Effect of Gas Conditions on Field-Induced Phase-Induced Denaturation by Magnetrons Sputtering

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Abstract. Vanadium dioxide was manufactured as thin films on the Sapphire substrate with magnetron sputtering methods in this work. It is shown that the threshold voltage of Vanadium dioxide's Metal-Insulator Transiton (MIT) can be adjusted within a certain range through optimizing deposition processes in order to meet the demands of practical applications. Meanwhile, the influence of sputtering pressure on film growth was analyzed, and the regularity between experimental processes and the growth trend of grains was summarized as well as crystal surface structure. Furthermore, the E-MIT characteristics of Vanadium dioxide thin films were also measured to evaluate their switching properties in a constant temperature test system. And the effects of oxygen-argon ratio used in sputtering were estimated on to the critical field of MIT and the variation of films’ conductivity.

1. Introduction
Vanadium dioxide (VO\textsubscript{2}) is stimulated by the outside world, and the conductivity of VO\textsubscript{2} is changed rapidly [1]; Intelligent material[2], and the phase transition of VO\textsubscript{2} has many kinds of excitation modes, such as thermal-induced phase change [3], electro induced phase transformation[4] and photo Phase change [5]. Its single crystal is often fractured into powdered matter, but it does not have this drawback when it is made into a thin film shape, instead undergo repeated phase transition without damaging [6], so people are more interested in VO\textsubscript{2}'s film morphology. VO\textsubscript{2} thin films are prepared in many ways, Besides ordinary reaction evaporation, evaporation of ionization reaction, evaporation of particle beam reaction, etc [7~10]. It's never been able to summarize. And the current study on the phase transition characteristics of vanadium dioxide film is limited to its thermal-induced color characteristics [11], using its light-color transmittance for intelligent cooling window laser protection materials. But VO\textsubscript{2} is also an electric field sensitive material [12]. Its field-induced or thermal-induced phase change behavior has similarities, its repeatable phase [13], change excellent characteristics, extremely strong electrical performance; ultra-fast response time [14] can be applied to a field-induced switch device and used in intelligent electromagnetic shielding material [15]. The effect of different sputtering conditions on the crystal structure and film composition of thin film was summarized by using DC magnetron sputtering to prepare high purity VO\textsubscript{2} by changing the oxygen partial pressure, sputtering temperature and sputtering pressure. The results show that the oxygen pressure of reactive sputtering has a great influence on the crystal composition, the sputtering temperature has a great influence on the grain growth trend and the sputtering pressure has a great influence on the crystal surface structure [16]. The switching characteristics of VO\textsubscript{x} film, the influence of film group on the phase change interval and the phase change multiples of the film, and the variation law of the critical phase change field strength of the film are analyzed, and it is instructive to apply it to the intelligent
electromagnetic shielding material.

2. Thin film characterization and analysis

![SEM characterization of different sputtering pressures](image)

**Figure 1.** SEM characterization of different sputtering pressures

By changing the sputtering temperature and oxygen partial pressure, the SEM test of the films under different technological conditions was carried out to study the effect of different sputtering pressure and oxygen partial pressure on the surface morphology, formation and grain size of VO\textsubscript{X} thin film. Set the sputtering time is 30min; sputtering oxygen argon ratio is 0. 015, the sputtering temperature was 400°C, the pressure adjusting interval of sputtering was 0.6Pa to 1.2Pa, the sample was characterized and analyzed, and the effect of different sputtering pressure on the morphology of the film was observed.

The surface morphology of the film has a better tendency with the increase of the sputtering pressure, while the sputtering pressure is 0. 6Pa, the film surface morphology is poor, the grain size is not uniform, the grain growth is very uneven, the film surface appears a lot of depression, when the sputtering pressure to 0. 8Pa, the surface morphology of the film is improved, the crystal length is even, but the grain size is still uneven, when the pressure of the cavity reaches 1. 0Pa, the film surface depression began to grow smaller, the growth of larger grains, surface morphology further improved, and continue to enhance the sputtering pressure, when the sputtering pressure reached 1.2Pa, the film surface depression began to contract, the crystal long-time also more consistent, the surface uniformity is better.

3. Field phase change test

To simulate an external electric field, In this paper, the phase change temperature test of three groups of thin films is carried out, the four-probe surface resistance test platform is used, the material is placed on the resistance heating plate, the resistance heating plate is controlled by the heating control element, and the infrared The thermometer is used for the auxiliary temperature measurement. The heating range of the resistance heating plate is set to 20°C ~80°C. The excitation temperature test of VO\textsubscript{2} film is mainly used as a four-probe temperature test system, and its actual test is shown in Figure
2. 

**Figure 2.** VO$_2$ film excitation temperature test principle diagram

By adding the temperature heating system to the four probe test system, the temperature heating system consists of the resistance heating plate, the heating control element and the temperature acquisition module, and the auxiliary hand-held infrared thermometer is used to test the phase change excitation temperature of VO$_2$ film by placing the film material directly on the resistance heating plate.

In order to study the effect of oxygen argon ratio on the field-induced phase transition, the sputtering time was 30min, the sputtering temperature was 450°C, the sputtering pressure was 1Pa. The effect of different oxygen argon ratio on the phase transition of the film was tested by field-induced phase transformation, and the experimental data were assembled.

Figure 3 is the diagram of the electric field intensity regulating the phase transition temperature, as shown in Figure 3, when the oxygen argon ratio is 0.012, the film itself has better conductivity. When the 2kV increases to 0.4kV, the film produces phase transition, at which point the front and rear phase change multiples are only 50 times, and the conductivity before and after the phase change has not changed dramatically. When the oxygen argon ratio is 0.014 to 0.016, the film phase change characteristics are better, with the external voltage increased from 0.2kV to 0.4kV, the film produces phase transition, which is about $2 \times 10^3$ before and after the transformation.

**Figure 3.** Regulation of the Electric Field Regulation Phase Change Diagram
This phenomenon indicates that the change of the ratio of oxygen and argon ratio in the preparation of vanadium dioxide can change the field-induced phase change ratio, the oxygen argon ratio is 0.0016. The phase change characteristic of 0.12 is not good, and the phase change characteristic is better when 0.014 to 0.016.

4. Conclusion
In this paper, using the method of contrast experiment, the V$_2$O$_Y$ film was prepared by magnetron sputtering DC method on sapphire base film of aluminum oxide, the preparation of high repeatability VO$_2$ film was achieved, and the effect of oxygen pressure on the crystal group was studied and the influence of the sputtering pressure on the crystal surface structure is analyzed, and the influence of the VO$_2$ film's switching characteristics and the film composition on the phase change interval and the phase change multiples of the membrane, and the variation law of the critical phase change field strength of the film are summarized as follows:

(1) The oxygen argon ratio will affect the variation of the conductivity of the film and the critical phase variable voltage range. The oxygen argon ratio is 0.012 to 0.016 interval, the conductivity of the film's conductivity changes as the increase of oxygen argon ratio increased, the optimum ratio of oxygen and argon should be 0.014 to 0.016, at this time before and after the change of the conductivity of the $2 \times 10^3$. Critical phase voltage interval increases with the increase of oxygen argon ratio, can be used to study the production technology of the actual needs, can achieve critical phase voltage regulation.

(2) The effect of the sputtering pressure on the uniformity of crystal growth is significant. The surface morphology of the film is becoming more and more homogeneous with the increase of the sputtering pressure, reaching the best at around 1.0Pa, and the sputtering pressure cannot be less than 0.8Pa and shell not exceed 1.2Pa, low pressure will cause the film to grow uneven and high pressure will due to high gas concentration, the gas molecules too many, the average free process is smaller, resulting in a small sputtering rate.

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