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3D nanofabrication by reverse contact UV nanoimprint lithography

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1. Introduction

In this work, we report our results on a newly developed nanofabrication technique, namely reverse contact UV nanoimprint lithography, which is a combination of nanoimprint lithography and contact printing lithography. This method results in resist pattern transfer without a residual layer thereby rendering unnecessary the etching steps typically needed in the imprint lithography techniques for three-dimensional (3D) patterning. 3D woodpile-like structures were successfully fabricated with this new technique. Potentially this method could be used to build up structures with several layers suitable for example for the fabrication of 3D photonic structures with deterministic defects, diffractive optical elements as well as to fabricate embedded nanochannel devices for biological application.

2. Experiments

The principle of this technique is illustrated in Figure 1. First a thin film of lift-off resist (LOR 1A from Micro Chem) is spin coated on a hybrid stamp with integrated 50 nm Cr protrusions. A photosensitive polymer, e.g. mr-NIL 6000, is spin-coated on the first polymer layer. Subsequently, reverse imprinting is performed onto a flat substrate or on a prepatterned surface. During this step stamp and substrate are heated to a temperature (90 °C) above the glass transition temperature (T_g) of mr-NIL 6000 while UV light is applied for a few seconds (3-5sec). After UV exposure, pressure is applied for a specific time (1min) to assist the adhesion of the two polymer layers. The unexposed polymer areas are rinsed away with acetone leaving behind the negative features of the original stamp. By repeating this procedure 3D structures are fabricated. In this technique it is essential to carry out the UV light exposure before applying pressure to ensure no polymer flow into the underlying protrusions. It is not necessary to treat the hybrid stamp with any anti-adhesive agents, since LOR 1A polymer layer acts as a sacrificial layer protecting the stamp from contamination and increasing the degree of planarization of the second polymer layer. Figure 2a shows SEM images of 800 nm line-width gratings reverse-contact imprinted onto a 1.5 µm period grating. Figure 2b shows that a third layer can be imprinted on top of the previous layer. We have applied this technique to the fabrication of nano-fluidic embedded channels of 500 nm wide and 350 nm high made from the same polymer (Fig. 3). The advantages of using the same UV curable polymer are to allow the nano channels to be uniform (smooth?) for bio and photonic application, having the same surface energy and refractive index, respectively. An additional benefit of using the same UV curable polymer is that, due to its nature (cross-linked polymer), it is mechanically stable at high temperatures. We will discuss the limits of this technique and compare it to competing 3D nanopatterning methods.

3. Summary

We have developed and demonstrated a new fabrication technique to realise multilayered polymer structures with sub-micrometer features. Using the same UV curable polymer, it was possible to pattern over topography building up several layers without having to etch the polymer residual layer at intermediate stages. The elimination of the oxygen RIE step enhances the throughput of nanoimprint lithography and the transfer pattern fidelity. This technique is reproducible over millimetres scale surface areas and gives encouraging results for the fabrication of integrated polymer photonic devices.

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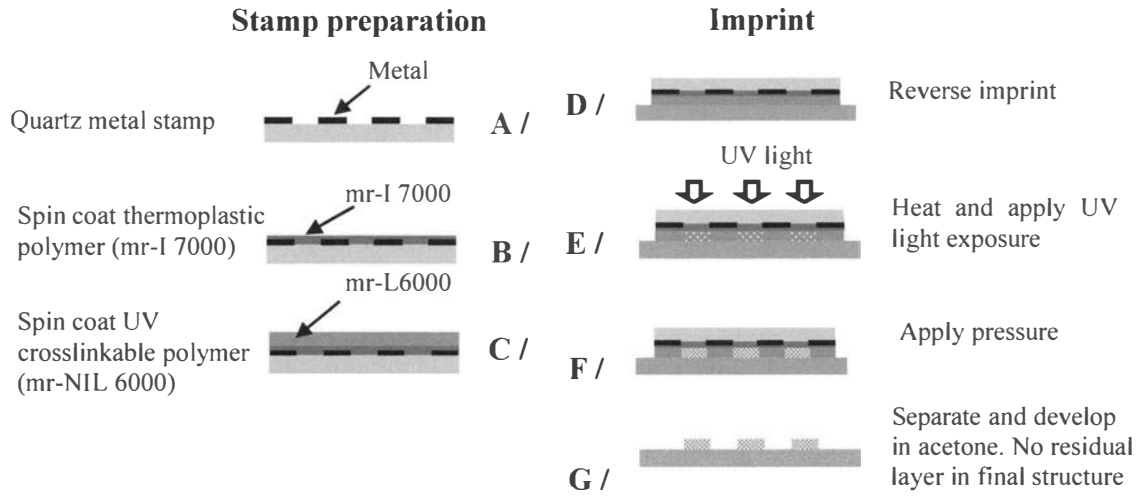


Fig. 1: Schematic of the stamp preparation steps (left column) and imprinting steps of RUVNIL technique (right column).

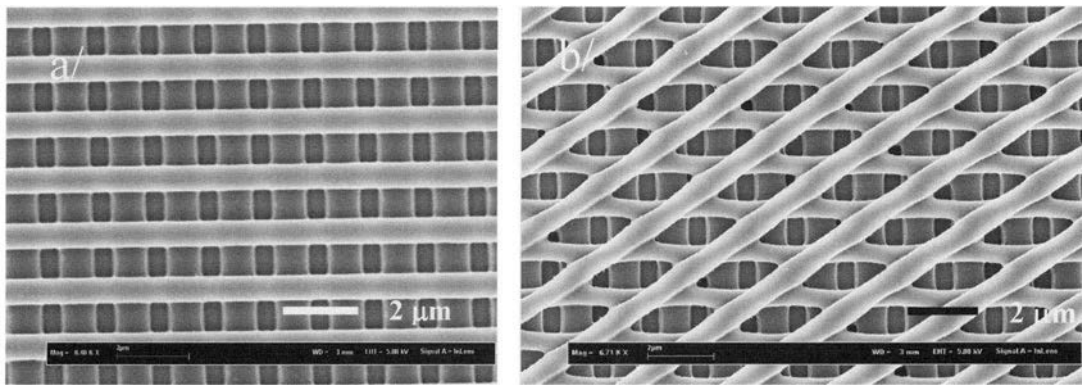


Fig. 2: SEM images of reverse contact UV imprinted features onto polymer gratings. a/ 800 nm gratings reverse contact imprinted onto 1 μ m feature size gratings. b/ SEM images of a three-layer woodpile-like structure fabricated by the reverse contact imprinting technique.

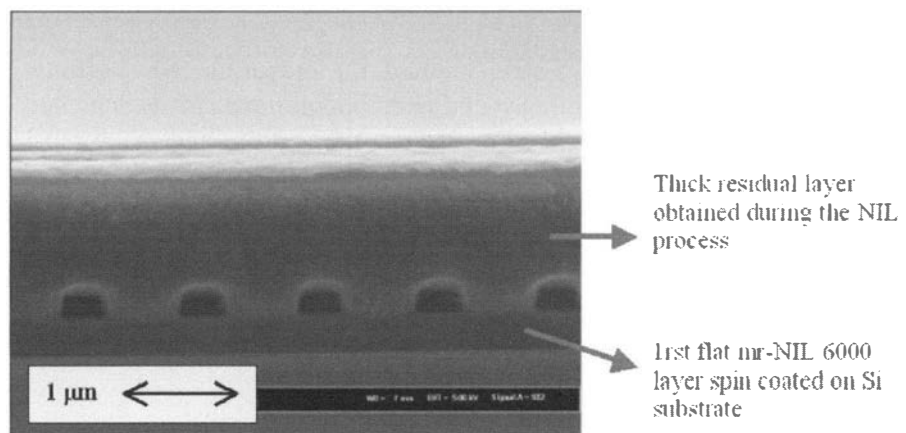


Fig. 3: Cross-section SEM image of ~500 nm embedded nano channels surrounded by the same UV crosslinkable polymer mr-NIL 6000.