Release Agent Properties in Ultraviolet Nanoimprint Lithography using High-Aspect-Ratio Nanoscale Molds

J. Taniguchi[1], J. Takahashi[1]
[1]*Department of Applied Electronics, Tokyo University of Science, 2641 Yamazaki, Noda, Chiba 278-8510, Japan*
junt@te.noda.tus.ac.jp

Ultraviolet nanoimprint lithography (UV-NIL) is a potentially powerful tool for nanofabrication. However, the strong force required during the release step degrades the release coating layer, which leads to defects in pattern replication and eventual breakage of the mold. Our previous report reveals high-aspect-ratio and large-surface-area molds have been fabricated by irradiation ion beam. And using these molds, assessment of release properties in UV-NIL is possible[1].

In this study, two types of release agent were evaluated. One is Optool DSX (Daikin Co.), which is perfluoropolyether structre and very long fluorine chain and has useful properties of reduced friction and easy to wipe off fingerprint. Another is $C_8H_4Cl_3F_{13}Si$ (trichloro(1H,1H,2H,2H-perfluorooctyl) silane, F13) (Sigma-Aldrich Japan Co.), that fluorine chain is shorter than Optool DSX.

The outline of this method is shown in Fig. 1. Fabrication of high-aspect ratio glassy carbon (GC) molds was irradiation by oxygen ion beam. The mold surface was less than 100 nm diameter and more than 1000 nm height conical structure (Fig. 1.1). Aspect ratio is more than 10. After the mold fabrication, tungsten was coated by sputter coating (Fig. 1.2). The deposited W was subsequently converted to WO_3 through reaction with oxygen in the atmosphere. After the deposition of W layer and oxidation, the surface was coated with the fluorinated silane coupling agent. The structures of Optool DSX and F13 were depicted at this figure (Fig. 1.3). In this study, five treatments were examined. These were only Optool, only F13, mixed Optool and F13 (1:1), first F13 treatment then Optool treatment, and first Optool treatment then F13 treatment. The concentration of Optool and F13 was 1 wt%. Dipping time was 24 hours for both agents. Bake conditions were 100 ^{o}C, 3 min for Optool and 120 ^{o}C, 5 min for F13. After the release coating, UV-NIL was carried out. UV curable resin was PAK-01 (Toyo Gosei, Co.) and UV dose was 100 mJ/cm^2 (Fig. 1.4). Repetition transfer was carried out until UV curable resin adhered on mold (Fig. 1.5)

Figure 2 shows SEM photos of transferred UV curable resin and number of possible repetition times. Using only F13, one time transfer is possible. Using only Optool, six times transfer is possible. Optool plus F13 could transfer 13 times (Fig. 2(a)). In the case of first F13 then Optool treatment, possible transfer number was only one (Fig. 2(b)). First Optool then F13 treatment could transfer 18 times (Fig. 2(c)). These results reveal Optool is effective for high-aspect-ratio pattern transfer because of long fluorine chain. In addition, mixture or post treatment of short fluorine chain is effective for mold life extension.

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[1]J.Takahashi, J. Taniguchi, Y.Kamiya, *J. Vac. Sci. Technol.* B **28**, C6M23 (2010).

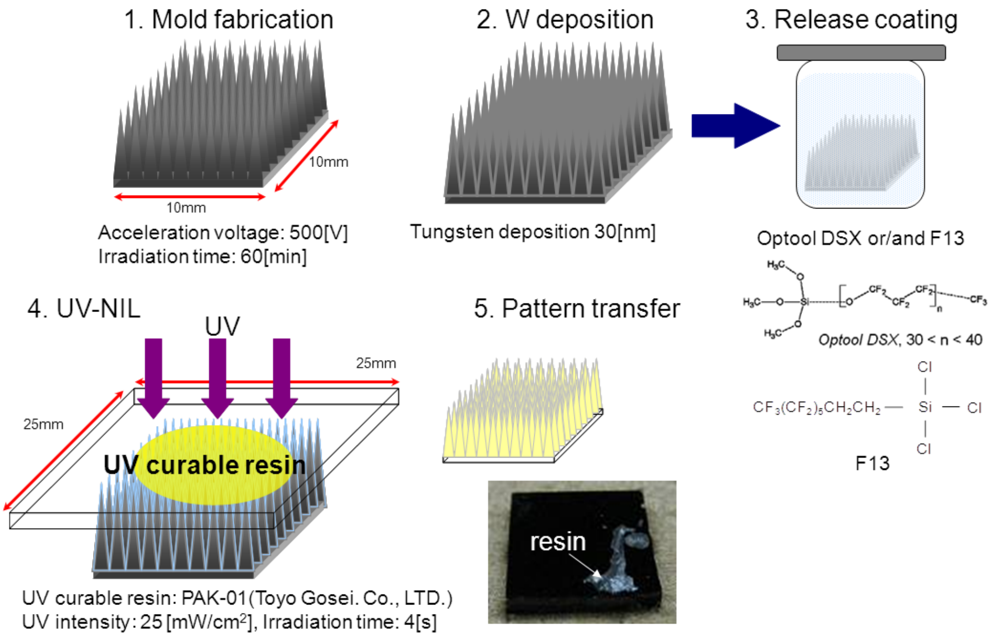

Figure 1: The outline of evaluation process on UV-NIL with high-aspect ratio mold using various release agents.

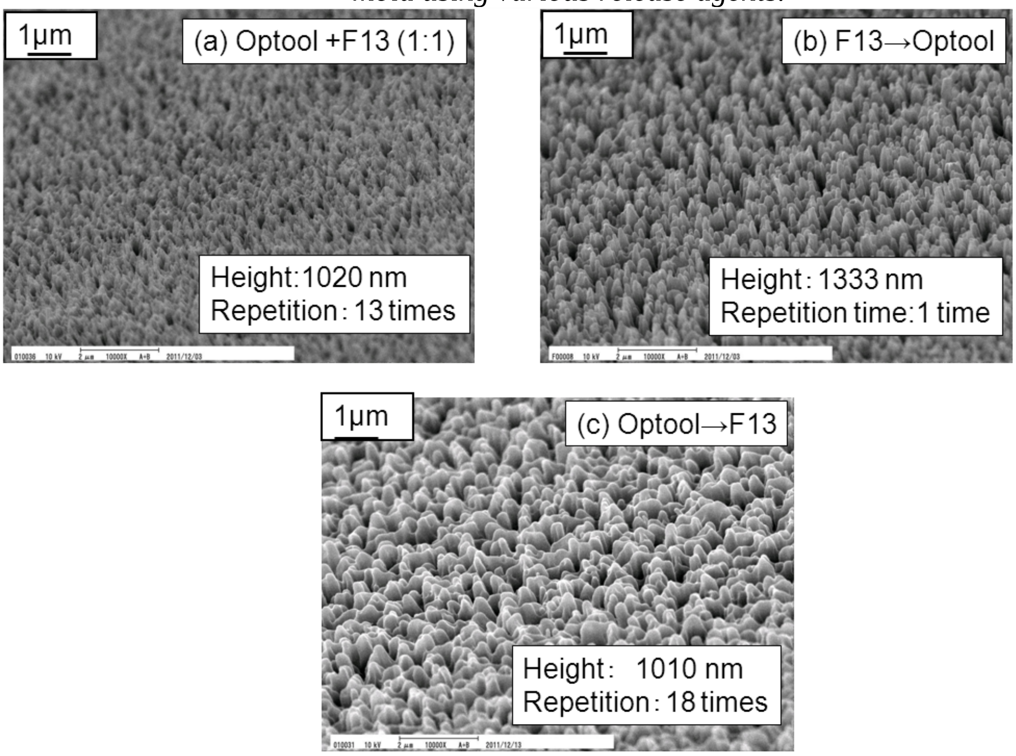

Figure 2: SEM photos of transferred UV curable resin and number of possible repetition times.