Electrically-tunable metasurfaces using dual epsilon-near-zero resonances

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In a new publication from *Opto-Electronic Advances*, Researchers led by Professor Jinghua Teng from Institute of Materials Research and Engineering, Agency for Science, Technology and Research (A*STAR), Singapore consider ultra-high extinction-ratio light modulation by electrically tunable metasurfaces.

Metasurfaces are the two-dimensional equivalent of metamaterials, composing discrete subwavelength structures, possessing the capability of full control of light properties, such as amplitude, phase, dispersion, momentum, and polarization. Metasurfaces are used in various applications covering electromagnetic spectra ranging from microwave, terahertz, infrared, visible, to ultra-violet. Active control of light propagation in visible and near-infrared spectra has practical and fundamental significance in autonomous vehicles, robots, displays, augmented and virtual reality, consumer electronics, telecommunications, and sensing devices. To tune a metasurface, one can change either the property of the unit cells or its ambient. This could be done by employing active materials in the metasurface, which can have their properties changed by an external stimulus.

In this article the authors propose a new electrically tunable metasurface for the modulation of polarized and unpolarized light. Here, the lossy nature of indium tin oxide (ITO) at epsilon-near-zero (ENZ) wavelength is used to design an electrically tunable metasurface absorber. The metasurface unit cell is constructed of a circular resonator comprising two ITO discs and a high dielectric constant perovskite barium strontium titanate film. The ENZ wavelength in the accumulation and depletion layers of ITO discs is controlled by applying a single bias voltage. The coupling of magnetic dipole resonance with the ENZ wavelength inside the accumulation layer of ITO film causes total absorption of reflected light. The reflection amplitude can achieve ~84 dB or ~99.99% modulation depth in the operation wavelength of 820 nm at a bias voltage of -2.5 V. Moreover, the metasurface is insensitive to the polarization of the incident light due to the circular design of resonators and the symmetrical design of bias connections.

High speed and high extinction-ratio light modulation with low power consumption at near-infrared spectrum has potential applications in many optical systems and devices including but not limited to optical signal processing, spectroscopy, switching, and light detection and ranging (LiDAR). Optical chopper and shutter, lithium niobate modulator, liquid crystal attenuator, and photoelastic modulator are among the commercially available devices to modulate the intensity of light. Optical chopper and shutter employ mechanical mechanisms, which are slow in speed and large in size while consuming high power. Lithium niobate modulator is controlled by electrical signal and has the highest modulation speed up to 40 GHz, however, requires high voltage. Photoelastic modulators use different types of bulk crystals for different operational wavelengths, require high electric voltage and extra polarizers which limit their applications. Liquid crystal beam shutter suffers from very low switching speed. The proposed electrically tunable metasurface utilizes the lossy nature of indium tin oxide (ITO) at epsilon-near-zero (ENZ) wavelength to modulate the intensity of reflected light, which can achieve up to ~84 dB or ~99.99% modulation depth at a very low voltage of ±2.5 Volts. The metasurface modulator is insensitive to the polarization of the incident light and thus suitable for a compact design without the needs of any extra polarizers. Moreover, the electrically tunable metasurface with dual ITO film design is capable of operating at gigahertz commutation rates.

More information: Arash Nemati et al, Ultra-high extinction-ratio light modulation by electrically tunable metasurface using dual epsilon-near-zero resonances, *Opto-Electronic Advances* (2021). DOI: 10.29026/oea.2021.200088

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