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X-ray study metal-insulator transition in W-doped VO_2 thin film

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An x-ray study in $V_{1-x}W_xO_2$ films has been carried out. The insulating phase for $x < 0.07$ exhibits cell-doubling with the V dimerization similar to bulk VO_2, while the insulating phase for $x > 0.11$ does not. The temperature and x dependence of superlattice reflection casts doubt about the direct relationship between the dimerization of V ions and metal-insulator transition. X-ray-induced persistent phase transitions are observed at low temperatures in each insulating phase in the vicinity of the boundary to the metallic phase regardless of the difference in the electronic structure.

1 Introduction

VO_2 is known to exhibit a metal-insulator transitions (MIT) accompanying structural deformation. At the transition temperature, the crystal structure changes from tetragonal to monoclinic with V dimerization. Shibuya *et al*. fabricated single-crystalline thin films of $V_{1-x}W_xO_2$ and obtained the phase diagram [1]. The MIT temperature decreases with increasing W for $x < 0.07$. For $x > 0.11$, the MIT temperature increases with increasing W. If the origins of the MIT for $x < 0.07$ and for $x > 0.11$ are different, some difference in the structural property is expected. VO_2-related materials have been attracting interest also from the viewpoint of photo-induced effects. Recently, x-ray-induced persistent insulator-to-metal transition was observed in an $x = 0.065$ film [2].

2 Experiment

$V_{1-x}W_xO_2$ films with thicknesses 80 nm were fabricated on rutile TiO_2 (001)-substrates by a PLD method [1]. Note that two electrons are doped by substituting the W^{6+} ion for V^{4+} ion. Synchrotron x-ray diffraction experiments were performed at BL-3A and 4C. Symmetry lowering was monitored by the emergence of (0 -1/2 3/2) and (1 0 2). The lattice spacing c was estimated from the peak position of (0 0 2) reflection.

3 Results and Discussion

Temperature dependence of the intensities of the superlattice reflection is compared with that of resistivity and c-axis length in Fig. 1 (a - c). For $x < 0.07$, the (0 -1/2 3/2) reflections appear at low temperatures, indicating that V ions are dimerized. The modulation vector of V-dimerization remains to be (0 1/2 1/2). This result would contradict a naive picture of Peierls-type MIT. Moreover, for $x = 0.065$, the cell doubling appears below room temperature, which is far above the MIT temperature, below which the c-axis length begins to increase. For $x = 0.11$, a MIT with a change of the c-axis length is observed. The transition temperature increases with increasing x to 0.17. The (0 -1/2 3/2) reflection is not observed in the $x = 0.11$ sample. These results suggest that the MIT and structural transitions without V dimerization take place.

We have investigated in detail the x-ray-induced phase transition in $V_{1-x}W_xO_2$ films. Figures 1 (d – i) show the temperature dependence of the diffraction profiles of (0 0 2) reflection before and after the irradiation of x-ray beam at 7 K. The shrinkage of the c-axis length is commonly observed, namely, the x-ray-induced phase transition generally takes place not only for $x < 0.07$ but also for $x > 0.11$. Detailed information is found in [3].

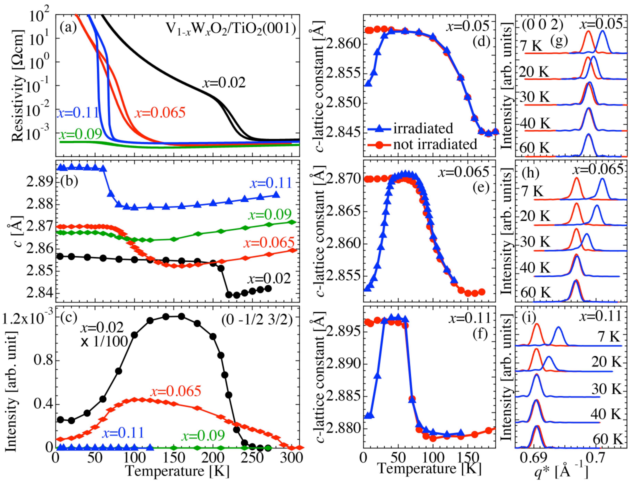

Fig. 1: Temperature dependences of resistivity (a), c-axis length (b), intensity of (0 -1/2 3/2) superlattice reflection in $V_{1-x}W_xO_2$. Temperature dependence of c-axis length and (0 0 2) profile for (d, g) $x = 0.05$, (e, h) 0.065, and (f, i) 0.11 before/after irradiation of strong x-ray.

References

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