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Fabrication of Al-doped ZnO high aspect ratio nanowires and trenches as active components in mid-infrared plasmonics

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Al doped ZnO (AZO) is a promising alternative plasmonic material with tunable optical and electrical properties in a wide range. AZO can be used as a plasmonic component in optical metamaterials where it can exhibit near-epsilon-zero regime and hyperbolic dispersion in the near and middle infrared region. Most studied metamaterial geometries include multilayers and pillars. Despite many existing techniques for AZO synthesis, only atomic layer deposition (ALD) will allow conformal coatings of high aspect ratio structures. This work demonstrates a method of pattering AZO high aspect ratio nanogratings and pillars on silicon substrates.

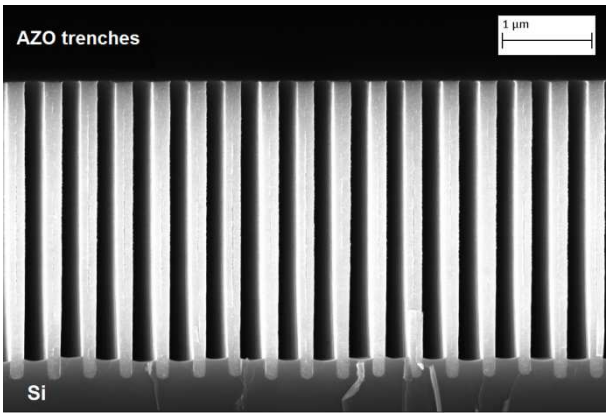
AZO has been synthetized using DEZ (diethylzinc), TMA (trimethylaluminum) and deionized water. Different Al doping in AZO has been achieved by placing a single TMA-water cycle in “n” DEZ-water cycles, where n was varied from 5 to 35.

Prior to device fabrication, AZO films with different Al concentration has been grown on flat Si (100) substrates in the temperature range of 150°C-250°C and physical, optical and electrical properties have been investigated. The applied characterization techniques include four point probe resistivity measurements, atomic force microscopy (AFM), scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), X-ray diffraction (XRD), and spectroscopic ellipsometry (SE).

Conventional deep-UV lithography was implemented for defining the gratings (lines with 400 nm pitch) and hole patterns (dots in a square lattice, with pitches of 400 and 500nm) on 2 cm2 scale chips. Thereafter, deep reactive ion etching was used to fabricate holes or trenches in silicon with a depth of 3 µm for trenches and 2 µm for holes. AZO with Al/ZnO cycle ratio 1:20 has been deposited on a prepared silicon template at the temperature of 200°C. The top part of AZO has been removed using Ar+ ion beam etching, so the silicon core gets exposed. At the end the silicon between the AZO trenches or pillars has been removed by SF6 plasma flow using reactive ion etching. Figure 1 and 2 shows fabricated freestanding AZO pillars and trenches as the final result.

Figur 1. AZO pillars

Figur 2. AZO trenches. (Cross-section view)



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