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Replicating blazed Si diffraction gratings for the X-ray range

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There are two principal ways to achieve ultra-high spectral resolution and maximal diffraction efficiency by blazed (with triangular groove profiles) gratings in the short-wave range (from hard X-rays to vacuum UV): (1) using high-orders diffraction with low and medium groove densities; (2) using first-orders diffraction with high and ultra-high groove densities. Due to the hard-to-solve problem of removing nubs obtained on monocrystal silicon grooves during anisotropic wet etching, most studies focused on the development of the most promising Si gratings with a blaze with small and ultra-small periods [1–4]. Our group has made progress in fabricating and testing master blazed gratings operating in high orders and having the record efficiency [5,6]. However, the production of high-quality large-size master gratings with any groove frequency is still a very complex technological task.

To ensure the possibility to produce diffraction gratings with the same parameters, as well as large-area gratings (e.g. for space telescopes), it is necessary to have an effective way to replicate master Si gratings. There is a copying technology using polyester resins, developed in the last century for replicating coarse ruled diffraction gratings. Besides, nickel and copper electroplated templates are used as stamps to imprint the profile into a polymer curable material. To copy objects with groove dimensions in the nanoscale, the so-called contact copying (nano-imprinting) is used, based on imprinting a template into a soft polymer film with subsequent thermal or UV curing. Replicated 3D nanoobjects can be used as final structures or for the manufacture of a reusable stamp. As studies show, even the latest commercial technologies of contact nanocopying of gratings provide low accuracy of transferring the shape of the master's grooves due to rounding of corners, changes in the blaze angle and/or depth of the groove, curvature of the reflective edge and an increase in the roughness of the reflective surface.

In order to accurately transfer shallow triangular reliefs and preserve perfect characteristics of masters of X-ray (short-wave) Si gratings during copying, we use atomic-level contactless methods of applying inorganic materials to the surface of the master grating grooves. To obtain a replica of a Si grating, thermally sprayed Au is used as a transfer layer, since it has poor adhesion to silicon and has good adhesion to metal, which serves as the material of the filling layer. In addition, gold is widely used as a reflective coating in the X-ray and IR ranges. We also selected galvanically applied Au as the material of the filling (alignment) layer, which allowed us to fill the profile and obtain a leveled plane for gluing. As a result, a gold grating is glued to the silicon substrate of the copy and mechanically separated from the Si grating master.

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