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Highly ordered Al-doped ZnO nano-pillar and tube structures for mid-infrared plasmonics

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Abstract: Fabrication of large area metamaterial structures in a reproducible manner is a tremendous challenge. Here, we realize the fabrication of plasmonic metamaterials for the mid-infrared wavelength region composed of Al-doped ZnO (AZO) pillars by a combination of atomic layer deposition and reactive ion etching.

A class of metamaterials that exhibit extremely high anisotropy with at least one of the components of its permittivity tensors being negative, while the others are positive, are called hyperbolic metamaterials (HMMs) [1]. HMMs exhibit hyperbolic iso-frequency contours with extremely large wavevectors, which are the key features to numerous photonics applications from subdiffraction imaging by superlens to sensing and spontaneous emission enhancement [1, 2]. Moreover, plasmonics for the mid-infrared wavelength range offer unique applications such as bio-sensing and thermal imaging, and the quest for novel materials and structures has been intensified in the last half decade [3, 4].

In this conference we report the realization of nano-pillar and tube structures made of aluminum-doped ZnO (AZO) in an attempt to create HMMs for the mid-infrared wavelength region. We fabricated the AZO-based structures by a combination of atomic layer deposition (ALD), deep UV photolithography, and deep reactive ion etching techniques. The same fabrication scheme can also be used to fabricate dielectric pillar and trench structures [5]. The AZO pillar structure has a high aspect ratio with a height of 1.8 μm , pitch of 400 nm, diameter of 300 nm, and a large surface area of 1 x 1 cm^2 as shown in Fig 1. The fabricated structures have been characterized by Fourier Transform Infrared Spectroscopy (FTIR) to characterize the effective ordinary permittivity ϵ_o and effective extraordinary permittivity ϵ_e for the certain range in the mid-infrared optical region (2-25 μm , 400-5000 cm^{-1}). The details of the characterization results will be reported at the conference.

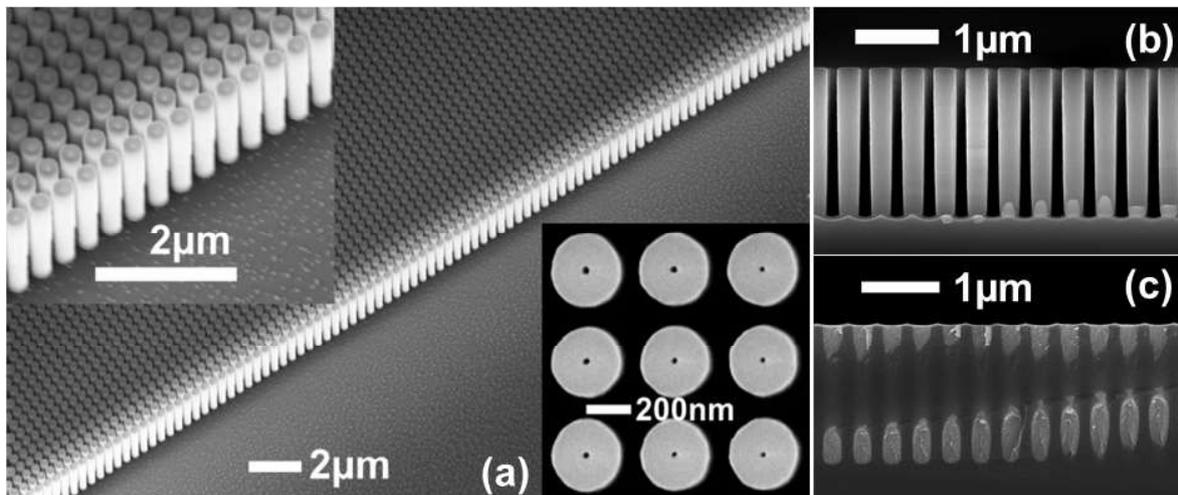


Fig. 1. (a) Scanning electron microscopy image of fabricated Al-doped ZnO (AZO) pillar structures in air surroundings with high aspect ratio. The insets show an enlarged view and a top view of the metamaterial. (b) Side view of AZO pillars in air and (c) AZO pillars in Si matrix.

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