TEM studies of phase separation in VO_2 films

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Vanadium dioxide (VO_2) undergoes a metal-insulator phase transformation (MIT). The MIT in VO_2 is accompanied by a structural phase transition from the high-temperature tetragonal (metal) phase to the low-temperature monoclinic (insulator) phase. The phase transition temperature (~340 K for unstrained bulk crystals) can be tailored by application of mechanical pressure and/or chemical doping [1]. As a result of those effects, the tetragonal phase can be retained in a room temperature. We here discuss about the basic morphology of phase separation, in which the residual tetragonal phase coexists with the monoclinic phase, observed in VO_2 films deposited on TiO_2-(001) substrate.

Figures 1(a) and 1(b) respectively show bright-field and dark-field transmission electron microscopy (TEM) images (cross-sectional observations) acquired at room temperature. The dark-field image was obtained by using a Bragg reflection from the monoclinic phase; i.e., the bright represents the monoclinic phase. More importantly, Fig. 1(b) revealed the triangular dark regions in the vicinity of the VO_2/TiO_2 interface. Electron diffraction identified these triangular regions to be of the tetragonal phase which appeared to be stabilized by the lattice strain near the VO_2/TiO_2 interface. Figure 2 shows a lattice image produced by high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM). The lattice image revealed distinct regions, labelled by "A" and "B", within VO_2 films. The digital diffractograms acquired from those regions were consistent with the electron diffraction patterns; i.e., the regions A and B were respectively identified to be monoclinic and tetragonal phases. A crystallographic trace analysis revealed that the interface between these two regions corresponds to a {011} plane with reference to the tetragonal phase. The {011} plane can a crystallographic habit plane which is favorable for minimizing the interface strain. The observations provide essential information for the engineering of VO_2 films deposited on the TiO_2 substrate [2].

[1] N. Bahlawane et al., Chem. Vap. Deposition 20, 299-311 (2014).
[2] Y. Cho et al., Mater. Res. Bull., in press (2018)
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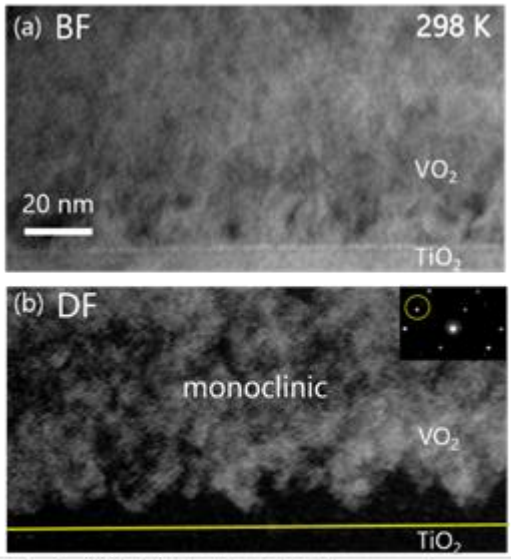

Fig. 1 (a) Bright-field TEM image observed at room temperature. (b) Dark-field TEM image obtained by using the $\bar{1}02$ spot (indicated in inset).

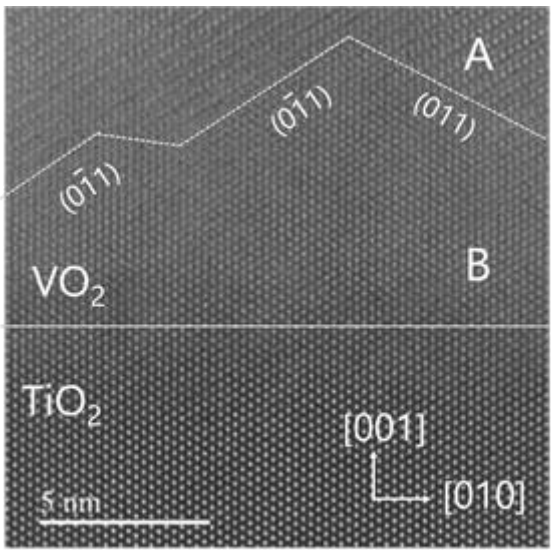

Fig. 2 HAADF-STEM image showing the residual tetragonal phase (region B) which coexists with the monoclinic phase (region A).