Efficient fabrication of photonic and optical patterns by imprinting the tailored photo-curable NIL resist «mr-NIL200» with bendable imprint stamps

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Over the course of the last years nanoimprint lithography (NIL) has become an established patterning technique for the fabrication of very versatile patterns in rather diversified areas [1]. Particularly, the manufacturing of (nano-) patterns for photonic and optical devices like e.g. photonic crystals, wire-grid polarizers, anti-reflective coatings etc. emerged as key application fields for NIL. Specifically, for the imprinting of low-viscous photo-curable NIL resists the widely used step-and-repeat NIL (SR-NIL) technique is a viable method demonstrating its suitability particularly for the patterning of high-resolution features [2, 3]. But, as the overall size of the applied stamp is relatively limited to typically a few square centimeters, multiple imprints are needed in order to fully pattern a larger area like e.g. a full wafer. In this regard, imprint techniques that enable a full wafer imprint in one single step seem to be more adequate and efficient in terms of high-volume and high through-put manufacturing which are key requirements for many industrial applications. Typically, those imprint techniques apply more flexible or bendable rather than rigid imprint stamps. Especially bendable COC-based (cyclic olefin copolymer) stamps feature a couple of very favorable characteristics like very high optical transparency, high chemical inertness toward different curing chemistries, facile fabrication as well as no need of an additional processing step for the preparation of an anti-sticking layer. Moreover, as they are sufficiently mechanically hard, they can be applied for the imprinting of sub-100nm features as opposed to typical (soft) PDMS-based stamps. However, besides the applied NIL technique and type of stamp, industrial high-through-put and high-volume manufacturing typically require NIL resists that meet a whole raft of different properties and material characteristics [4].

Accordingly, we have developed and already commercialized the specially designed photo-curable NIL resist «mr-NIL200». Because of its modular design, critical material properties and parameters are directly implemented and addressed by the admixture of selected monomers, initiators and/or additives to the NIL resist formulation. In detail, «mr-NIL200» stands out due to a negligible oxygen sensitivity of the curing reaction, a superior demolding performance by virtue of a surface-active fluorinated additive and an excellent performance in various standardized dry-etch plasma processes. But even more strikingly and practically important are its integrated adhesion properties, that make an additional adhesion promoter layer superfluous for many important substrate materials like silicon, aluminum, quartz, sapphire, PET and PC foils to name but a few. This feature is directly linked to a highly efficient substrate-active additive that strongly supports excellent film forming characteristics as well as prolonged storage times of spin-coated films.

In order to show and verify the general compatibility and broad versatility of «mr-NIL200» resist with COC-based imprint stamps for the processing of very different types of photonic patterns, we performed an empirical imprint study with various imprints featuring dimensions of the imprinted patterns on the nanometer as well as on the micrometer scale. Accordingly, Figure 1 shows an impeccable imprint of a densely packed pillar arrays while Figure 2 displays a defect-free imprint of larger (slightly curved) line-and-space patterns (for a use as reflective zone plate for X-rays) illustrating both exemplarily the broad applicability and excellent imprint performance of the «mr-NIL200» with bendable stamps for a use in photonic and optical applications.

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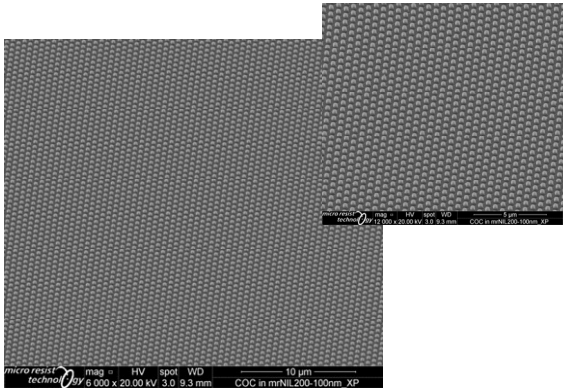

Figure 1. SEM images of an imprinted array of pillars (area: 20 x 20 mm^2, hexagonal lattice, pillar height: 200 nm; period: approx. 600 nm; diameter: 300 nm) onto a bare Si wafer using photo-curable mr-NIL200 resist and a COC-based stamp; imprint parameters: LED UV-illumination @365 nm: 0.3 min @ 53 mW/cm^2, p = 0.2 bar.

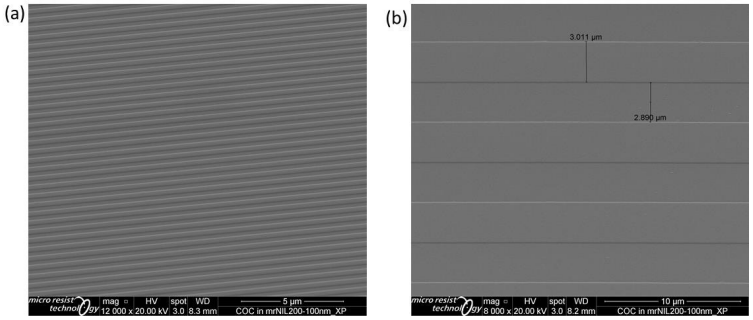

Figure 2. SEM images of imprinted patterns (slightly curved line-and-space patterns for a use as reflective zone plates for X-rays applications) onto a bare 2 inch Si wafer using the photo-curable mr-NIL200 resist and a COC-based stamp, height of structures: approx. 60 nm; period: approx. 550 nm (a) and ca. 3 µm (b), imprint parameters: LED UV-illumination @365 nm: 0.3 min @ 53 mW/cm^2; p = 0.2 bar.