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X-RAY DIFFRACTION ON THE CRYSTALLINE LATTICE OF SILICON IN ACCORDANCE WITH BRAGG'S LAWS

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Abstract. Diffraction gratings are commonly used as dispersion spectral devices and monochromators. This article explores the production of crystalline diffraction gratings and investigates their X-ray optical diffraction properties.
Key words: diffraction, grating, optica, phase-shifting, cross-section.

Introduction. Fabrication Technology of Gratings.

The planar technology, illustrated in Fig. 1, was employed for the fabrication of crystalline diffraction gratings. In Fig. 1(a), the technological process of manufacturing the diffraction grating based on profiling a Si crystal is presented. This technology involves the use of electron beam lithography to create a grating pattern in the resist. Subsequently, a 10 nm thick layer of Al is deposited using magnetron sputtering. After the "lift-off" operation, the surface of the Si substrate retains the structure of the future grating in the form of an Al mask, which is later utilized as a masking coating during plasma etching. Following the etching process, a deep diffraction grating is formed on the surface of the Si crystal. The formation of phase diffraction gratings is of particular interest, and the technological process is depicted in Fig. 1(b). In this case, the planar technology for manufacturing the diffraction grating is also based on the use of electron beam lithography, during which the resist forms the pattern of the future diffraction grating. Subsequently, a phase-shifting metal layer (Au, W) is deposited using magnetron sputtering. Further, explosive lithography "lift-off" operations are conducted, resulting in the formation of a diffraction grating on the surface of the Si crystal from the phase-shifting metal layer. This, combined with the original Si substrate, constitutes the crystalline diffraction grating. Of specific interest is the possibility of selectively chemically etching Si through a masking coating, enabling the formation of deep crystalline diffraction gratings.

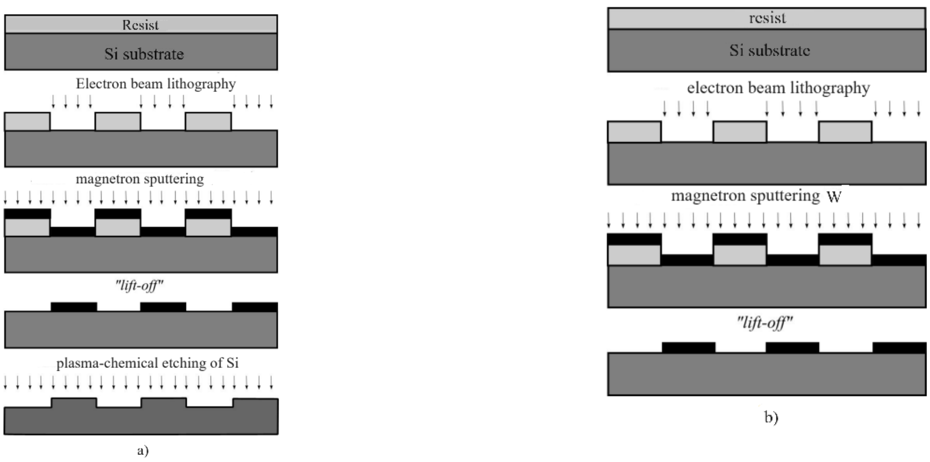

Figure 1. Technology for manufacturing crystalline diffraction gratings: (a) Si profiling; (b) creation of the phase-shifting layer W.

Si Diffraction Grating

Figure 2 shows a cross-section of a crystalline diffraction grating with a period of D = 2 μm. The diffraction grating was manufactured on the surface of a Si(111) crystal using the planar technology depicted in Figure 1(a). The height of the diffraction grating stripes is 500 μm.

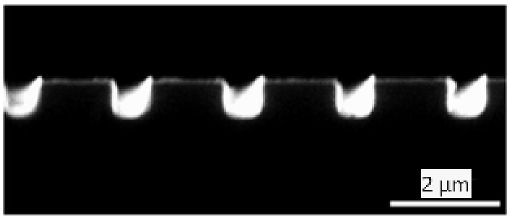

Figure 2. Cross-section of the crystalline diffraction grating based on Si(111) with a period of D = 2 µm.

Investigation of the Diffraction Properties of the Si Grating

Figure 4 presents the results of studying the diffraction properties of the Si grating with a period of D =2 µm. The rocking curve is shown in Figure 3(a), where numerous diffraction satellites can be observed around the intense Bragg peak.

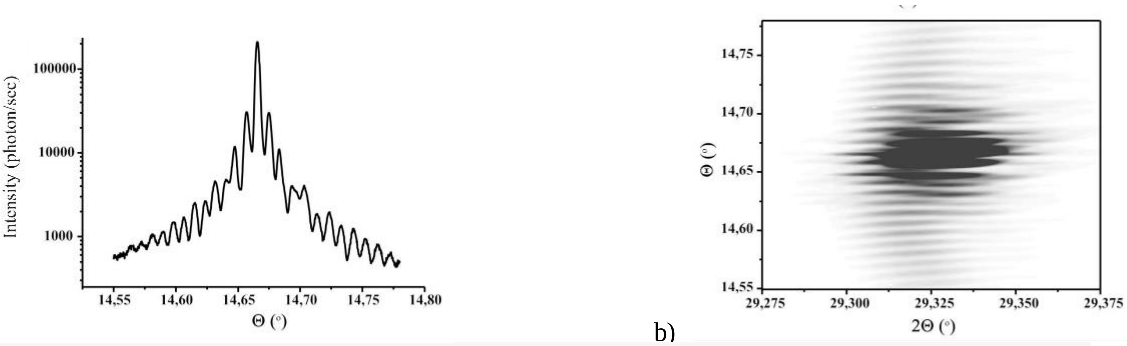

Figure 3. Si diffraction grating: (a) rocking curve of the crystalline diffraction grating, (b) 2D map of the distribution of diffracted X-ray intensity. Si(111) reflection, Bragg angle Θ = 14.665°, grating period D = 2 µm.

The angular divergence between satellites is ΔΘ = 0.0084°, consistent with the calculated value from expression (1). In Figure 3(b), a two-dimensional map of the distribution of diffracted X-ray intensity is displayed, revealing the splitting of diffraction satellites. The splitting of satellites is associated with the refraction of X-ray radiation at the upper and lateral boundaries of the stripes of the diffraction grating.

Conclusion.

In summary, the planar technology successfully produced crystalline diffraction gratings on a Si(111) crystal, utilizing electron beam lithography, magnetron sputtering, and lift-off operations, with particular interest in the selective chemical etching of Si for deep grating formation, as demonstrated by the diffraction properties presented in Figure 3.

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РЕНТГЕНОВСЬКА ДИФРАКЦІЯ НА КРИСТАЛІЧНІЙ ГРАТЦІ КРЕМНІЮ ВІДПОВІДНО ІЗ ЗАКОНАМИ БРЕГГА

Анотація. Дифракційні решітки широко використовуються як дисперсійні спектральні пристрої та монохроматори. У цій статті розглядається виробництво кристалічних дифракційних ґраток і досліджуються їхні рентгенівські оптичні дифракційні властивості.
Ключові слова: дифракція, решітка, оптика, фазозсув, переріз.

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