PHASE STRUCTURE POLYMORPHS AND DISLOCATION EFFECTS ON METAL-INSULATOR-TRANSITION OF NANOSTRUCTURED VO_2 FILMS

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The manufacturers of integrated circuit technology are currently facing the inevitable failure of present CMOS technology to fulfil Moore's law requirement below 20 nm line width. Although some technological solutions still exist, costs and the fundamental limit of quantum mechanical tunnelling, etc. effects around 10 nm-node form huge challenges. New solutions require utilization of new materials capable of implementing novel functionality, such as the metal insulator transition (MIT) effect of vanadium dioxide VO_2. For example, strain engineering controlled MIT offers method for fabrication of two-dimensional (2D) electron gas switching components, like transistors.

Pulsed laser deposition (PLD) was utilized to grow epitaxial vanadium dioxide VO_2 thin films on *a*-, *r*-, and *c*-cut Al_2O_3, and MgO(100) substrates. Films grown on *c*-cut Al_2O_3 substrates were also studied as a function of thickness ranging from 20 nm to 240 nm. The preferred epitaxial orientation of the VO_2 films varied between (100) on *a*- and *r*-cut, (010) on *c*-cut, and (110) on MgO(100). Transition temperatures T_{MIT} scaled between 64 °C and 82 °C depending on the specific sample structure. X-ray diffraction (XRD), Raman spectroscopy, transmission electron microscopy (TEM), and atomic force microscopy (AFM) experiments showed that, in insulating state, the films were composed of combinations of polymorphs of VO_2 including mainly M1 phase together with M2, and A phases with dislocations in the film-substrate interface so that the residual misfit strain was minimized. Especially, on *c*-cut Al_2O_3 substrates, the MIT was observed to be controlled by M2 phase in the films thinner than 100 nm, and by M1 phase in thicker films. However, XPS depth profile measurements did not reveal any other than pure VO_2 phases in the film-substrate interface. The presence of polymorphs together with dislocations in the film-substrate interface leads to higher charge carrier density, and thus to increased conductivity due to 2D electron gas, and to decreasing resistivity and broader MIT effect with decreasing film thickness, which is opposite to conventional Fuchs-Sondheimer relationship.

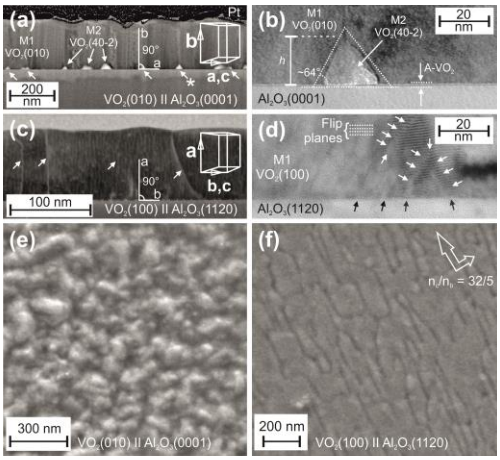

Figure 1. SEM and TEM micrographs of VO_2 thin film **(a-d)** substrate interface cross-sections and **(e-f)** surfaces.