18p-A11-5

VO_2 薄膜の相転移温度における基板熱膨張率効果

Impact of thermal expansion of substrates on phase transition temperature of VO_2 films

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1. Introduction

VO_2 shows thermally- induced structural phase transition from MoO_2- type monoclinic (M1) to rutile- type tetragonal (R) structures at 341 K under no strain. It is known that elongation (shrinkage) of its c_R axis length results in higher (lower) transition temperature, T_{tr}.[1,2] For $(010)_{M1}$- [or $(100)_R$-] oriented VO_2 films, one can expect that a larger thermal expansion coefficient (α) of the substrates, α_{sub}, would result in shorter c_R, and thus lower T_{tr}. In the present study we demonstrate the α_{sub} effect on T_{tr} of VO_2 thin films grown on the same buffer layers, Pt (111) / SiO_2, but on different kinds of substrates.

2. Experimental

We chose four substrates materials, amorphous SiO_2 (fused silica), Si (001), Al_2O_3 (0001), and CaF_2 (001), whose α_{sub} values are widely ranging. 20 to 30 nm- thick SiO_2 layers and 100 nm- thick Pt layers were deposited by an RF sputtering method. 50 nm- thick VO_2 layers were then deposited with a pulsed laser deposition method. The deposition temperature for both Pt and VO_2 layers was set to 823 K. XRD 2θ–ω scans and temperature-controlled micro-Raman spectroscopy measurements were performed. To extract T_{tr} values, M1 phase occupation ratio at each temperature was evaluated from Raman spectra, with a method previously described.[3]

3. Results and discussion

The XRD peak around 40˚ in 2θ–ω profiles of each sample [Fig. 1(a)] is considered to be an overlap of diffraction signals from Pt *111* and VO_2 020_{M1} planes. The difference of peak positions was clearly seen among the samples. Figure 1(b) shows the M1 ratio plotted against the temperature for all samples, again, demonstrating the difference of T_{tr} among them.

We define the linear shrinkage ratio ($\Delta L/L$) of the material during cooling from 823 to 293 K, as $\Delta L/L = \{L(293K) - L(823K)\} / L(823K)$ where $L(T)$ is the in-plane lattice parameter (or simply the sample size in case of an amorphous material) at T K. Lattice spacings of Pt *111* and VO_2 020_{M1} diffraction planes, estimated from deconvoluted XRD peak positions, and T_{tr} values are plotted in Fig. 2 as functions of $\Delta L/L$ of the substrates. One can see tendencies that the substrates with higher shrinkage ratio (higher α_{sub}) give larger out-of-plane spacings of both Pt and VO_2, and lower T_{tr} of VO_2 films, as expected. It is suggested that α of the substrate is a parameter that causes a significant influence onto phase transition properties of VO_2 thin films.

[1] Muraoka & Hiroi, APL **80**, 583 (2002).
[2] Cao *et al.*, Nano Lett. **10**, 2667 (2010).
[3] Sakai *et al.*, JAP **113**, 123503 (2013).

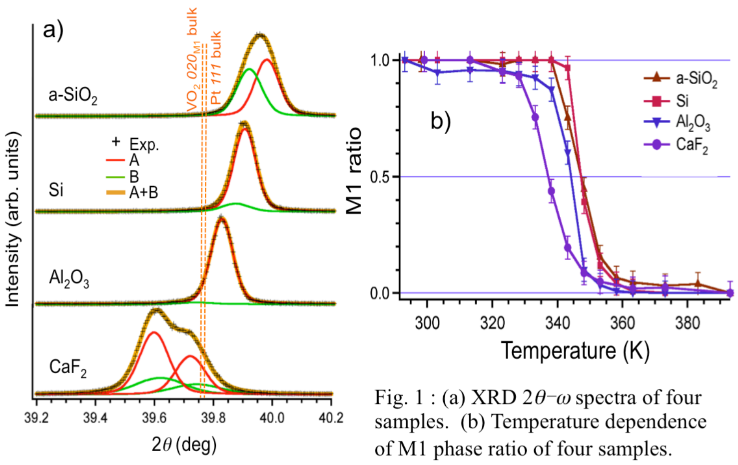

Fig. 1 : (a) XRD 2θ–ω spectra of four samples. (b) Temperature dependence of M1 phase ratio of four samples.

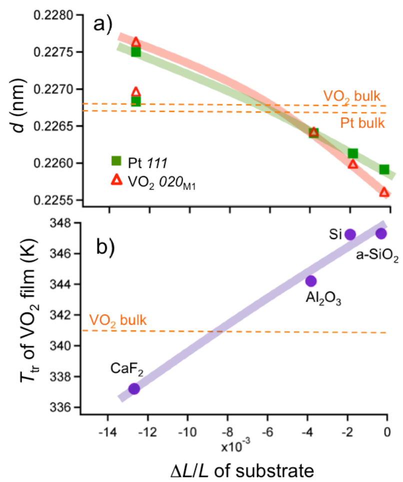

Fig. 2 : (a) Out-of-plane lattice spacings of Pt *111* and VO_2 020_{M1} diffractions, and (b) T_{tr} of VO_2 films, as functions of $\Delta L/L$ of the substrates.