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X-ray induced insulator-metal transition in electron-doped VO_2 thin film

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Introduction

Photo-induced phase transition (PIPT) is a fascinating phenomenon. Especially, photo-induced insulator-metal transition can be applied for photo-controlled swithcing devices. $Pr_{0.7}Ca_{0.3}MnO_3$ and $CuIr_2S_4$ bulk-materials show PIPT from charge ordering insulator phase to disorder metal phase [1, 2]. However, in these materials, only small variations of the resistivity are observed. For photo-controlled devices, a large variation of the resistivity at PIPT is preferable.

Experimental results and Discussions

The target material is electron-doped VO_2 thin film fabricated on a TiO_2 (001) substrate. Hereafter, the concentration of W is described as $V_{1-x}W_xO_2$ formular. Note that two electrons are doped by substituting the W^{6+} ion for V^{4+} ion. The W-doped VO_2 thin films show the metal-insulator phase transitons in a broad range of W-doping concentration [Fig.1 (a)] [3]. Especailly, at x=0.07, the metalic phase persists down to 2 K. In the vicinity of the critical region at x=0.065, we found an x-ray (photo-) induced phase transiton. As shown in Fig.1 (b), the peak height of (0 0 2) reflection in the insulator phase (black circle) decreases with increasing the irradiation time at 9 K, which means that the c-lattice constant of VO_2 film dramatically changes. The resistivity (red line) simultaneously decreases. Huge changes both in the intensity of (0 0 2) and in the resistivity take place, if the threshhold photon flux (~$3*10^{16}$ photons/cm^2) is irradiated. Further, this phase transition proceeds with only an x-ray irradiation. The temperature dependence of the lattice constant calculated from the (0 0 2) peak position and resistivity before and after PIPT are shown in Fig.1 (c,d). A simple increase of the lattice constant and resistivity (red color) can be shown below the phase transition temperature ~100 K, at which the metal-insulator transition takes place with the dimerization of V^{4+} ions. In contrast, after PIPT, the lattice constant and the resistivity dramatically decrease. This photo-induced phase may have same nature with the metallic phase above 100 K. This phase seems to collapses above 50 K and then the insulator phase recovers. Detailed information is found in ref. [4].

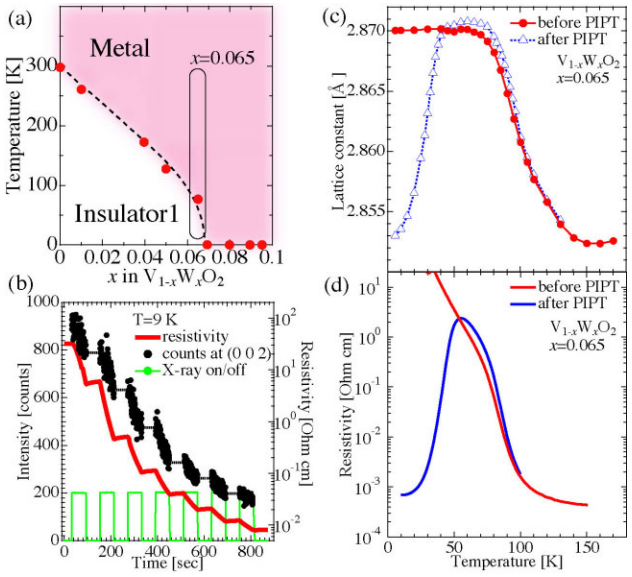

Fig. 1: (a) Metal-insulator phase diagram of $V_{1-x}W_xO_2$ thin film. (b) X-ray irradiated-time-dependences of resistivity and the peak top intensity at (0 0 2) reflection in the insulator phase. (c,d) Temperature dependences of lattice constant calculated from the scattering angle of the (0 0 2) reflection (c) and resistivity (d). Red (blue) marks and lines indicate the data before (after) occurrence of the photo-induced phase transition.

References

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