Ultrafast control of plasmonic nanoantennas driven by hot-spot induced phase-transitions in VO2

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Abstract

Efficient and reversible switching of plasmonic modes at visible and near-infrared wavelengths is one of the key desirable properties for tunable devices [1]. Phase-change materials offer technologically relevant opportunities as they can provide very large changes in the dielectric response [2]. So far most studies have reported the effects of a global phase transition of these materials on the plasmonic response of nanoparticles and metamaterials. Compared to chalcogenide phase-change materials which offer slow, rewritable memory functionality at relatively high temperatures, vanadium oxide (VO_2) provides an ultrafast, reversible phase transition at only modestly elevated temperatures around 68°C [3].

Here, we exploit for the first time resonant pumping and nanometer-scale plasmonic hot-spots to induce an optical change of the nanoantenna response through highly localized phase-changes in the underlying substrate. Multifrequency crossed gold antenna arrays were fabricated on top of high-quality VO_2 films (nanoantenna-VO_2 hybrids). Optical experiments show that fully reversible switching of antenna resonances at the picosecond timescale are possible using resonant pumping schemes. Simulations revealed that the change in optical response of the antennas stems from the change in dielectric properties of VO2 regions neighboring the nanoantennas. Moreover, it is demonstrated that the phase transition mediated by local pumping of a plasmon resonance does not influence the resonance of a perpendicular nanoantenna positioned less than 100 nm away from the modulated antenna.

The nanoantenna-VO2 hybrids enable new directions in all-optical ultrafast switching at picoJoule energy levels, and open up the possibility for plasmonic memristor-type devices exploiting nanoscale thermal memory.

References

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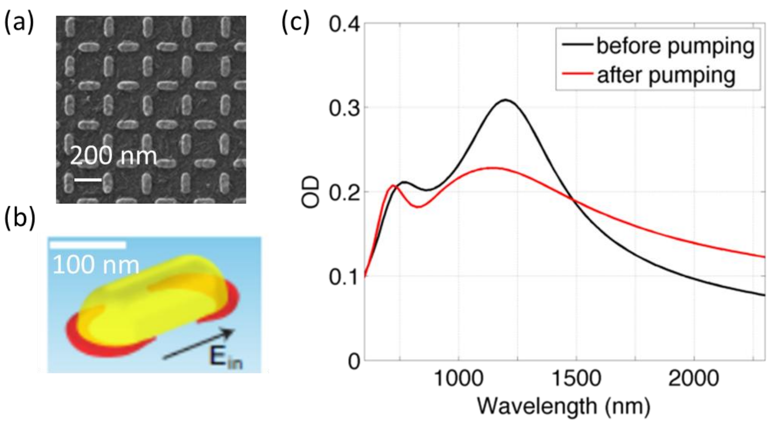

(a) Example of a fabricated antenna-VO2 hybrid. (b) Simulated 68°C isosurfaces showing the phase-changed hot-spots around the nanoantennas generated by resonant pumping. (c) Change in the optical response of the nanoantenna array as a consequence of the picoJoule pumping.