Electrically Tunable Metasurfaces Based on Transparent Conducting Al-doped ZnO

Jun Ding*(1), David George(2), Sensong An(1), Bowen Zheng(1), Yuankun Lin(2), and Hualiang Zhang(1)
(1) The University of Massachusetts Lowell, Lowell, MA 01854
(2) The University of North Texas, Denton, TX 76203

Metasurfaces composed of planar arrays of subwavelength resonators attract enormous attention because of their unprecedented capability for light manipulations. Applications of them include ultra-thin flat lenses, wave plates, holograms, beam generators, etc., over a very large range of the electromagnetic spectrum. However, one of the major drawbacks of the conventional metasurfaces made from dielectric or plasmonic resonators is that the optical phase responses of the designed structures cannot be altered or tuned after the fabrication, which greatly hinders their use in a broad range of applications. To date, a few investigations have been proposed to design tunable metasurfaces, including mechanical stretching, refractive index modulations with liquid crystal, or loading with active devices. Recently, a gate-tunable metasurface (Yao-wei Huang, *et al*, Nano. Lett. 2016, 16, 5319-5325) was demonstrated to dynamically control the reflected phases of the subgroups by applying electrical biases. This tunable metasurface relied on that the refractive index of the Transparent Conducting Oxide (TCO) materials could be changed due to the carrier concentration variation in the accumulation layer formed at the interface of the TCO and an oxide layer after applying an electrical bias. More importantly, the TCO can achieve an epsilon-near-zero (ENZ) region in the near infrared, which can be shifted in the accumulation layer with an electrical bias. Here, we propose a design to realize spatial-varying phase modulation at subwavelength scale using transparent conducting Aluminum-doped Zinc Oxide (AZO), which is composed of a gold grating, a thin alumina film, and a thin AZO film followed by a distributed Bragg reflector acting as a reflective mirror. We simulate a tunable metasurface in the ENZ region of AZO to steer the reflected beam by using the proposed structure, which could provide a nonlinear phase shift over 250º with a moderate electrical bias of around 5V. The proposed structure could open up new avenues to novel tunable applications, such as dynamic holograms, tunable ultra-thin lenses, reconfigurable beam generators, etc.