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Surface plasmon and Mott transition in strongly-correlated oxide VO_2

The Univ. of Tokyo [1] and ISIR-Sanken Osaka Univ.[2]

°Hiroaki Matsui [1], Teruo Kanki [2], Hidekazu Tanaka [2], Jean-Jacques Delaunay [1], and Hitoshi Tabata [1]

E-mail: hiroaki@ee.t.u-tokyo.ac.jp

Recently, functional oxides have received much attention for alternative plasmonic materials [1-3]. Plasmonic manipulations based on Mott transition provide new insight im many areas of scientific and practical fields, which produce an additional means of tuning plasmonic properties in a manner that is not as readily available in metals. In this presentation, we report the control of surface plasmons in VO_2 nanodots by the Mott transition from an insulating to a metal phase.

Plasmon resonance energy ($h\nu_{sp}$) of a VO_2 nanodot array sample with a size of 816 nm was observed at 0.39 eV [inset in Fig. 1(a)]. The plasmon energy showed a blue-shift with decreasing dot size down to the size down to 250 nm. The plasmon lifetime ($\tau_{sp} = 2\hbar/\Gamma$) related to the spectral line-width increased with red-shifted $h\nu_{sp}$ and a τ_{sp} value as large as 12 fs for nanodot size of 816 nm was observed [Fig. 1]. This property is attributed to the electronic properties of VO_2. Indeed, 3*d* orbitals localized below 1.2 eV from the Fermi level act as plasmon damping based on an inter-band transition. Therefore, plasmon excitations become effective by suppression of the plasmon damping in the mid-IR range. The modified long-wavelength approximation (MLWA) can theoretically acquire spectral information, revealing that the experimental τ_{sp} values were in reasonable agreement with MLWA theory for 2D-coupled dipoles, in contrast to the single dipole case [Fig. 1]. This indicates that plasmon excitations in VO_2 nanodots were derived from collective resonance based on the 2*D* regular arrays.

Figure 2(a) shows the temperature-dependent resonance peak intensity, revealing that the intensity provided a hysteresis (ΔT) having a width (ΔT) 32°C. In contrast, the resonant peak energy exhibited a narrow ΔT value of 16°C [Fig. 2(b)]. A critical temperature of Mott transition temperature (T_{MI}) was different between the resonant peak intensity and energy. Surface plasmons on 2D nanodot arrays are based on two types of interactions, namely, near-field and far-field couplings. The sharp ΔT in peak energy is related to a near-field coupling between the nanodots, as suggested by the red-shift of the peak energy. It is thought that the resonant peak energy is dominated by the formation of metallic nanodot clusters, which is different from the mechanism of the temperature-dependent peak intensity [Fig. 2(c)].

Control of Mott transition has been thus far performed using various methods such as lattice-strains and dynamic/static electron-doping. It is expected that the control of Mott transition based on near-field techniques will be available in the near future.

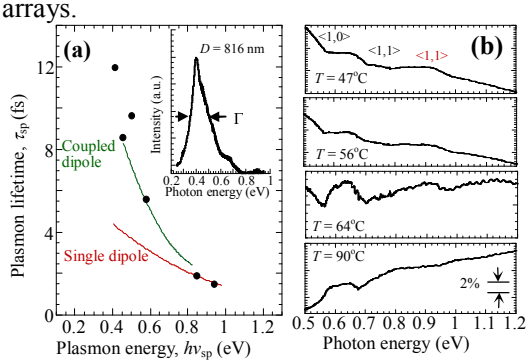

Fig. 1 (a) Plasmon lifetime (τ_{sp}) as a function of resonant peak energy ($h\nu_{sp}$). Inset indicates surface plasmon spectrum of VO_2 nanodots with a size of 816 nm. (b) Temperature-dependent high-order modes derived from in-plane diffractions of VO_2 nanodots with a size of 816 nm.

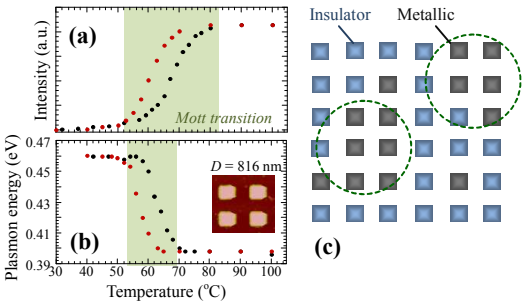

Fig. 2. Temperature dependence of plasmon resonant intensity (a) and energy peak (b). (c) schematic picture of local cluster formation in the nanodot arrays.

References

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