

Nano Electrode Arrays

In-situ identification and quantification of chemicals in water

Overview

Nano electrodes and templates will provide the use of functionalized nanoelectrodes as sensor-array system for rapid, noncontaminating field analysis. An array of suitably functionalized nanoelectrodes could be incorporated into a small, integrated sensor system that can identify many species rapidly and simultaneously under field conditions without chemical addition with signal to noise ratios (S/N) up to 10³-fold greater than conventional electrodes.

Microelectrodes have advantages over conventional planar electrodes. Limiting current of Macroplanar electrode: $i_d = n F D C (1/(\pi D t)^{1/2} + 1/r_0)$ "Microelectrode" if size $< (\pi D t)^{1/2}$ for timescale of measurement, typically $< 50 \mu\text{m}$. For $r_0 \ll (D t)^{1/2}$, i.e., diffusion layer larger than electrode, current is time-independent, i.e., steady-state condition.

Conditions on Microelectrodes for which spherical diffusion can be applied.

In terms of the ratio between the Nernst diffusion layer thickness δ , $\delta = (\pi D t)^{1/2}$, and the radius of the electrode or by the δ and the distance between two electrodes, L .

Case 1 $\delta/r < 0.3$ (semi-infinite linear diffusion)

$$i_d = [n F D C^0 / (\pi D t)^{1/2}] (r/L)^2 \quad \text{Time dependent}$$

Case 2 $\delta/r > 3$ but $\delta/L < 0.3$ (No influence from nearby electrode)

$$i_d = (n F D C^0 / r) (r/L)^2 \quad \text{Independent of time}$$

Case 3 $\delta/r > 3$ (complete overlap)

$$i_d = (n F D C^0 / (\pi D t)^{1/2}) \quad \text{Time dependent}$$

For a given fast transient, Case 3 will yield the highest diffusion-limited current density. Although, for Case 3 to hold $r \ll \delta \ll L$

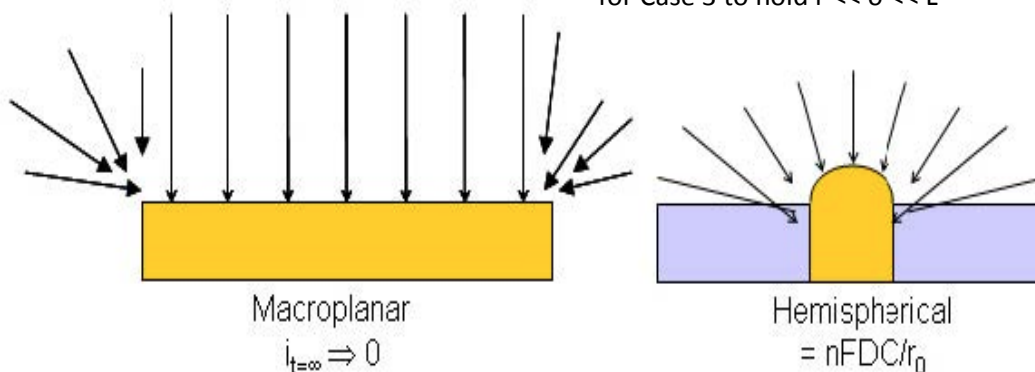


Figure 1.

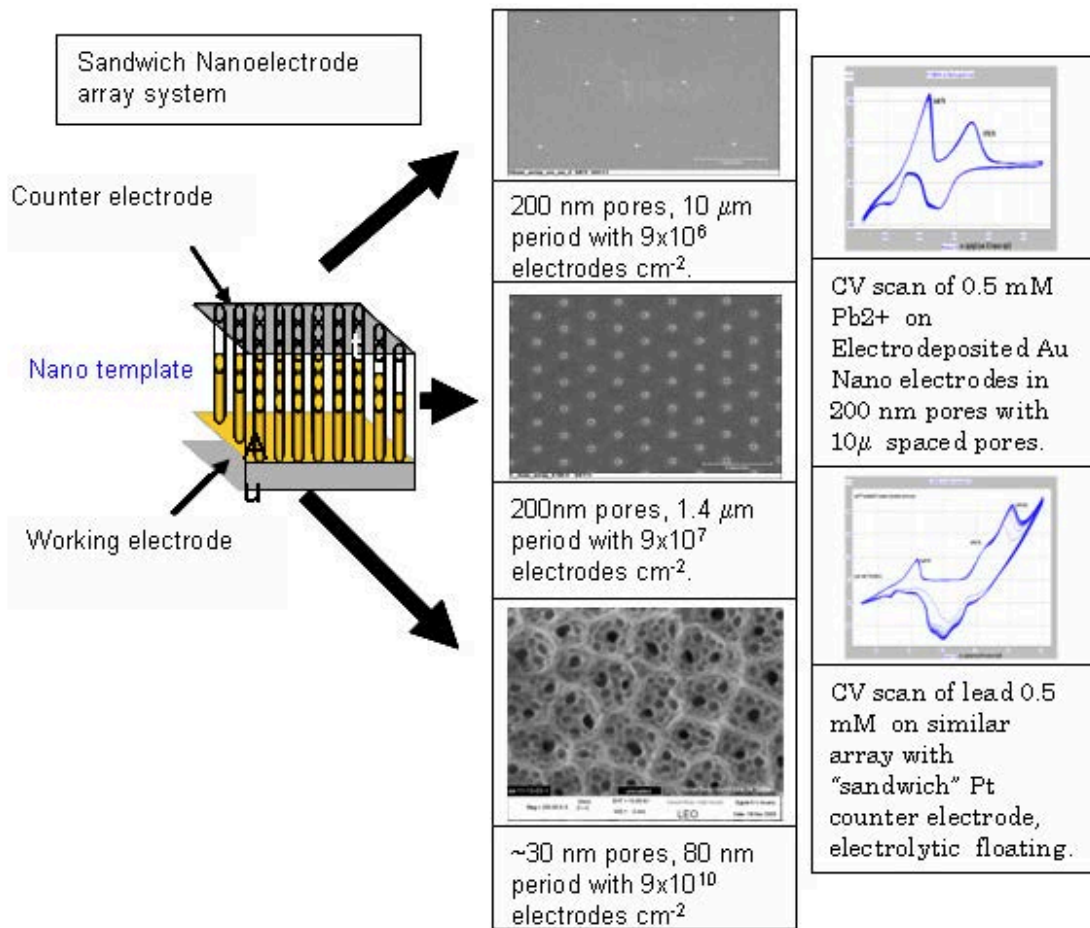


Figure 2.

For nanoelectrodes arrays with $r = 100$ nm detecting a 1 nM analyte concentration.

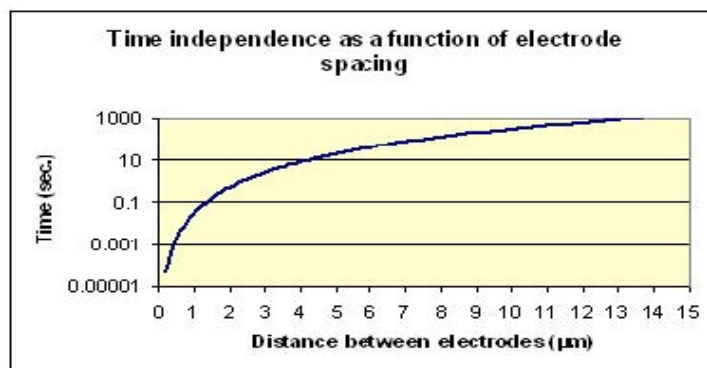


Figure 3.

The 10 μm -array and 1.4 μm -array are 200 nm pores space 10 and 1.4 microns respectively. These first two microphotographs are copper substrates with evaporated nickel and gold followed by a layer of PMMA. The holes are generated by laser lithography to give the above pattern of pores. Then a counter electrode of Platinum is deposited on top of the PMMA. Then any metal connections between the Au and Pt are cleared. After which periodic pulse electrodeposited processes (pore filling) are used to create a layer of nano electrodes using either Au or Ag.

Arrays spaced on a 10 micron period yield ~9 million electrodes /cm². Ones spaced 1.4 microns apart yield ~90 million electrodes /cm². The third electrode design is the anodized aluminum templates with randomly deposited gold electrodes, these are 30-50 nm diameters spaced any where between 50 -500 nm from each other. This array is being optimized at University of New Mexico.

The following pictures are of the sampling head that holds these array and the water sample (another design is in the process that holds separate counter and working electrodes). This device makes the necessary connections to the "Top" of the counter electrode, and "bottom" of the working (nanoelectrode arrays). The banana clips at the bottom are designed to connect into our small Potentiostat.

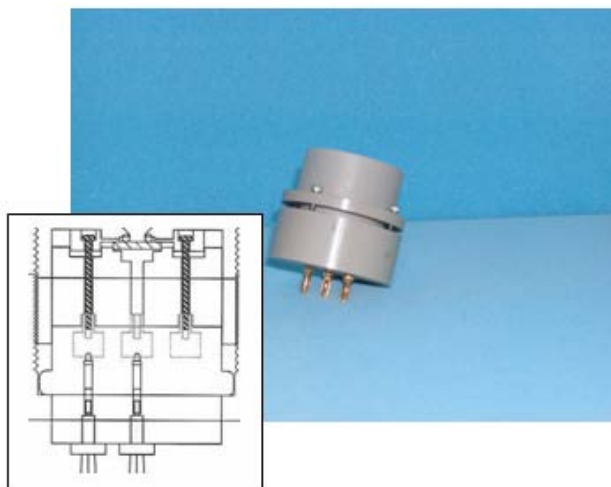


Figure 4.

The last photo shows the sampling head connected to a blue box which serves as a means to connect the sampling head a commercial Potentiostat.



Figure 5.

For additional information or questions, please email us at BioNano@sandia.gov.