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Conductive oxides trench structures as hyperbolic metamaterials in mid-infrared range

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Nanostructures that possess hyperbolic iso-frequency contours exhibit unique properties of high anisotropy and extremely large wavevectors, which are the key issue to numerous photonic applications from subdiffraction imaging and superlens to sensing and spontaneous emission enhancement [1,2]. Moreover plasmonics for mid-infrared offer unique applications such as bio-sensing, thermal imaging and quest for novel materials and structures has been continuing [3]. In this report we show that vertical trench structures made of, for example, aluminum-doped ZnO (AZO) or other transparent conductive oxides can function as hyperbolic metamaterials (HMMs) for the mid-infrared wavelength region.

We fabricated a probe sample by a combination of atomic layer deposition (ALD) and dry etch techniques. We templated a Si wafer with deep UV photolithography and made trenches by deep reactive ion etching. Subsequent deposition of an AZO layer by the ALD technique forms vertical AZO trenches with a high aspect ratio (Fig.1a). After homogenization procedure the structure exhibits hyperbolic dispersion (Fig.1b) serving as an attractive platform for light manipulation [4]. Characterization results will be reported at the conference.

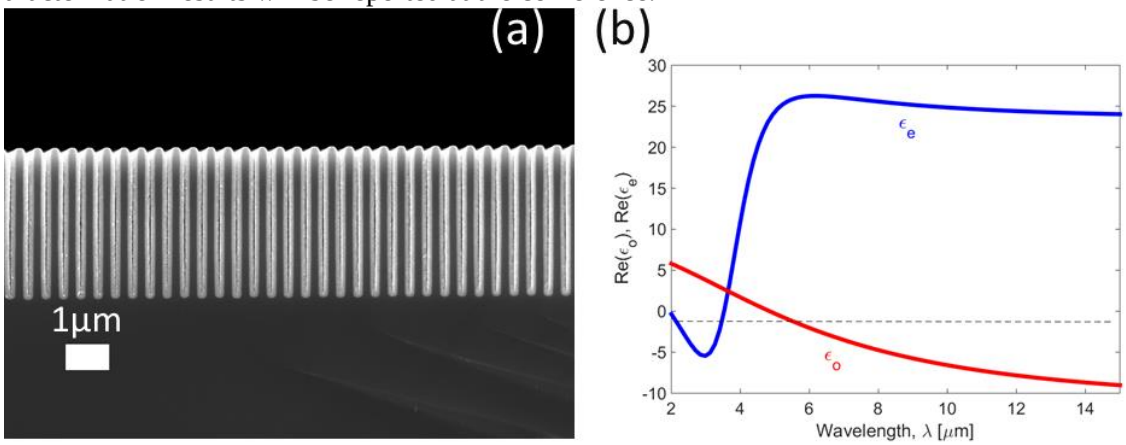

Fig. 1: (a) Electron micrograph image of fabricated Al-doped ZnO (AZO) structures between Si trenches with high aspect ratio. (b) Effective ordinary and extraordinary permittivities, ε_o and ε_e of the AZO trench structure based on effective media approximation, showing the hyperbolic properties of the structure for wide range of mid-infrared wavelength region.

[1] A. Poddubny, I. Iorsh, P. Belov, and Y. Kivshar, *Nature Photon.* **7**, 948 (2013).
[2] Y, Guo, W. Newman, C. L. Cortes, and Zubin Jacob, *Advances in OptoElectronics* **2012**, 452502 (2012).
[3] S. Law, V. Podolskiy, and D.Wasserman, *Nanophotonics* 2, 104 (2013).
[4] A. V. Kildishev, A. Boltasseva, and V. M. Shalaev, Planar photonic metasurfaces. *Science* **339**, 1232009 (2013).