Design of polymers for thermal nanoimprint lithography based on rheological investigations

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The rheological characterisation of polymers for thermal nanoimprint lithography (NIL) is a successful tool to adjust the molecular weight and the imprint parameters (imprint temperature, pressure and time). Short cycle time and moderate temperature, which can be controlled by the flow behaviour of the polymer, are among the important requirements to an efficient industrial thermal nanoimprint process. Since bulk polymer properties are found in thin films to thickness lower than 100 nm they can be taken to tailor polymers for NIL. The rheological and mechanical behaviour of bulk polymers is related to their zero viscosity and molecular weight. On the one hand low molecular weight polymers showing low zero viscosities enable strongly reduced imprint times while on the other hand these polymers do not have sufficient cohesion forces during the mould release and rip off due to lacking of entanglements between the macromolecules. Thus the adjustment of the molecular weight has to be a trade-off between these properties.

In this contribution bulk thermoplastic mr-I 8000E (acrylate based polymer with Tg 115 °C developed for pattern transfer) of *micro resist technology* is characterised by dynamic-mechanical-thermal analysis (DMTA) above the glass transition at frequencies between 0.01 and 100 rad/s. The zero viscosity and the entanglement molecular weight (M_e) were calculated based on the analysis of master curves according to the Williams-Landel-Ferry (WLF) equation [1] and the loss factor according to van Gurp-Palmen [2], respectively. Polymerizations were carried out to get the most beneficial molecular weight corresponding to the calculated critical molecular weight and taking the pattern transfer fidelity into account.

As shown in the example in Fig. 1 complete filling of the structures was only achieved after adjustment of the molecular weight. The imprint time required for complete filling of structures with specified widths was correlated to that obtained from the Stefan equation [3]. The maximum feature size, which can be patterned under specified process conditions, was estimated for a polymer with given molecular weight combining the data of the WLF and Stefan equations. The correlation between the calculated critical molecular weight and the experimental best one was established by patterning of nano-trenches with different widths. As well the influence of the polydispersity of the polymers on the flowability and mechanical stability was investigated. The requirements to the consistency and tolerance of a polymer for thermal NIL are also discussed.

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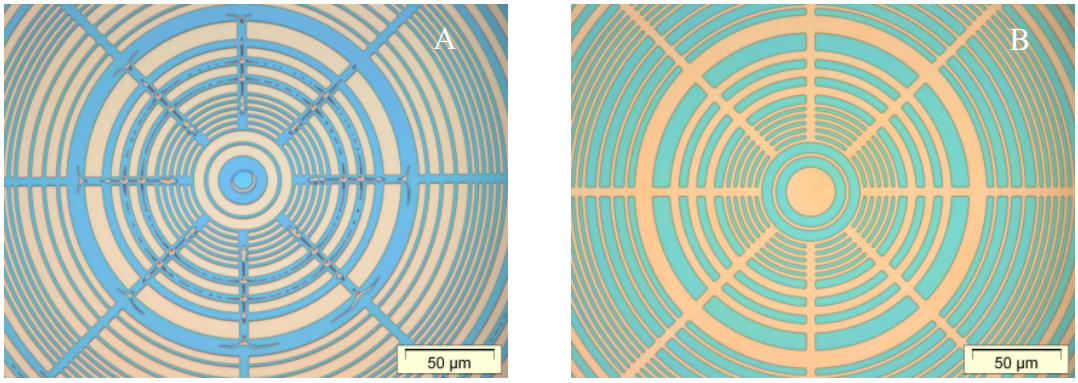

Fig. 1: Optical micrographs of imprints using acrylate polymer. Imprint conditions: Film thickness 350 nm, temperature 175 °C, time 60 s, pressure 30 bar. A) mr-I 8000E polymer with too high molecular weight, B) mr-I 8000E polymer with adjusted molecular weight