

Surface Force Measurement of Nanoimprint Lithography Molds and Resin Materials

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Nanoimprint lithography (NIL) is promising method for mass-production of nano-scale pattern. In particular, Ultraviolet NIL (UV-NIL) is room temperature operating, thus, high-throughput process is possible. However, UV-NIL is necessary of release coating to prevent a transfer resin adhesion. The release coating is usually used fluorinate silane coupling agents and its life time is evaluated by using contact angle (CA) measurement¹. However, merely CA measurement cannot judge the life time and deterioration of release coating. Therefore, precise and novel characteristics of release coating surface method is necessary. The measurement of surface force is candidate methods to grasp the release coating surface and resin surface. We have developed the surface force analyzer equipment (ESF-5000, Elionix Co., Ltd.) and evaluated mold surface and resin materials.

Figure 1 shows surface force measurement principle (a) and explanation of surface force (b). The measurement probe was $\phi 1$ mm glass ball. First, evaluation sample and probe was evacuated at less than 200 Pa. Then sample stage moved up and contacted the probe. When the probe releases from sample surface, surface force (Fig.1 (b)) is required. This equipment can measure this surface force by accuracy positioning system (1 nm Z-resolution), displacement system (0.3 μ m resolution) and force measurement system (4 nN resolution).

Silicon molds with 180 nm line and space pattern and UV-curable resins were evaluated with this equipment. Ozone cleaned Si mold surface and release coated Si mold surface were measured. The release agent was fluorinate silane coupling agent (Optool DSX, Daikin Co., Ltd). PAK-01 CL (Toyo Gosei Co. Ltd.), which is acrylate and radical polymerization system, and PARQIT OEX-028-X433-3 (Autex Co., Ltd), which is epoxy and cation polymerization system were used as UV-curable resin surfaces. UV-curable resins were cured by enough UV dose. Figure 2 shows relationship between displacement and force of cured PAK-01 CL surface (measured three times). The surface force was obtained from minimum value of force. In this case, surface force was -84.6 μ N. Table 1 is summarized of surface force results. The surface force (absolute value) of release coated Si was smaller than that of without release coating. Thus, surface force can evaluate of NIL materials. Measurement of surface force of mold surface during repetition UV-NIL could evaluate the life time of release coating quantitatively.

1. D. Yamashita, J. Taniguchi, H. Suzuki, *Microelectron. Eng.* 97 (2012) 109.

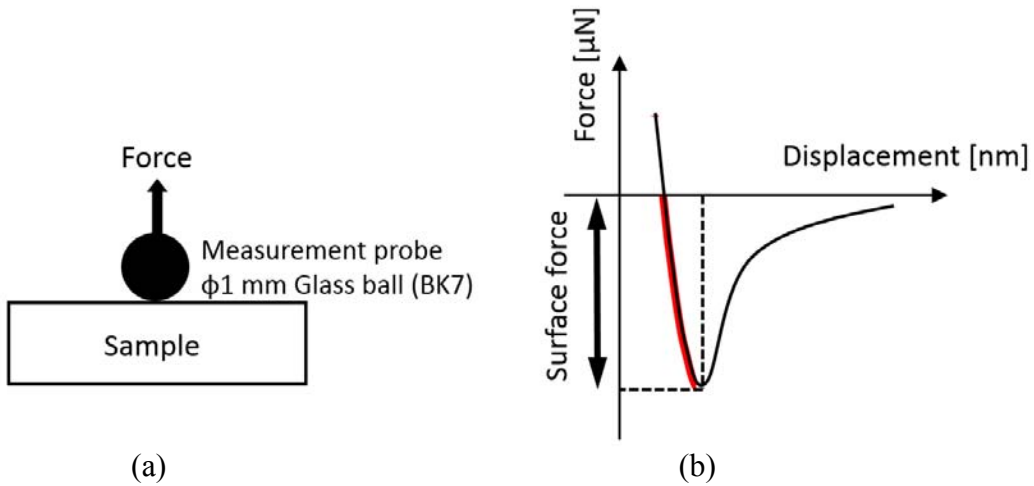


Figure 1: Surface force measurement principle (a) and explanation of surface force (b).

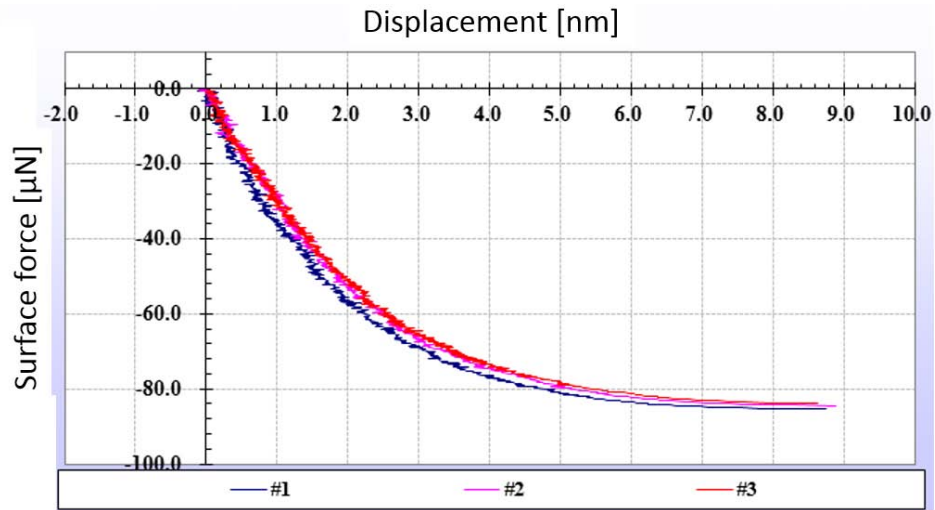


Figure 2: The relationship between displacement and force of cured PAK-01 CL surface (Measured three times).

Table 1: The summarize of various surface force

Measurement materials	UV-curable resin		Si mold with L&S pattern	
	PAK-01 CL	X433-3	Ozone cleaned surface	Release coated surface
Surface force [μN]	-84.6	-123.4	-61.5	-39.9