Fabrication of fine slanted diffraction gratings by electron beam lithography and nickel electrolytic plating

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AR/MR glasses, which are the next generation displays, are becoming smaller and more popular. The slanted diffraction gratings play an important role in this AR glass. The slated diffraction gratings can be fabricated by UV-NIL in a high refractive index resin using a working stamp[1]. The master mold for the slanted diffraction gratings is fabricated using electron beam lithography (EBL) and oblique ion beam etching. As this method requires many steps, we have developed a method in which we first delineate a diffraction grating on an inclined substrate using EBL, and then make a sturdy master mold using nickel electrolytic plating. Figure 1 shows a fabrication process of slanted diffractive grating. Positive tone EB resist (ZEP520A) was coated on silicon substrate (Fig. 1(1)). Thickness of this resist was 500 nm. This substrate was installed in EBL machine with titled angle of 45^{o} and EBL with acceleration voltage of 4kV was carried out (Fig. 1(2)). The drawing patterns were a L&S pattern with a line width of 90 nm and an interval of 270 nm, and a L&S pattern with a line width of 180 nm and an interval of 270 nm. After development (Fig.1(3)), nickel coating with thickness of 50 nm was carried out using resistance heating vacuum deposition machine (Fig.1(4)). This process is necessary to impart electrical conductivity to the surface of the resist. Then, nickel electrolytic plating was carried out (Fig. 1(5)). After that, EB resist was removed by solvent (Fig. 1(6)). Then, Ni master mold with convex slanted diffraction gratings was fabricated. To make working stamp, this Ni master mold was release coated and transferred to UV-curable resin by UV-NIL (Fig. 1(7)). Figure 2 shows fabricated Ni slanted diffraction gratings. The drawing design of Fig. 2(a) was a L&S pattern with a line width of 90 nm and an interval of 270 nm. The drawing design of Fig. 2(b) was a L&S pattern with a line width of 180 nm and an interval of 270 nm. The fabricated Ni line widths were wider than the design values. Also, the angles were slightly off from 45°. This is thought to be due to the effect of forward scattering of EB. These issues can be improved by optimizing the EB dose, acceleration voltage, and EB resist. Figure 3 shows transferred patterns for UV-curable resin using Ni master mold by UV-NIL. The reverse patterns of the Ni master mold were obtained, which allows the making of a working stamp from the Ni master mold.

1. T. Akasaki, R. Tanaka, T. Osaki, Proceedings Volume Optical Architectures for Displays and Sensing in Augmented, Virtual, and Mixed Reality (AR, VR, MR) V, 129130V (2024) https://doi.org/10.1117/12.3004959L.

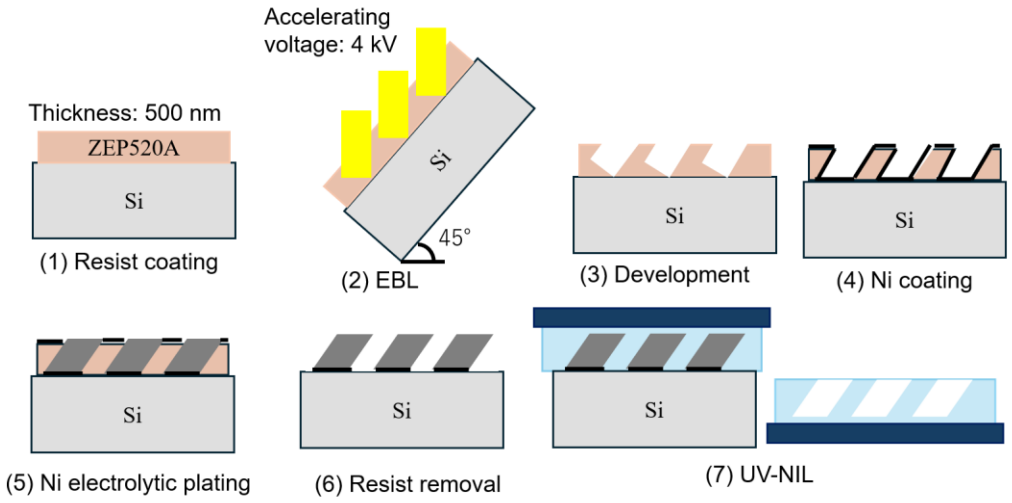
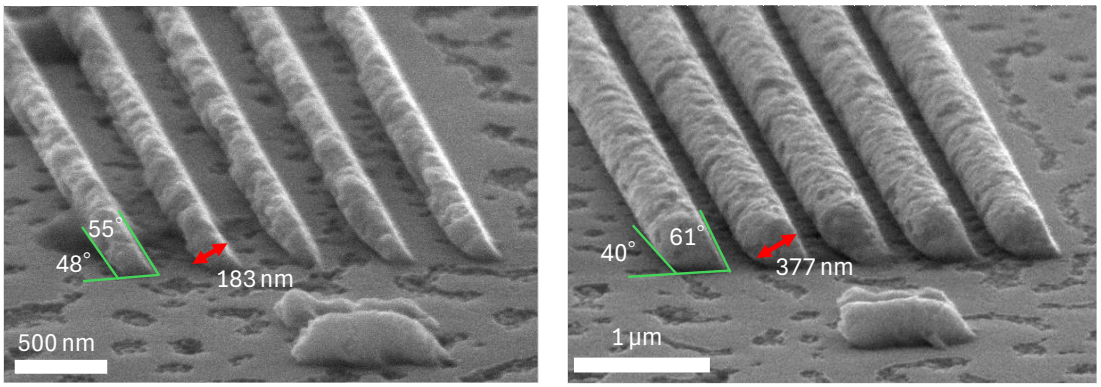
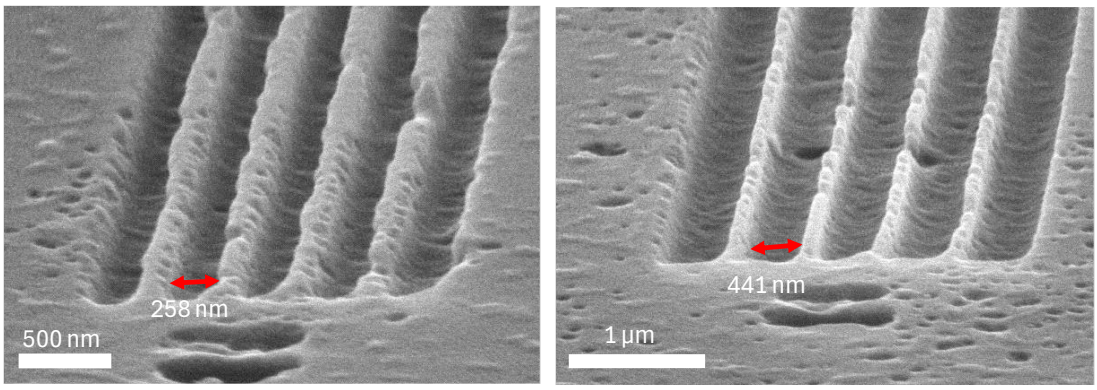


Figure 1: Fabrication process of slanted diffractive gratings.



(a) (b)

Figure 2: Fabricated Ni slanted diffraction gratins. (a) 90 nm line width design (b) 180 nm line with design.



(a) (b)

Figure 3: Transferred UV-curable resin patterns. (a) 90 nm line width design (b) 180 nm line with design.