

論文 / 著書情報
Article / Book Information

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論文要約

THESIS OUTLINE

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Fabrication of VO₂ Films and VO₂-based Magnetic Layered Structures

Vanadium dioxide (VO₂) is a kind of vanadium oxides which could show the phase transition. The resistivity could decrease several orders which is caused by the phase transition. This phenomenon is called the metal-insulator phase transition (MIT). During this procedure, the crystal structure also will change and is called the structural phase transition (SPT). For VO₂, the phase transition temperature is about 68 °C. At room temperature, it is a kind of n-type semiconductor. The most stable phase is monoclinic M1 phase. After the phase transition happen, the crystal structure will change to rutile phase. The crystal structural before and after phase transition is shown in Fig. 1. And the lattice constant of each of them are shown in Table 1. By calculating the difference of the lattice constant, the parameter alone a-axis of monoclinic (M1) phase will change the most, nearly 1%.

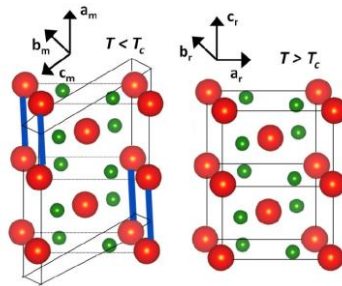


Fig. 1 The crystal structure of VO₂ for M1 phase (left) and R phase (right).

Table 1 Lattice constant of M1 phase and rutile phase

	a / Å	b / Å	c / Å	β / °
M1	5.75173	4.52596	5.38326	122.6148
R	4.55349	4.55349	2.84944	90

On the other hand, CoPt is a kind of ferromagnetic material. The magnetic property is sensitive. By introducing an in-plane tensile stress, the CoPt films could obtain perpendicular magnetic anisotropy (PMA), which means the preferential magnetization orientation changes from in-plane direction to out-of-plane direction. Therefore, the objectives of this research is as follow: Firstly, to study on the fabrication of high-quality VO₂ films on the glass substrate under different forming conditions. Secondly, to study the effect of VO₂ phase transition on the magnetic properties of VO₂-based magnetic layered structures.

The outline of this dissertation is as follow:

Chapter 1 Introduction: Firstly, it is a brief introduction about the characteristics of vanadium dioxide (VO₂) and CoPt. And then, it explains the mechanism of magnetic anisotropy and the anomalous Hall effect (AHE). Finally, it shows the objects of this research.

Chapter 2 Fabrication of VO₂ Films on Glass Substrate: Single VO₂ films were successfully prepared on the glass substrate by DC magnetron sputtering. Firstly, it was deposited on the substrate at room temperature with 2.09% oxygen ratio. Then the films were in-situ annealed at about 550 °C for 1 hour in 5 Pa with 20% oxygen ratio to be oxidized to VO₂ and improve the crystallinity. Finally, the films were cooled down to the room temperature in the same atmosphere. The peaks in XRD results (Fig. 2a) and the sharp jump of the resistivity in the R-T curve (Fig. 2b) confirms the fabrication of high-quality monoclinic (M1) VO₂ which could show metal-insulator phase transition.

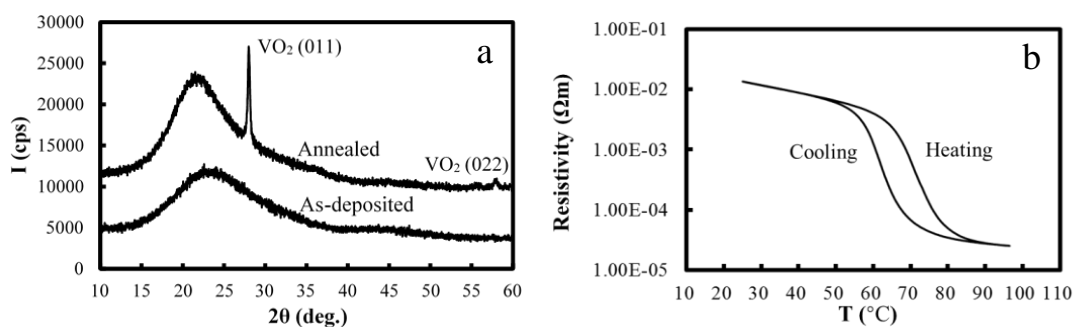


Fig. 2 (a) XRD results of VO₂ films, and (b) R-T curve of in-situ annealed VO₂ film

Chapter 3 Influence of Preparation Conditions on the Formation of VO₂ Films: In this chapter, the influence of the changed preparation parameter during the fabrication process would be discussed. In as-deposition process, the larger oxygen ratio would make pure vanadium be oxidized to vanadium oxides, finally it would be oxidized to α -V₂O₅. The change of the resistivity (Fig. 3a) could confirm the oxidization process and the XRD results (Fig. 3b) could confirm the formation of α -V₂O₅. In in-situ annealing process, the XRD results (Fig. 4a) shows the crystallinity of the as-deposited films are improved after in-situ annealing process. On the other hand, the characteristic of VO₂ films after in-situ annealing process is related to the annealing conditions, which could be explained by dynamic equilibrium model (Fig. 4b). The concentration of the oxygen atoms in the films is maintained as a dynamic equilibrium state. When the dynamic equilibrium state could be maintained as an optimized state for VO₂, the crystallinity could be improved by in-situ annealing process and fabricate high-quality monoclinic (M1) VO₂ films which could show the metal-insulator phase transition behavior.

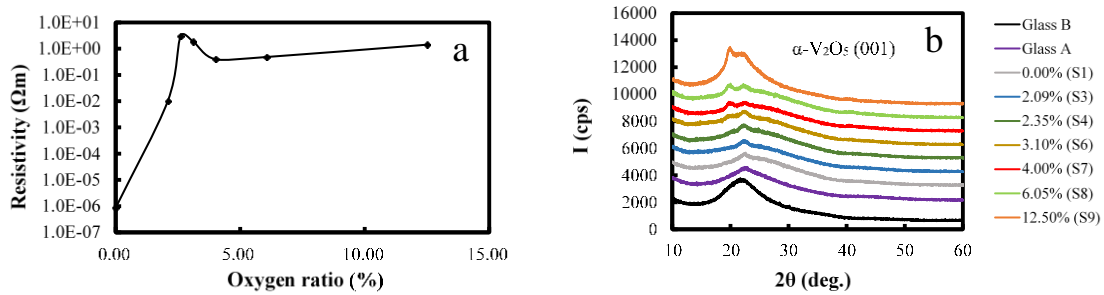


Fig. 3 (a) Resistivity and (b) XRD results of the films with different oxygen ratio.

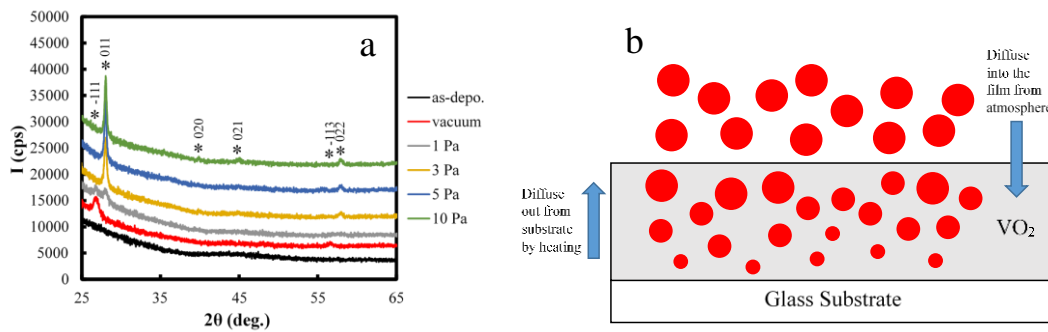


Fig. 4 (a) XRD result of the VO₂ films in-situ annealed under different pressures, and (b) schematic illustration of the dynamic equilibrium model.

Chapter 4 Magnetic Characteristics of CoPt/VO₂ Bilayer Films on Glass Substrate: Based on 30 nm VO₂ films, 3 nm, 5 nm and 8 nm CoPt films were deposited at 350 °C. The hysteresis loops of the samples (Fig. 5) show the different magnetic anisotropy of bilayer films with different thickness of CoPt layer. With 3 nm CoPt, the bilayer film shows perpendicular magnetic anisotropy (PMA). It is a comprehensive effects of the tensile stress, the interface anisotropy and the electron hybridization between Co and O. In addition, the Hall resistance curve measured at high temperature is used to study the change of out-of-plane coercivity of 3 nm-CoPt/VO₂ bilayer film during heating (Fig. 6). The decrease of the coercivity (Fig. 6d) is due to the relaxed interfacial stress applied during the fabrication process. Unfortunately, it doesn't show an abrupt change due to the structural phase transition. On the other hand, the decrease of the maximum Hall resistance (Fig. 6e) is caused by VO₂ metal-insulator phase transition.

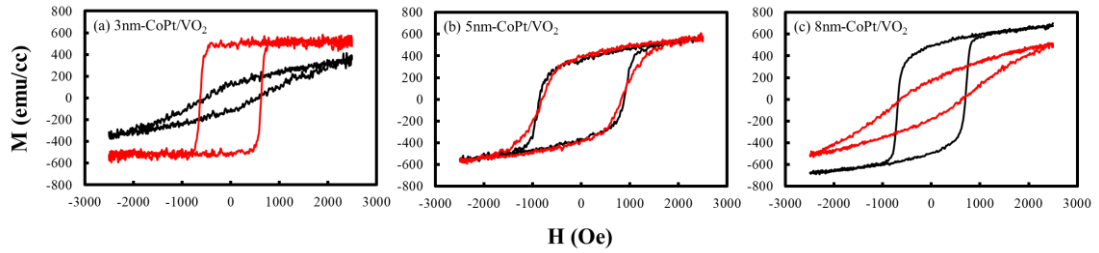


Fig. 5 Room-temperature hysteresis loops of the CoPt/VO₂ bilayer films with the 3 nm, 5 nm and 8 nm CoPt layers. Black line: in-plane direction, red line: out-of-plane direction.

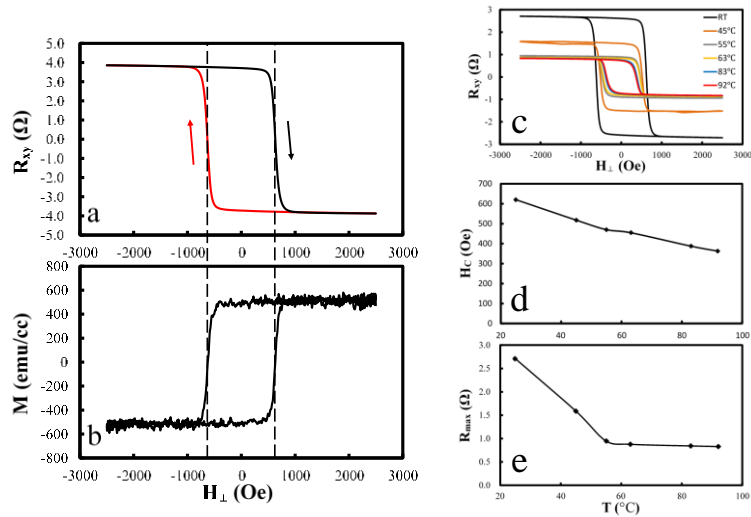


Fig. 6 (a) Hall resistance R_{xy} vs H_{\perp} curve and (b) out-of-plane hysteresis loop measured at room temperature, (c) Hall resistance R_{xy} vs H_{\perp} curves in the range from room temperature (black line) to 92 °C (red line), (d) out-of-plane coercivity H_C vs T curve and (e) maximum Hall resistance R_{max} vs T curve for 3nm-CoPt/VO₂ bilayer film.

Chapter 5 Magnetic Characteristics of CoPt/VO₂/Pt/CoPt/Pt Multilayer Films on Glass Substrate: In this chapter, the CoPt/VO₂/Pt/CoPt/Pt multilayer films were prepared (Fig. 7). The hysteresis loop of the multilayer films measured at room temperature (Fig. 8a) shows strong PMA and there is a step in out-of-plane hysteresis loop. The VSM results of these samples are shown in Fig. 8b and 8c. For the bottom CoPt layer, it shows isotropic magnetic characteristics and the top CoPt layer shows PMA. Considering the VSM results of the reference samples with only one ferromagnetic layer (Fig. 8b and 8c), it shows the magnetic moments in two CoPt layers in multilayer film are decoupled at room temperature and lead to the appearance of the step in out-of-plane hysteresis loop. In addition, the Hall resistance curve (Fig. 9a) is used to study the change of the out-of-plane coercivity of the multilayer films and the derivative of the curves is calculated to clearly obtain the step (Fig. 9b). According to the high-temperature results (Fig. 9), the step in room-temperature curve will disappear at high temperature, which might due to the decrease of the out-of-plane coercivity of the top CoPt layer in the multilayer film.

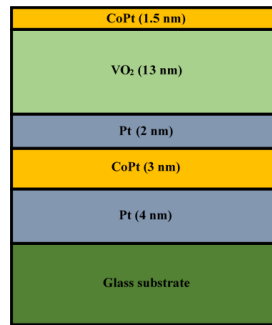


Fig. 7 Sketch of the CoPt/VO₂/Pt/CoPt/Pt multilayer film.

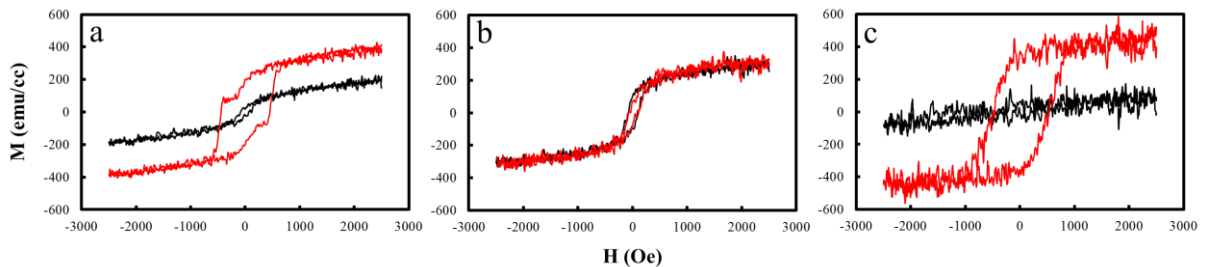


Fig. 8 Room-temperature hysteresis loops of (a) CoPt/VO₂/Pt/CoPt/Pt multilayer film, (b) VO₂/Pt/CoPt/Pt four-layer film and (c) CoPt/VO₂ bilayer film. Black line: in-plane direction, red line: out-of-plane direction.

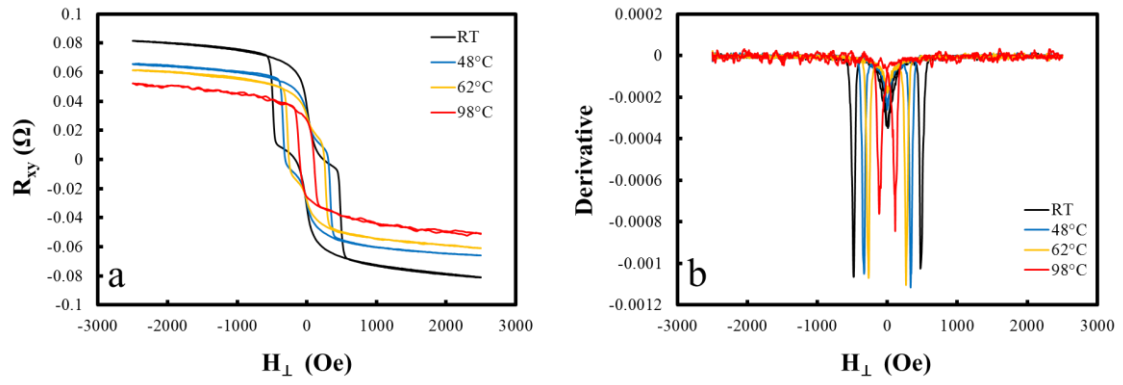


Fig. 9 (a) Hall resistance R_{xy} vs H_{\perp} curves and (b) Hall resistance derivative vs H_{\perp} curves in the range from room temperature to 98 °C for the CoPt/VO₂/Pt/CoPt/Pt multilayer film.

Chapter 6 Conclusion: Make a conclusion of this dissertation.