Demonstration of Multi-Layer Antireflective Treatments for Gradient Index Silicon Optics at THz frequencies

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***Abstract*— Future instruments for millimeter- and submillimeter-wave astronomy applications can benefit greatly from ilicon optics with broadband antireflection treatment. Silicon is an ideal material at these wavelengths, but its high index (n = 3.42) requires antireflection (AR) coatings to avoid reflections. We report on the development of multi-layer flat gradient index (GRIN) silicon optics for wide spectral bandwidths.**

***Keywords*— Antireflective treatments, Deep reactive ion etching, Vacuum window, Silicon optics.**

I. Introduction

Numerous branches within the fields of astronomy and cosmology, such as studies of CMB polarization, the Sunyaev-Zeldovich effect, dusty sources, and millimeter-wave transients would benefit significantly from the utilization of low-loss, wide bandwidth, flat optics operating at submillimeter and terahertz (THz) frequencies. Silicon has favorable characteristics such as high refractive index (3.42), achromaticity, absence of birefringence, mechanical strength, while being low loss; and as such emerges as an optimal optical material for these frequencies. However, the challenge lies in the antireflection (AR) treatment due to silicon's high refractive index. Over the past few years, we have successfully developed multi-layer integrated AR treatments that we are now combining with our flat gradient index (GRIN) silicon optics.

II. Design, Simulations and Fabrication

We use a multi-step deep reactive ion etching (DRIE) [1] process to etch subwavelength features (posts and/or holes) into 100 mm diameter high-resistivity silicon wafers to locally vary silicon's effective refractive index: by creating multiple layers with different refractive indices, we obtain a very wide-bandwidth antireflection (AR) treatment. And by varying the index of a silicon wafer radially we can create flat low-loss gradient index (GRIN) lenses [2]. Our two-layers AR structure has been shown to yield reflections of < 1% over the frequency range of 180 – 310 GHz (1.6:1 bandwidth) [3]. Our three-layer AR surfaces are designed for a 2.3:1 bandwidth (190-350 GHz) and < 1% reflectance and currently we are combining those wafers with flat-faced gradient index (GRIN) optics, see Fig. 1a. Finally, our latest four-layer AR structure is optimized to give −20 dB reflection between 130 – 400 GHz (3.1:1 bandwidth), see Fig. 1b and 1c. Complete results will be presented and discussed along with future designs for five-layer and six-layer AR treatments to cover bandwidths up to 5.7:1 (73-415 GHz and 23-130 GHz).

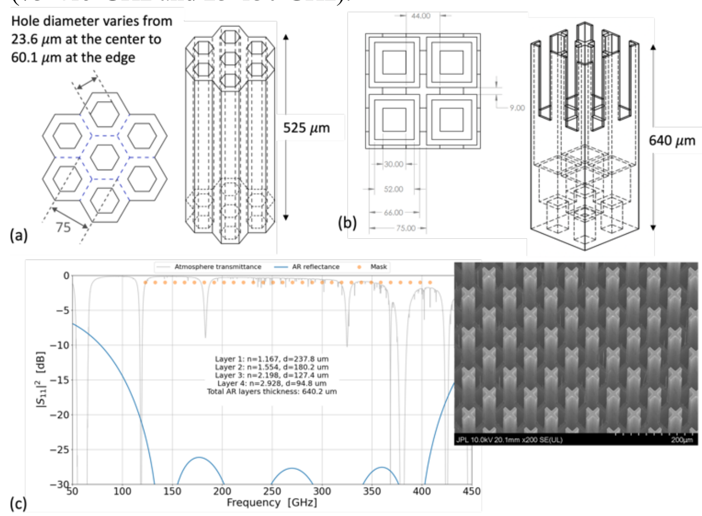

Fig 1: (a) and (b) Representations of our GRIN pattern and our four-layer AR pattern. (c) Simulation for our 4-layer AR surface, with an SEM image of the fabricated wafer.

References

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