Radiation Physics and Chemistry 176 (2020) 109077

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Effects of low-dose γ-irradiation on the structural, morphological, and optical properties of fluorine-doped tin oxide thin films

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ARTICLE INFO

Keywords:
Fluorine-doped tin oxide thin films
Low-dose γ-irradiation
Structural property
Optical property
Surface morphology
Spacecraft thermal control coating

ABSTRACT

This paper presents the effects of low-dose γ-irradiation on the structural, morphological, and optical properties of Fluorine-doped tin oxide (FTO) thin films for application as a passive thermal control coating in future miniaturized lightweight spacecraft. Commercial-grade FTO films on glass substrate (Pilkington Ltd, UK) with a bulk density of 2.5 g/cm^3, sheet resistance of 12 $\Omega.sq^{-1}$, coating thickness of 450 nm, optical band-gap of 3.80 eV, a carrier concentration of 1.50×10^{20} cm^{-3} and a mobility of 15 cm^2/Vs were irradiated at room temperature and atmospheric pressure using a ^{60}Co gamma source (with gamma energies of 1.17 MeV and 1.33 MeV) at iThemba Laboratory for Accelerator Based Sciences, Cape Town, South Africa. Each sample was exposed to γ-rays for a different span of time to achieve a series of different integrated absorbed doses of 20, 30, and 50 Gy, at a dose rate of 0.207 Gy/min. Evolution in structural properties of the films was characterized using a Bruker AXS D8 Advance XRD with Cu-Kα ($\lambda = 1.54056$ Å) scanned in the 2θ degree range of 20 – 80 degrees. Surface properties were analyzed using a VEECO Dimension 1100 AFM machine. Meanwhile, variations in optical transmittance of the films was investigated using a Cary 5000 UV-vis-NIR spectrophotometer of Varian, Inc. model internal DRA- 2500 in the wavelength range of 200 – 2500 nm. XRD results indicate an enhancement of crystallization after irradiation, slight peak shifts, and variations in crystallite sizes with increasing dose. Surface roughness decreased with increasing dose and the grain structures also seen to vary with dose. No significant variations in optical transmittance of the FTO films.

1. Introduction

Fluorine-doped tin oxide (FTO) is a transparent conducting oxide (TCO) with widespread applications that include touch panel contacts (Adjimi et al., 2018), gas sensors and electrodes in thin film solar cells (Lavanya et al., 2016), transparent light emitting diodes (Zeng et al., 2003), smart windows (Batzill and Diebold, 2005), thin film transistors and catalyst (Sharma et al., 2013), and flat panel displays and optoelectronic devices (Adjimi et al., 2018; Tuyen et al., 2019), among others. These applications are owed to FTO's desirable broad qualities such as high electrical conductivity combined with a high optical transparency in the visible spectrum range (Banyamin et al., 2014; Chowdhury et al., 2013; Zeng et al., 2003), high reflectivity in the infrared (IR) region despite being significantly transparent in the visible region (Banyamin et al., 2014; Chowdhury et al., 2013), high melting point, high mechanical strength and hardness, high electrochemical stability, good adherence to substrates, relatively a large bandgap (> 3 eV) (Sharma et al., 2013; Shi and Xu, 2017). Besides, FTO offers a relatively better economic favor as compared to indium-based tin-oxide (ITO) due to the relative abundancy and low cost of tin mineral (Chowdhury et al., 2013). All these qualities combined make FTO a potential candidate for heat management as a thermal control coating (TCC) on future long mission and cost effective miniaturized spacecraft such as the CubeSats.

A TCC is a passive thermal management system (PTMS) made of single- or multi-layer thin coating of select materials with high reflectivity in the IR region designed to protect internal equipment. This is achieved either by confining heat produced by the spacecraft electronic components within the spacecraft during extreme cold weather or reflecting heat fluxes from the Sun into space (Gilmore, 2002;

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https://doi.org/10.1016/j.radphyschem.2020.109077
Received 19 April 2020; Received in revised form 15 June 2020; Accepted 23 June 2020