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Diamond-like carbon 코팅기술을 사용한 UV-임프린트 스탬프 제작

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Fabrication of UV imprint stamp using diamond-like carbon coating technology

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Abstract

The two-dimensional (2D) and three-dimensional (3D) diamond-like carbon (DLC) stamps for ultraviolet nanoimprint lithography (UV-NIL) were fabricated using two kinds of methods, which were a DLC coating process followed by the focused ion beam (FIB) lithography and the two-photon polymerization (TPP) patterning followed by nano-scale thick DLC coating. We fabricated 70 nm deep lines with a width of 100 nm and 70 nm deep lines with a width of 150 nm on 100 nm thick DLC layers coated on quartz substrates using the FIB lithography. 200 nm wide lines, 3D rings with a diameter of 1.35 μm and a height of 1.97 μm, and a 3D cone with a bottom diameter of 2.88 μm and a height of 1.97 μm were successfully fabricated using the TPP patterning and DLC coating process. The wafers were successfully printed on an UV-NIL using the DLC stamp. We could see the excellent correlation between the dimensions of features of stamp and the corresponding imprinted features.

Key Words : UV-nanoimprint lithpgraphy, diamond-like carbon, two-photon polymerization, focused ion beam lithography

1. Introduction

Ultraviolet nanoimprint lithography (UV-NIL) [1-3], which is performed at low pressure and room temperature, is known as a low-cost method of fabricating nano-scale patterns as small as 10 nm. In UV-NIL, a stamp with nano/micro-scale patterns is pressed on a thin resin layer or resin droplets and then UV light is exposed from above the stamp to cure the resin. After tens of seconds, in general, the stamp is separated from

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the patterned layer on the substrate; finally, anisotropic etching is used to transfer the patterns onto the substrate.

The stamp is made from quartz or glass because it is required to allow UV light to pass through. The fabrication of a quartz or glass stamp requires the use of reactive ionic etching (RIE) to achieve the desired nano-scale patterns. After electron-beam lithography step, the patterns are etched into hard mask layer on a quartz or glass substrate via RIE. The patterned hard mask layer is then used to etch the substrate. Compared to quartz or glass, diamond-like carbon (DLC) [4] shows advantages such as lower surface energy and higher hardness. Thus, the stamp made from DLC does not require the use of anti-adhesion layer. DLC layer can be produced by a wide range of deposition methods such as ion beam deposition, magnetron sputtering, ion beam sputtering, etc. The DLC stamp fabricated by focused-ion-beam chemical vapor deposition (FIB-CVD) was applied to a thermal-type NIL [5]. The DLC stamp for UV-NIL can also be fabricated on a transparent substrate using electron-beam lithography and lift-off technique while a quartz or glass stamp can be fabricated only by etching. In lift-off technique a thin layer of DLC is deposited on a patterned PMMA layer on top of the transparent substrate followed by lift-off cleaning.

In this paper, the two-dimensional (2D) and 3D DLC stamps are fabricated using two kinds of methods, which were a DLC coating process followed by the focused ion beam (FIB) lithography and the TPP patterning followed by nano-scale thick DLC coating. It is demonstrated that the DLC stamp with no anti-adhesion layer can used for imprinting wafers on UV-NIL.

2. Results and discussion

The DLC coating technique enables the effective use of polymer stamp in UV-NIL. The application of nano-scale thick coating of DLC to the surface of polymer patterns achieves an increase in surface hardness and a decrease in adhesion strength with the stamp and UV-NIL resist polymer. In general, the polymer stamp can be fabricated by several methods such as electron beam lithography and replication of a silicon master. In this study, the two-photon polymerization (TPP) technology [6] using femto-second laser beam is employed to fabricate three-dimensional (3D) nano- and micro-scale polymer pattern followed by nano-scale thick DLC coating. In the TPP, a sliced layer of the 3D pattern is solidified according to the scanning paths; upper layer is fabricated after translating the location of the beam spot along the z-axis using the piezoelectric stage, which is then added to the previous solidified layers. The 3D pattern is fabricated sequentially with this method.

DLC has only one disadvantage that it has low UV transparency. The UV transparency of DLC coated substrate is highly dependent on DLC coating thickness. In case of coating thickness of 100 nm, UV transparency values were measured to be 5% to 18% in the 350 nm to 450 nm wavelength. In case of coating thickness of 200 nm, the UV transparency values decreased to the range of 2% to 8%. We typically used the DLC layers with thickness of less than 150 nm for the fabrication of a stamp because of the low UV transparency.

The 2D and 3D DLC stamps were fabricated using the DLC coating process followed by the FIB lithography (figure 1) and the TPP patterning followed by nano-scale thick DLC coating (figure 2). We fabricated 70 nm deep lines with a width of 100 nm and a space of 50 nm (figure 3(a)) and 70 nm deep lines with a width of 150 nm and a space of 50 nm (figure 3(b)) on 100 nm thick DLC layers coated on quartz substrates using the FIB lithography. The wafers were printed on an UV-NIL using the DLC stamp and a photocurable resin, PAK01[3]. Figures 3(c)-(d) show corresponding imprinted features.

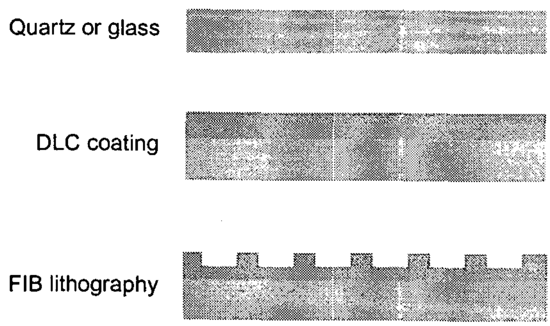

Fig. 1 Stamp fabrication method using DLC coating process and FIB lithography.

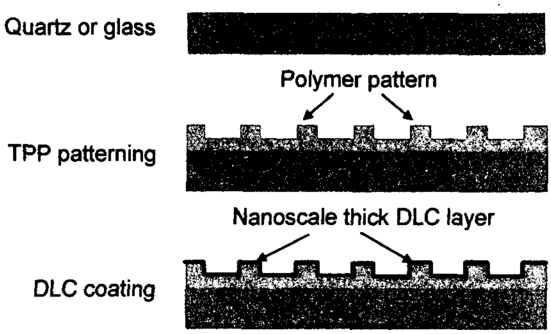

Fig. 2 Stamp fabrication method using TPP patterning and DLC coating process.

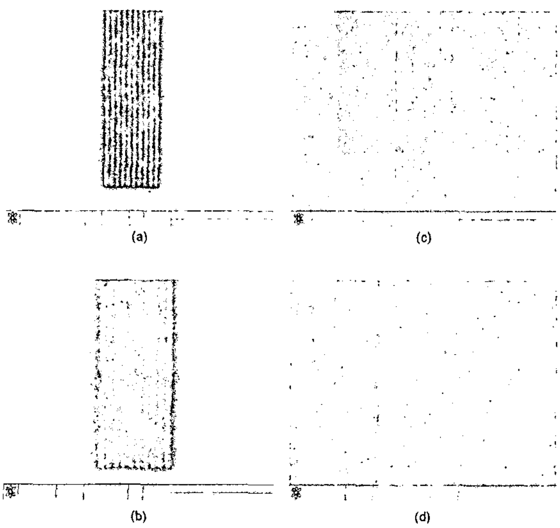

Fig. 3 SEM images of DLC stamp with (a) 70 nm deep lines with a width of 100 nm and a space of 50 nm and (b) 70 nm deep lines with a width of 150 nm and a space of 50 nm by fabricated using DLC coating process and FIB lithography. SEM images of corresponding imprinted structures (c-d).

The DLC layers on top of the quartz substrates of stamp were deposited using the radio frequency plasma enhanced chemical vapor deposition (RF-PECVD) process. The RF-PECVD system was operated at 13.56 MHz. The bias voltage used for the deposition was 400 V and each 100 nm thick deposition was conducted for 15 min. Methane (*CH4, 99.9999%*) gas was used as a precursor. All the substrates were plasma cleaned using Argon prior to deposition to increase surface energy and improve adhesion of DLC. The base pressure was 10-3 Torr and working pressure was maintained at 10 mTorr. FIB patterning was performed using FSEM/FIB dual beam system (FEI Nova200 Nanolab). A focused Ga+ beam with an energy of 30 keV was used for patterning at beam currents from 10 to 50 pA.

Figures 4(a)-(c) show the scanning electron microscope (SEM) images of 200 nm wide lines with a height of 300 nm, 3D rings with a diameter of 1.35 μm and a height of 1.97 μm, and a 3D cone with a bottom diameter of 2.88 μm and a height of 1.97 μm, fabricated using the TPP patterning and DLC coating process. The coated DLC was 5 nm thick. Figures 4(d)-(f) show the SEM images of corresponding imprinted features. We can see the excellent correlation between the dimensions of 3D features of stamp and the corresponding imprinted features.

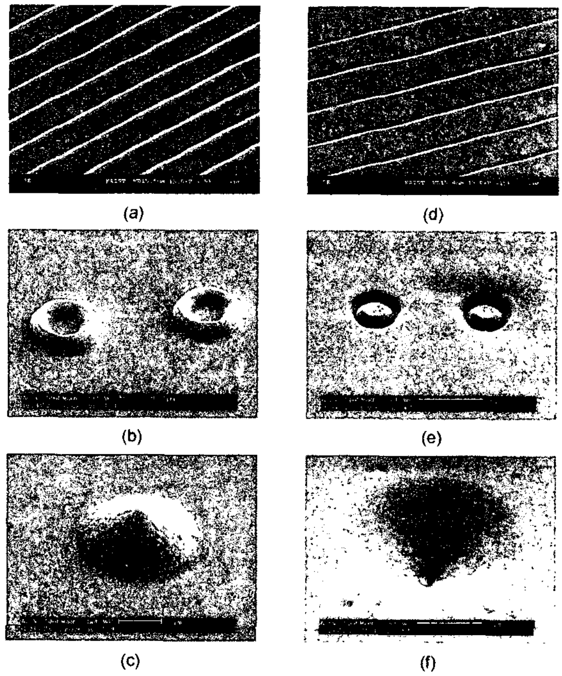

Fig. 4 SEM images of DLC stamp with (a) 200 nm wide lines with a height of 300 nm, (b) 3D rings with a diameter of 1.35 μm and a height of 1.97 μm, and (c) a 3D cone with a bottom diameter of 2.88 μm and a height of 1.97 μm by fabricated using TPP patterning and DLC coating process. SEM images of corresponding imprinted structures (d-f).

3. Conclusions

The 2D and 3D DLC stamps for UV-NIL were fabricated using the DLC coating process followed by the FIB lithography and the TPP patterning followed by nano-scale thick DLC coating. We fabricated 70 nm deep lines with a width of 100 nm and a space of 50 nm and 70 nm deep lines with a width of 150 nm and a space of 50 nm on 100 nm thick DLC layers coated on quartz substrates using the FIB lithography. 200 nm wide lines with a height of 300 nm, 3D rings with a diameter of 1.35 μm and a height of 1.97 μm, and a 3D cone with a bottom diameter of 2.88 μm and a height of 1.97 μm were successfully fabricated using the TPP patterning and DLC coating process. The wafers were successfully printed on an UV-NIL using the DLC stamp. We could see the excellent correlation between the dimensions of features of stamp and the corresponding imprinted features. It was demonstrated that the DLC stamp with no anti-adhesion layer can used for imprinting wafers on UV-NIL.

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