Chalcogenide Phase-Change Metamaterials for All-Optical, High-Contrast Switching in a Fraction of a Wavelength

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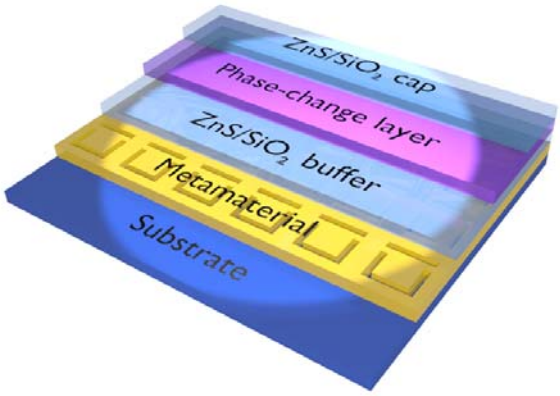

To realise the significant performance gains to be made from all-optical data processing, compact, rapid and high modulation contrast devices need to be produced that can rapidly change their refractive index and absorption[1]. Phase-change metamaterials are an amalgamation of two existing material concepts to provide new optical functionalities in a single planar device less than 100 nm thick (see figure). The phase-change layer is typically a chalcogenide glass ($Ge_2Sb_2Te_5$) that can be optically switched between two phases: crystalline and amorphous. The layer will remain in either of these states until it is switched again, providing a reversible 'memory' effect. The metamaterial layer consists of repeating unit cells of asymmetric split ring resonators milled from a thin layer of plasmonic material, such as gold. Such a layer will produce sharp resonance peaks in transmission and reflection in the near-IR, the spectral positions of which are sensitive to the local dielectric environment[2].

The combined device results in a tuneable metamaterial that can be reversibly switched to different resonant frequency states through optical crystallisation or amorphisation of the phase-change layer. The device can obtain effective refractive index changes impossible in conventional, unstructured materials, and has applications as an all-optical light modulator with a tuneable operational wavelength and a memory of its previous state[3].

Results from femtosecond pulse-induced crystallisation of the GST thin film are presented, along with spectra demonstrating the corresponding shift in the metamaterial resonances. The extension of this device as a two-dimensional pixelated reconfigurable metamaterial is also explored, along with potential functionalities such as accumulation and logic.

1. Zheludev, N. I. The road ahead for metamaterials. *Science* **328**, 582–3 (2010).

2. Luk'yanchuk, B. *et al.* The Fano resonance in plasmonic nanostructures and metamaterials. *Nature Materials* **9**, 707–15 (2010).

3. Sámson, Z. L. *et al.* Metamaterial electro-optic switch of nanoscale thickness. *Applied Physics Letters* **96**, 143105 (2010).