Impact of Hydrofluoroether on Contact Force of Thermal Nanoimprint

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We propose a technique to minimize unfilling areas using hydrofluoroether (HFE) with low boiling point to achieve thermal nanoimprint at a low contact force. Liquid HFE in the cavity of mold patterns evaporates when heated. The residual HFE gas, under a contact force higher than HFE's vapor pressure, liquefies and merges into the softened plastic. This technique enabled the transfer of several 100 nm wide line/space patterns on the surface of engineering plastic sheets at, or below, the conventional contact force of 1/3. When the contact force is decreased from its usual value, any residual air trapped in the cavity of the mold pattern obstructs the cavity's filling with softened thermoplastic. The insertion of HFE can solve this problem.

A convex electroformed-Ni mold NIM-100L RESO (NTT Advanced Technology) was fixed with a Kapton double-faced tape on the upper ceramic heater of a desktop T-NIL system NI-1075 (Nano Craft Technologies). The size of mold surface was 10 mm square with a layout of 100 nm deep line/space patterns with their linewidths of 80 to 3000 nm. Engineering plastic sheets of 15 mm square and 0.5 mm thickness were set on the bottom ceramic heater of the T-NIL system. The liquid HFE in a pipette was dropped between the mold and a molding material heated up to its glass transition temperature (T_g) before the start of the press operation (fig. 1). Three kinds of engineering plastics, namely polyethylene terephthalate (PET, T_g = 75 ºC), polymethyl methacrylate (PMMA, T_g = 105 ºC), and polycarbonate (PC, T_g = 150 ºC) were selected as molding materials. According to the T_g of each engineering plastic, three kinds of fluids Novec (3M Company) 7100, 7200, and 7300 with boiling points of 61 ºC, 76 ºC, and 98 ºC were used (table 1). Figure 2 shows the imprinted patterns observed by a CCD microscope. The contact time was fixed to 10 s and the heating temperatures of PET, PMMA, and PC were set to 105, 155, and 185 ºC. In the left figure the contact force was 1000 N, same as in the usual T-NIL. Various lines/space patterns were transferred on each plastic. However, when the contact force was gradually decreased to 500 N, defective molding began to appear. For 300 N contact force the results are shown in the central figure. The nano-/micro-patterns were not transferred in the corners of pattern area; and the filling in the central mold pattern was also imperfect as shown in the FE-SEM images. However, imprinted patterns did appear in the surrounding parts, after the HFE liquid was inserted even where the imprint condition was the same. The introduction of liquid HFE thus improved the molding accuracy because the edge of patterns was comparatively sharp as shown in the right figures.

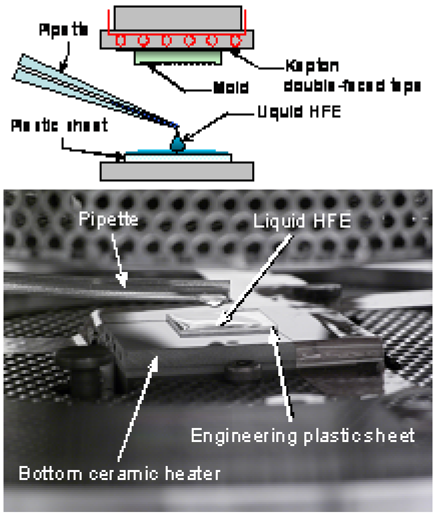

Figure 1: Illustration and photograph in insertion operation of liquid HFE.

Table 1. Typical physical properties of Novec 7100, 7200 and 7300.

	Novec		
	7100	7200	7300
Formulation	$C_4F_9OCH_3$	$C_4F_9OC_2H_5$	$C_6F_{13}OCH_3$
Average molecular weight	250	264	350
Boiling point (ºC)	61	76	98
Thermal conductivity* (W/mK)	0.069	0.069	0.062
Vapor pressure* (MPa)	0.028	0.016	0.006
Viscosity* (Pa·s)	5.8×10^{-4}	5.7×10^{-4}	1.2×10^{-3}
Coefficient of thermal expansion* (m^3/m^3K)	0.00171	0.00158	0.00144

* All values at 25 ºC.

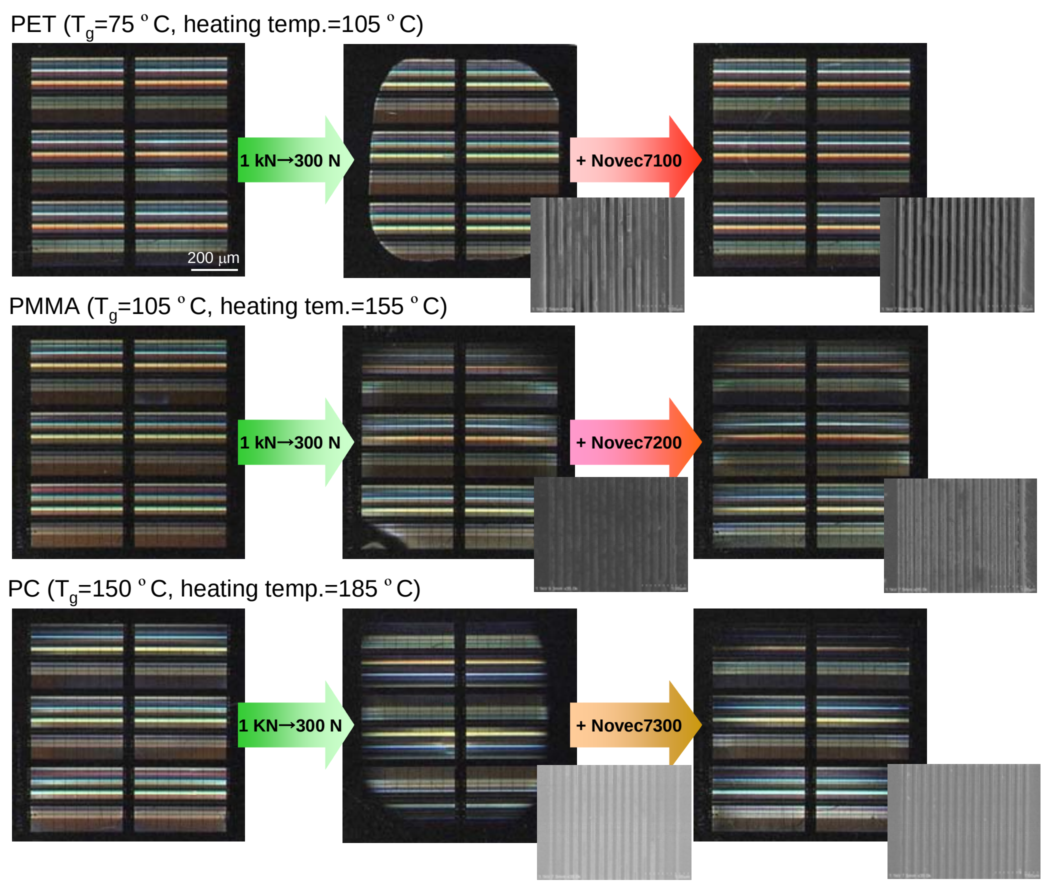

Figure 2: Optical micrographs of imprinted area and FE-SEM images of 100-nm-width line/space pattern imprinted on each engineering plastic. In the case of the left and central figures, the contact forces were 1000 and 300 N. The right figures show the results in the contact force of 300 N using liquid HFE.