Journal of ELECTRONIC MATERIALS, Vol. 42, No. 5, 2013
DOI: 10.1007/s11664-012-2326-9

Vanadium Oxide Thin Films Alloyed with Ti, Zr, Nb, and Mo for Uncooled Infrared Imaging Applications

ADEM OZCELIK,[1,4] ORLANDO CABARCOS,[2] DAVID L. ALLARA,[1,2] and MARK W. HORN[3]

1.—Materials Science and Engineering Department, Penn State University, University Park, PA 16802, USA. 2.—Chemistry Department, Penn State University, University Park, PA 16802, USA. 3.—Engineering Science and Mechanics Department, Penn State University, University Park, PA 16802, USA. 4.—e-mail: ademozcelikpsu@gmail.com

Microbolometer-grade vanadium oxide (VO_x) thin films with $1.3 < x < 2.0$ were prepared by pulsed direct-current (DC) sputtering using substrate bias in a controlled oxygen and argon environment. These films were systematically alloyed with Ti, Nb, Mo, and Zr using a second gun and radiofrequency (RF) reactive co-sputtering to probe the effects of the transition metals on the film charge transport characteristics. The results reveal that the temperature coefficient of resistance (TCR) and resistivity are unexpectedly similar for alloyed and unalloyed films up to alloy compositions in the ~20 at.% range. Analysis of the film structures for the case of the 17% Nb-alloyed film by glancing-angle x-ray diffraction and transmission electron microscopy shows that the microstructure remains even with the addition of high concentrations of alloy metal, demonstrating the robust character of the VO_x films to maintain favorable electrical transport properties for bolometer applications. Postdeposition thermal annealing of the alloyed VO_x films further reveals improvement of electrical properties compared with unalloyed films, indicating a direction for further improvements in the materials.

Key words: Vanadium oxide thin films, microbolometers, sputtering, temperature coefficient of resistance, uncooled infrared imaging, microstructure

INTRODUCTION

Remote thermal imaging with uncooled infrared (IR) detector arrays has evolved to become a crucial technology in both military and civilian applications, with advances driven primarily by the development of cost-effective, thin-film detector materials[1] which can be configured as resistive microbolometers with high temperature coefficient of resistance (TCR). In operation the resistivity dependence of each micropixel on the absorbed IR radiation provides an image of the thermal field of view.[2] Vanadium oxide (VO_x) films, with $1.3 \le x \le 2.0$, have been shown to be optimum for applications because of the favorable combination of high TCR, low resistivity, and low $1/f$ noise, with $x \approx 1.8$ for the best films.[2–4] Even though VO_x films have been the choice of the majority of US manufacturers for room-temperature microbolometers, significant improvements in the materials are still needed to increase frame speeds and sensitivities. Progress towards these advances will depend to a large extent on improving our limited understanding of the correlations of the microstructure, transport mechanisms, and stability with the operating characteristics.

It has only been in the last 5 years that reports of the detailed microstructure of VO_x bolometer films have appeared.[3–13] A variety of studies reveal a two-phase structure which is a combination of defective nanocrystalline rock-salt VO phases embedded in laterally adjoining regions of amorphous phases.[3–8,13] Of particular interest, Gauntt et al.[4] found

---

(Received July 24, 2012; accepted October 9, 2012;