Adhesion and frictional forces measurement by scanning probe microscopy under pentafluoropropane gas atmosphere

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It is known that the bubble defects in UV nanoimprinting is a one of the important issues. Hiroshima et al. reported that the bubble defects are eliminated by UV nanoimprinting under pentafluoropropane (PFP) gas atmosphere.[1)] In addition, the adhesion force between the mold and resin in demolding process reduce by this method.[2)] To examine the PFP gas effect in nanometer-scale area, we measured the adhesion and frictional forces by scanning probe microscopy (SPM) under PFP gas atmosphere.

We used the E-sweep/NanoNavi Station (SII NanoTechnology Inc.), which is used to control the chamber vacuum, as the SPM system. We measured the adhesion and frictional forces by SPM under air, N_2 gas and PFP gas atmospheres. The measurement process was as follows; (1) The SPM chamber was evacuated until about 15 Pa by using a rotary pump. (2) The valve between the chamber and the rotary pump was closed after vacuuming and the PFP or N_2 gases then flows to the chamber. (3) The SPM measurement was carried out on the Si substrate.

A Si cantilever with a spring constant of 0.15 N/m was used. The contact force was about 10 nN. Figures 1(a)-1(c) show the force curves measured by SPM under air, N_2 gas, and PFP gas atmospheres, respectively. The adhesion forces measured under the air, N_2 gas, and PFP gas atmospheres were 1.5, 1.5, and 0.9 nN, respectively. The adhesion force measured under PFP gas atmosphere was lower than that under air and N_2 gas atmosphere. We also measured frictional curve by SPM under air and PFP gas atmosphere. In this measurement, we used a Si cantilever with SiO_2 particle (diameter is 1 μm). Figures 2(a) and 2(b) show the frictional curves measured by SPM under air and PFP gas atmosphere, respectively. The frictional force measured in PFP gas atmosphere was about 3 times lower than that in air. These results indicate that the PFP gas is effective to reduce the adhesion and frictional forces in nanometer-scale area.

1) H. Hiroshima and M. Komuro: J. Vac. Sci. Technol. B **25** (2007) 2333
2) H. Hiroshima: J. Vac. Sci. Technol. B **27** (2009) 2862

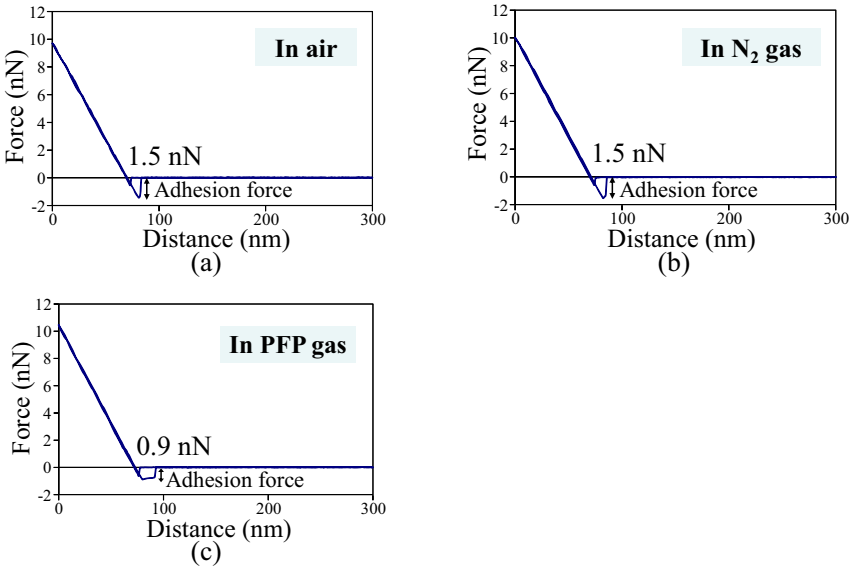

Fig. 1 Force curves measured by SPM under (a) air, (b) N_2 gas, and (c) PFP gas atmospheres.

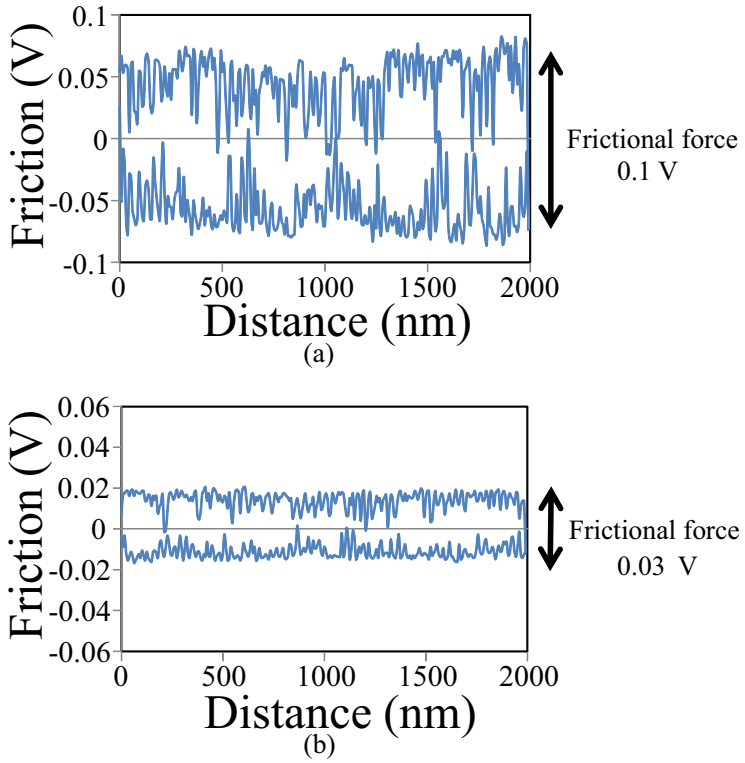

Fig. 2 Frictional curves measured by SPM under (a) air and (b) PFP gas atmosphere.