Active Photonic Metamaterials

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Nanostructured photonic metamaterials with narrow-band responses provide a promising platform for applications ranging from slow-light and polarization control to optical modulation and the 'lasing spaser'. We show that the introduction of functional (nonlinear, switchable, gain, etc.) media into such structures provides a powerful paradigm for the active control of their resonant properties, for the enhancement of nonlinear responses and for strong switching performance in sub-wavelength devices.

In particular, we experimentally demonstrate substantial resonance frequency tuning in a photonic metamaterial hybridized with a thin film of gallium lanthanum sulphide (GLS) - a semiconducting, CMOS/SOI-compatible chalcogenide glass with a transparency band extending from 500 nm to 11 μm, which can undergo reversible, non-volatile, electrically- and optically-induced threshold switching between amorphous and crystalline states on the nanosecond timescale. Such phase-switching in the GLS nano-layer brings about a dramatic shift in the near-infrared resonance wavelength of an asymmetric split-ring array, providing transmission modulation functionality with a contrast ratio of 4:1 in a structure only one third of a wavelength thick (Fig. 1).

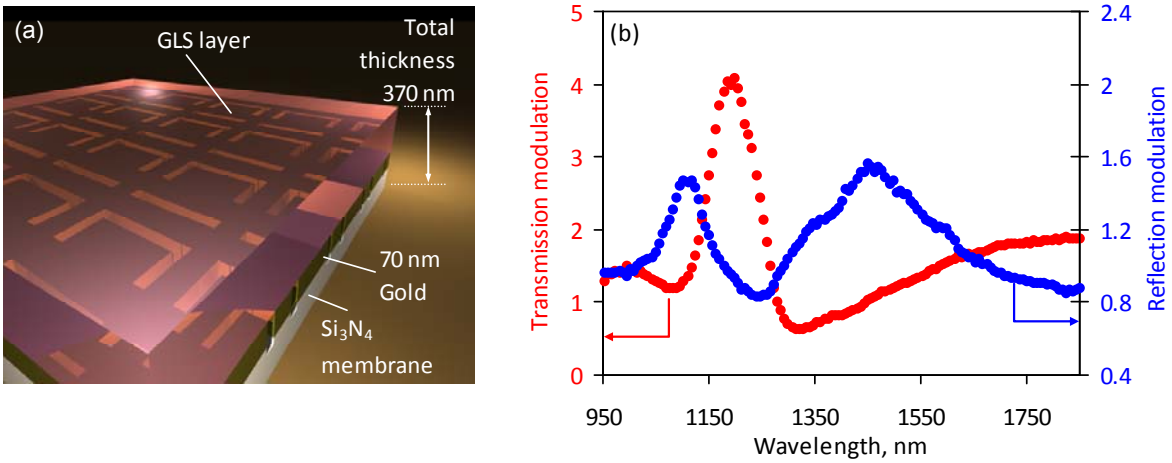

Figure 1: (a) Artistic impression of a hybrid device structure comprising a planar gold plasmonic metamaterial on a silicon nitride membrane, covered with gallium lanthanum sulphide (GLS) chalcogenide glass [Image by G. Adamo]. (b) Experimentally measured spectral dispersion of transmission and reflection modulation contrast associated with GLS phase switching in such a hybrid structure.

With resonance wavelengths engineered by design, active photonic metamaterial hybrid structures can offer novel nanophotonic and optoelectronic functionalities across a broad visible to mid-infrared wavelength range.