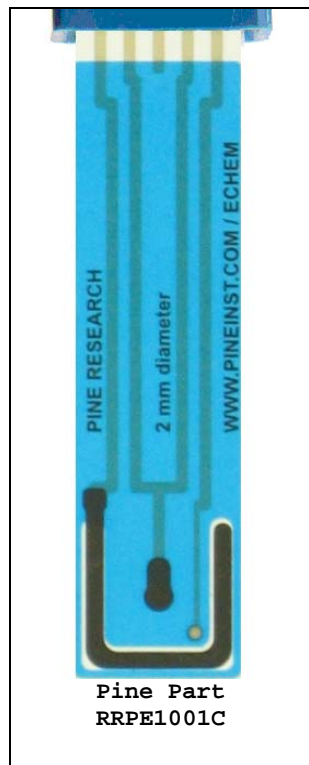


### FOR USE IN AQUEOUS SOLUTIONS ONLY



#### Screen Printed Carbon Electrodes

Conductive carbon inks have been employed for many years<sup>(1)</sup> in a variety of biosensor applications—most notably in disposable blood glucose detectors. A typical strategy involves placing an enzyme on the working electrode (either by coating the electrode or pre-mixing the ink with the enzyme) in order to enhance the electrochemical response for a given analyte. For example, most blood glucose detectors make use of a modified form of *glucose oxidase* on the working electrode, and this redox enzyme mediates the oxidation of glucose, thereby boosting its electrochemical signal.

The surface of a screen printed carbon electrode is not nearly as pristine as more traditional electrodes fashioned from glassy carbon or pyrolytic graphite. Screen printed carbon surfaces are rough (making an exact determination of electrode area difficult), the proprietary binder compounds found in the carbon ink may introduce stray (but small) features in voltammograms, and the heterogeneous kinetics at these electrode surfaces are a bit sluggish. None of these problems are of great concern when using these electrodes for academic teaching purposes; however, the electrochemical purist is likely to find fault when comparing screen printed carbon to more expensive glassy carbon electrodes.

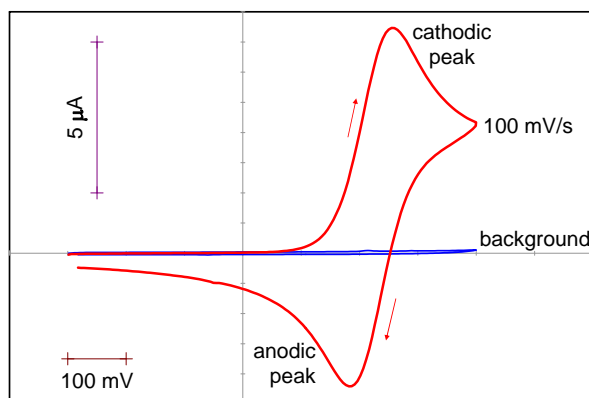
#### Screen Printed Silver-Chloride Reference Electrodes

The demand for commercial blood glucose detectors has also driven the development silver/silver chloride inks suitable for printing stable reference electrodes. Printed AgCl reference electrodes are most stable when used in an aqueous solution containing chloride ions, and in an academic instructional context, it is an easy matter to make sure that students work in a chloride-based electrolyte solution (such as 1.0M KCl).

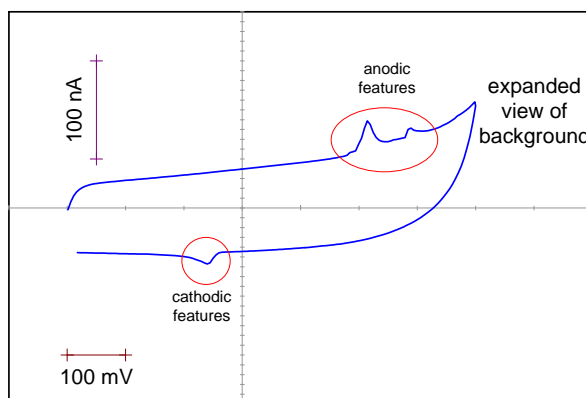
When using a printed Ag/AgCl reference electrode, it is important to allow the electrode to equilibrate with the test solution for at least 60 seconds before performing an experiment.

#### Example Voltammograms

The printed carbon electrode shown in the above photograph has been used to perform cyclic voltammetry in a solution containing a popular electroactive ion, rutheniumhexamine. This ion exhibits a well-behaved, reversible redox couple at about -0.44 volts versus the Ag/AgCl reference electrode printed on the same substrate.



Voltammogram of 10mM  $\text{Ru}(\text{NH}_3)_6^{3+}$  in 0.1M KCl

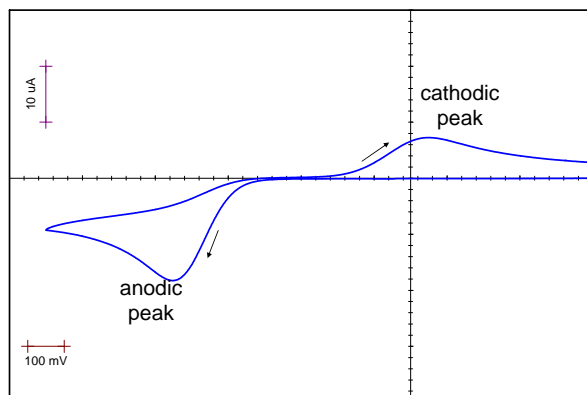


Background Voltammogram in 0.1M KCl

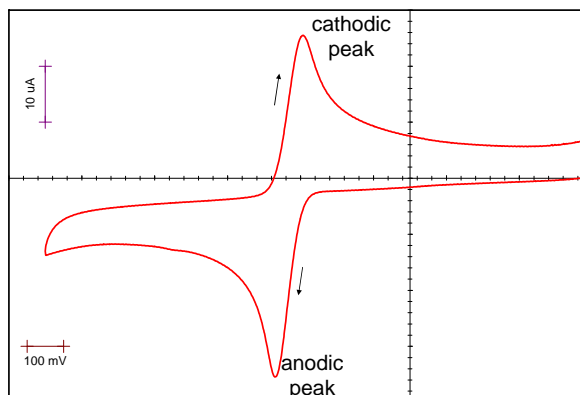
The electrochemical behavior the rutheniumhexamine ion at the screen printed carbon electrode is well suited for teaching cyclic voltammetry. Note that a background scan reveals a few small features on both the anodic and cathodic scans which are characteristic of the carbon ink itself. In the presence of a reasonable concentration of the target analyte (*i.e.*, 10 mM), these background features tend to be dwarfed by the voltammogram of interest.

## Activation of Carbon Surface

Many other popular electroactive ions (including ferricyanide, dopamine, and ascorbic acid) are not as well-suited for teaching purposes because sluggish heterogeneous kinetics tend to distort the shape of the voltammogram significantly. For example, the peak splitting on a cyclic voltammogram of ferricyanide may be as large as 400 mV (much greater than the expected 59 mV). To address this common problem with carbon electrodes, researchers have, over the years, proposed many recipes for activating the carbon electrode surface. These include electrochemical cycling<sup>(2)</sup> the potential to extreme anodic potentials, heat treatment,<sup>(3)</sup> and oxygen plasma<sup>(4)</sup> treatment. An example of the improvement that can be achieved using oxygen plasma cleaning is shown below, where the voltammogram for dopamine is significantly better after treatment than before treatment.



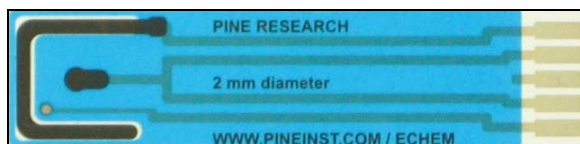
10mM dopamine in 0.1M KCl (before plasma)



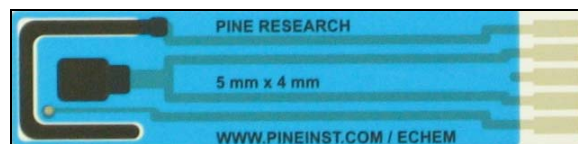
10mM dopamine in 0.1M KCl (after plasma)

## Available Electrode Patterns

The following printed electrode patterns are available from Pine Research Instrumentation. Both patterns share the same Ag/AgCl reference electrode (thin grey line) and carbon counter electrode (thick black line) geometry. The two patterns differ with respect to the working electrode shape (disk or rectangle). Overall card dimensions are 15 x 61 x 0.36 mm.



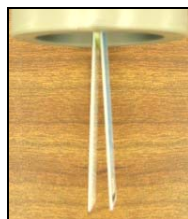
**RRPE1001C** 2.0 mm OD carbon disk  
recessed in insulating layer



**RRPE1002C** 5x4 mm carbon rectangle  
recessed in insulating layer

The disk shaped electrode is suitable for routine use in an educational setting. The rectangular working electrodes offer a larger area to those researchers wishing to drop coat an appreciable amount of enzyme on to the working electrode. A blue insulating layer surrounds and also coats the extreme outside perimeter of the carbon working electrode. The thickness of the carbon, silver, and insulating layers is typically 7 to 13  $\mu\text{m}$ .

## Mounting Screen Printed Electrodes



Screen printed electrodes are thin enough (0.36 mm) that two SPE cards can (and should) be mounted in the cell cap at the same time. This configuration is useful when one card is to be used for a “control” or background scan while the other card (presumably modified with an enzyme layer) is to be used as the sensor.

To connect to a particular card, connect the mini-USB cable to the port which is on the left when facing the card in question (as shown in photo).



## References

- (1) JP Hart, A Crew, E Crouch, KC Honeychurch and RM Pemberton, *Some Recent Designs and Developments of Screen-Printed Carbon Electrochemical Sensors/Biosensors for Biomedical, Environmental, and Industrial Analyses*, Anal. Lett. 37 (2004) 789.
- (2) WJ Blaedel and RA Jenkins, Anal. Chem. 46 (1974) 1952; RC Engstrom, Anal. Chem. 54 (1982) 2310.
- (3) GW Hance, T Kuwana Anal. Chem. 59 (1987) 131; DT Fagan, IF Hu and T Kuwana, Anal. Chem. 57 (1985) 2759.
- (4) JF Evans and T Kuwana, Anal. Chem. 51 (1979) 358; JL Anderson and T Kuwana, Anal. Chem. 49 (1977) 1632; EJ Kim, T Haruyama, Y Yanagida, E Kobatake and M Aizawa, Anal. Chim. Acta. 394 (1999) 225.