Nanoimprinting of 3D, undercut structures - unsolvable challenge or feasible route to 3D fabrication?

Heinz D. Wanzenboeck, Patrick Schuller, Philipp Taus, Markus Schinnerl and Emmerich Bertagnolli
Vienna University of Technology, A-1040 Vienna, Austria
Heinz.Wanzenboeck@tuwien.ac.at

Michael Muehlberger
Profactor GmbH, Steyr, Austria

Stefan Ruttloff
Joanneum Research, Weiz, Austria

Adrian Prinz
Stratec, Salzburg, Austria

Nanoimprint Lithography (NIL) stands out among all structuring techniques by the capability to directly replicate 3D nanostructures. To generate 3D (3D) structures directly by NIL avoids costly multi-layer patterning by lithography and high accuracy alignment technology. NIL has successfully accomplished patterning of T-shaped gates for high speed transistors [1]. Using spherical lenses or Fresnel lenses featuring slanted side walls also 3D lens structures were replicated by NIL. Up to now most 3D stamps featured smooth surfaces and a side wall inclination between 1° and 90° (vertical). In this work we report on structures with overhanging sidewalls with an inclination of 90° to 170° or “undercut” structures. Multiple overhanging features are of interest as structural colours inspired by the wing structure of the Morpho Blue butterfly (Fig. 1)

NIL of such overhanging and undercut 3D features faces two major challenges: (i) The fabrication of NIL stamps with overhanging features and (ii) the imprinting and the release of the undercut structures. In this work we present and compare 2 approaches for stamp fabrication. A focused ion beam (FIB) system has been used for generating 3D structrures either by additive direct-write lithography or by ion dose controlled etching of silicon. Alternatively, a more industrially relevant process involving an optically patterned layer was developed (Fig. 2). The optical patterning was performed resistless and maskless and allows structuring of 4” substrates. The patterned layer was used as hardmask for subsequent etching of a material stack. By controlling the parameters of the etching procedure either vertical side walls (Fig. 3) or underetched features (Fig. 4) have been realized. The results of imprinting into a polymer layer by UV-NIL are reported. Based on first experimental results the roll-to-plate and roll-to-roll imprinting will be compared and optimization procedures will be discussed.

Finally, an outlook on the future potential and realization approaches of imprinting of 3D undercut structures will be given. A critical comparison to other patterning techniques will be made.

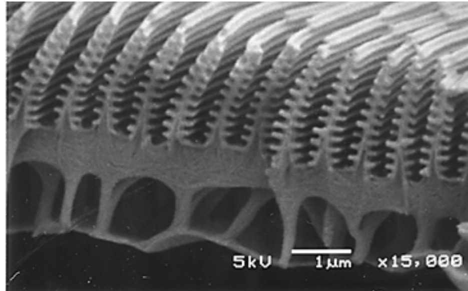

Fig. 1. Electron microscope image of a "Morpho blue" butterfly wing. The tree-like structures reflect light to create iridescent colors.
(© NISE, S. Yoshioka, Osaka Univ.)

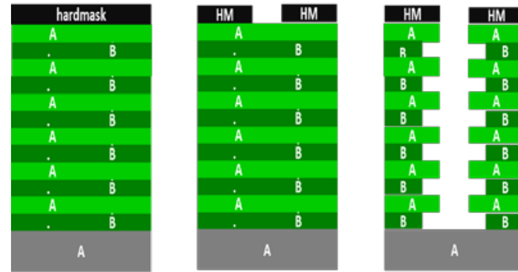

Fig. 2. Schematic illustration of the patterning process for the 3D stamp with undercut features.

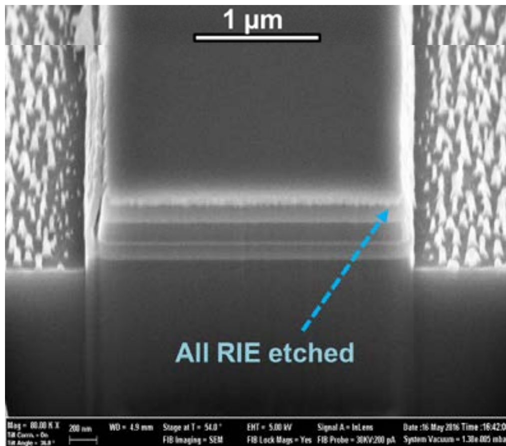

Fig. 3 Structure fabricated by a highly anisotropic etch process (process scheme as in Fig.2).

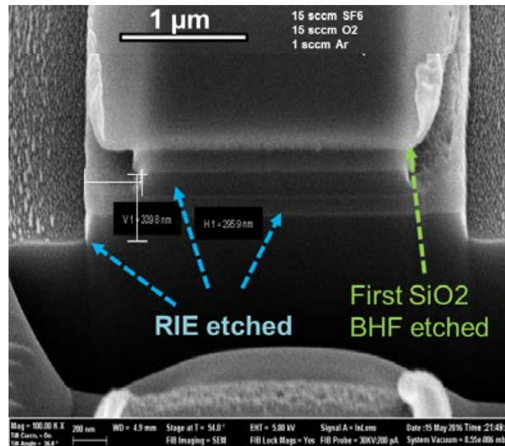

Fig. 4. Structure with underetched features (process scheme as in Fig.2).

References:

[1] Peng, C., Liang, X., Chou, S.Y., A novel method for fabricating sub-16 nm footprint T-gate nanoimprint molds, Nanotechnology 20 (18) 185302 (2009)
[2] Waid, S., Wanzenboeck, H.D., Muehlberger, M., Gavagnin, M., Bertagnolli, E., Generation of 3D nanopatterns with smooth surfaces, Nanotechnology 25 (31), 315302 (2014)