NANOPATTERNING USING THE BIOFORCE NANOENABLER

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Abstract. This paper discusses the opportunities, offered by novel nanopatterning facilities, namely, BioForce NanoeNabler™ (NeN), in the area of sensors development, with the focus on microsensor arrays for biological, environmental and medical fields. The NeN can deliver attolitre to picolitre volumes of liquid, such as small molecules, biomolecules, including proteins and nucleic acids, nanoparticles, reactive solutions and so forth, with a high degree of spatial accuracy. It is envisaged that the reduction in the sensors size would result in their new advanced functionalities.

Keywords: BioForce NanoeNabler™; sensors arrays; nanopatterning; microdevices; point-of-care diagnostics

1. Introduction

Nanostructuring surfaces in order to improve the quality of determinations, in terms of detection limit and signal-to-noise ratio, had received a great attention in the last years 1-3. The possibility to routinely pattern surfaces on the micron- and submicron spatial scales with biomaterials opens the door for a development of a vast spectrum of ultraminiaturized bioanalytical tests and devices, with special focus on point-of-care diagnostics. For example, the work is ongoing towards creation of a diagnostic biochip that uses just a few cells of blood for critical biomedical analysis4.

The pH sensor has many uses in chemistry, biology, environmental monitoring, especially water quality control and so forth. Advances in semiconductor sensor technology, medical diagnostics and health care needs boosted a rapid research into miniaturized pH sensors, which can be used as

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well for in-vivo diagnostics. This paper reports on a novel nanopatterning technology offered by BioForce NanoeNabler™, which is tested for developing various sensors, including pH and bacteria, for applications in the biological, environmental and medical fields. The NanoeNabler™ can deliver attoliter to picoliter volumes of liquid with a high degree of spatial accuracy.

The operation of the sensing elements is based on the properties of polymers, which exhibit a change in their electrical characteristics (such as conductivity, potential or capacitance), on exposure to solutions with different concentrations of pH value. A number of different polymers are being used to form the sensor arrays (fabricated using novel technology offered by BioForce NanoeNabler™), with each array element having unique selectivity and sensitivity properties. The strategy of simultaneous measurement of a number of sensor arrays relies on the application of pattern recognition techniques, similar to the one in e-nose systems.

2. Applications

Numerous applications benefit from the micro/nano patterning using BioForce NanoeNabler™, some examples are listed below:

- The first category of the applications deals with the development of molecular detection devices, usually to detect protein biomarkers, nucleic acids or pathogens. They often have some kind of sensor, which needs to be functionalized by adding a small affinity capture domain, such as antibody or single stranded DNA. These sensors are sometimes couples with microfluidics for sample handling to create lab-on-chip devices.

- The second category of applications is oriented more towards studying single cells and creating bioassays for extremely small volumes. These applications can provide insight for the researchers working in drug discovery and diagnostics. The most popular application from this group includes patterning molecules onto the surfaces that can subsequently be used to study cellular interactions with the patterned features.

- The third category of NeN applications involves patterning non-biological materials onto surfaces to create physical structures. The authors of this paper are with the Micro Electronics and Semiconductor Research Centre in the University of Limerick, Ireland and are working on a number of projects, mainly oriented towards shrinking previously developed sensors system to the nanoscale level.

For example, a nanotechnology-based sensors system is being developed to detect and monitor the quality of food. Attention is focused on one type of
bacteria group, namely the Bacillus cereus group, which is commonly found in liquid, milk powder and mixed food products. An array of sensors is used to achieve more accurate reading results. Material properties of various formulations are the key parameter to allow for fast sampling rates, high discrimination and fast recovery times and so forth. Devices exhibit a dynamic resistive or capacitive response as the mechanism through which bacteria are identified. The prototype of this system is illustrated in Figure 1.

Figure 1. A prototype of the nanotechnology-based sensors system for the quality of food monitoring.

There are a number of parameters that have to be considered when using this novel nanopatterning technology. Following substrates were tested: BioForce Sindex™ chip (Si coated with Au), alumina, glass and transparent polymer substrate. The materials were back loaded onto a Surface Patterning Tool (SPT) via hand pipetting. Material-substrate interaction is vital and patterning surface should be hydrophilic. This was achieved by UV-ozone surface treatment. Additionally, polymer/solvent composition should be adjusted to allow uniform patterning.

Fig. 2 presents optical image of 4x4 array consisting of 1-2.5 μm spots distanced by 5 μm. These are printed on a BioForce Sindex™ chip; individual silicon pads measure 100 μm x 100 μm. There is a laser-based force feedback system to ensure reproducible printing. Fig. 3 depicts an image of “University of Limerick” logo, printed in an identical manner, with 1-2.5 μm spots distanced at 5 μm. Fig. 4a and Fig. 4b illustrate the dots and line, respectively, patterned using pH sensitive polymer solution that forms a basis for miniaturized sensors array system. Printed dots measure ~2.32 μm in diameter.
Figure 2. Optical image of 4x4 array, consisting of 1-2.5 μm spots distanced by 5 μm. These are printed on a BioForce Sindex™ chip; individual silicon pads measure 100 μm x 100 μm.

Figure 3. “University of Limerick” logo, consisting of 1-2.5 μm spots that are distanced at 5 μm.

Figure 4a. Dots of pH sensitive polymer based solution that forms a basis for miniaturized sensors array system. These dots measure ~2.32 μm in diameter and are printed on transparent flexible substrate. Fig. 3b demonstrated ~52 μm long line of polymer material, drawn by the cantilever with 1 μm opening. When printing transparent materials on transparent substrates, the visualization of the printing is impaired and dyes could be used to enhance process visibility.
The BioForce NanoNabler™ system uses a liquid dispensing process via specially designed surface patterning tool (SPT), which is microfabricated cantilever with an integrated passive microfluidic system\(^6,7\). Fluid loaded into the reservoir flows down the microchannel by capillary flow until it reaches the gap at the end of the SPT. During the deposition process, which typically takes less than 100 msec, SPT end touches the surface and a volume of fluid is instantly transferred.

We use an array of sensors to achieve more accurate reading results, where sensors would differ in dimensions and/or material composition. The optimal number of sensors and their parameters will be determined, based on material properties of various formulations. Suitable sensor materials will be formulated for printing as the active film layers, using nano-size precursors. The response of various materials will be optimised by designing and selecting the most effective topologies that allow for fast sampling rates, high discrimination and the best cost-effectiveness.

References

4. www.bioforcenano.com

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