THz modulation performance of VO_2 film grown on Al_2O_3/Si substrate

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Abstract: High quality VO_2 thin film was successfully deposited on Si substrate with Al_2O_3 as a buffer layer. The electrical and optical performance of the film was great enhanced. Reflective terahertz modulation is characterized and the modulation amplitude of 55% is obtained. The VO_2-on-Si buffered by Al_2O_3 can be widely used for THz devices.

Keywords: VO_2 thin film, Terhertz, Modulation.

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1. Introduction

The metal-insulator transition (MIT) of VO_2 thin film leads to great changes in its electrical and optical properties, such as the electrical resistivity, reflectivity and transmissivity [1-3]. Based on its abrupt changing of performance, the VO_2 films were widely applied within the terahertz frequencies, especially to the temperature control modulator [4, 5]. But the preparation of VO_2 films with excellent phase transition properties is a basic foundation for real applications. In the work presented here, Al_2O_3 buffer layer was used to enable integration of VO_2 thin films with Si (001) substrates. Giant phase transition properties were observed in the VO_2 film in terahertz range.

2. Experiments

The VO_2 films were prepared by RF magnetron reactive sputtering using Al_2O_3 as an intermediate buffer layer, which was grown by atomic layer deposition technology. After deposition, the microstructures, electrical properties and optical performances of the thin film were systemically studied.

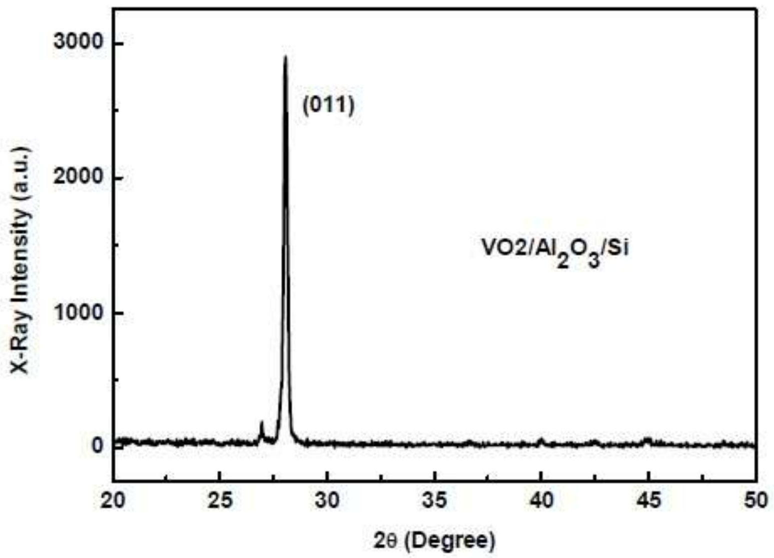
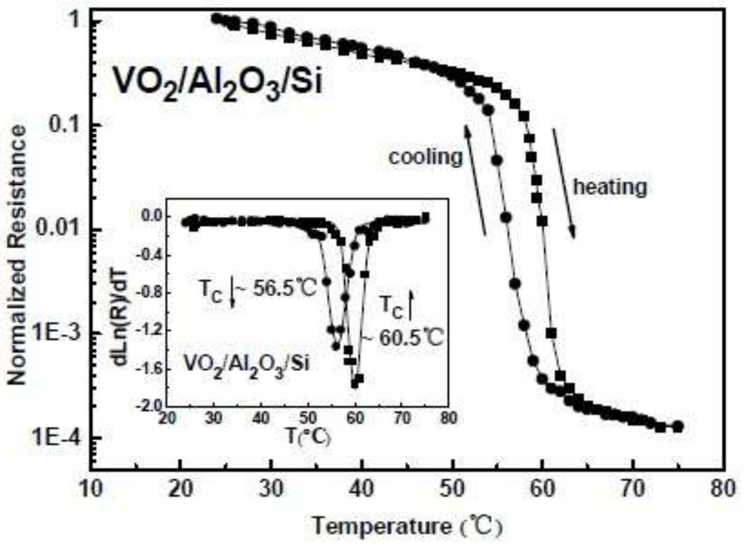


Fig. 1 The XRD pattern of VO2 thin film on Si substrate buffered by Al_2O_3.

Figure 1 shows the XRD pattern of the film. We can see a dominant peak at 2θ = 28, which refers to (011) planes of monoclinic phase of VO_2 films. The preferred orientation (011) is so obvious that it fades the other orientation away. It shows that the VO_2 on Si substrate buffered by Al_2O_3 is significantly textured.

The VO_2 films we prepared here were observed with nearly four orders of magnitude resistance change in thermal-MIT, as shown in figure 2. It indicates a quite high quality of VO_2 films consistent well with the XRD results. The MIT temperature T_C of the VO_2-on-Si buffered by Al_2O_3 is determined to be 60.5 ℃ and 56.5 ℃ during the temperature ramping up and down, respectively.



We display reflection spectra for our sample in the frequency range of 0.4-1.6 *THz* with temperature changing from 25 ℃ to 80 ℃. Variations of the THz reflection with frequencies are illustrated in Figs. 3.

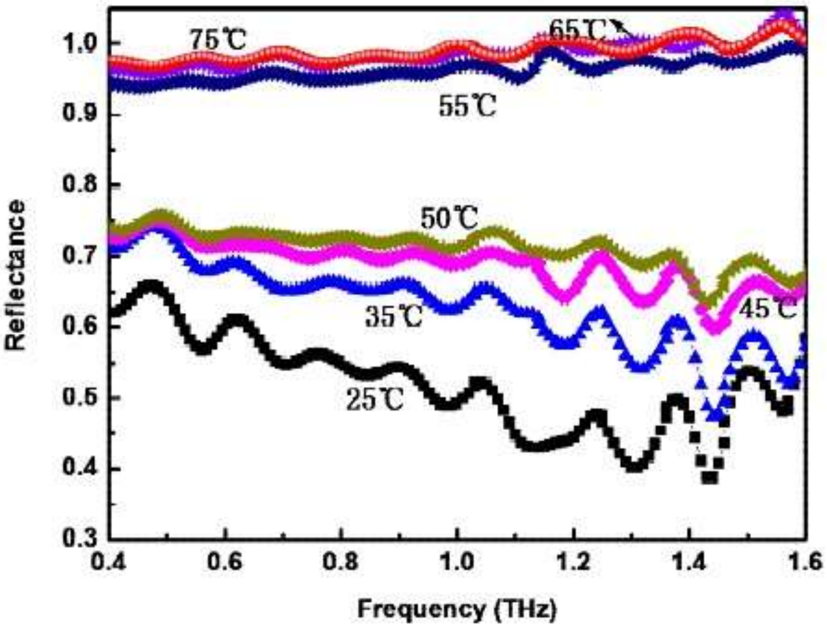


Fig. 3 Variations of the reflection with frequencies.

We set the reflection at 80 ℃ as 100%, then a series of relative reflection is obtained. As the temperature ramping down, the VO_2 film switches toward to its insulation phase, then we observed the significant modifications to the THz signal. A bit higher reflection was produced due to the heavily doped silicon substrate. As an active THz device, a large modification amplitude over 55% was obtained here. Moreover, the modulation rate can be achieved as high as 2%/ ℃, when the temperature changes from 50 ℃ to 55 ℃.

In summary, the VO_2 thin film deposited on Si substrate buffered by Al_2O_3 shows perfect crystallinity and an orientational crystallization of (011). Dramatic change in electrical resistivity (ÄR=10^4 *Ohm/*□) was observed. THz reflection modulation was characterized by terahertz time domain spectrum, and the results demonstrate that the VO_2 film with the modification amplitude of 55% can be widely applied to THz switching devices.

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