Durability assessment of mold release agents for ultraviolet nanoimprint lithography

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Ultraviolet nanoimprint lithography (UV-NIL) is very useful for manufacturing nano-scale patterns. However, it is known that UV curable resin adhesive to the mold causes transfer failure. Then, a release agent is regarded as one of the means to solve the problem. It is very important to keep coating the mold surface with the release agent to prevent the adhesion of UV curable resin, but the problem of the durability of the release agent remains. In previous study[1], durable tests were performed to measure the durability of the release agent by using actual equipment of the nanoimprint. As the release agent, Optool DSX (Daikin Co.) and $C_8H_4Cl_3F_{13}Si$ were used. In the results, $C_8H_4Cl_3F_{13}Si$ showed the better durability than Optool DSX. However, the test time is so long because of the use of the actual equipment. Hence, it is difficult to obtain a sufficient number of the test data. Therefore, the development of an evaluation method under accelerated conditions is needed.

In this study, we investigated the durability of the release agent by using a pin-on-plate reciprocating tribotester. The tests were performed at a load of 20 N, sliding speed of 1.0 mm/s, amplitude of 10 mm. UV curable resin was attached to the pinpoint edge. The radius of curvature of the edge is 18 mm. The specimen was the Si substrate and its size was 20 mm square and covered with Optool DSX or $C_8H_4Cl_3F_{13}Si$. After the sliding test, the worn surface was analyzed by Fourier Transform InfraRed spectrometer (FT-IR) and Atomic Force Microscopy (AFM).

Figure 1 shows the friction coefficients in the sliding tests. It is observed that Optool DSX showed a stable value of the friction coefficient. In the case of $C_8H_4Cl_3F_{13}Si$, the friction coefficient increased with the time progress at the beginning of the test, and showed a stable value after 70 times reciprocating. After the tests, it was observed that UV curable resin was removed in both cases.

FT-IR analysis was performed to compare the molecular state of the release agent films on the surface before and after the sliding test. In the case of Optool DSX, the change of spectrum of the absorbance intensity is very small. On the other hand, the decrease of absorbance intensity was observed after the sliding test in the case of $C_8H_4Cl_3F_{13}Si$. It is considered that this decrease was caused by exfoliate of the release agent film. From the results, Optool DSX maintained the durability, whereas $C_8H_4Cl_3F_{13}Si$ was worn and could not maintain the durability. In order to confirm the presence of UV curable resin, we analyzed the sliding trace by AFM. Figure 3 shows the distribution of the friction force on the sliding trace after the tests. In the both cases, the area which has higher friction force was seen remarkably. It is confirmed that adhesive material shows the high friction area.

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[1] D. Yamashita., et al.: "Lifetime evaluation of release agent for ultraviolet nanoimprint lithography", Microelec. Eng., 97 (2012) 109-112.

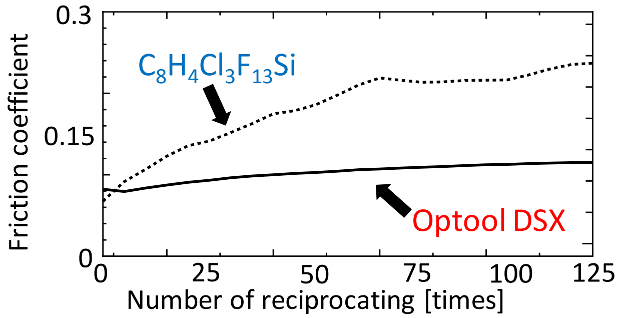


Figure 1: Friction behavior in tribotester

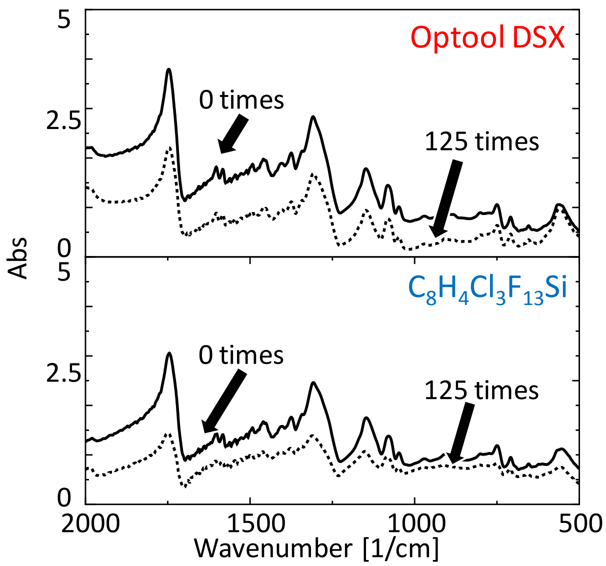
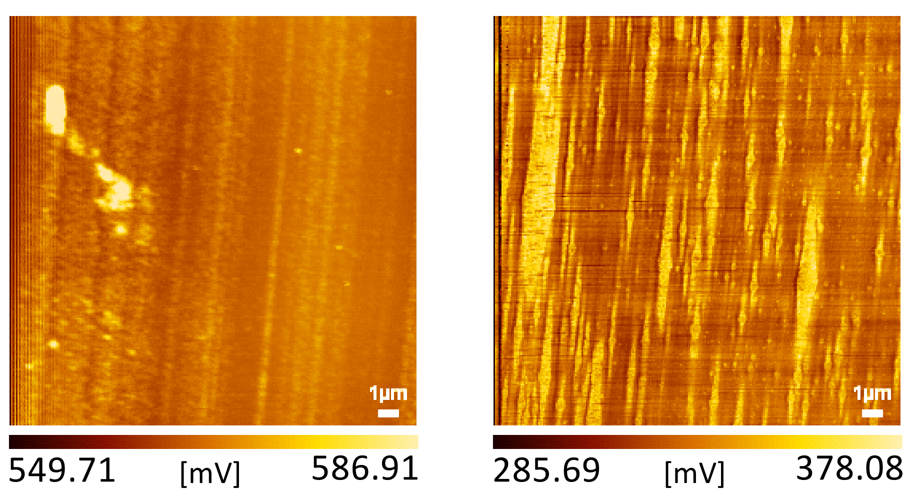


Figure 2: Time variation of FT-IR spectra of Optool DSX and $C_8H_4Cl_3F_{13}Si$



(a) Optool (b) $C_8H_4Cl_3F_{13}Si$

Figure 3: Distribution on friction force of sliding trace