Chalcogenide Glass Metamaterial Optical Switch

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Abstract: The technology behind rewritable optical disks offers a new switching paradigm for metamaterials. A switch comprising resonant plasmonic metamaterial and electro-optic chalcogenide glass layers provides 75% optical transmission modulation in a device of sub-wavelength thickness.

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Photonic metamaterials – nanostructured media with extraordinary properties not found in nature – have recently become the subject of intense investigation for revolutionary applications across major industries from telecommunications and defence to renewable energy and healthcare.

Here, we demonstrate a new dimension in metamaterial functionality: an active switching device achieved through the hybridization of metamaterials with functional electro-optic materials. For this purpose we have exploited the active properties of chalcogenide glasses. These phase-change media, which can be reversibly switched between amorphous and crystalline states on a nanosecond timescale by optical and electronic excitations, underpin the functionality of today's re-writable optical data storage media and are set to form the basis of next-generation electronic memory chips known as phase change memory.

We studied an electro-optical device consisting of a planar metamaterial array, with resonant transmission features, sandwiched between a thin layer of Ga:La:S chalcogenide glass and a supporting silicon nitride membrane (Figs. 1a, b). The functionality of the asymmetric split-ring metamaterial structure, milled by focused ion beam in a gold film, depends on so-called 'trapped (closed) mode' plasmon resonant excitations.

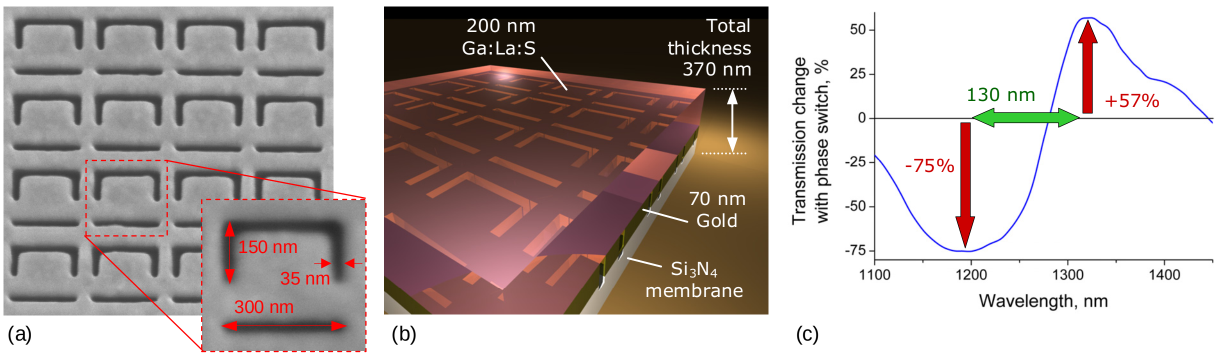

Figure 1: (a) Electron microscope image of an asymmetric split ring (ASR) array formed by focused ion beam milling in a 70 nm thick gold film supported on a silicon nitride membrane. (b) Artists impression of the hybridized ASR metamaterial / Ga:La:S glass structure. (c) Change in hybridized metamaterial transmission resulting from the electro-optic switching of Ga:La:S from its amorphous state to its crystalline state.

An electric signal to control the device was applied between the structured gold layer and an electrode on the surface of the chalcogenide film. Switching the structural phase of the Ga:La:S from amorphous to crystalline (a transition that can be reversed by another electrical or optical input) leads to a strong change in the refractive index of the glass layer ($\Delta n \sim 0.35$). This in turn drives a blue shift of ~130 nm in the device's resonant transmission spectrum. The device that is only 370 nm thick provides a 75% electro-optically controlled resonant transmission modulation at a wavelength of 1200 nm (Fig. 1c).

We show that by changing the structural parameters of the metamaterial array the resonant frequency of the device may be shifted throughout the visible and near-infrared parts of the spectrum.