Evaluation of SiOx containing UV nanoimprint resin

S. Omoto[1, 2], M. Okada[1, 2, 3],Y. Kang[1, 2, 3], Y. Nakai[1, 2], Y. Haruyama[1, 2], H. Umekawa[4] and S. Matsui[1, 2]
[1]University of Hyogo, Kamigori, Ako, Hyogo 678-1205, Japan
[2]JST-CREST, Sanbancho, Chiyoda-ku, Tokyo, 102-0075, Japan
[3]JSPS, 6 Ichibancho, Chiyoda-ku, Tokyo, 102-8471 Japan,
[4]TOKUYAMA Co., 40 Wadai, Tsukuba, Ibaraki300-4247, Japan
E-mail: s.omoto@lasti.u-hyogo.ac.jp

UV nanoimprint lithography (UV-NIL) is a high-throughput, low cost and room temperature process capable of achieving replication at nanoscale. The imprint resin with high dry etching durability is required for the device applications. So, we synthesized SiOx containing UV curable resin by adding SiOx component to organic UV curable resin in order to improve the dry etching durability. In this study, we examined the comparison of characteristics between organic UV curable resin (T1) and SiOx containing UV curable resin (T2).

Firstly, to obtain information on the chemical bonding of T1 and T2 cured by UV irradiation, FT-IR spectra were measured between 500 and 1500 cm^{-1}, as shown in Fig. 1. From the result, the peak of Si-O bond was observed at 1100cm^{-1} in T2 spectra. Following, we examined the etching rates of T1, T2 and SiO_2 for CHF_3 and O_2 reactive ion etching (RIE), as shown in Fig.2. The CHF_3 gas flow rate, gas pressure and RF power were 50 sccm, 2 Pa and 100 W, respectively. And the O_2 gas flow rate, gas pressure and RF power were 50 sccm, 5 Pa and 100 W, respectively. The etching rate of T2 was about 300 times lower than that of T1 in O_2 RIE. We confirmed that the etching rate of T2 for O_2 RIE drastically improved by adding SiOx to T1. On the other hand, the etching rate of T2 was nearly the same as that of T1 for CHF_3 RIE.

Next, to evaluate the surface modification of SiOx containing UV resin after O_2 RIE, we performed X-ray photoelectron spectroscopy (XPS) analysis. O_2 plasma in RIE apparatus was irradiated onto T2 of SiO_2 containing UV resin for 1 min. Figure 3 shows the spectra of Si 2p area. The peak at 99.5 eV is assigned to the emission of electrons from the Si 2p. The peak of Si 2p of O_2 plasma irradiated T2 shifted to the high energy side, and took a value close to 103.5 eV of SiO_2, as shown in Fig 3. The result indicates that the surface of SiO_2 containing UV resin surface becomes a SiO_2 like structure by O_2 RIE.

Then, we measured the-photo-DSC to investigate curing time and calorific value of T1 and T2. Measurement conditions were as follows. The sample weight was 10 mg. UV wavelength, intensity and irradiation time were 365 nm and 30 mW/cm^2 and 6 minutes in air, respectively. Figures 4(a) and 4(b) show the photo-DSC results of T1 and T2, respectively. The curing times of T1 and T2 were 0.1s and 0.18s, respectively. On the other hand, the calorific values of T1 and T2 were 187 mW and 0.53 mW, respectively.

Subsequently, we performed UV nanoimprint by using T2. The imprint pressure was 1.0 MPa. Figure 5 shows SEM image of imprinted patterns by UV nanoimprint with T2. We successfully performed the transcription of 16nm high resolution fine patterns by UV nanoimprint with T2.

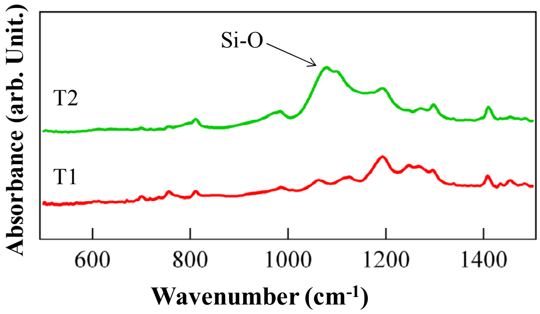


Fig.1. FT-IR spectra of T1 and T2.

	T1	T2	SiO_2
CHF_3	**16.0** nm/min	**14.7** nm/min	**26** nm/min
O_2	**200** nm/min	**0.7** nm/min	**0** nm/min

Fig. 2. Etching rates of T1, T2 and SiO_2.

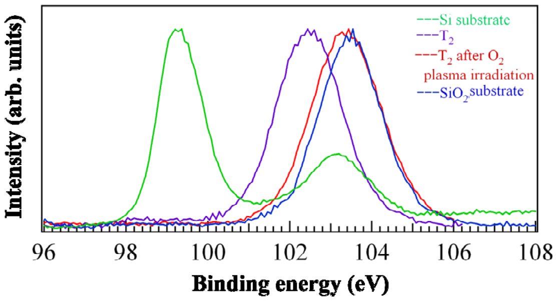
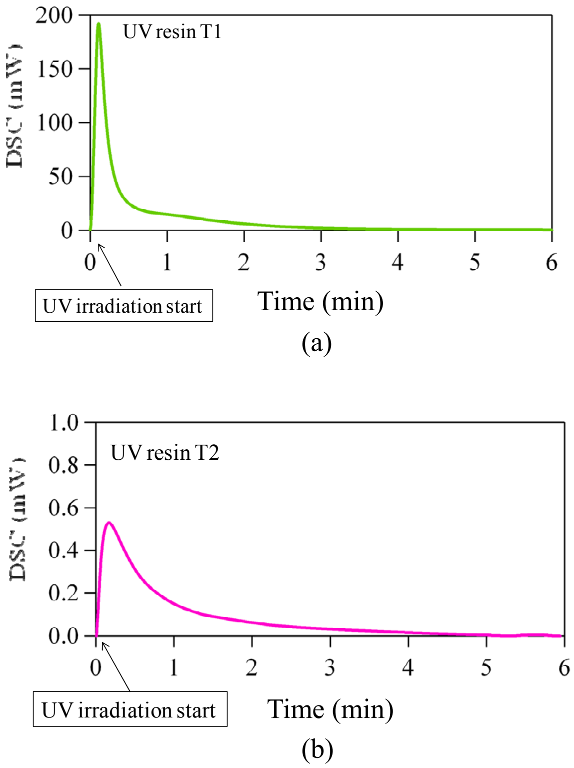


Fig.3. XPS spectra of Si 2p region.



(a)

(b)

Fig.4. Relationship between UV irradiation time and photo-DSC results of (a) T1 and (b) T2.

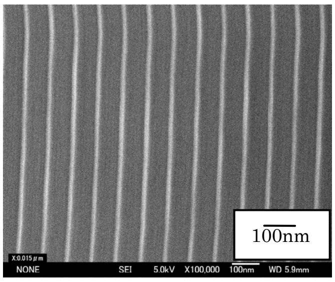


Fig.5. SEM image of imprinted patterns by UV nanoimprint with T2.