Fabrication of Antireflection Structures for Binary Diffraction Gratings

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Subwavelength nanostructures are well known to have broadband, omnidirectional antireflective (AR) properties if properly designed [1]. These nanomaterials effectively function as gradient-index media that eliminate Fresnel reflection losses by adiabatic optical impedance matching. Various methods have been used to implement such structures, such as lithographically defined sub-wavelength nanostructures [2], deposition of multilayer porous films [3], and plasma etching of randomly positioned nanoscale tips [4].

Diffractive optical elements also suffer from reflection losses due to index mismatch. These elements, such as gratings, Fresnel zone plates, and holograms, often have undesirable multiple reflected orders. Recently, we have proposed the theoretical design and optimization of a novel gradient-index AR structures for diffraction gratings that can significantly suppress such reflections, shifting all energy into the transmitted orders [5]. These structures can lead to more efficient diffractive devices for thin-film integrated photovoltaics, waveguide couplers, and holographic optical elements. Here we present the fabrication process and the implementation of this AR diffractive structure.

The proposed AR structure for a binary grating is depicted in Figure 1, where its main function is to eliminate all reflected orders. The grating has period Λ_1, and consists of tapered subwavelength nanostructure with period Λ_1 on both the ridge and groove regions. A more detailed illustration of the AR structure is shown in Figure 1(b), where both the substrate and the tapered structure have index n_s. In this configuration, the periodic index modulation in x increases gradually in the z-direction.

Preliminary fabrication results are shown in Figure 2. A cross-section micrograph of a 4 μm period grating with the surfaces patterned with 200 nm period subwavelength tapered structure is shown in Figure 2(a). The structure is fabricated using both interference and nanosphere lithography, and etched into silicon using reactive ion etching. The subwavelength structure shown has a relatively low aspect ratio of 1. Figure 2(b) depicts the results from an improved etch process, where a subwavelength AR structure with aspect ratio of ~8 has been fabricated. We will utilize this process to fabricate the next generation AR diffractive structures.

In this work we describe the fabrication process for an AR structure for diffractive gratings. We will present the processing conditions in detail, the theoretical modeling and experimental testing results of the fabricated structure. These novel AR structures can lead to more efficient diffractive optical elements.

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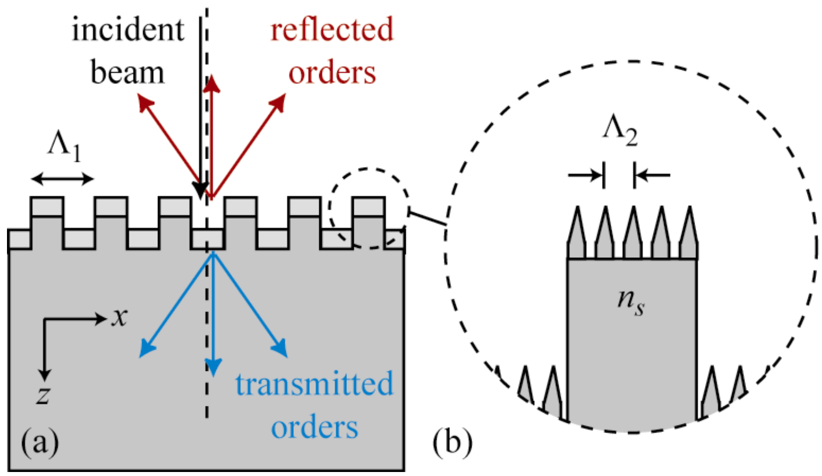

Figure 1 *Schematic of the (a) proposed AR structure for a binary grating. (b) The structure consists of tapered subwavelength nanostructures on both the ridge and the groove of the grating.*

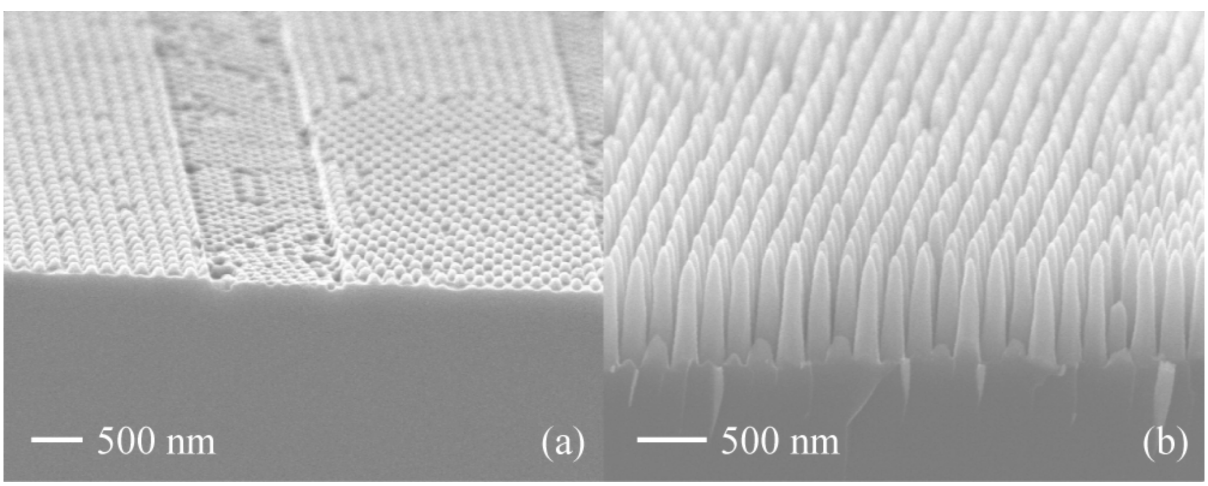

Figure 2 *Cross-section micrographs of (a) fabricated antireflection diffractive structure. The grating consists of subwavelength textured surfaces. (b) Subwavelength tapered structure etched ~800 nm into silicon.*

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