METHODS FOR MICRO- AND NANOSTRUCTURING POLYMER SURFACES DEVELOPED RECENTLY AT THE BARCELONA SCIENCE PARK

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Polymers are increasingly replacing their inorganic counterparts in the production of apparatus for a variety of fields, including biomedical applications. Hence, methods to structure polymers at micro- and nano-dimensions become increasingly important, especially in fields which require interactions with surfaces at these scales. One of the most common polymers used for such applications is poly(methyl methacrylate) (PMMA). PMMA is an amorphous, thermoplastic acrylate polymer with excellent optical properties (including an optical clarity which rivals that of glass). It is commonly used in polymer forming applications due to its highly applicable physical properties. It is also biologically inert. We have succeeded in culturing Osteoblast-like MG63 cells on the surface of non-structured PMMA, proving the biocompatibility of the polymer [1].

It is possible to structure free-standing PMMA at micro- and nano-dimensions using nanoimprint lithography techniques (Figure 1) [2]. Nanoimprint lithography has been performed using an Obducat nanoimprinter (Obducat AB, Sweden). The polymer is placed onto an unstructured piece of the material used to produce the master stamp, positioned on the base of the nanoimprinter. The mould is placed on top of the polymer, with the surface to be embossed in contact with the polymer, and imprinting proceeds in a typical fashion. The use of a freestanding piece of polymer, sandwiched between the mould and the piece of mould material (as opposed to using a polymer film spun down onto the piece of mould material, as is usual when nanoimprinting), means that the imprinted polymer can be used in applications where the polymers inherent transparency is necessary, such as biomedical applications where optical microscopy is required. As the resolution of the NIL is dependent on the mould, the production of features with nanometric dimensions is possible.

Other techniques, based on micro-contact printing (μCP), have been used to pattern the surface of the PMMA with biomolecules to study the effect patterns of these molecules have on cell cultures. We have recently published a method for printing biomolecules in a liquid environment, which overcomes a number of problems that occur in conventional μCP (Figure 2) [3]. The liquid supports the stamp and allows stamps with aspect ratios up to 83 to be used, in air the aspect ratio is limited to ~10. By reducing the dimensions of the structures in the stamp, it is hoped that the liquid-supported contact printing will allow us to print sub-micrometer patterns.

We have also developed a new technique for nano-contact printing (nCP) using thermoplastic poly(methyl methacrylate) (PMMA) stamps. We have used nanoimprint lithography apparatus to produce nanometric structures in PMMA (Figure 5), which we have then inked with biomolecules. The nanoimprint lithography apparatus has been used to assist with the nCP by applying even pressure to the back-side of the stamp at pressures of ~$7x10^5$ Pa. In this way, we have been able to print Streptavidin on PMMA substrates, and prove that Neutravidin printed in the same way remains active (Figure 3) [4]. Lines of Streptavidin have been printed with 150 nm width. This technique has advantages over other nCP techniques currently under development elsewhere, because the high aspect ratios involved mean it is possible to produce stamps with densely packed structures.

References:

[1] C. A. Mills, et. al., *Journal of Biomedical Materials Research A* 76, **2006**, 781-787.

[2] C. A. Mills, et. al., *Journal of Nanoscience and Nanotechnology* (accepted for publication)

[3] F. Bessueille, et. al., *Langmuir* 21, **2005**, 12060-12063.

[4] M. Pla-Roca, et. al., *Langmuir* (submitted)

Figures:

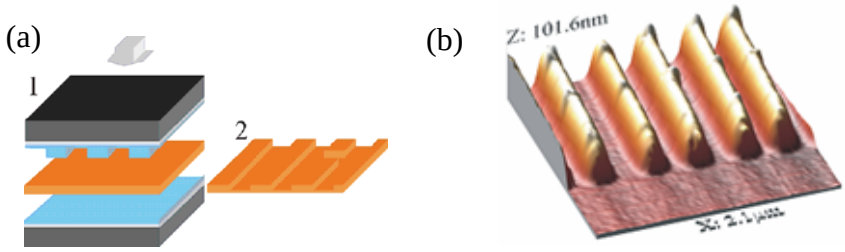

Figure 1. (a) Nanoimprint Lithography technique for embossing micro- and nano-structures in free-standing PMMA sheets. (b) Line structures embossed in PMMA, 100 nm tall, 100 nm wide and 80 μm long.

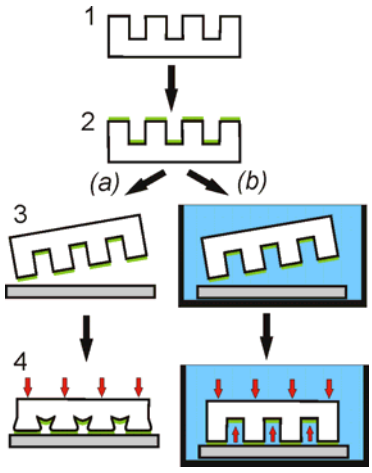

Figure 2. (a) Conventional and (b) "submerged" micro-contact printing techniques. The stamp (1) is inked with the required molecules (2) before being submerged in water (3). The molecules are transferred to the substrate upon contact with the stamp (4) [3].

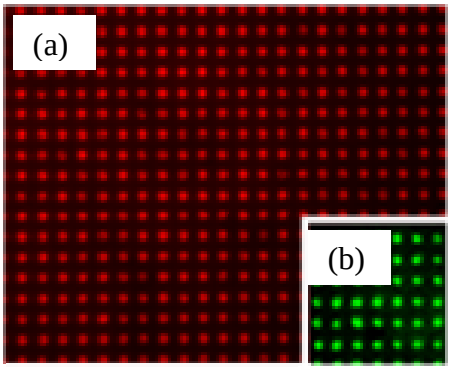

Figure 3. (a) 200x magnification fluorescence image of Texas Red-labelled Streptavidin patterns printed on PMMA. (b) Repetition of the printing using Neutravidin followed by staining with biotin-4-fluorescein shows that the protein remains active after printing [4].