Broadband THz Anti-Reflection Moth-Eye Structures Formed by Femtosecond Laser Processing

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The terahertz (THz) frequency range has become increasingly important for the study of the physics of materials, including superconducting materials and topological insulators. One of the features of THz waves is high field compared with IR and visible light, and this feature is used for the study of nonlinear carrier dynamics and electron acceleration. THz wave detectors with high sensitivity have also been developed and used for the observation of the cosmic microwave background. In addition to physics applications, THz technologies are expected to contribute to security related instrumentation and wireless communications applications. The extraordinary properties of THz waves are expected to open up approaches to new devices and technologies. However, electromagnetic waves in this frequency region resonate with vibration modes of molecules and bandgaps in materials. This resonance causes large absorption and therefore a limited number of materials with less absorption are available for the THz region. Even for materials with less absorption, Fresnel reflection is a serious problem. For example, high-resistivity silicon is one of the most important optical materials for making optical components due to its high transparency to the far-infrared to microwave frequencies, including the THz region. However, since its refractive index in the THz range is about 3.4, 30% of the radiation is lost at every air-silicon interface. As a result, about half of the incident power will be lost for every passive THz silicon component regardless of absorption.

Broadband anti-reflection (AR) functionality has been realized by a moth-eye structure consisting of arrayed tapered protrusions of the substrate material with sub-wavelength dimensions[1]. I will describe the basic principle, the design constraints, fabrication technique and the experimental results which we have achieved with moth-eye structures on high-resistivity silicon as shown in Fig. 1 [2]. The moth-eye structure on sapphire substrates will be also described [3].

[1] S. Wilson and M. Hutley, Opt. Acta 29(7), 993(1982).
[2] H. Sakurai, et al., OSA CONTINUUM 2, 2764 (2019)
[3] R. Takaku, at al., IRMMW-THz 2019, Th-Po4-93,Paris (2019)

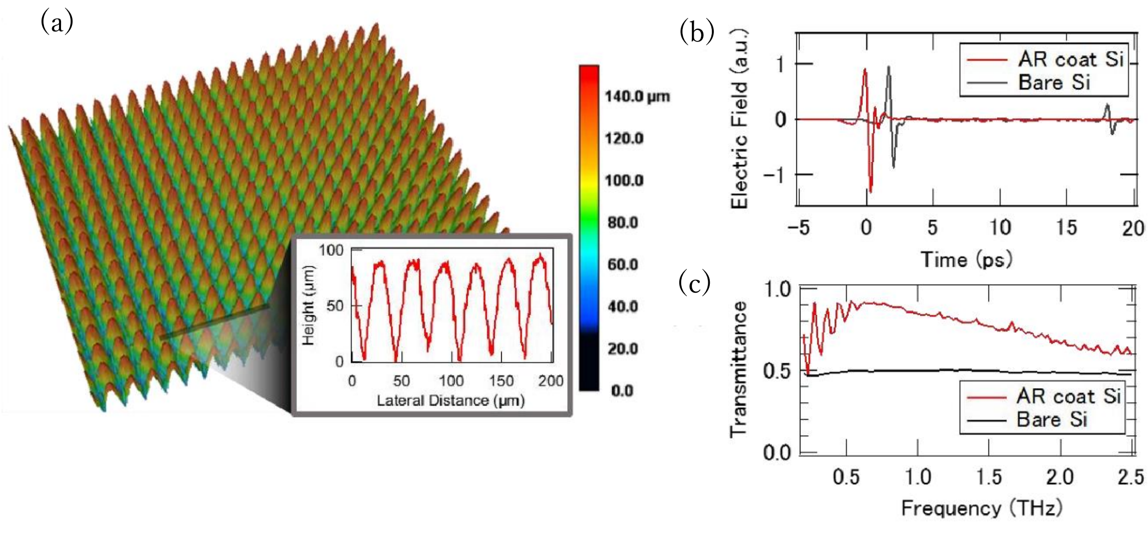

Fig.1 (a) 3D height profile of a moth-eye-processed silicon substrate, (b) THz-TDS transmission signal and (c) the improved transmission (red) of TDS signal