Electrical Switching Triggered by Plasmonic Nanoheater

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1. Introduction

Vanadium dioxide (VO_2) is a phase transition material, which accompanies a drastic change in resistivity of 3 orders of magnitude between insulator and metallic phases. [1] Under room temperature, VO_2 shows an insulator phase with higher resistivity, on the other hand, above the phase transition temperature, it becomes a metallic phase with low resistivity. Its phase transition can be triggered by applying heat, voltage, and light, resulting in a hysteresis characteristic which realizes the electrical or light switching devices.

The problem for the electrical or light switching of VO_2 is that these stimuli need much energy to induce joule heat which induces the VO_2 phase transition.

In recent years, we found that plasmonic nanostructure can assist the phase transition of VO_2, resulting in a decrease of the phase transition temperature apparently, since the plasmonic nanostructure can work as nano heaters. This plasmon-assisted phase transition will realize the low power switching of VO_2, leading to the energy-saving functional devices. In this talk, we investigated the possibility for the low-power switching of VO_2 assisted by plasmon resonance of metal nanostructure.

2. Experimental sections

Ag nanorod (NR) array were fabricated on a VO_2 thin film with a thickness of 250 nm by electron beam lithography. The resistivity of the sample was measured under the polarized monochromatic light irradiation which can induce the plasmon resonance of Ag NRs. The light intensity of the monochromatic light was 13 mW/cm^2 at 500 nm.

3. Results and Discussions

Fig. 1 is comparisons of the VO_2-Ag NRs resistivity with its transmission spectrum under short- and long-axis polarizations. The wavelength-dependence resistivity showed similar behaviors to the transmission spectra, indicating plasmon resonance of Ag NRs assisted the phase transition of the VO_2, resulting in slight decreases of its resistivity. It is well known that plasmonic nanostructure releases heat, which is caused by an internal decay of hot electrons inside it, resulting in a significant heating of the nanostructure and its surrounding media at the nano scale. We guess local heat generated on Ag NR was conducted to the surrounding VO_2 film, increase the VO_2 temperature locally, resulting in resistivity decrease of the film. In this experiment, the power of the irradiation light was too low to induce the VO_2 phase transition by itself. This result indicates that Ag NR plasmon showed a possibility to realize the low-power switching of VO_2.

References

[1] T. Driscoll, "Memory Metamaterials" Science 325, 1518-1521 (2009).

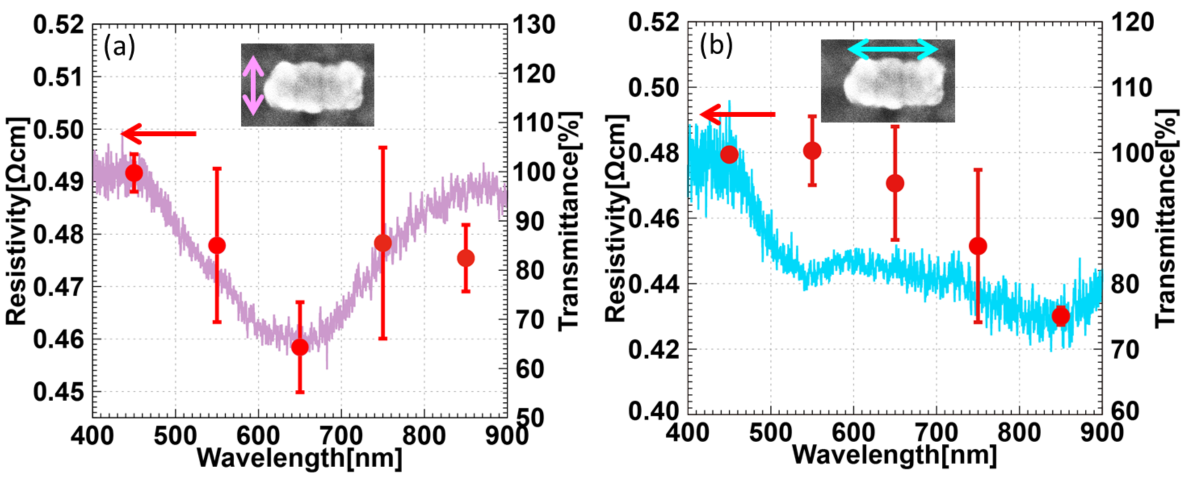

Fig. 1 Comparison of VO_2 resistivity with the transmission spectrum of Ag NRs under (a) short-axis, and (b) long-axis polarizations. Short- and long-axis plasmon resonances of Ag NRs were 620 and 830 nm, respectively. The small absorption around 520 nm in (b) is attributed to VO_2 absorption and has no concern with plasmon.