Roll-to-Roll Hot Embossing of Micron and Nanoscale Structures for the Fabrication of Plastic Devices

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Polymer replication techniques such as hot embossing and injection molding have been successfully applied in the manufacturing of low cost consumable plastic chips. Taking cue from the conventional hot embossing process and roll-to-roll web processing methods, a roll-to-roll embossing machine (EVG750 R2R) for fabricating of polymeric devices was built. Roll-to-roll embossing (R2R) is a modification of the batch type hot embossing. Using rolls, instead of plates enable continuous molding with significant advantages in operational speed and device throughput[1]. In roll-to-roll hot embossing, a thermoplastic sheet passes between two rotating rollers. The deformation of the thermoplastic material under the pressure and elevated temperature of the mold imprints the structures into the polymer. The manufactured equipment consists of an unwinding, rewind unit which handles 300 mm thermoplastic foils with thicknesses ranging from 100 µm to 1000 µm at a speed up to 20 m/min an embossing unit with a heat able structured top roller comprising a thin structured metal film bended around the smooth roller and a compression cylinder. Preheating of the substrate can also be conducted before it is fed into the rollers.
In any case, the structuring roller temperature is set significantly above the polymer glass transition temperature. This paper aims to discuss the effects of varying the important process parameters for roll-to-roll hot embossing such as embossing pressure, substrate preheating, roller temperature and roller speed on the embossed channel depth for PMMA and PC thermoplastic material. In addition, mold channel orientation and pattern density effects will also be highlighted as crucial factors that could affect the fidelity of pattern transfer[2]. The above parameters and factors were explored with the goal of achieving process optimization.

With a modest web width of 300 mm and a maximum rolling speed of 6 m/min, the embossing throughput as high as 4000 pieces per hour of polymer microfluidic chips of the size of a standard glass slide can be expected

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[1] H. Tan, A. Gilbertson and S.Y. Chou. Roller Nanoimprint Lithography. Journal Vac. Sci. Technol. B, 16(6):3926-3928, 1998

[2] S.H: Ng and Z.F. Wang. Hot roller embossing for the creation of microfluidic devices. In Proceedings of DTIP Conference 2008, Nice, France, EDA Publishing. 2008

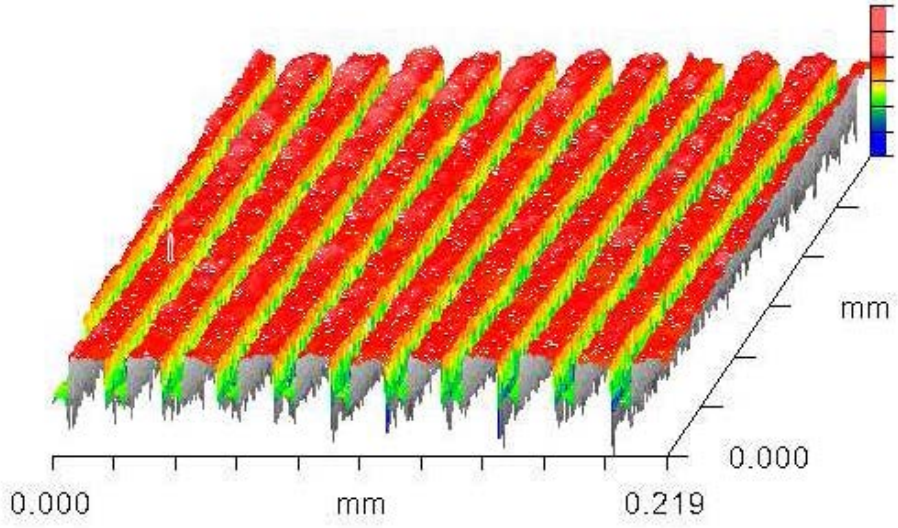

Figure 1: Optical white light Interferometer image of 20 µm PMMA embossed channels @ 9.5 kN and 0.5 m/min

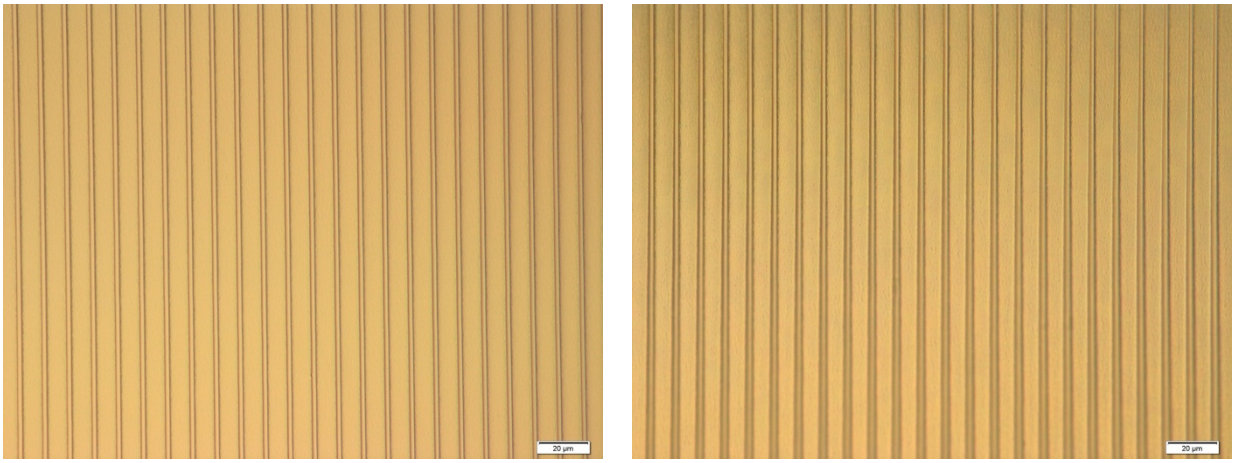

Figure 2: Optical microscope image of 6 µm embossed PMMA channels at 1 m/min (left Image) and 5 m/min (right image)