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Plasmonic Interactions between Gold Nanoantennas and Vanadium Dioxide at Near Infrared Energies[1]

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Nanocomposites made of noble metals and phase-changing materials are an interesting class of switchable metamaterials, as the localized surface plasmon resonance (LSPR) frequency of the nanocomposite can be modulated by the phase transition. Of this class of nanocomposites, gold nanoparticle (NP) arrays embedded in a vanadium dioxide (VO_2) film has several unique advantages, including the ability to induce the semiconductor-to-metal (SMT) phase transition of the VO_2 at a critical temperature of only 68°C. For lithographically produced arrays of NPs between 140 nm and 180 nm, the LSPR has significant overlap with the 1.4 eV electronic transitions of the VO_2 3d band. These electrons become strongly-correlated during the phase transition and delocalize to form the metallic conduction band at higher temperatures. Here we use an array of 180-nm diameter Au NPs embedded in a 60-nm VO_2 film as a nanoscale probe of the SMT in the VO_2. Temperature-dependent extinction measurements were carried out on the nanocomposite array using the plain VO_2 film as a reference to observe the hysteresis of the LSPR energy and linewidth. The interaction resulted in a 30% reduction in plasmon dephasing time as the effective dielectric function of the VO_2 transitions from Lorentzian resonance to a Drude metal near 1.4 eV. Also, an array of 140-nm diameter Au NPs were used toincrease the efficiency of low-intensity laser switching in the nanocomposite compared to a plain 60-nm thick VO_2 film. An analytical model of laser heating was developed and suggests that the nanocomposite can be optimized to tune both optical and photothermal switching properties of an active metamaterial.

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