Frequency Selective Metasurface Fabricated with Two-Photon Polymerization

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2023 IEEE Research and Applications of Photonics in Defense Conference (RAPID) | 978-1-6654-2352-6/23/$31.00 ©2023 IEEE | DOI: 10.1109/RAPID54473.2023.10264730

***Abstract*—Metasurfaces, in the form of perfect reflectors, have received attention for their sensing and filtering capabilities. Plasmonic metasurfaces allow for frequency filtering by controlling the input polarization. We demonstrate a frequency filtering metasurface composed of an array of subwavelength metallic pluses fabricated using two-photon polymerization.**

***Index Terms*—metasurface, infrared, reflector, direct laser writing**

I. Introduction

Optical metamaterials are a group of engineered materials that are composed of an arrangement of artificial structures, which result in properties that are not exhibited in naturally occurring compounds. Metamaterials are designed to manipulate phase, amplitude, and polarization of electromagnetic radiation by implementing an array of subwavelength components with arbitrary optical properties which eliminates the need for classically bulky optical systems [1]. Metasurfaces are a subset of metamaterials which eliminate the height dimension of metamaterials in favor of a simpler design permitting an easing of the precision of fabrication requirements.

Plasmonic metasurfaces are composed of a metallic array of components that utilize the plasmonic resonances, known as surface plasmon polaritons, to manipulate the optical response of incoming electromagnetic radiation and have a wide field of applications [1]–[3]. A few examples of metasurface applications include beam steering, planar metalenses, holography, and narrow and broadband filters [1], [2], [4], [5].

Metasurfaces can be fabricated using many techniques, for example, electron beam lithography, focused ion beam milling, interference lithography, and nano-imprint lithography, to name a few. Two-photon polymerization has been established as a mask-less lithographic technique which allows the fabrication of metasurfaces [6], [7]. In this study, we explore the polarization sensitivity of plasmonic metasurfaces for creating narrow band filters.

II. Materials and Methods

A schematic of the unit cell of the investigated plasmonic metasurface can be seen in Figure 1. The plasmonic metasurface was composed of a Au array of asymmetric bars arranged as a plus. Fused silica glass was used as the substrate. The infrared optical response of the plasmonic metasurface was calculated using finite element modeling (FEM) simulations (COMSOL Multiphysics). Accurate dielectric function data for fused silica glass and Au was obtained using spectroscopic ellipsometry and were used for the FEM calculations [6].

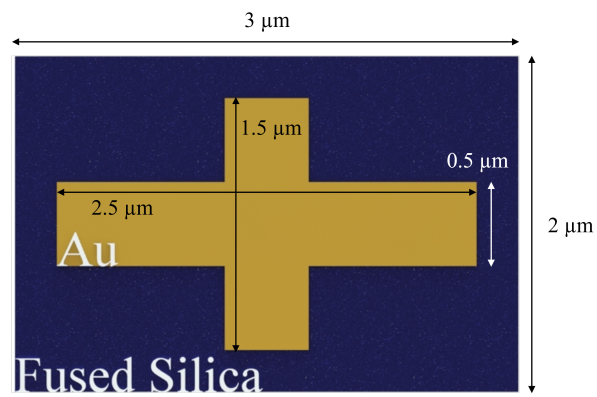

Fig. 1. Depiction of the unit cell used in COMSOL modeling. The metallic component is composed of a 50 nm Au thick film. Fused silica is used as a substrate.

The plasmonic metasurfaces investigated here will be fabricated using a three-step process: two-photon polymerization (Photonic Professional GT, Nanoscribe GmbH) of the sacrificial layer, followed by Au metallization (Kurt J. Lesker PVD 75), and lastly a lift off of the polymer sacrificial layer.

III. Results and Discussion

The metasurface is composed of a series of plus like geometries as shown in Figure 1. When incident radiation is polarized linearly along the long or short axis direction of the geometry a particular frequency will resonate to produce a reflection maximum. Using the polarization sensitivity of the metasurface will allow for the filtering of a certain frequency band. For the case of the parameters listed in Figure 1 a reflectance maximum will occur at 5.3 µm and 4.5 µm when incident radiation is at normal incidence and is polarized along the long axis and short axis of the geometry respectively Figure 2.

This research was funded by the National Science Foundation (1624572) within the IUCRC Center for Metamaterials and by the NSF MRI 1828430, the Army Research Office (W911NF-14-1-0299), and the Department of Physics and Optical Science of the University of North Carolina at Charlotte.

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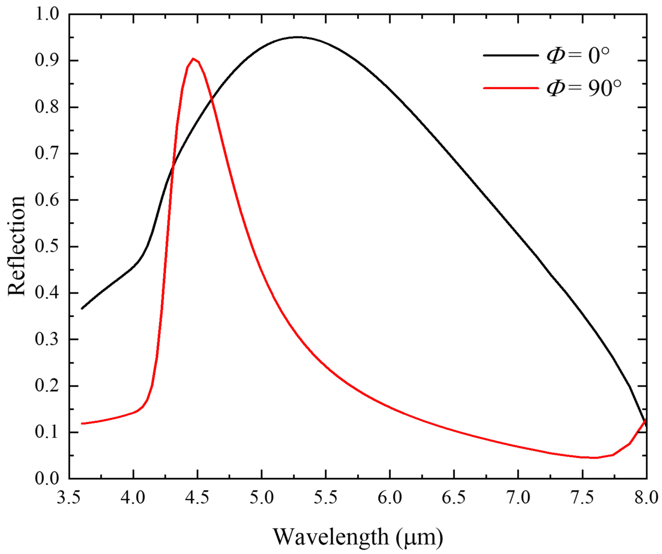

Fig. 2. Theoretical polarized reflectance spectra of the asymmetric plus geometry taken at normal incidence. Polarization along the long axis ($\Phi = 0°$) of the plus resonates at 5.4 μm. Polarization along the short axis ($\Phi = 90°$) of the plus results in a narrowband reflection at 4.5 μm.

IV. Conclusion

Plasmonic metasurfaces for select frequency filtering were theoretically demonstrated using finite element simulation. An asymmetric arrangement of metallic bars forming the geometry of a plus allows for frequency selection of the reflected spectrum by utilizing the input polarization of incident radiation.

The determined geometry can be fabricated in a three step process utilizing two-photon polymerization to synthesize an inverse sacrificial layer of the desired array, metallic deposition, and a lift-off of the sacrificial layer, leaving only the desired metallic surface.

The synthesized geometry displays a spectral shift depending on the input polarization. When incident radiation is polarized along the long axis of the unit cell the central reflectance maximum occurs at 5.3 μm and when polarized along the short axis of the geometry the reflectance maximum appears at 4.5 μm. This study shows that the fabrication of such a geometry allows for the frequency filtering of a metasurface dependent on the input polarization of the incident radiation.

This metasurface has applications in narrow band filtering as well as building on applications outlined in a previous publication [8]. The frequency filtering of the current metasurface can be used for the encoding of polarization sensitive frequency information by altering the orientation of the metallic components of the metasurface.

Acknowledgment

We would like to acknowledge the valuable discussions with AFRL within the NSF IUCRC for Metamaterials.

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