The joint virtual event of the
African Light Source AfLS2020
and the
African Physical Society AfPS2020

Contribution ID: **36** Type: **Poster Presentations**

Radiation-induced defects on pulsed laser deposited VO2 thin films

Friday, 20 November 2020 17:25 (1 hour)

A growing interest in the development and use of small satellites in interplanetary missions with more up to date technologies is becoming a considerable option than large conventional satellites. Future development of these small satellites will require the application and use of passive thermochromic layers to achieve good thermal control for longer mission life and cost-effective launches. Vanadium dioxide (VO2) thin films present an imminent prospect as a passive smart radiator device (SRD) for thermal control management in nano and microsatellites. The thermochromic response of VO2 based SRDs is channeled by low emissivity at lower temperatures to preserve the heat, and high emissivity at high temperatures to fritter away the additional unnecessary heat. Different radiation species in a space environment interacts with materials, and induce properties modifications in different ways. Hence; VO2 coatings need to demonstrate deep-space radiation tolerance based on their structural, electronic, and electrical properties. This review article provides a focussed overview of the radiation response and phase transition characteristics of VO2 thin films subjected to gamma rays, neutrons, and magnesium ions with energy and projectile doses similar to those accosted by spacecraft. A broad overview of the radiation effects and their interaction mechanisms on pulsed laser deposited VO2 thin films.

Summary

The optimization of the PLD system successfully deposited vanadium dioxide thin films on a large scale of 3″ Si wafers. Exhibiting good film homogeneity, reproducibility, and making it an imminent prospect to transfer VO2-based functionalities into viable optoelectronic applications such as smart radiator devices. The effects of high energy irradiation on VO2 based SRDs were investigated experimentally to complete a detailed and systematic study of the radiation responses of VO2 materials in different radiation conditions. A material with a significantly different crystalline structure and properties; phase transition evolution of VO2 was investigated for comparative purposes by gamma, neutrons, and magnesium ion irradiation. The crystal structure studies complemented by electronic studies showed that the stoichiometric bulk structure of VO2 is unaffected by γ-irradiation for high doses around 100 kGy, although Frenkel defects and microscopic defects within the crystal lattice were pronounced at doses above 3 kGy. The neutron-irradiated VO2 films at different fluence revealed similar radiation responses to those of gamma-irradiated films. No chemical gradient was induced by the neutron beam, whilst the stress and strain effects were pronounced as a consequence of multiple displacement damage incurred by the neutron beam on VO2 thin films. Fast high neutron beam flux induces thermal displacement spikes which induce heat deposition as they come to rest, inducing physical alteration and color-like formation on the surface of VO2 films. Whilst structural and thermochromic analysis of Mg ion sputtered VO2 thin films revealed a drastic reduction of the MIT of VO2. Pulsed laser deposited VO2 films bombarded by charged and neutral ions exhibited good thermodynamic stability and radiation response. Therefore; VO2 films exhibit radiation tolerance properties and could be potentially used as SRDs in small spacecraft. In situ studies of the microstructure and morphology of defects accumulation of VO2 thin films would be needed for a comprehensive study on the irradiation, and atomic displacement damage. Further studies using swift heavy ions should also be performed to correlate with the present results.

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Track Classification: AfLS2020 track