A new fabrication process of vanadium oxides(VO_x) thin films showing high TCR and low resistance for uncooled IR detectors

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Abstract

Vanadium oxide (VO_x) thin films are very good candidate material for uncooled infrared (IR) detectors due to their high temperature coefficient of resistance (TCR) at room temperature. But, the deposition of VO_x thin films showing good electrical properties is very difficult in micro bolometer fabrication process using sacrificial layer removal because of its low process temperature and thickness of thin films less than 1000Å. This paper presents a new fabrication process of VO_x thin films having high TCR and low resistance. Through sandwich structure of VO_x(100Å)/V(80Å)/VO_x(500Å) by sputter method and post-annealing at oxygen ambient, we have achieved high TCR more than -2%/℃ and low resistance less than 10KΩ at room temperature.

Key Words : Vanadium oxide (VO_x), Temperature Coefficient of Resistance (TCR), Bolometer, and Infrared (IR) detector

1. INTRODUCTION

Developing micromachining technologies have made it possible to fabricate large focal plane array (FPA) IR detectors of thermal type having high detectivity and operating at room temperature. There are three types of thermal detectors : bolometer, thermopiles, and pyroelecric detectors. Among these, bolometers are good in easiness of fabrication and have high responsivities[1].

There are many materials for bolometer such as metal[2], vanadium oxides[1,5] semiconductor such as YBaCuO[3] and SiGe[4]. Among these materials, Vanadium oxides(VO_x) thin films are very good candidate material for uncooled IR detectors due to their high temperature coefficient of resistance(TCR) at room temperature. Fig.1 shows a schematic of bolometer with floating structure made by surface micromachining by Honeywell[5].

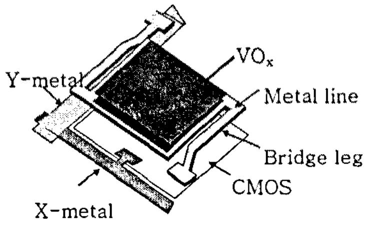

Fig.1. A schematic of bolometer structure made by Honeywell using surface micromachining

As showed in Fig. 1, deposition of VOx thin films showing good electrical properties is very

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difficult in micro bolometer fabrication process using sacrificial layer removal because of its low process temperature below 300℃ and thickness of thin films less than 1000Å.

There are many forms in vanadium oxides such as VO_2, V_2O_5, V_2O_3, etc. these materials undergo transitions from insulator or semiconductor to metal. Especially, V_2O_3 undergoes this transition at -123℃[6], so it shows a low resistance at room temperature. Also, V_2O_3 has low formation energy than VO_2 and V_2O_5. To reduce noise of device, it is necessary to reduce resistance of device. Therefore, use of V_2O_3 phase showing low resistance at room temperature is very important. In this paper, we describe a new fabrication process of VO_x thin films having high TCR and low resistance at room temperature for uncooled IR detectors.

2. EXPERIMENT

We have fabricated sandwich structures of vanadium and vanadium oxide : VO_x / V / VO_x as showed in Fig. 2(a) by conventional radio frequency sputtering. As substrates, we have used SiN_x/Si by PECVD to measure electrical properties and silicon wafers to analyze structural properties in size of 12 X 12mm^2.

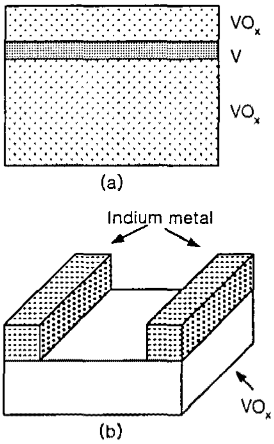

Fig. 2. A schematic diagram of (a) sandwich structure and (b) indium metallization.

Table 1. Sputtering conditions.

Target	99.99% V metal(4inch)
Distance	90mm
Base pressure	3.0×10^{-6} Torr
Working pressure	6 mTorr
Sputtering power	350W
Substrate temperature	Room temperature

To fabricate sandwich structures, we have deposited vanadium oxide thin films for 10 minutes in thickness of 500Å, vanadium metal thin films for 10 ~ 30 seconds in thickness of 20 ~ 120Å, and finally vanadium oxide for 2 minutes in thickness of 100Å. Ratio of O_2 / Ar + O_2 for vanadium oxide depositions was 50%. Sputter conditions was presented in Table. 1. And then, we have annealed in O_2 ambient for various time at 300℃.

We have deposited indium by evaporation to measure electrical properties such as Fig. 2(b). With bolometer tester controlled by computer, we have measured resistance varying temperature from 20 to 50℃, and calculated TCR at room temperature by linear fitting. And we have analyzed structural properties by SEM for surface morphology, XRD for phase analysis.

3. RESULTS AND DISCUSSION

Firstly, to analyze phase changes of metal layer inserted in sandwich structure, we have deposited metal films (1200Å), annealed for 30 minutes in air and O_2 ambient at 300℃, and analyzed XRD spectra. As showed in Fig. 3, we can know that vanadium metal changes into vanadium oxides such as mainly V_2O_3 , V_2O_5, and other phases.

Then, we have measured resistance of vanadium oxide thin films having vanadium metal thickness of 40, 80, 120Å as inserted layer, increasing temperatures.

VO_x thin films having vanadium metal layer of 40Å as inserted layer show high resistance above 20KΩand slightly low TCR below -1.5%/℃

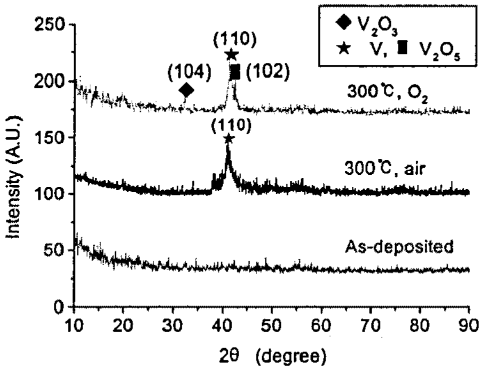

Fig. 3. XRD curves of vanadium metal thin films (1200Å) annealed for 30minutes.

at room temperature with annealing time of 10, 20, 30 minutes. These can be explained by supposing that vanadium metal layer is easily oxidizes into mainly V_2O_5 phase because of very thin metal thickness.

And VO_x thin films having vanadium metal layer of 120Å show very low resistance below 1KΩ and low TCR below -1%/℃ at room temperature with annealing time of 30, 60, 120 minutes. These also can be explained by supposing that vanadium metal layer is not entirely oxidized and changed into unstable intermediate phases owing to the thick film thickness at low annealing temperatures.

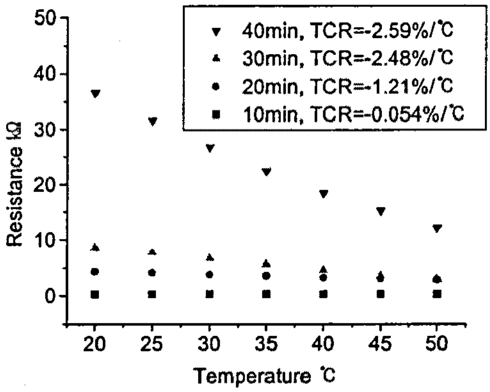

Fig. 4. Resistance versus temperature curve of VO_x thin films having vanadium metal layer of 80Å and annealed in O_2 ambient at 300℃ for various time.

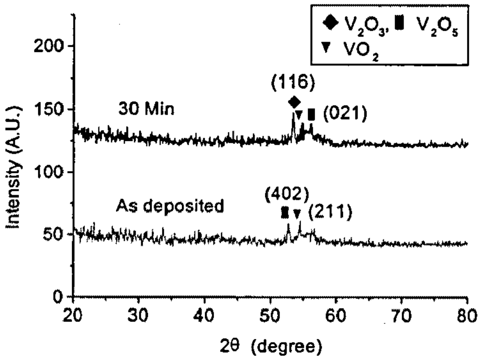

Fig. 5. XRD curve of VO_x thin films having vanadium metal layer of 80Å and annealed in O_2 ambient at 300℃.

As for VO_x thin films having vanadium metal layer of 80Å, we have obtained suitable resistance below 10KΩ and high TCR above -2.0%/℃ at annealing time of 30 minutes as showed in Fig. 4. Through XRD spectra in Fig. 3 and Fig. 5, we can conclude that as increasing annealing time, V_2O_5 decomposes into V_2O_3 and vanadium metal is oxidized into mainly V_2O_3 phase and that more annealing time result in oxidation of vanadium metal into mainly V_2O_5 phase, so resistance at room temperature increases above 30KΩ.

Finally, through SEM measurement, we have analyzed effect of surface morphology on electrical properties. But, because of low annealing temperature, surface morphology was not almost changed. So, we can suppose that effect of surface morphology on the electrical properties was not important in this process.

4. SUMMARY

We have fabricated sandwich structure of VO_x / V / VO_x and annealed in O_2 ambient at 300℃ for various temperatures to improve electrical properties of vanadium oxide thin films for uncooled IR detectors. and we have achieved high TCR above -2%/℃ and low resistance below 10KΩ at conditions : vanadium metal thickness of 80Å as inserted layer in sandwich structure, annealing in O2 ambient at 300℃ for 30 minutes.

ACKNOWLEDGMENTS

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