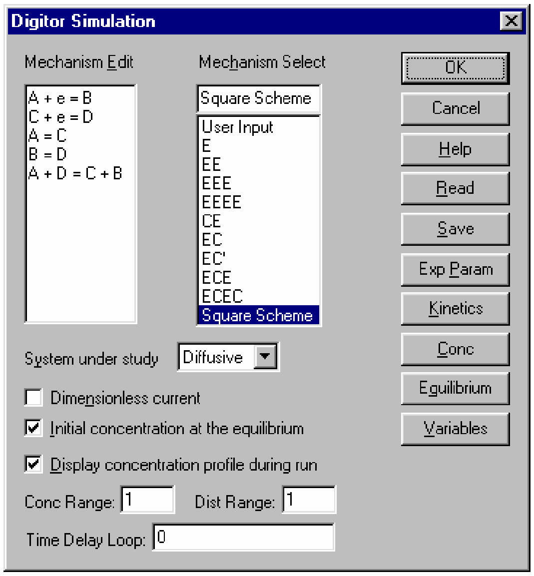
System setup allows any convention of current and potential polarity.



Macro Command Editor:

```
cellon
initeoff
tech=lsv
ei= -0.3
ef = 1.2
qt = 3
v = 1
si = 0.002
sens=1e-4
run
ei = 1.2
ef = -0.3
qt = 1.2
v = 0.5
run
for = 15
```

The Macro command allows a series command to be executed in a sequence..



Mechanism Edit

```
A + e = B
C + e = D
A = C
B = D
A + D = C + B
```

Mechanism Select: Square Scheme

- User Input
- E
- EE
- EEE
- EEEE
- CE
- EC
- EC'
- ECE
- ECEC
- Square Scheme

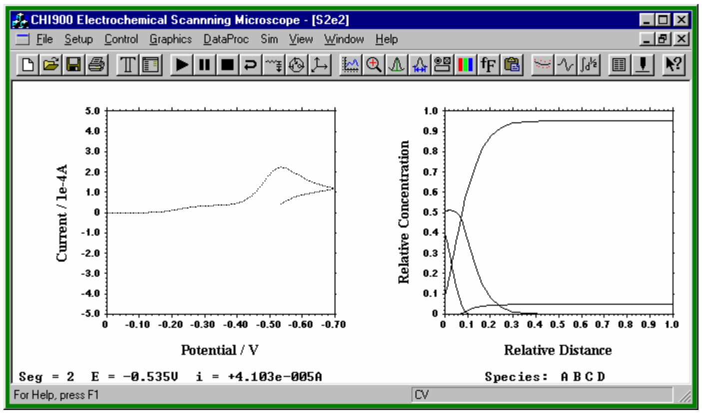
System under study Diffusive

☐ Dimensionless current
☑ Initial concentration at the equilibrium
☑ Display concentration profile during run

Conc Range: 1 Dist Range: 1
Time Delay Loop: 0

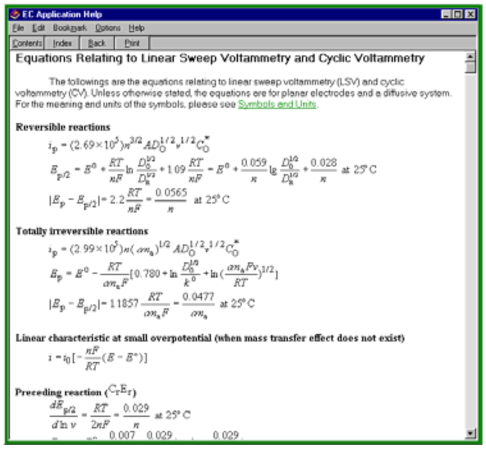
User interface for digital simulator.

Highlights



```
Seg = 2   E = -0.535V   i = +4.103e-005A          Species:  A B C D
```

Digital Simulator displays both current response and the concentration profiles of different species during the simulation process.



Equations Relating to Linear Sweep Voltammetry and Cyclic Voltammetry

The followings are the equations relating to linear sweep voltammetry (LSV) and cyclic voltammetry (CV). Unless otherwise stated, the equations are for planer electrodes and a diffusive system. For the meaning and units of the symbols, please see Symbols and Units.

Reversible reactions

$$i_p = (2.69\times10^5)n^{3/2}AD_O^{1/2}v^{1/2}C_O^*$$

$$E_{p/2} = E^0 + \frac{RT}{nF}\ln\frac{D_O^{1/2}}{D_R^{1/2}} + 1.09\frac{RT}{nF} = E^0 + \frac{0.059}{n}\lg\frac{D_O^{1/2}}{D_R^{1/2}} + \frac{0.028}{n} \text{ at } 25^\circ\text{C}$$

$$|E_p - E_{p/2}| = 2.2\frac{RT}{nF} = \frac{0.0565}{n} \text{ at } 25^\circ\text{C}$$

Totally irreversible reactions

$$i_p = (2.99\times10^5)n(\alpha n_a)^{1/2}AD_O^{1/2}v^{1/2}C_O^*$$

$$E_p = E^0 - \frac{RT}{\alpha n_a F}[0.780 + \ln\frac{D_O^{1/2}}{k^0} + \ln(\frac{\alpha n_a Fv}{RT})^{1/2}]$$

$$|E_p - E_{p/2}| = 1.1857\frac{RT}{\alpha n_a F} = \frac{0.0477}{\alpha n_a} \text{ at } 25^\circ\text{C}$$

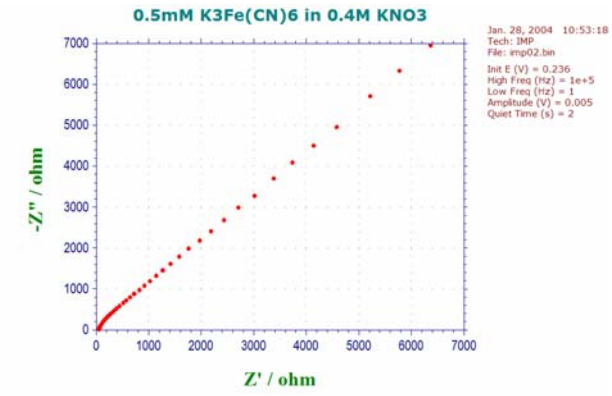
Linear characteristic at small overpotential (when mass transfer effect does not exist)

$$i = i_0[-\frac{nF}{RT}(E - E^\circ)]$$

Preceding reaction (C_rE_r)

$$\frac{dE_{p/2}}{d\ln v} = \frac{RT}{2nF} = \frac{0.029}{n} \text{ at } 25^\circ\text{C}$$

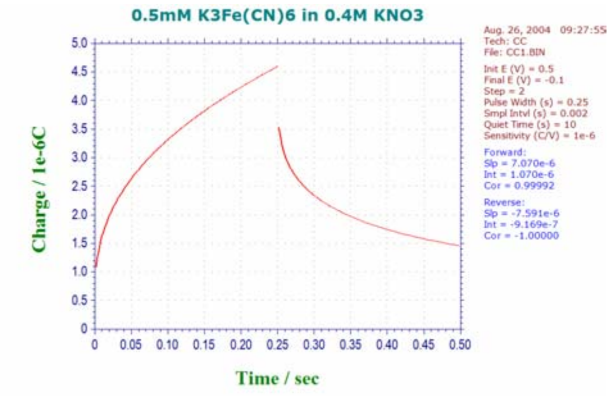
Equations relating to various techniques can be viewed on line.



Jan. 28, 2004 10:53:18
Tech: IMP
File: imp02.bin

Init E (V) = 0.236
High Freq (Hz) = 1e+5
Low Freq (Hz) = 1
Amplitude (V) = 0.005
Quiet Time (s) = 2

Impedance data plot.



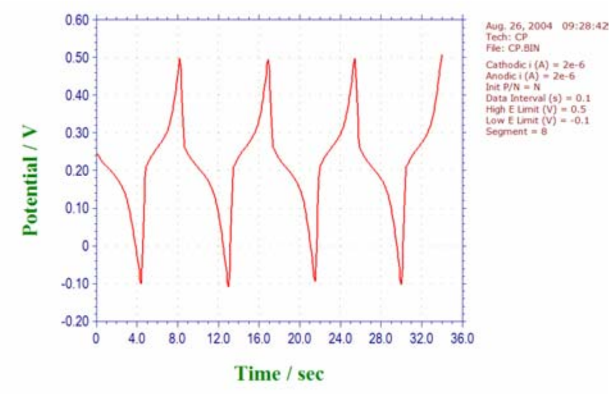
Aug. 26, 2004 09:27:55
Tech: CC
File: CC1.BIN

Init E (V) = 0.5
Final E (V) = -0.1
Step = 2
Pulse Width (s) = 0.25
Smpl Intvl (s) = 0.002
Quiet Time (s) = 10
Sensitivity (C/V) = 1e-6

Forward:
Slp = 7.070e-6
Int = 1.070e-6
Cor = 0.99992

Reverse:
Slp = -7.591e-6
Int = -9.169e-7
Cor = -1.00000

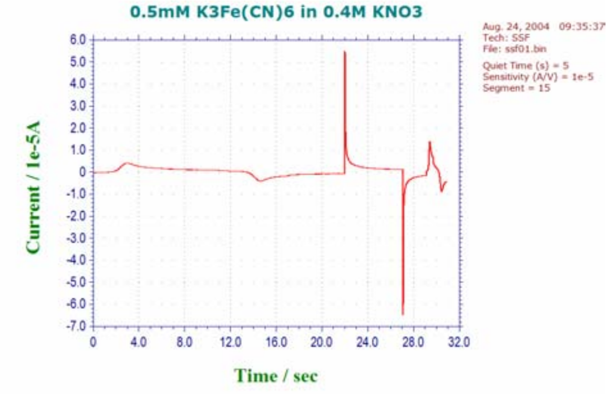
Chronocoulometric data.



Aug. 26, 2004 09:28:42
Tech: CP
File: CP.BIN

Cathodic i (A) = 2e-6
Anodic i (A) = 2e-6
Init P/N = N
Data Interval (s) = 0.1
High E Limit (V) = 0.5
Low E Limit (V) = -0.1
Segment = 8

Multi-cycle chronopotentiometric data.



Aug. 24, 2004 09:35:37
Tech: SSF
File: ssf01.bin

Quiet Time (s) = 5
Sensitivity (A/V) = 1e-5
Segment = 15

Multi-segment sweep-step functions data..

Accessories

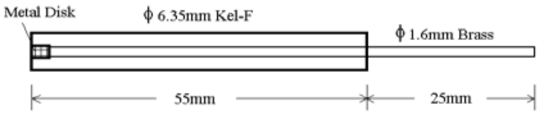
Part No.	Description	Unit
CHI101	2 mm dia. Gold Working Electrode	1
CHI101P	2 mm dia. Gold Working Electrode	3/pk
CHI102	2 mm dia. Platinum Working Electrode	1
CHI102P	2 mm dia. Platinum Working Electrode	3/pk
CHI103	2 mm dia. Silver Working Electrode	1
CHI104	3 mm dia. Glassy Carbon Working Electrode	1
CHI104P	3 mm dia. Glassy Carbon Working Electrode	3/pk
CHI105	12.5 μm dia. Gold Microelectrode	1
CHI105P	12.5 μm dia. Gold Microelectrode	3/pk
CHI106	25 μm dia. Gold Microelectrode	1
CHI106P	25 μm dia. Gold Microelectrode	3/pk
CHI107	10 μm dia. Platinum Microelectrode	1
CHI107P	10 μm dia. Platinum Microelectrode	3/pk
CHI108	25 μm dia. Platinum Microelectrode	1
CHI108P	25 μm dia. Platinum Microelectrode	3/pk
CHI111	Ag/AgCl Reference Electrode	1
CHI111P	Ag/AgCl Reference Electrode	3/pk
CHI112	Non-Aqueous Ag/Ag^+ Reference Electrode [1]	1
CHI112P	Non-Aqueous Ag/Ag^+ Reference Electrode [1]	3/pk
CHI115	Platinum Wire Counter Electrode	1
CHI116	10 μm dia. Platinum SECM Tip	1
CHI116P	10 μm dia. Platinum SECM Tip	3/pk
CHI117	25 μm dia. Platinum SECM Tip	1
CHI117P	25 μm dia. Platinum SECM Tip	3/pk
CHI118	1-5 μm dia. Platinum SECM Tip	3/pk
CHI120	Electrode Polishing Kit [2]	1

Part No.	Description	Unit
CHI125A	Polished, Bounded, Mounded 100A Ti + 1000 A Gold Crystal for EQCM	1
CHI127	EQCM Cell	1
CHI128	Reference Electrode for EQCM Cell	1
CHI129	Pt Wire Counter Electrode for EQCM Cell	1
CHI130	Thin-Layer Flow Cell	1
CHI131	GC Working Electrode for Flow Cell	1
CHI132	Au Working Electrode for Flow Cell	1
CHI133	Pt Working Electrode for Flow Cell	1
CHI134	Reference Electrode for Flow Cell	1
CHI135	25 um Spacer for Flow Cell	4/pk
CHI140A	Spectroelectrochemical Cell	1
CHI150	Calomel Reference Electrode	1
CHI151	Mercury/Mercurous Sulfate Reference Electrode	1
CHI152	Alkaline/Mercurous Oxide Reference Electrode	1
CHI172-Model #	Electrode leads for a particular instrument model number	1
CHI200	Picoamp Booster and Faraday Cage [3]	1
CHI201	Picoamp Booster	1
CHI202	Faraday Cage	1
CHI220	Simple Cell Stand [4]	1
CHI221	Cell Top (including Pt wire counter electrode, not a replacement part for the CHI200 cell stand) [5]	1
CHI222	Glass Cell	1
CHI223	Teflon Cap [5]	1
002047	IDA Gold Electrode	1
002048	IDA Platinum Electrode	1
002049	IDA Carbon Electrode	1
011235	CS-2 Remote Controllable Cell Stand	1
011343	QCM Flow Cell	1
TE100	Printed Electrodes (3-electrodes)	40/pk
SE101	3mm dia. Printed carbon electrode	40/pk

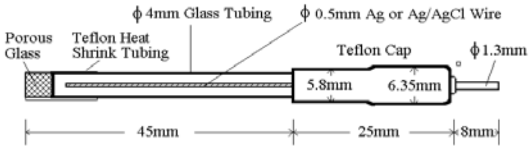
Notes:

1. A Ag^+ solution (typical 10 mM) should be prepared with the supporting electrolyte and $AgNO_3$ (not included). This solution is then filled into the reference electrode compartment using a syringe (not included). The instructions will come with the components.
2. The electrode polishing kit contains 1 bottle of 1.0 micron Alpha alumina powder, 1 bottle of 0.3 micron Alpha alumina powder, 3 bottles of 0.05 micron Gamma alumina powder, 2 glass plates for polishing pads, 5 pieces of 73 mm diameter 1200 grit Carbimet disks (grey in color), 5 pieces of 73 mm diameter Mastertex polishing pads (white in color), and 10 pieces of 73 mm diameter Microcloth polishing pads (brown in color).
3. Picoamp Booster and Faraday Cage allows the current measurement down to 1 pA. It is fully automatic and compatible with Model 6xxC and 7xxC series instruments. However, it only works for the primary channel of the 7xxC series .
4. Made of stainless steel and Teflon (see figure below). ***Not*** remote-controllable. Four glass cells are included.
5. Not a replacement part for the CHI220 Cell Stand.

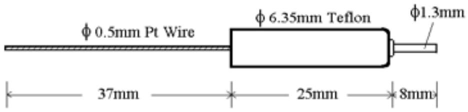
Accessories and Instrument Chassis



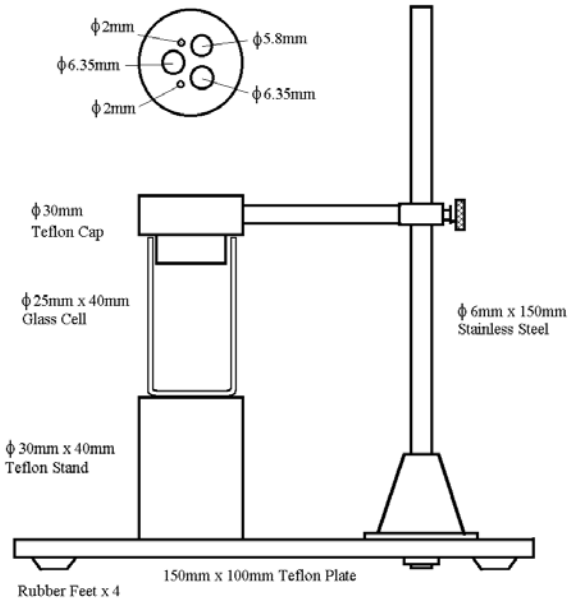
CHI101/102/103/104 Working Electrodes



CHI111/112 Reference Electrodes

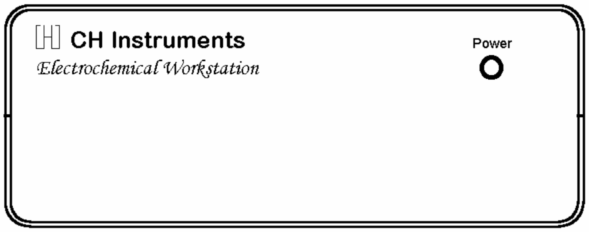


CHI115 Pt Wire Counter Electrode

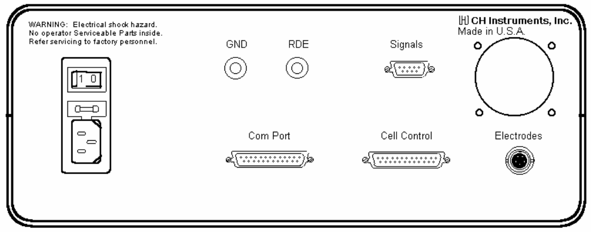


CHI220 Cell Stand

CHI130 Thin-Layer Flow Cell



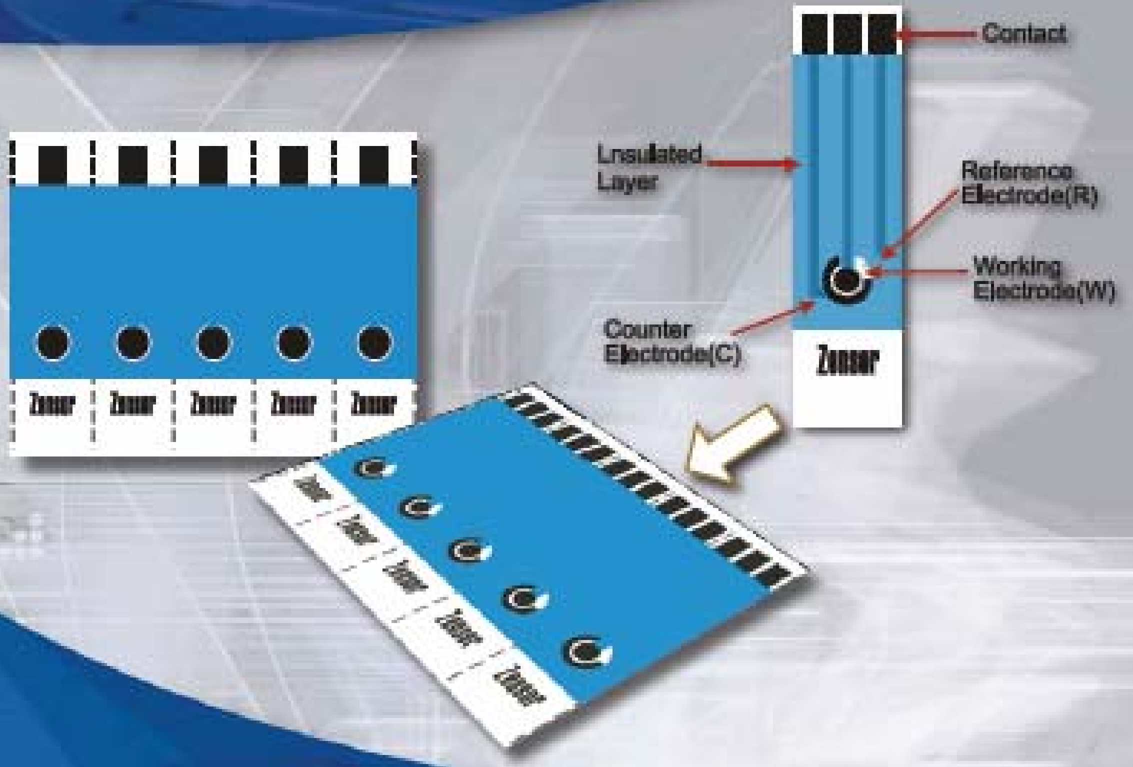
Front View



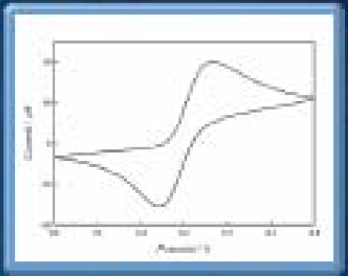
Rear View

Front and rear view of the Model 400A, 600B, 700B, 800B, 900B, 1000, and 1100A series instruments

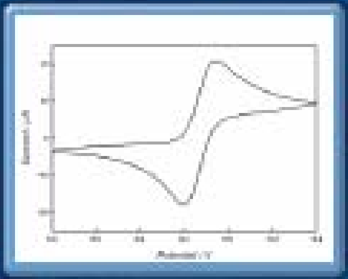
Screen-Printed Electrode

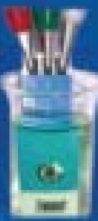


Glassy Carbon Electrode



Screen-Printed Electrode



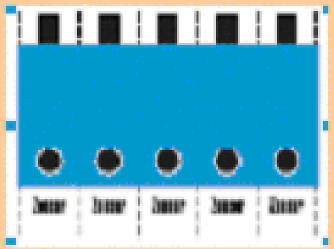
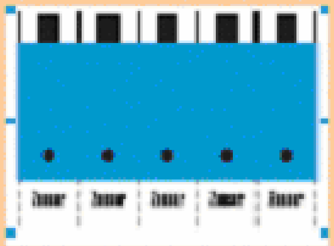
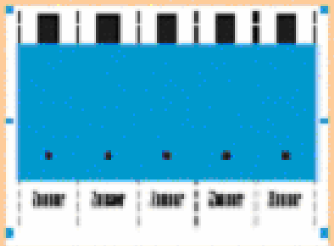


- Disposable/Reusable
- Extendable Applicability after Preanodization
- Needless of Polishing Electrode
- Easy for Chemical Modification
- Superior in Combinatorial Study
- Low Cost
- In-Built Three-Electrode Configuration

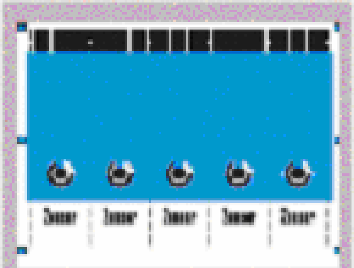
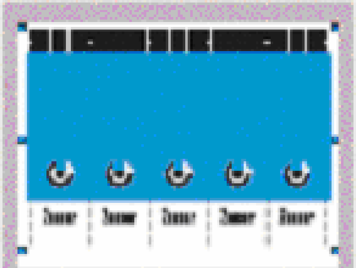
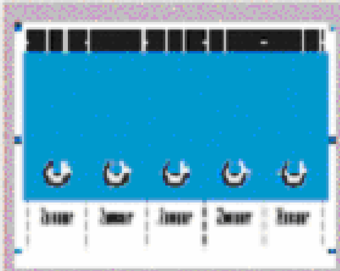
Screen-Printed Electrodes

Screen-Printed Electrode

Single Working Electrode Configuration

NO.#	SE100	SE101	SE102
Working Diameter/ Area	5 mm / 0.196 cm^2	3 mm / 0.071 cm^2	1.5 mm / 0.018 cm^2
Picture			

In-Built Three-Electrode Configuration

NO.#	TE100	TE101	TE102
Working Diameter/ Area	3 mm / 0.071 cm^2	2 mm / 0.031 cm^2	1.5 mm / 0.018 cm^2
Picture			

CH Instruments
http://www.chinstruments.com/

Bridge on Colorado River,
Austin, Texas

Our office building in
Austin, Texas.

Warranty:

One-year warranty on electronic parts and labour. 90-day warranty on mechanical parts.

Demo Software:

Free demo software available upon request.

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