Active terahertz nano plasmonics: full transmission control of terahertz waves by external optical pumping

Ji-Soo Kyoung[a], Hyeongryeol Park[a], Soobong Choi[b], Sukmo Koo[c], Hyun-Sun Kim[a], Kwangjun Ahn[a], Namkyoo Park[c], Bong-Jun Kim[d], Hyun-Tak Kim[d], and Dai-Sik Kim[a,*]

[a]*Center for Subwavelength Optics and Department of Physics and Astronomy, Seoul National University, Seoul 151-747, Korea*
[b]*JILA, University of Colorado and National Institute of Standards and Technology, Boulder, CO 80309-0440, USA*
[c]*Photonic Systems Laboratory, School of EECS, Seoul National University, Seoul 151-744, Korea*
[d]*Metal-Insulator Transition Lab., ETRI, Daejeon 305-350, Korea*

**E-mail:dsk@phya.snu.ac.kr*

Thin layers of semiconductors and strongly correlated electron systems have been strong candidates for all-optical switching devices at long wavelength regime, due to their excellent optical properties such as fast carrier dynamics and pump-induced large nonlinearity. For the thin film, however, despite the large nonlinearity, corresponding transmission change $\Delta T/T$ (the ratio between the differential transmission and the transmission through the film) is too small, limiting photonic applications because nearly constructive multiple interference in the thin film tends to push the transmittance towards unity even when the thin film dielectric constants are large.[1] Namely, the nonlinear response, the product of the pump-induced change of the absorption coefficient $\Delta\alpha$ and the film thickness or nonlinear interaction length L, is much less than one.[2-4]

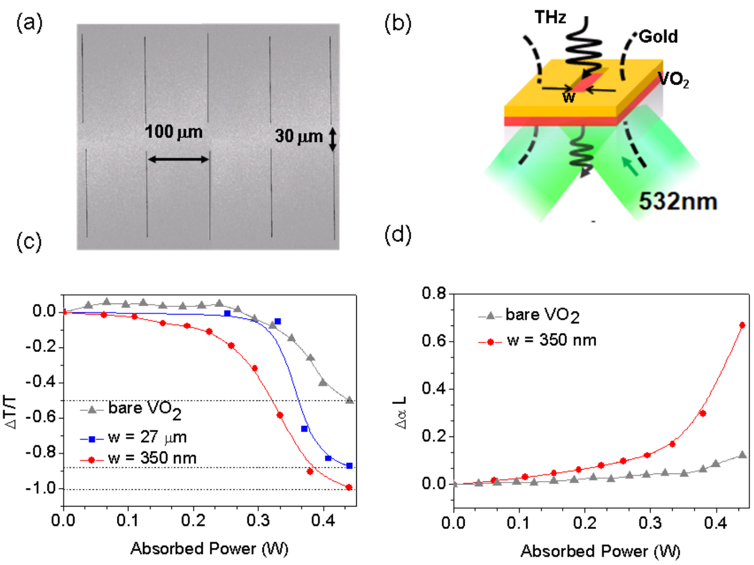

Fig. 1: (a) Scanning Electron Microscope (SEM) image of our nanoresonators. (b) Schematic diagram of photo excitation experiments. (c) The differential transmission signals of various sampes. (d) Nonlinear response of bare and *w*=350 nm resonator patterned sample.

One effective way to overcome the small nonlinear response is to fabricate metamaterials on semiconductor substrates[5, 6]. In this work, we show that the absolute switching ($\Delta T/T \approx -1$) of terahertz electromagnetic wave with optical pump can be achieved by fabricating THz plasmonic slot antennas whose width is in nanometer scale, nanoresonators, on a vanadium dioxide (VO_2) thin film which undergoes insulator to metal phase transition at critical temperature 340 K.[7] Figure 1 (a) shows Scanning Electrom Microscope (SEM) image of our 350-nm-width nanoresonators patterned on 100-nm-thick VO_2 films. Figure 1 (b) illustrates schematic diagram of our photo excitation experiments. We use 532 nm wavelength pump laser to induce phase transition of VO_2.

The differential transmission $\Delta T/T$ as a function of absorbed power is presented in figure 1 (c). For the bare film, the differential change was limited at -0.5 meaning the change of transmission was only 50 % even though the pumping power reached 500 mW. In stark contrast to the bare film, the 350-nm-width nanoresonator patterned sample showed almost perfect switching $\Delta T/T \approx -0.9999$ by the same optical pumping power. The corresponding nonlinear response was gigantically enhanced and finally reached 0.7 while the bare film remained only 0.1. This unprecedentedly large nonlinearity originates from the insulator-to-metal phase transition drastically reducing the localized surface plasmons induced by nanoresonators.

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