Direct Laser Interference Patterning of Nickel Molds/Sleeves used for thermal Plate-to-Plate and Roll-to-Roll Nanoimprint Lithography

A. Rank, T. Hoffmann, A. F. Lasagni
Technische Universität Dresden, Institute of Manufacturing Technology,
George-Bähr-Straße 3c, 01069 Dresden, Germany

T. Kunze, A. F. Lasagni
Fraunhofer Institute for Material and Beam Technology, Winterbergstraße 28,
01277 Dresden, Germany
E-mail: Andreas.rank@tu-dresden.de

In this study, we present a simple single-step approach for fabricating micrometer structures on metallic hot embossing molds using direct laser interference patterning (DLIP). Usually to fabricate NIL molds slow and costly techniques like electron beam lithography (EBL), extreme ultraviolet lithography (EUV) or focused ion beam lithography (FIB) can be used.[1] Compared to those technologies, DLIP is capable to afford simultaneously high resolution and low cost processing. In DLIP, two or more laser beams are guided to overlap on the substrate by using different optical elements. This leads to the formation of a periodic variation of the laser energy, where the material is photo-thermally or photo-chemically ablated at the interference maxima positions, thereby creating a periodic pattern.[2,3] The advantage of this technique is that it is a single step method and no mold or mask is needed to produce the periodic structures.

Line-like patterns with spatial periods of 1.8 µm and 2.5 µm were structured on a nickel-mold (Figure 1a and b) and used for Plate-to-Plate hot embossing a PET-foil (Figure 2a and b). The influence of the laser parameters used on the structure height of the produced patterns on the metallic substrate as function of the spatial period was investigated. A rapid increase in structure height was observed to a specific laser fluence level from which it stays constant for both periods (Figure 3a). Thermal simulations by finite element method were realized permitting to find a linear correlation between the measured structure heights and the simulated amount of molten material at the maxima positions of the interference pattern (Figure 3b and 3c). Hot embossing of PET foils using the produced mold, considering the imprint time and temperature, were successfully performed. The results show that both the used imprint temperature and time do not have any significant influence on the structure height of the imprints.

Furthermore Roll-to-Roll nickel sleeves where structured with 1.5, 3, 4.5 and 6 µm line structures using a 3D direct laser interference patterning system. The advantage of this system is that a seamless sleeve can be fabricated with high speed and low cost compared to other techniques like EBL. Using these sleeves seamless imprints can be produced either with thermal or UV Roll-to-Roll NIL.
The Roll-to-Roll experiments were carried out using a Roll-to-Roll system which can process foils with a width of 250 mm with a speeds of up to 50 m/min. First experiments show that imprinting of PET foils with a speed above 20m/min without any bigger defects is possible. In future experiments speeds up to 50m/min will be used with sub-micrometer structures sizes

In summary, we have been able to demonstrate that DLIP is a well suited method to fabricate periodic surface patterns on metallic hot embossing molds and sleeves, thereby being an attractive alternative to more costly methods. Furthermore first Roll-to-Roll imprint experiments show that high speed fabrication of micrometer or even sub-micrometer sized structures is possible.

References
Figure 1. DLIP fabricated Ni-mold for (a) 1.8 µm and (b) 2.5 µm spatial periods

Figure 2. Imprint of (a) 1.8 µm period and (b) 2.5 µm period patterns on a PET foil.

Figure 3. (a) Influence of the laser fluence on the structure height of the Ni-mold for 1.8 µm and 2.5 µm spatial periods. (b) Influence of the laser fluence on the melt area for both periods (thermal simulation). (c) Correlation between the structure heights and the calculated melt area