Tunable conducting oxide epsilon-near-zero meta-devices

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Abstract: This talk will review our recent development on an electrically tunable conducting oxide metasurface that can tune the optical phase and amplitude and a broadband, tunable, and ultrathin conducting oxide epsilon-near-zero perfect absorber.
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Light harvesting and high-resolution optical technologies demand optical coatings with strong light absorption. Recent studies suggest that epsilon-near-zero (ENZ) materials can be useful to make perfect ultrathin film absorbers [1-3]. The ultrathin ENZ layers support radiative Berreman and bound ENZ modes [2, 4]. Excitation of these modes in two different incident light configurations leads to resonant absorption. In this work, a broadband perfect absorber has been demonstrated by using a stack of Transparent conducting oxide (TCO) nanolayers with gradually varying electron concentration and hence ENZ frequency. The light absorption dependence on the ENZ layer thickness in the multilayer stack was optimized so that absorption >95% was achieved at deep subwavelength ENZ thicknesses. Electronically tunable absorption via formation of electron accumulation/depletion layer in the field-effect devices was studied.

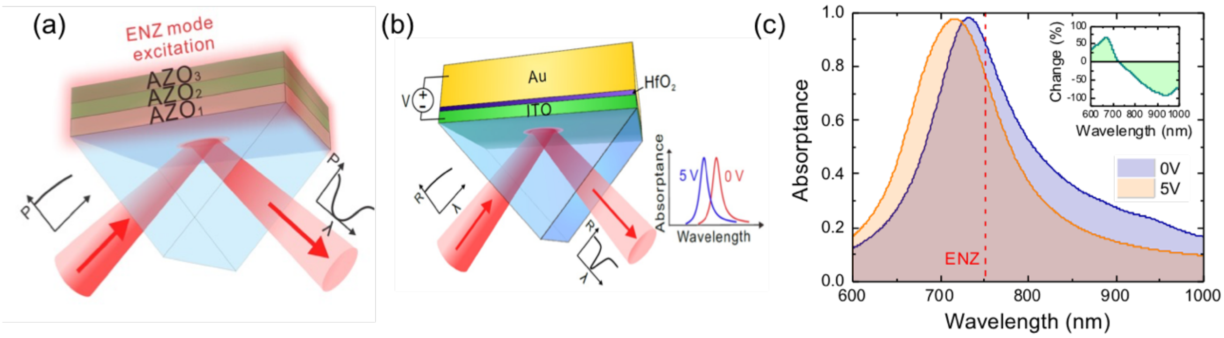

Fig.1 Schematic of (a) broadband and (b) field-effect tunable metal-oxide-semiconductor (MOS) ENZ perfect absorbers. Perfect absorption tuning: absorptance of the unbiased and 5V-biased MOS field-effect perfect absorber at the incidence angle of 60°.

The ENZ multilayers are composed of 3 AZO nanolayers (Fig. 1a). The optical properties of the AZO are modelled using free electron Drude model. We found that the highest absorption can be achieved with the AZO thickness of ~ 10-30 nm in the ENZ multilayers. The absorptance is attributed to the excitation of the radiative Berreman mode. The ENZ multilayer is supported by a thick gold reflector [5]. The electron concentration decreases, and ENZ wavelength increases, from the top to the bottom of the multilayer stack. Broadband maximum absorption >95% and field enhancement are observed at the ENZ wavelengths by exciting Berreman mode. Excitation of the bound ENZ mode in the Kretschmann-Raether configuration) results in resonant light absorption with much borader bandwidth than the Berreman mode. The absorptance of >95% for more than 400 nm wavelength range is observed for the multilayer stack with 8-nm thin AZO layers [6].

Tunable absorption can be enabled by the field-effect dynamic in metal-oxide-semiconductor (MOS) configuration (Fig. 1b). The MOS device consists of a metal substrate, single 8-nm thin ITO layer, and 5-nm-thin HfO_2 layer between them. Electron accumulation occurs in ITO at the ITO-HfO_2 interface when bias is applied between metal and ITO, thus modifying the complex dielectric constant of the ITO. Electron accumulation increases plasma and ENZ frequency and therefore leads to a blue shift of the absorption peak in wavelength (Fig. 1c) [7]. The larger absorptance change (> 300%) is observed at shorter wavelengths due to larger field enhancement in the accumulation layer. These results open the path to develop ultrathin tunable ENZ absorbers and thin-film modulators.

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