300mm soft-NIL of functional materials for photonic- and bio- applications

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In this paper we will address the requirement set out below for nano-patterning that are needed for cost effective production as needed for e.g. LEDs, lasers, augmented reality, meta-lenses, diffractive optical elements and bio-/gas-sensors applications. By using a combination of inorganic imprint resist, a wafer scale soft stamp up to 300mm and a capillary force driven imprint method we can achieve these goals.

Requirements for (photonic) nano-patterns are:

- High refractive index → Strong light-matter interaction / device efficiency
- No adhesion layer → No efficiency loss and enhanced coupling efficiency
- 100% inorganic → Device stability / lifetime (temperature + UV stability)
- Binary- , blazed- & slanted-grating patterns → Efficiency & freedom of design
- Slanted gratings (all directions and orientations) → One-step replication & freedom of design
- Very low to no haze → Low optical loss
- Pattern replication with <2nm variations → Yield
- Minimal residual layer thickness (RLT) → High efficiency by enhanced coupling
- Stamp material compatibility → Long stamp lifetime (>500 imprints) without varying pattern size
- Wafer scale accurate overlay → < 1µm overlay and double-sided aligned processing

Due to our sol-gel based imprint materials we can directly pattern inorganic metal oxides.[1] These materials are temperature stable up to 400°C and can endure high fluxes of UV and deep blue light. The combination of the inorganic materials and the imprint process which is capillary force driven allows for highly reproducible patterning of sub-100nm features. Especially for AR/VR and meta-lens applications the typically features are between 50nm and 500nm and their absolute size needs to be reproducible within ~2nm in order to function.

In Fig. 1 SEM images show high aspect ratio pillars that are directly replicated into our inorganic resist with an index of n=1.45 and n=1.7 (@550nm). No defects or broken pillars are observed. A novel scatterometry method is used to measure regular arrays of nano-patterns and extract the features geometry with 1-2nm accuracy.[2] Figure 2. shows some of the data used in the optical model which is fitted to the measured data for a line grating on silicon. Lastly, a different novel application that uses engineered magnetic dots.[3] The dots are functionalized with bio-markers and should eventually be used in-vivo where these will selectively bind to cancer cells. Non-bound dots will be excreted by the body due to their small size. The magnetic property of the dots is used with an external magnetic field to rotate these. The mechanical action will kill the cancer cells. See Fig. 3 for examples of micro-dots made using a directly imprinted hard mask (SiO_2) for ion-beam etching.

[1] Adv. Opt. Techn. 6(3-4): 243–264 (2017)
[2] J. Opt. 24 094002 (2022)
[3] Appl. Phys. Lett. 121, 182407 (2022); doi: 10.1063/5.0100657

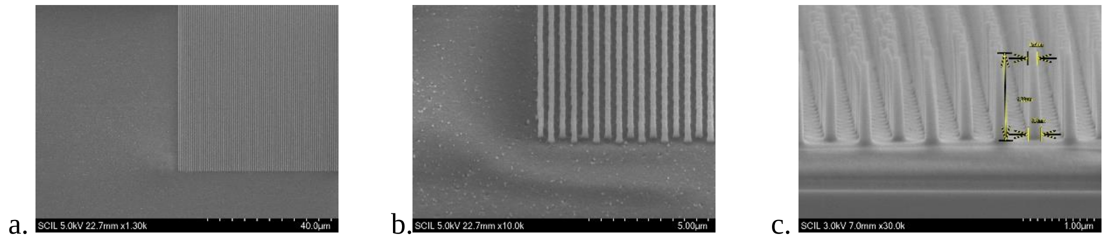

Figure 1. SEM images of directly imprinted high aspect ratio pillars. In top view under 45° (a., b.) for an index of n=1.7 and cross section (c.) with an index of n=1.43.

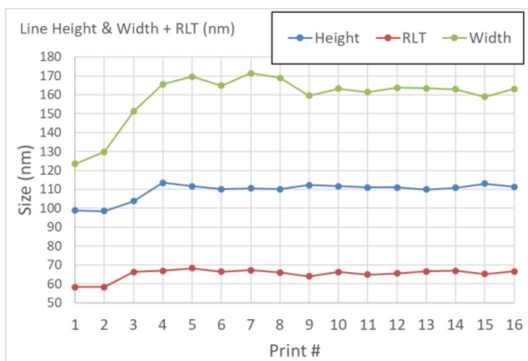

Figure 2. Extracted data from the optical model to fit the scatterometry data for an imprint series in a material with an index of n=1.97. Line height and width and the residual layer thickness (RTL).

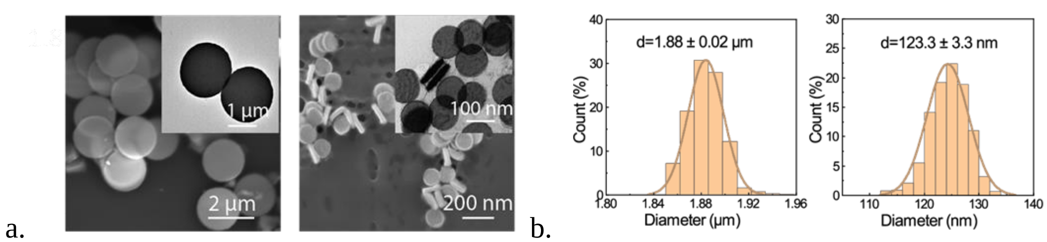

Figure 3. Substrate conformal imprinted fabrication of synthetic antiferromagnetic nanoplatelets (a.) and the size distribution for (b.) micro-sized and sub-micron sized platelets.