

Advancing Indium Tin Oxide Thin Films and Protective Coatings for Next-Generation Applications

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Thin conducting films (TCFs) have surpassed bulk materials in popularity during the past few decades due to their special mechanical, electrical, optical, and physical properties. TCFs are of considerable interest for commercial and space applications, particularly in solar cells, flat panel displays, and electrochromic windows. Recently, NASA space travel applications have established requirements for environmentally robust anti-reflection (AR) TCFs that require <0.5% total losses (e.g., reflection, absorption, and scattering). The guidance, navigation, and control (GNC) LIDAR systems utilized in NASA's VIPER (SQRLi), Dragonfly (Ocellus), and OSAM-1 (Kodiak) missions require pulsed transmit beams with exceptionally high-power densities. The implementation of refractive optics, which must withstand radiation, dust particles, and high-energy particles present in space, is essential for the functionality of these sensors. Direct exposure to radiation may result in the accumulation of charges on non-conductive surfaces, particularly on the space-facing surfaces of refractive components. To address this issue, we are focused on the development and manufacturing of an environmentally friendly, transparent, conductive, and AR coating suitable for use in GNC LIDAR and other space-flight applications.

In accordance with the specified requirements, we have developed a six-layer thin film-designed device optimized for spectral characteristics at the targeted wavelength of 1064 nm. This design incorporates a thin layer of Indium Tin Oxide (ITO) positioned between the outermost TiO₂ and SiO₂ layers. The reason behind the inclusion of ITO compared to alternative TCFs is that it is advantageous due to its exceptional balance of optical transparency, electrical conductivity, and environmental stability. We have successfully deposited optimized ITO thin films utilizing a controlled radio frequency (RF) sputtering process with varying gas flow, substrate temperature, and pressure, employing Ar as the working medium. The transmittance at a wavelength of 1064 nm was recorded at 100%. Additionally, the sheet resistance measured was 362.1 ohms per square, which closely aligns with conditions found in outer space, thereby ensuring the mitigation of static dust particle accumulation. The surface morphology and topological characterization were conducted comprehensively. Furthermore, optical characterization, including the determination of the refractive index, extinction coefficient, and dielectric properties—was performed utilizing an ellipsometer to evaluate the device's photo response. In addition to the experimental work, a simulation employing first-principal calculations was executed to assess the correlation between the theoretical predictions and the experimental data of the fabricated device. Future studies will concentrate on improving coating compositions for ultra-thin ITO films in order to increase device performance and improve radiation resistance.

Funder Acknowledgement(s): This research was funded by NASA Bridge Funding- Grant number 80NSSC24K0403 and Air Force Office of Scientific Research Grant number FA9550-22-1-0534

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