Low temperature thermal imprint via frequency assistance

A. Mayer, S. Möllenbeck, K. Dhima, H.-C. Scheer
University of Wuppertal, Faculty of Electrical, Information and Media Engineering, Rainer-Gruenther-Str. 21, D-42119 Wuppertal
amayer@uni-wuppertal.de

With thermal imprint (T-NIL) choice of the appropriate temperature is an important factor to achieve a viscosity that is low enough to deform the polymer layer under pressure. Unfortunately, high imprint temperature results in long heating and cooling phases slowing down the overall process. Thus, it is aimed at a reduction of the imprint temperature. Second, polymer material may suffer from high imprint temperature, a fact, which in addition makes temperature reduction preferable, particularly as an increase of the pressure applied (which could compensate for a temperature reduction) is not beneficial. One means to reduce the temperature required seems to be to make use of the fact that a number of polymers show shear thinning, a reduction of the viscosity at high shear rates or at increased frequency. Recently, this route has been addressed via ultrasonic agitation[1].

Our approach is different. We use piezo translators for frequency dependent agitation. In total, 3 piezo translators are arranged at 120° positions and supply a maximum force of 3 x 30 kN, which is counter-balanced by a stepping motor used to provide the overall stamp and sample movement. The actual force is measured via 3 force sensors beneath the piezo translators. Parallel control of the piezo translators is provided by a frequency generator.

Imprint experiments were performed with 350 kg/mol polystyrene (T_g = 95°C) layers (400 nm) on Si with a standard stamp featuring mixed patterns. The temperature range investigated was 100°C to 130°C, which is only slightly above the glass transition temperature of the imprint material. A static force of 4 kN was superimposed by a dynamic force of 1 kN at a frequency of 5 Hz (sinusoidal/rectangular waveform). In order to assure direct transfer of the dynamic force applied, Al sheets (35-70 µm) were used as a cushion layer instead of polymeric heat conduction foils, which are applied typically. Fig. 1 and Fig. 2 show an example obtained at a temperature as low as 100°C. The imprint depth achieved with dynamic agitation is increased compared to the static experiment at an identical temperature; the dot patterns are imprinted only marginally without dynamic agitation. A substantial decrease of viscosity is also expected by the extrapolation of frequency dependent dynamic measurements of the polymer response (see Fig. 3). It turned out that any shearing motion is critical and may destroy the imprinted pattern (see Fig. 4).

---

[1] H. Mekaru et al, J. Vac. Sci. Technol. **A 27** (2009) 785

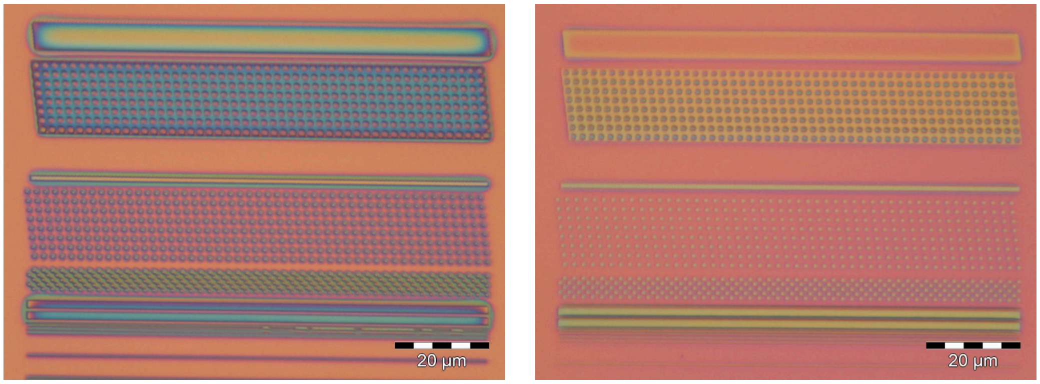

Figure 1: Imprint result obtained at 100°C in 400 nm thick PS (350 kg/mol) on Si. Left: dynamic force 1 kN superimposed to static force of 4 kN, sinusoidal agitation. Right: similar experiment with static force only.

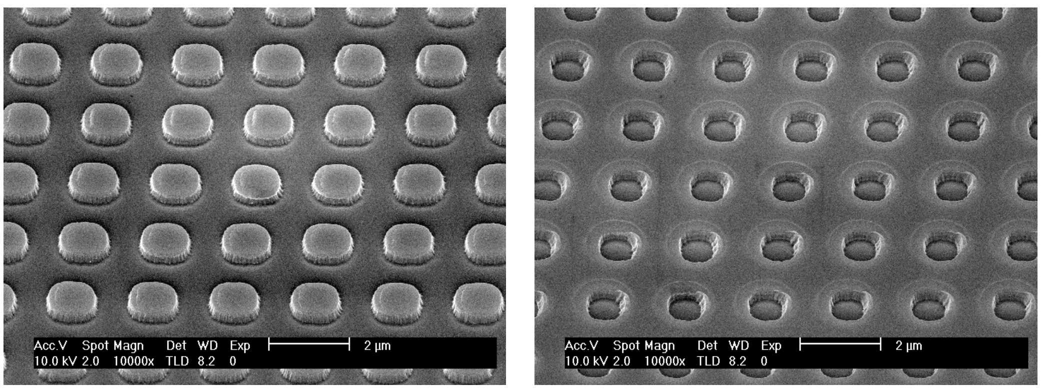

Figure 2: Detail of imprinted positive and negative dot pattern in Fig. 1, left. The imprint depth obtained is about 200 nm, and positive as well as negative structures are replicated comparably.

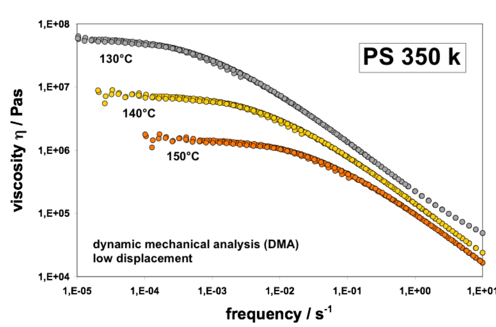

Figure 3: Frequency-dependent viscosity of PS (350 kg/mol) at temperatures of 130 to 150°C.

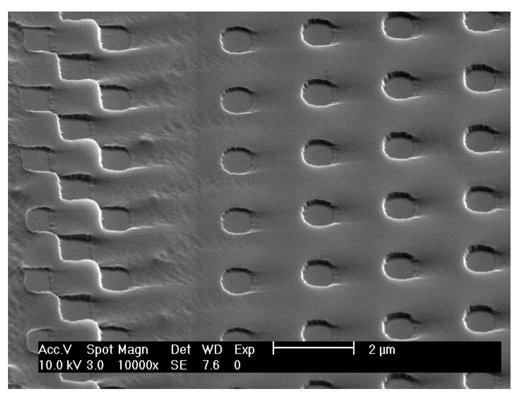

Figure 4: Imprinted pattern destroyed by inappropriate shearing motion during dynamic agitation.