Ultrafast control of plasmonic nanoantennas driven by hot-spot induced phase-transition in VO_2

N. Zabala[1,2], L. Bergamini[1,2], Y. Wang[3], J. M. Gaskell[4], C. H. de Groot[3], D. W. Sheel[4], Otto L. Muskens[3] and J. Aizpurua[2]

[1] Department of Electricity and Electronics, UPV/EHU, Spain
[2] CFM, CSIC-UPV/EHU and DIPC, Spain
[3] Faculty of Physical Sciences and Engineering, University of Southampton, UK
[4] Materials and Physics Research Centre, University of Salford, UK

nerea.zabala@ehu.eus

Efficient and reversible switching of plasmonic modes at Vis and NIR wavelengths is one of the key desirable properties for tunable devices [1]. Phase-transition materials offer technologically relevant opportunities as they can provide notable 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. Unlike chalcogenide phase-transition materials which offer slow, rewritable memory functionality at relatively high temperatures, vanadium dioxide (VO_2) provides an ultrafast, reversible phase-transition at only modestly elevated temperatures around 68°C [3].

In this work, we exploit for the first time resonant pumping and nanometer-scale plasmonic hot-spots to induce an optical change of the nanoantenna (NA) response through highly localized phase-transitions in the underlying substrate [4]. Multifrequency crossed gold antenna arrays were fabricated on top of high-quality VO_2 films (NA-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 VO_2 regions neighboring the NAs. Moreover, it is demonstrated that the phase transition mediated by local pumping of a plasmon resonance does not influence the resonance of a perpendicular NA positioned less than 100 nm away from the modulated antenna.

The nanoantenna-VO_2 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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Figures

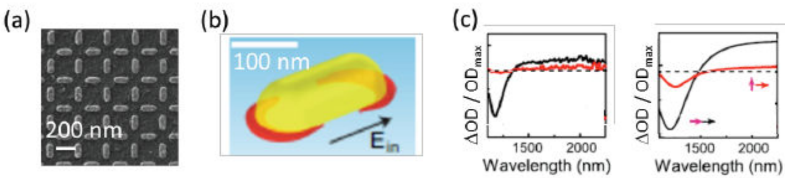

Figure 1: (a) Example of a fabricated NA-VO_2 hybrid. (b) Simulated 68°C isosurfaces showing the phase-switched hot-spots around the nanoantennas generated by resonant pumping. (c) Difference in the OD of the antennas, induced by the hot-spots of (b), for both (black curves) parallel and (red curves) perpendicular pump-probe polarization. (left) Experiments and (right) simulations.