Reactive Ion-beam Etched SiC Gratings

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High heat load endurance is required for diffraction gratings of monochromators installed in soft X-ray beamlines at SPring-8, as well as the first reflecting mirrors. SiC is an excellent mirror material for high power synchrotron radiation. Therefore, SiC gratings on which grooves are directly cut are considered to be one of the best optical elements on the soft X-ray beamlines.

We fabricated SiC laminar gratings by reactive ion-beam etching and holographic exposure. Figure 1 shows the fabrication process of the SiC gratings.Step (1):coating of positive photoresist(OFPR5000) of 4000Å thickness on a SiC substrate, step(2):formation of photoresist mask by holographic recording of interference fringes by two laser beams, step(3):reactive ion beam etching in $Ar+CHF_3$ mixture, and step(4):removal of photoresist mask by O_2 plasma ashing. We found that the ratio of the etch rate of SiC to that of photoresist was the largest when $67\%Ar+33\%CHF_3$ mixture was used as etchant.

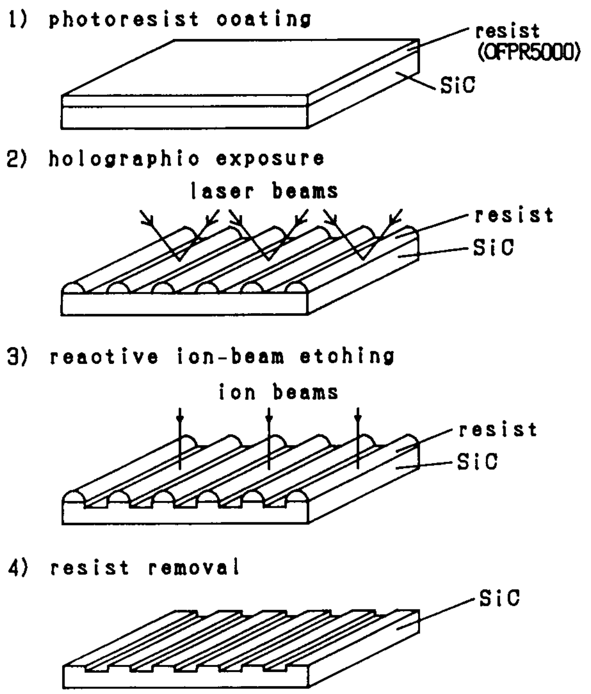

Fig.1.Fabrication process of holographic SiC grating by reactive ion beam etching.

Figure 2 demonstrates SEM micrographs of the cross section of a SiC grating fabricated according to the procedure shown above. The view shows a good groove structure with a width of 1μm, depth of 1100Å and slope of approximately 60°. Some scratches of polishing were observed on both the top and bottom of the grooves. No "rough texture" or "spike" structure as usually observed in plasma etching[1],[2] were seen in the etched surface.

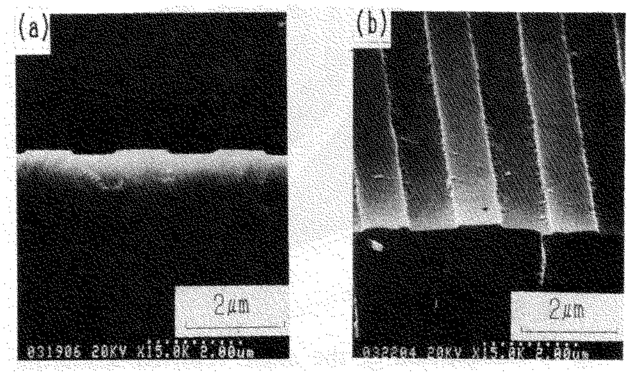

Fig.2.SEM micrographs of SiC grating fabricated by means of reactive ion-beam etching. (a)cross sectional view and (b)perspective view of the etched pattern on the surface. The grating has 500 l/mm grooves and the depth of 1100Å.

Diffraction efficiencies of an ion-beam etched SiC grating were measured in the soft X-ray region. The grating was produced by etching a SiC mirror with RMS roughness of 3.44Å. The groove density was 1200 l/mm, the depth 75Å and the groove width-to-spacing ratio 0.5. The surface was coated with gold of 750Å thickness. The maximum efficiencies of the m=+1 diffraction line were 5.3% at λ=8.34Å, 5.6% at 22Å, 4.7% at 45Å, 5.4% at 60Å, 9.4% at 90Å and 5.8% at 120Å. The scattered component of the diffracted lights was remarkably small.

Irradiation test of SiC gratings was performed with intense radiation of power density of 2.7 W/mm^2 emitted from a multipole wiggler installed on the 2.5 GeV Photon Factory ring. An uncoated and a gold coated gratings with 1200 l/mm groove density were used as samples. No visible damages and no reduction of the diffraction efficiencies were observed for the uncoated SiC grating after irradiation, while a remarkable deformation of deposited Au layer and increase of the scattered light component were observed for the grating coated with Au.

From the results, we can expect that ion-beam etched SiC gratings are a candidate for diffraction elements for intense VUV and soft X-ray radiations in SPring-8.

References

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