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불화 함유 다이아몬드 상 탄소 스탬프를 사용하는 UV 나노 임프린트 리소그래피

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UV-Nanoimprint Lithography Using Fluorine Doped Diamond-Like Carbon Stamp

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Abstract

A fluorine-doped diamond-like carbon (F-DLC) stamp which has high contact angle, high UV-transmittance and sufficient hardness, was fabricated using the following direct etching method: F-DLC is deposited on a quartz substrate using DC and RF magnetron sputtering, PMMA is spin coated and patterned using e-beam lithography and finally, O_2 plasma etching is performed to transfer the line patterns having 100 nm line width, 100 nm line space and 70 nm line depth on F-DLC. The optimum fluorine concentration was determined after performing several pre-experiments. The stamp was applied successfully to UV-NIL without being coated with an anti-adhesion layer.

Key Words: Fluorine-doped diamond-like carbon (불화 함유 다이아몬드 상 탄소), Ultraviolet nanoimprint lithography, stamp fabrication (UV 나노임프린트 리소그래피 스탬프 제작)

1. Introduction

Ultraviolet nanoimprint lithography (UV-NIL) is a cost-effective method of fabricating nano-scale patterns at room temperature and low pressure [1-2]. In UV-NIL, a transparent stamp is pressed onto a photo-curable resin that is dispensed on a substrate. Then, UV light is exposed to the resin, so that, the resin is cured having the patterned shape of the stamp surface. Finally, the stamp is separated from the cured polymer.

Glass and quartz are widely used as the stamp material in UV-NIL because of their high optical transmittance. However, glass and quartz have high surface energy so an anti-adhesion layer needs to be coated on the stamp. The anti-adhesion layer has a certain lifetime so, in a mass production, it needs to be recoated time by time.

Diamond-like carbon (DLC) can be a promising stamp material for UV-NIL due to its superior mechanical properties. DLC has relatively lower surface energy than glass and quartz but still DLC stamps need an anti adhesion layer in order to obtain patterns having high aspect ratio or sub-100 nm scale patterns. Fluorine doping seems to be a good solution to this problem since the contact angle of DLC can be increased by fluorine doping [3,4].

In this letter, we presented the fabrication method of fluorine doped DLC (F-DLC) stamp to be used in UV-NIL. We fabricated a DLC stamp having high contact

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angle, high UV-transmittance and sufficient hardness. The F-DLC stamp was applied to UV-NIL without coating an anti-adhesion layer.

In Fig. 1, our proposed fabrication method is depicted. Firstly, DLC without fluorine is deposited on the quartz substrate for a better adhesion to the substrate. Then, F-DLC layer was deposited in about 30 minutes. The fluorine concentration was raised gradually to the desired value in a few minutes. PMMA is spin coated as the third layer and patterned using e-beam lithography to be used as the etch mask. Finally, O_2 plasma etching is used to transfer the patterns to the F-DLC. As seen, this method is a direct etching method with the PMMA as the etch mask. The etch rate of the PMMA is quite high, so having a high a etch rate that is comparable to PMMA is important for F-DLC in order to be able to obtain patterns having high aspect ratio.

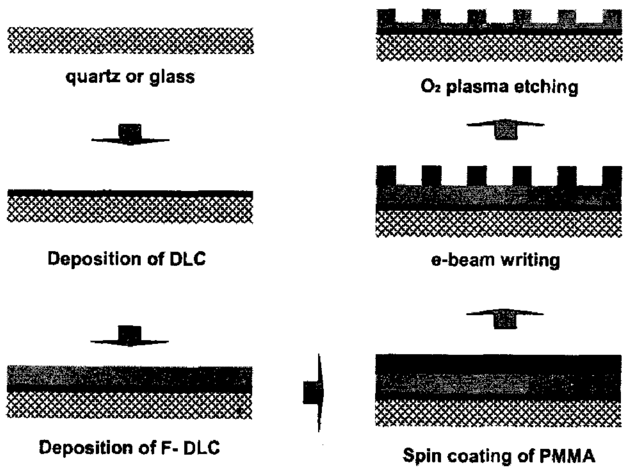


Fig. 1 Schematic illustration of the fabrication procedure of F-DLC stamp.

2. Experiments and Results

Pre-experiments to determine an optimum fluorine concentration of F-DLC by preparing F-DLC samples having different fluorine concentrations and performing tests to measure their contact angle, UV-transmittance, hardness and etch rate.

Before depositing F-DLC, a DLC film layer was deposited on the quartz. Then, F-DLC films were synthesized using DC and RF magnetron sputtering on the DLC layer. In the process, a 3-inches diameter graphite target and PTFE target were mounted on the DC gun and the RF gun, respectively. Table I shows the applied power and bias voltage in depositing the F-DLC samples as well as the results of X-ray photoelectron spectroscopy (XPS) analysis that shows the fluorine, oxygen and nitrogen contents. It can be observed from Table I that applying a bias voltage increased the fluorine concentration. Fig. 2 shows UV-transmittance, contact angle and hardness of the test samples as well as some supplementary materials.

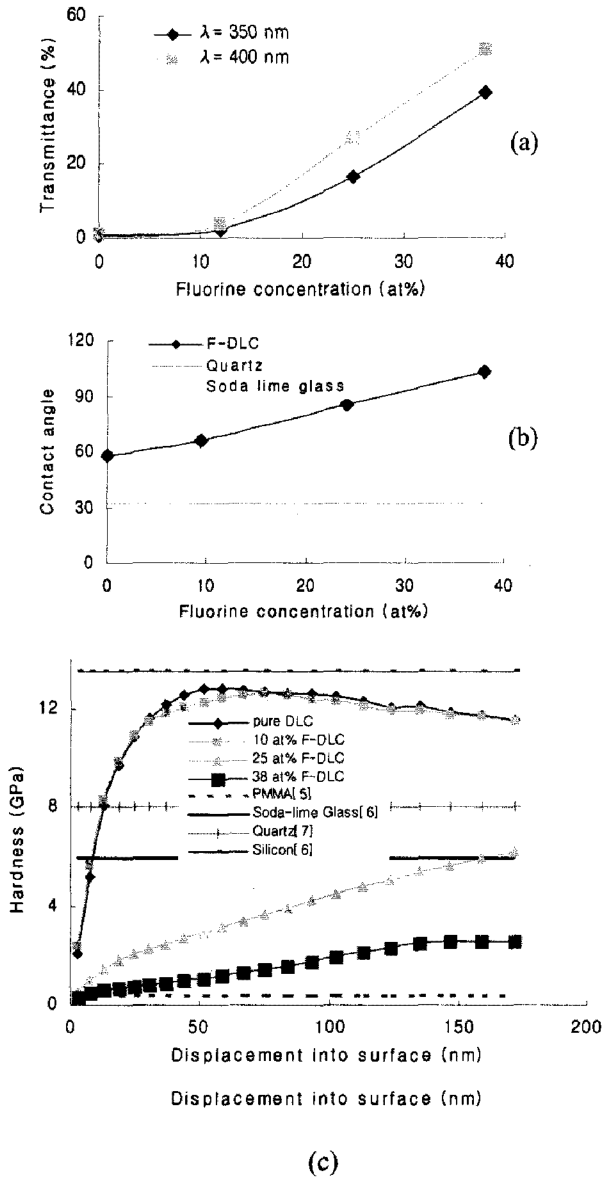
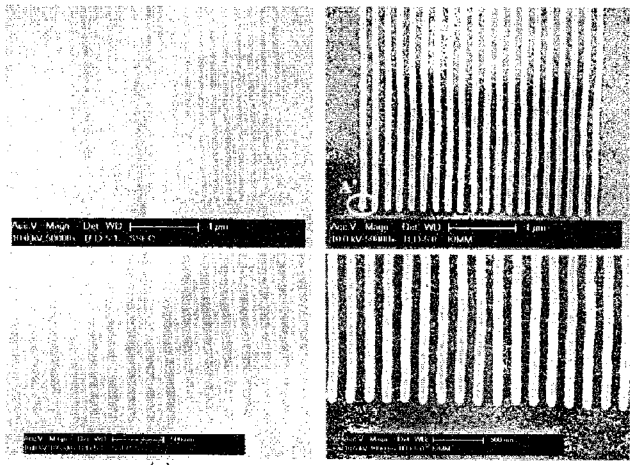


Fig. 2 Variation of (a) UV-transmittance, (b) contact angle, (c) hardness of the samples with different fluorine concentrations.

The etch rate test was performed on the samples and PMMA. Etching was done at 400 mTorr with O_2 and Ar, having the flow rate of 200 sccm and 10 sccm, respectively. Etch rates of PMMA, pure DLC and F-DLC samples having 10 at%, 25 at% and 38 at% were measured to be 130 nm/min, 8 nm/min, 10 nm/min, 70 nm/min and 71 nm/min respectively.

As seen from the results 25 at% F-DLC has high contact angle, UV-transmittance, etch rate and a sufficient hardness. Therefore, 25 at% F-DLC was selected as the material of the stamp. The 150 nm thick 25 at% F-DLC film was deposited on a quartz substrate after depositing a thin DLC layer. Then, it was spin-coated with PMMA layer that is 130 nm in thickness. After the spin-coating, line patterns were formed on the PMMA using e-beam lithography. Finally, patterns on the PMMA were transferred to F-DLC using O_2 plasma etching for 60 seconds, having the same etching parameters stated above.



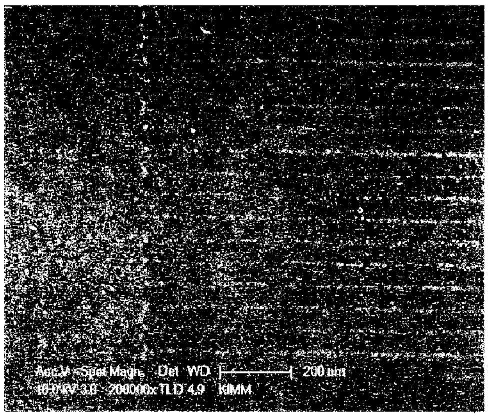
(a) (b)

Fig. 3 SEM images of the (a) F-DLC stamp and (b) the imprinted polymer having line patterns of the imprinted polymer with 100 nm line width and 100 nm line space and 70 nm line depth. The fine replication of the patterns can be observed by considering the marked region of the stamp (A) and the imprinted polymer (A').

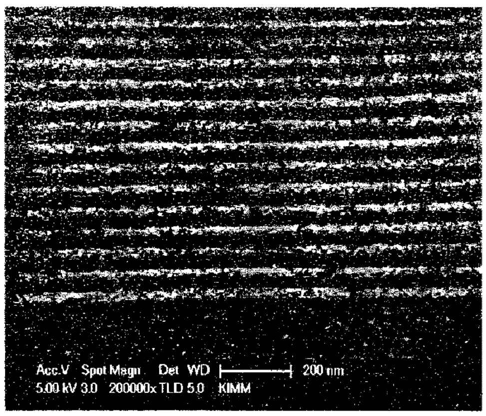
Fig. 3 shows the SEM images of the line patterns on the fabricated F-DLC stamp and the imprinted polymer. The line width, the line distance and the line depth of the patterns are 100 nm, 100 nm and 70 nm, respectively. We could also imprint the lines with a width of 50 nm and a space of 10 nm as shown in Fig. 4.

3. Conclusions

25 at% F-DLC stamp was fabricated with direct etching method and applied to UV-NIL successfully without coating any anti-adhesion layer. 25 at% F-DLC stamp has very satisfactory contact angle of 85o and UV-transmittance of 16.4%-26.8%. Hardness of 25 at% F-DLC stamp is 4.5 GPa, that can be considered as sufficient for UV-NIL. Higher contact angle means easier and finer replication of the imprinted patterns having high aspect ratios. Higher UV-transmittance makes it possible to reduce either the intensity of the UV light - that increases the life of the UV exposure tool- or to reduce the exposure time -that decreases the fabrication time-. In addition, higher UV-transmittance allows us to fabricate thicker stamps.



(a)



(b)

Fig. 4 SEM images of F-DLC stamp with (a) lines with a width of 50 nm and a space of 10 nm and corresponding imprinted structures (b).

The stamps were applied to the UV-NIL. Using this method, features smaller than 50 nm could also be obtained effectively.

Acknowledgements

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References

[1] I. Haisma, M. Verheijen, K. Heuvel, J. Vac. Sci. Technol. B, 14 pp. 4124-4128, 1996.

[2] J. H. Jeong, Y. S. Sim, H. K. Sohn, and E. S. Lee, Microelectron. Eng. 75 pp. 165-171, 2004.

[3] H. Schulza, T. M. Leonhardtb, H. J. Scheibeb and B. Schultrich, Surf. and Coat. Technol., pp. 1123-1126, Mar. 2005.

[4] M. Grischke, K. Bewilogua, K. Trojan and H. Dimigen, Surf. and Coat. Technol. pp. 739-745, Oct. 1995.

[5] B. J. Briscoe, L. Fiori and E. Pelillo, J. Phys. D: Appl. Phys. pp. 2395–2405, Oct. 1998.

[6] Y. G. Jung, A. Pajares, R. Banerjee, B. R. Lawn, Acta Materialia, pp. 3459-3466, Jul. 2004.

[7] K. H. Lee, O. Takai, Surf. and Coat. Technol., pp. 2428-2432, Dec. 2005.