1st WORKSHOP ON NANOBIOSENSORS FOR WATER MONITORING

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Demonstration: Lab-on-chips fabrication

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The last years, the use of microfluidic platforms for electroanalysis has increased in a remarkable way. This can be explained by the fact that microdevices work under hydrodynamic conditions which enhance mass transport toward the detector surface resulting in an increase of the obtained current and sensitivity compared to the classical static measurement modes. Furthermore simple and miniaturized microplatforms are especially interesting for their low consumption of sample and reagent, smaller times of analysis, increased reliability and repeatability, portability and the integration of conventional analytical techniques.

Soft lithography can be viewed as a complementary extension of photolithography. Originally, standard photolithography was mainly developed to deal with semiconductors used in the microelectronics industry. Similarly, photolithography is inherently well adapted to process photoresists. Thereby, most microfluidic devices still rely on photolithography for fabricating SU-8 masters.

In the demonstration, we will see how to produce PDMS microdevice from a SU-8 master from the molding of this elastomer to the sealing of the final device.

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Demonstration: Ink-Jet Printed Electrodes Fabrication

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Inkjet printing technology is a direct writing technique used for office printing and which becomes a serious candidate to produce flexible and low-cost electronics. It is frequently used for the fabrication of organic electronic devices and tends also to be used to produce complete electrochemical biosensors.

The advantages of inkjet technology are its low cost, simplicity, high resolution, speed, reproducibility, flexibility, noncontact, and low amount of waste generated. A huge variety of substrates (glass, plastics, ceramics, paper) and inks can be used. Different kind of inks can be deposited by inkjet from metallic nanoparticles solutions (silver, copper, gold) to carbon-based solution (carbon no-natubes, graphene) and conducting polymer (PEDOT...).

A drop of ink is ejected from a nozzle by thermal or piezzo actuation and falls onto a substrate creating a design. Depending of the ink/substrate interaction reliable direct patterning with line and space dimensions in the 10 to 100 µm range can be produced. The thickness of these electrodes is in the range of hundreds of nanometer.

Once the pattern has been printed, the ink should be sintered in order to join the particles between them and to reach good conductivity. This process can be performed thermally just by heating the sample with a hotplate or a hoven, or locally by infrared, or chemically.

This printing technique will be presented in this demonstration using a commercial silver ink as proof of concept.

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Demonstration: Electrocatalytic nanoparticle-based detection systems

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In the last decade metal nanoparticles have been extensively investigated with the aim to enhance the sensitivity of detection techniques and sensing platforms. Nanoparticles in general have special surface characteristics for their use in catalytic processes, mainly due to the proportion of atoms at the surface of small nanoparticles that can be much higher than in the bulk state and results in a high surface to volume ratio.

In the wide range of nanomaterials, gold nanoparticles (AuNPs) grab a lot of attention once they have been applied in innumerous studies. Bulk gold is considered an inert material towards redox processes due to the repulsion between the filled d-states of gold and molecular orbitals of molecules like O_2 or H_2, but small AuNPs show a different behaviour since contain a large number of coordinative unsaturated atoms in edge positions. The quantum effects related with shape and size of AuNPs originated by d band electrons of the surface which are shifted towards the Fermi-level, promote the ability to interact in electrocatalytic reactions. All these features allow the occurrence of adsorption phenomena with catalytic properties, and places AuNPs in the palette of materials with potential interest to be used in electrocatalyzed reactions. Furthermore they exhibit good biological compatibility and excellent conductivity that highlights them for biosensor applications.

In this demonstration we will make use of the advantageous characteristics of screen-printed carbon electrodes (SPCEs) in terms of low cost, miniaturization possibilities, low sample consuming and wide working potential range in the Hydrogen Evolution Reaction (HER) in presence of AuNPs. 20 nm-sized AuNPs detection will be carried out taking advantage of the chronoamperometric mode. Chronoamperograms will be obtained by placing a mixture of 25 µL of 2 M HCl and 25 µL of the AuNP solution (3 nM) onto the surface of the electrodes and, subsequently, holding the working electrode at a potential of +1.35 V for 1 min and then a negative potential of -1.00 V for 1 min. The intensity of the cathodic current recorded in chronoamperometric mode during the stage of hydrogen ion electroreduction is related to the presence of AuNPs on the surface of the SPCE. The absolute value of the current at 1 min (response time of the sensor) is chosen as the analytical signal and used for quantification of the AuNPs. A background (blank curve) will be recorded by placing 50 µL of a 1 M HCl solution onto the electrode surface and following the same electrochemical protocol.

Finally, the same procedure will be applied for the detection of a model protein (human IgG) in a sandwich immunoassay (previously performed in the lab) using magnetic bead platforms (2.8 μm; Dynabeads®) and AuNP labels.

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Demonstration: A microarray platform

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Antibody microarrays is a technology that enables to quantify target proteins into a multiplexed assay. These analytical devices possess four distinct characteristics: (a) microscopic target elements or spots, (b) planar substrates (printing surface), (c) rows and columns of elements and (d) specific binding between microarray target elements on the substrate (capture antibodies for antibody micorarrays) and probe molecules in solution (analytes). The more antibodies are spotted the more analytes are captured after assay steps.

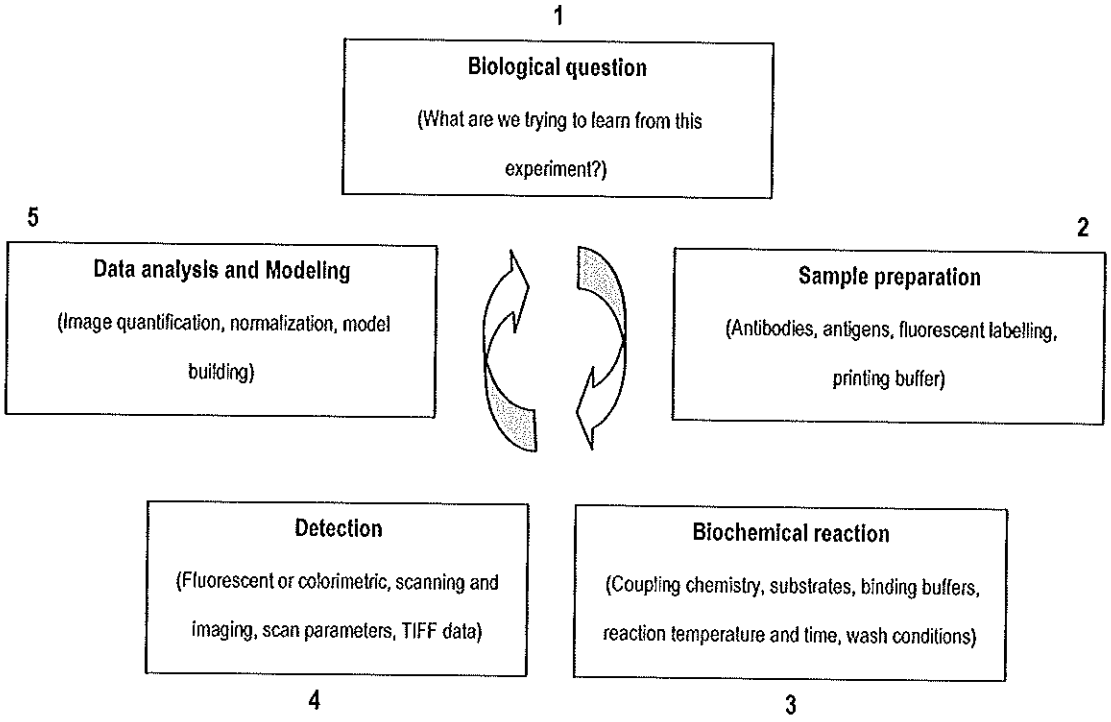

Figure 1. Protein Microarray experimental cycle. Displayed are the five stops of protein microarray experimentation: step 1, biological question; step2, sample preparation; step 3, biochemical reaction; step 4, detection; and step 5, data analysis and modeling. (Schena, 2005)

Protein microarrays use the same fundamental concepts as DNA microarrays. The five-step assay cycle (biological question, sample preparation, biochemical reaction, detection and data analysis and modelling) is identical in both types of assay (Figure 1). Protein microarrays extensively leverage the traditional tools of biochemistry and molecular biology including: cloning and expression of recombinant proteins, monoclonal and polyclonal antibody production, direct and indirect labelling strategies, and the principles of fluorescence and colorimetric detection. Data analysis and modelling is similar for DNA microarrays and protein microarrays. Perhaps the most important difference between DNA and protein

microarrays pertains to the structure of the target and probe molecules. DNA and most other nucleic acids impart their function mainly via the information contained in their primary nucleotide sequences, whereas proteins are intricate globular macromolecules with myriad structures, and these structural elements are essential to protein function (regulation, defence, transport, catalyzation, etc.)

As a simple demonstration of this technology, we will perform a quick experiment to report a model protein (Human IgG) which has been previously micro-patterned in a microarray-fashion (spots of ca. 150 µm). The spotted IgG (at ~0.5 mg/mL) is biotinylated, as consequence, it can be easily reported using an organic dye conjugated to streptavidin (e.g. streptavidin-Alexa 647). Starting from 0.6 µg/mL, several dilutions of this organic dye will be prepared (0.6, 0.3, 0.15, 0.07, 0.03, 0.01 µg/mL) and incubated (100 µL/well, during 8 minutes) onto the microarray slides so as to obtain a gradient of fluorescent signals. The slides will be washed (using PBS supplemented with Tween 20 at 0.05%), dried (using a stream of nitrogen) and finally scanned (through a microarray scanner, excitation wavelength 630 nm, emission wavelength ~670 nm) to obtain microarray images.

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