An experimental approach to measurement and reduction of demolding force in UV-Nanoimprint Lithography

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Taking advantage of being a fast and room temperature process, low resist viscosity and therefore ease of resist filling at the molding stage, UV nanoimprint lithography (UV-NIL) strives to replace the thermal counterpart. Most of UV resists are based on adhesive materials such as epoxy and acryl, and adhesion between the imprinted pattern and the mold surface is significant despite application of an anti-adhesion coating, making it difficult to achieve high aspect ratio patterns and often resulting in structural failure during demolding. X. Ye et al. [1] investigated the effect of exposure time on demolding force in UV-NIL and found that partial curing of the UV resist decreases the demolding force due to lower Young's Modulus (E) of the resist. Partial resist curing, however, is not practical because controllability and repeatability of the degree of curing are poor mainly due to diffraction of UV light at the edges of the mold insert and also exothermic and almost self-propelled nature of UV-polymerization reaction. In this paper, E of the resist was manipulated by varying composition of the cross-linking agent and the influence of E of UV resist on the demolding process in UV-NIL was studied by measuring demolding force, the force required to separate mold insert from the molded substrate.

UV-curable polymeric blends containing polypropylene glycol diacrylate (PPGDA), trimethylolpropane triacrylate (TMPTA), and Irgacure 651 as the base, crosslinking agent and photo-initiator, respectively, were used as a model system for UV resists. Demolding force was measured using a tensile test machine equipped with homemade fixtures for the stamp and substrate. E of fully-cured resists and shrinkage during curing were obtained via force-distance curves in atomic force microscopy and contact angle measurement system, respectively. As the cross-linking agent content increases from 0 to 49 wt%, demolding force as well as E of the resists increases, seemingly following a linear relationship (Fig.1 and Fig.2). Fig.3 shows the changes in demolding force (measured experimentally) and adhesion force (calculated by a formula given by [2]) versus E of resist. The demolding force is generally larger than the adhesion. This difference is attributed to additional stress in the resist generated during shrinkage and friction force between the two surfaces which resists demolding. The dependence of E of the resists will be further discussed in terms of pattern fidelity and degree of cross-linking estimated by Fourier transform infrared spectra of the various resists.

References:

[1] X. Ye, Y. Ding, Y. Duan, H. Liu, B. Lu, J. Vac. Sci. Technol. B, 27(5), 2091 (2009).

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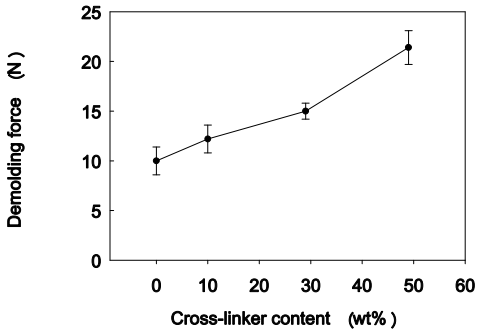

Figure 1. Demolding force vs. cross-linking agent concentration.

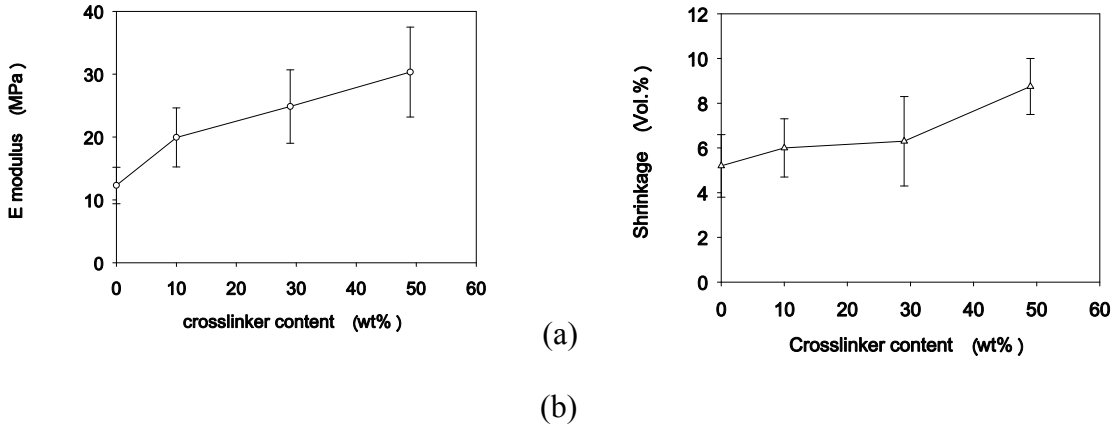

Figure 2. (a) Young's modulus and (b) polymerization shrinkage vs. crosslinker content.

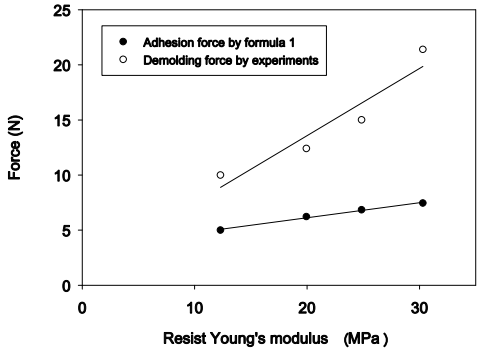

Figure 3. Changes in demolding force (measured experimentally) and adhesion force (measured by the formula above) versus resist E modulus.