2021 46th International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz) | 978-1-7281-9424-0/21/$31.00 ©2021 IEEE | DOI: 10.1109/IRMMW-THz50926.2021.9567007

High Q Asymmetrical Terahertz Metasurface For Frequency Selective Applications

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***Abstract*—Optical resonators are of significant interest due to their strong light confinement ability. However, the resonator performance is often limited by the out-of-plane scattering caused by fabrication defects. A physical mechanism known as bound states in the continuum can potentially suppress the scattering, leading to improved optical devices. Using the concept, here we propose a standard metasurface having two elliptical silicon (Si) blocks to create out-of-plane asymmetry. The device parameters are optimized by the Genetic Algorithm (GA). Fabrication of the device is carried out following standard fabrication methods. The experimental outcome shows that the metasurface can achieve a high Q factor of 236 which is in good agreement with the simulation. Owing to its strong light confinement ability the metasurface can be used as a frequency selective device, filter, and biochemical sensor.**

INTRODUCTION

LIGHT guidance by optical resonator carries significant interest because of its strong light manipulation ability. However, the performance of a metasurface is always limited by fabrication imperfections. A physical mechanism known as the bound states in the continuum [1] can suppress the issue and allow the metasurface to perform at its best. Considering the mechanism, we design and develop an asymmetrical metasurface for high Q terahertz applications.

There is significant research carried out to develop high Q metasurface devices in the optical frequency region [2], however, very limited research can be found in the terahertz regime [3]. Considering this fact and to commercialize devices in the developing frequency regime (terahertz) we design and develop a high Q terahertz metasurface. Experimental analysis shows that the metasurface can achieve a high Q-factor of 236, benefitting from a narrow-sharp resonance peak. Benefitting from the narrow band sharp resonance peak, the metasurface is attractive for highly sensitive biological sensors, where the resonance peak shifts will be visible.

I. Design, Fabrication, and Experiment

The design and simulation of the metasurface are carried out using a CST microwave studio-frequency domain solver. The parametric optimization is done using a genetic algorithm (GA). After optimizing the metasurface, the fabrication tolerance is also considered and found that the metasurface works well for around 5% variation of the geometrical parameters.

The material COC (Cyclic Olefin Copolymer) is chosen for is remarkably low loss, and high thermal and chemical stability at terahertz [4]. Silicon is chosen as a resonator material for its high dielectric permittivity. This helps to confine the electromagnetic wave to the outer surface of the metasurface.

To realize the metasurface absorber, an unconventional fabrication procedure was carried out. Typically, the fabrication processes involve a standard photolithography patterning and plasma etching process to establish the resonators on polymers. The experimental analysis was carried out by a terahertz spectroscopic measurement. An SEM image of the fabricated device and the experimental outcome is shown in Fig. 1 and Fig. 2 respectively. The reflected power (Fig. 2a), absorption (Fig. 2b), and reflection (Fig. 2c) are analyzed using terahertz time-domain spectroscopy. The analysis shows that there is a sharp reflection peak obtained at 1.303 THz where the full width at half maxima is 0.0055, this gives the high Q factor of the device, calculated as 236.

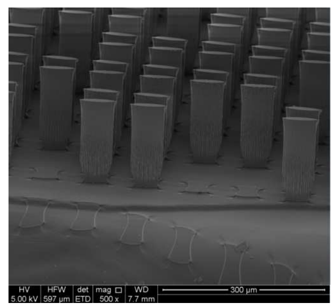

Fig.1. SEM image of the fabricated sample, showing the elliptical silicon pillars on a SU8 adhesion. The bulk material is Zeonex.

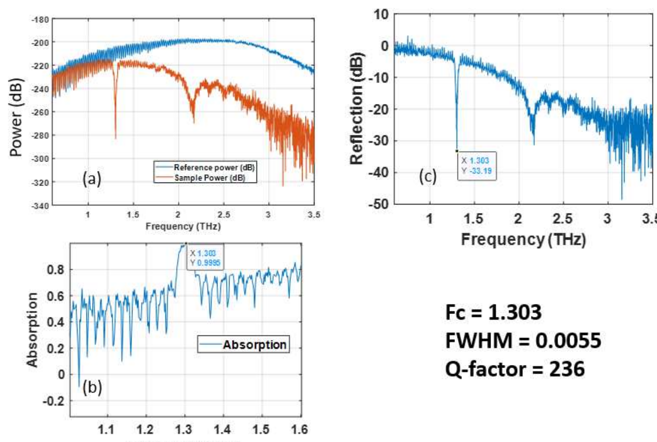

Fig. 2. Experimental outcomes of the metasurface. (a) power of reference and sampled signal, (b) the reflection measurement showing a sharp resonance peak, (c) absorption of the metasurface showing almost unit absorption.

To check the performance of the metasurface with different parameter variations, the fabrication with a slightly different geometry is going on which will be experimented with once the fabrication is finished. The plan is also to functionalize the metasurface for specific biomarker detection.

In summary, we design, fabricate, and experiment on a high Q terahertz metasurface device. Based on the optical characteristics the metasurface shows its potential in the application like frequency selective surface, filter, and biochemical sensor.

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