Surface Stress-induced Domain Dynamics and Phase Transitions in Epitaxially Grown VO_2 Nanowires

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We demonstrate that surface stresses in epitaxially grown VO_2 nanowires (NWs) have a strong effect on the appearance and stability of intermediate insulating M_2 phases, as well as the spatial distribution of insulating and metallic domains during structural phase transitions. During the transition from an insulating M_1 phase to a metallic R phase, the coexistence of insulating M_1 and M_2 phases with the absence of a metallic R phase was observed at atmospheric pressure (See Fgiure 1). In addition, we show that for a VO_2 NW without the presence of an epitaxial interface, surface stresses dominantly lead to spatially inhomogeneous phase transitions between insulating and metallic phases. In contrast, for a VO_2 NW with the presence of an epitaxial interface, the strong epitaxial interface interaction leads to additional stresses resulting in uniformly alternating insulating and metallic domains along the NW length. In order to demonstrate the detailed structural changes and coexistence of two different insulating phases (M_1, M_2), we prepared naturally bent NWs with uniform local curvature and non-clamped (strain-free interface) on a *c*-cut sapphire substrate using a PDMS transfer method, which is a technique widely used for transferring graphene. Raman measurements were carried out at two featured positions; i) the non-clamped, straight part of a NW (A in the upper inset of Figure 4a), and ii) the largest bent part of a NW with the high tensile strain at the centre of the outer edge of the local curvature region (B in the lower inset of Figure 2a). As shown in Figure 2a, the evolution of Raman spectra obtained from the straight region of a NW (A), which exhibits direct structural changes from M_1 to M_2 phases, is quite similar to that measured on a transferred NW non-clamped shown in Figure 1. Interestingly, in the bent part of a NW (B), coexistence of both M_1 and M_2 phases as evidenced by peaks associated with only M_1 and M_2 phases were observed even at room temperature. As the temperature increases, the intensity of M_1 peaks gradually decreases and that of M_2 peaks continuously increases, showing the evolution of M_1-M_2 phases. When the temperature increases further, R phases start to appear.

References

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Figures

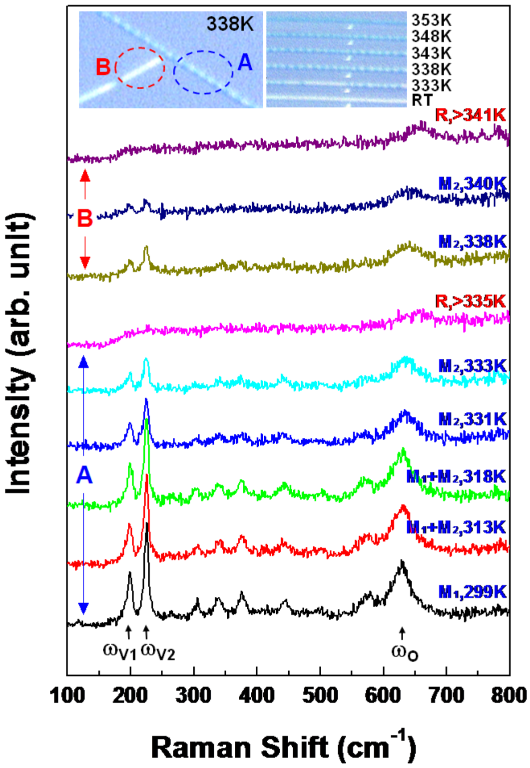

Figure 1. Temperature dependence of Raman spectra of transferred individual VO_2 NWs. As the temperature increases, phonon frequencies shift toward higher frequencies and phase transitions from an M_1 to an R phase occur spatially along the NW length. Raman spectra indicated by A, B and C were obtained from the circle region of the NWs, respectively (left inset). Optical images of bright and dark domain patterns corresponding to insulating and metallic phases, respectively (right inset), reveal spatial phase transitions along the NW length.

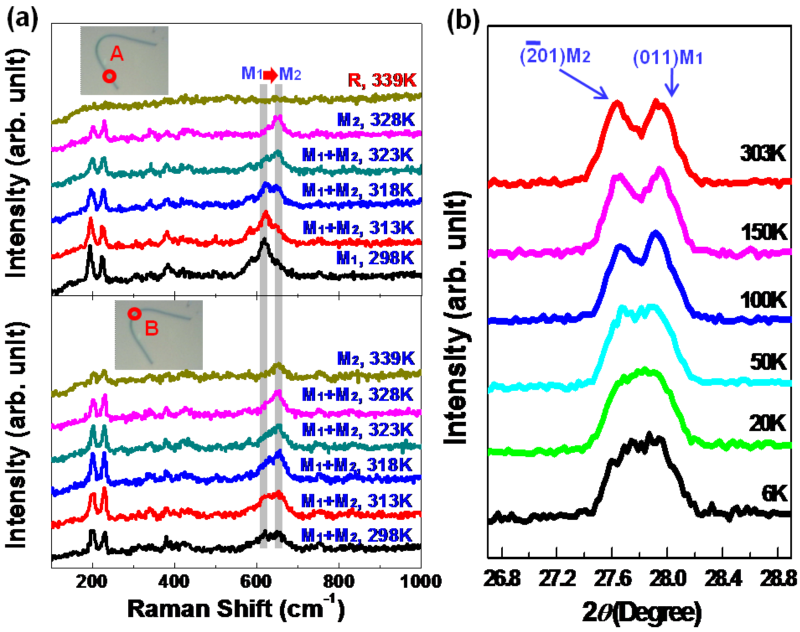

Figure 2. (a) Raman spectra obtained from the straight part (A in the upper inset) and bent part (B in the lower inset) of a VO_2 NW, which show the direct evolution of M_1-M_2 phases. **(b)** Temperature dependence of XRD data from ensembles of epitaxially grown VO_2 NWs, measured during cooling from 303 K to 6 K. These results demonstrate that M_1 and M_2 phases can coexist with the absence of an R phase at atmospheric pressure.