Metal-insulator transition in electron-doped VO_2 thin films

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The metal-insulator transition in VO_2 takes place at around 340 K, accompanying the structural transition from high-temperature rutile to low-temperature monoclinic phases. There has been an enduring interest in controlling the metal-insulator transition temperature of VO_2 by chemical substitution not only from a basic understanding of physics but from the viewpoint of device application. However, physical properties of electron-doped VO_2 are not well understood because only few studies have been carried out in single crystals and the doping concentration was limited to x = 0.060, where insulating phase still survives below 180 K.

We have fabricated epitaxial $V_{1-x}W_xO_2$ ($0 \leq x \leq 0.33$) thin films on TiO_2 (001) substrates. The metal-insulator transition temperature is systematically reduced by W doping, and eventually a metallic ground state is realized at $0.08 \leq x \leq 0.09$. Tiny resistivity upturn around 50 K observed for these films suggests an electronic phase separation between a majority metallic matrix and minority insulating puddles. The structural change was confirmed by XRD, and the structural transition temperature is consistent with the metal-insulator transition temperature determined by resistivity data. It is found that electron doping destabilizes the formation of V-V dimerization.

The V-V dimerization was found to be disordered by synchrotron X-ray irradiation for a sample with x = 0.065 in close vicinity to the metallic region showing an insulator-metal transition at around 80 K. The X-ray induced phase transition was persistent and was accompanied with the revival of metallic conduction. The transition is well-scaled by the time-integrated photon density, independent of flux density. The metallic phase returns to the original insulating one at around 50 K due to a thermal annealing effect.

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