Nanoimprint replication of three-dimensional structure fabricated by FIB-CVD

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Nanoimprint lithography (NIL) is a very useful technique to replicate two-dimensional nanostructure with low cost and high throughput.[1)] On the other hand, three-dimensional (3D) micro- and nano-fabrication technique such as focused-ion-beam chemical vapor deposition (FIB-CVD) have been extensively studied toward various applications including micro- and nano-electromechanical systems and bio-tool etc.[2)] But the throuput is lower than that of conventional lithographic approaches, because 3D fabrication technique is based on direct writing of an ion beam. As a replication method of two-photon-polymerized 3D structure, microtransfer molding replication technique using a poly(dimethyl siloxane) (PDMS) mold was reported. [3)] However, the feature size was the order of several tens of micrometers. In this study, to achieve 3D replication with fine feature size less than sub-micrometer, we proposed a new 3D replication method using a combination of nanoimprint and FIB-CVD.

Figure 1 shows a replication process of 3D structure fabricated by FIB-CVD using NIL with PDMS copy mold. The process is as follows. (1) First, diamondlike carbon (DLC) micro-wineglass with 1.5 μm external diameter and 3 μm height was fabricated on a Si substrate by FIB-CVD using phenanthrene ($C_{14}H_{10}$) gas source. We fabricated FIB-CVD mold using a commercially available FIB apparatus operating at a beam of 30 keV Ga^+ ions and 1pA beam current. (2) And then, the FIB-CVD mold was treated by a fluorinated anti-sticking agent (HARVES Co., DURASURF HD1101-TH). (3) Following, PDMS copy mold was fabricated by spin-coating PDMS prepolymer mixed with its cross-linking catalyst at the ratio of 10: 1 (Dow Corning Co., Sylgard 184) on the FIB-CVD mold. The rotating speed and time were 500 rpm and 3 sec. (4) Next, PDMS coated substrate was baked at 80 ℃ for 30 min to cure the PDMS. After curing of PDMS, PDMS copy mold was de-molded from the FIB-CVD mold. (5) Following, photopolymer (Kayaku Microchem Co., SU-8-5) was spin-coating on a Si substrate. (6) Next, the PDMS copy mold was pressed onto the Si substrate. And then, UV light was passed through the PDMS copy mold at an exposure dose of 150 mJ/cm^2. (7) Following, Si substrate was heating at 90 ℃ for 5 min to solidify cationic polymer. (8) Finally, the PDMS mold was removed from the Si substrate, and then SU-8 3D structure were completely replicated on the substrate.

Figure 2 shows FIB-CVD structure and SU-8 structure imprinted by PDMS copy mold. The 0.3 MPa of imprint pressure was successful structure transfer. But the lower imprint pressure (0.2 MPa) made the topless wineglass because the SU-8 couldn't fill up into the cavity. On the other hand, the higher imprint pressure crushed the wineglass. This result indicates that the suitable pressure made the fine 3D replica structure by NIL with PDMS copy mold. As setting the optimum condition, we successfully fabricated sub-micro-wineglass, as shown in Fig.3. In the presentation, we will demonstrate nano-size 3D replication by this method.

Reference

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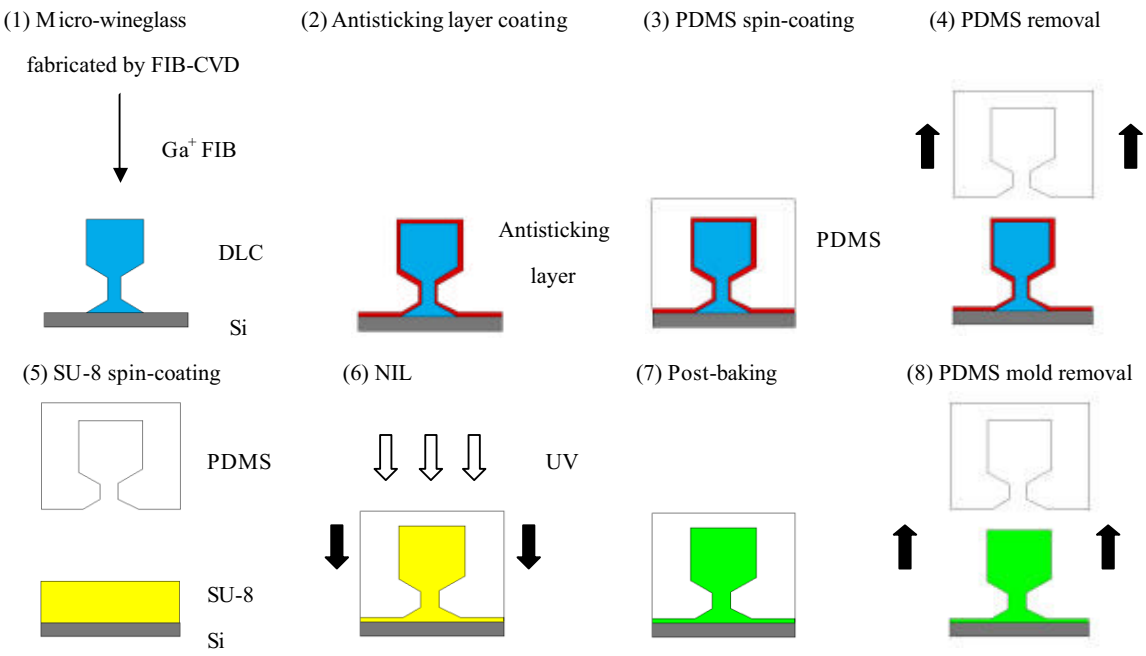


Fig. 1 Replication process of 3D structure fabricated by FIB-CVD using NIL with PDMS mold.

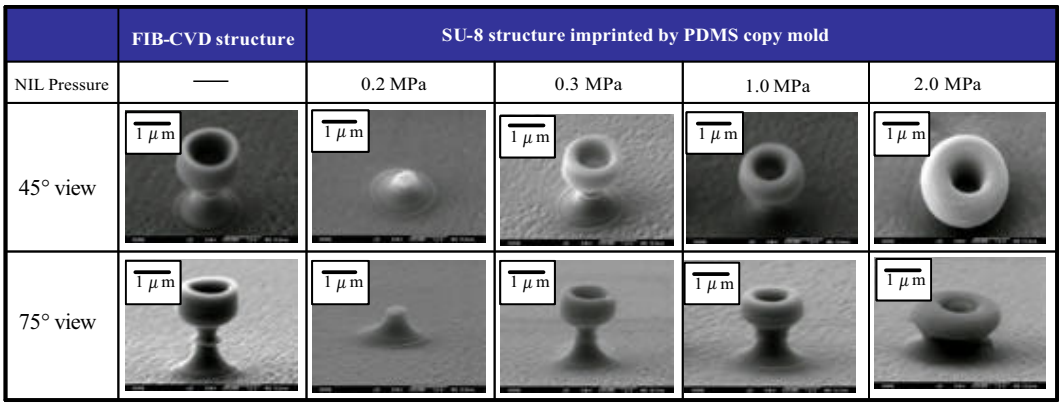
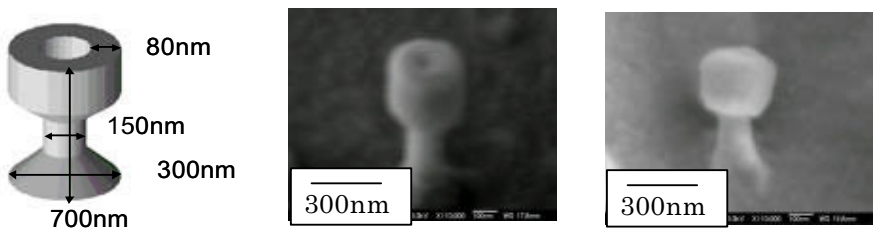


Fig. 2 SEM images of the wineglass pattern



(a) CAD model (b) FIB-CVD structure (c) SU-8 structure

Fig. 3 SEM images of the sub-micro-wineglass