Release force reduction in UV-nanoimprint by mold orientation control and by gas environment

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UV-nanoimprint is a promising ultra-fine lithography technology. The resin used in UV-nanoimprint is naturally UV-curable and we could say the resin is a kind of UV-adhesives. Therefore, the cured resin shows a high adhesive force and reduction of release force is desirable for reliable UV-nanoimprint. We investigated the impact on release force not only by inclined mold release but also pentafluoropropane used as bubble ellimination.[1] Figure 1 shows the schematic of the mold orientation control of our UV-nanoimprinter.[2] Three linear actuators support a mold table and the orientation of the mold is in advance adjusted parallel to the wafer and the mold normally moves up and down with keeping the orientation by synchronized telescopic motion of linear actuators. For inclined mold release, only one linear actuator first completes push up operation of the mold table and then the others start push up. The joint module between the mold table and linear actuator composes of a pivot and a linear guide to enable orientation control without strains. The nominal release speed is 3.7 mm/s for parallel release and the speed for inclined release is one third of that for parallel release. During inclined release, the mold inclines 3.4 mrad at the maximum. A 10 mm $\times$ 10 mm quartz mold having 300-μm-wide 150-nm-deep checker pattern was treated by perfluorosilan (Gelest Aquaphobe CF). UV-curable resin (Toyogosei PAK-01) film with a thickness of 80 nm was spun on a 0.8 mm thick Si wafer. The wafer was pressed by the mold in pentafluoropropane or occasionally in air with an imprint pressure of 0.5 MPa and cured by UV light with an exposure dose of 100 mJ/cm^2. Then, the mold was released from the wafer by parallel or inclined release manner. The release force was monitored and logged through step and repeat UV-nanoimprint. Figure 2 shows release force trend for parallel release and inclined release where the two release methods were randomly adopted. It is difficult to say that inclined release gives lower release forces but found that inclined release gives 20% lower release force in average in comparison to parallel release. Figure 3 shows release force map including 5 results without pentafluoropropane introduction namely UV-nanoimprint in air. We can easily distinguish the results obtained in air from those in pentafluoropropane. The result reveals that release force in pentafluoropropane becomes one third of that in air.

[1] H. Hiroshima and M. Komuro, J. Vac. Sci. Technol. **B 25** (2007) 2333.

[2] H. Hiroshima, Jpn. J. Appl. Phys. **45** (2006) 5602.

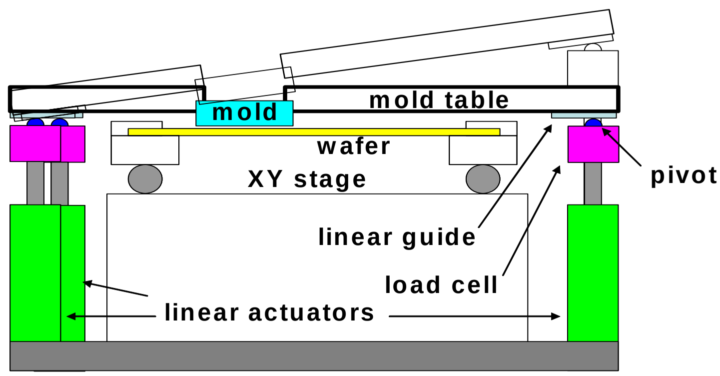

Fig1: Schematic of UV-nanoimprinter equipped with mold orientation control system. The superimposed figure indicates an intermediate state of inclined mold release.

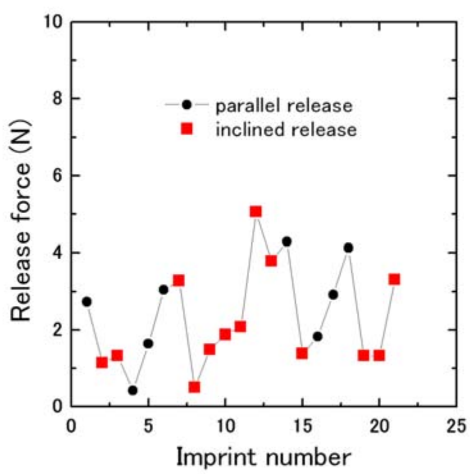

Fig 2: Release forces by parallel release and inclined release. No trend was observed but it is found that the release force by inclined release is 20% lower in average than that by parallel release.

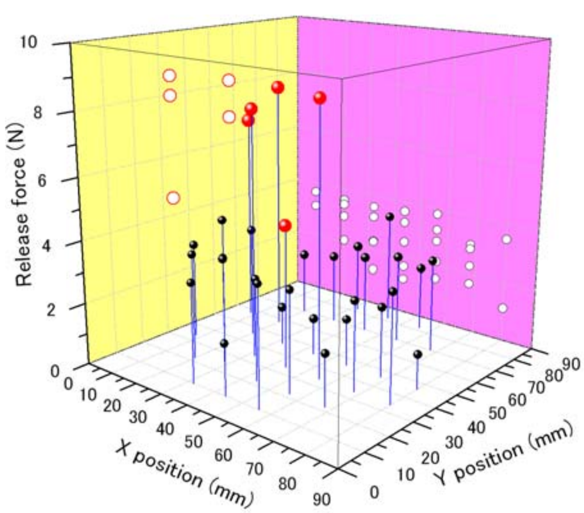

Fig 3: Release force map for UV-nanoimprint in pentafluoropropane and in air where larger plots are the results in air. For easy observation, release forces are projected onto the vertical planes in the graph according to the UV-nanoimprint conditions namely in pentafluoropropane or in air.