Novel Structuring Process for Injection Molding Inserts By Free-Form Reverse Nanoimprint Lithography

Ariadna Fernández[1], Juan Medina[1], Achille Francone[1], Clivia M. Sotomayor Torres[1,2], Nikolaos Kehagias[1]
[1]*Catalan Institute of Nanoscience and Nanotechnology (ICN2), ICN2 Building, UAB Campus, 08193 Bellaterra, Barcelona, Spain,*
[2] *ICREA, Institució Catalana de Recerca i Estudis Avançats, 08010 Barcelona, Spain*
Christian Benkel[3], Markus Guttmann[3]
[3] *Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, D-76344 Eggenstein-Leopoldshafen, Germany*
Lasse H.Thamdrup[4], Brian Bilenberg[4], Theodor Nielsen[4]
[4]*NIL Technology ApS Diplomvej 381, DK-2800 Kongens Lyngby, Denmark*

nikos.kehagias@icn.cat

Patterning of micro/nano structures on non-planar surfaces is a technological challenge which has attracted increasingly attention of the nano manufacturing community. Imprint-based technologies have demonstrated the ability to selectively imprint thin polymer films over large areas resulting in 3D imprints over flat, curved or pre-patterned surfaces. The need to advance industrial manufacturing processes has led the lithography community to merge nanofabrication technologies and to work towards industrial competitive processes. The realization of sub-micro meter patterns on metal surfaces is an example of a novel perspective for the nano manufacturing community in view of advanced technological developments.

In this paper we demonstrate an alternative processing method to generate structured free-form injection molding inserts. Our manufacturing chain (figure 1) includes step-and-repeat nanoimprint lithography (S&R-NIL) to upscale our targeted features, a reversal imprint lithography (RNIL) step to generate residual layer patterns on our mold and a Nickel up plating process to create a fully metallic mold insert. The unique feature of the RNIL technique is the possibility to control the presence or not of the residual layer. Our zero residual layer imprints create the mask to additively generate nickel structures on steel substrates. These nickel up-plated steel substrates are used as insert molds for (nano) injection molding featuring tailored functionalities, such as hydrophobicity effects, on replicated plastic products.

The versatility of our RNIL technique allows us also to pattern over non-planar and pre-patterned surfaces (figure 2). We have demonstrated the fabrication of three-dimensional micro/nano structures addressing the development needs and requirements to uptake nanoimprint-based technique to industrial manufacturing processes. All Reverse NIL imprinting was performed using the desktop CNI tool (from NIL Technology ApS) at moderate temperatures ($T_{imp} \approx 110^{o}$ C) and pressures (1 bar).

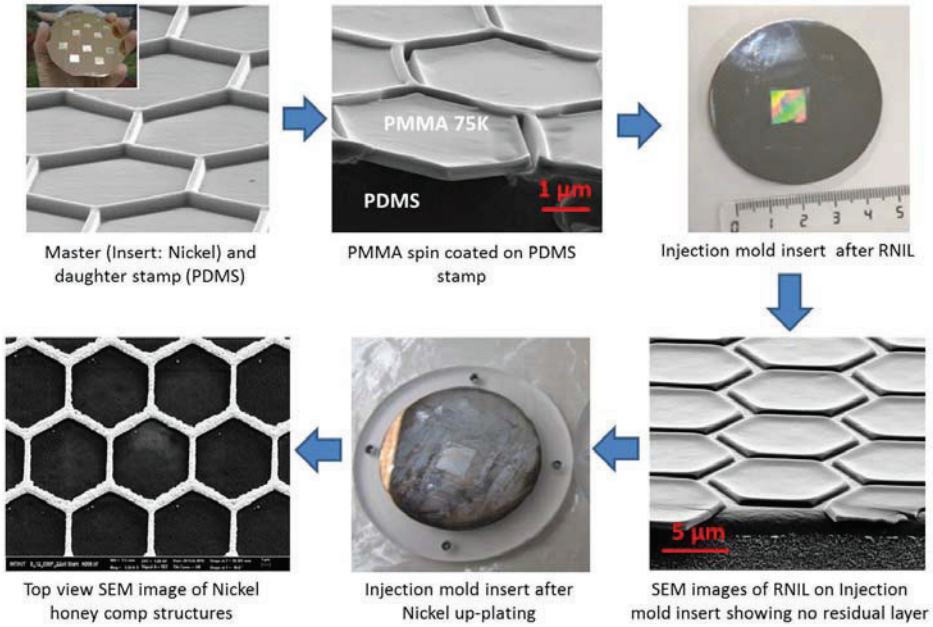

Figure 1: Manufacturing for micro/nano scale patterned injection mold inserts. Clockwise: PDMS working stamp copied from a larger (4 inch) master stamp (Nickel shim). PMMA was spin coated within the stamp cavities. RNIL on a nickel-coated steel substrate creating residual layer-free patterns. A nickel up-plating process was performed on the steel substrate to generate a fully metallic mold insert.

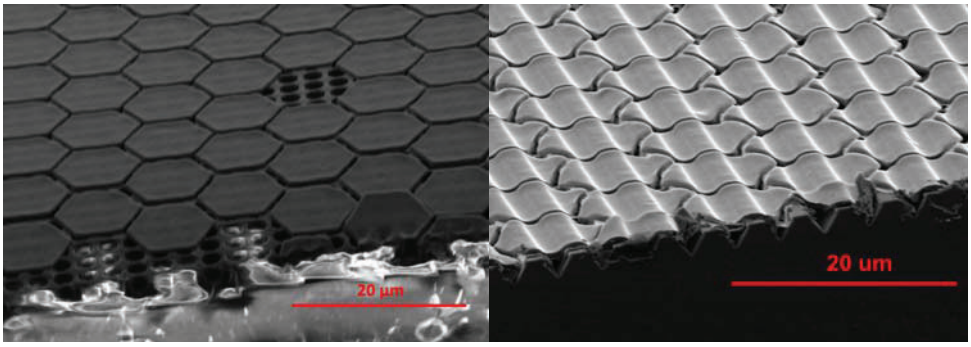

Figure 2: Tilted view scanning electron microscope (SEM) images of free-form patterning of polymer micro/nano structures by reverse nanoimprint lithography. Honey comb polymer structures reverse imprinted on a pre-patterned square lattice via (left) and V-groove grating structures (right). The underlying substrates are Ormostamp and silicon, respectively, while no residual layer is observed on the 3D patterned substrates.

Acknowledgment

This work is funded by the European Commission (FP7-2012-NMP-ICT-FoF) under Grant Agreement number 314345, project PLAST-4-FUTURE (www.plast4future.eu). The Severo Ochoa Program (MINECO, Grant SEV-2013-0295) is gratefully acknowledged.