Enhancing Structural and Optical Properties in AZO Co-doped MgZnO Thin Films via Post-Annealing for Advanced Photonics

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The incorporation of aluminum (Al) and magnesium (Mg) doping in zinc oxide (ZnO) has gained significant attention for its ability to modulate optoelectronic properties, making it a promising strategy for advancing ZnO-based photonic technologies [1]. Specifically, magnesium-doped zinc oxide (MgZnO, MZO) has emerged as an effective front contact material for cadmium telluride (CdTe) solar cells due to its high transparency and conductivity [2]. In this study, MZO thin films are synthesized using RF-magnetron sputtering, followed by co-doping with aluminum-doped zinc oxide (AZO) to enhance the structural and optoelectronic properties. The films are then subjected to post-annealing treatments at 350 °C, 450 °C, and 550 °C to investigate the effects of temperature on film characteristics. The significance of the present study lies in the utilization of a synergistic approach for combining Al and Mg doping, along with post-annealing treatment, to optimize both structural and optical properties of AMZO films for photonic device applications including solar cells, photodetectors, and sensors.

Fig. 1a demonstrates the X-ray diffraction (XRD) analysis of MZO and AMZO films at varying annealing temperatures. The significant increase in peak intensity with rising annealing temperature reveals an improvement in crystallinity and a predominant cubic zinc blende (002) plane. Field emission scanning electron microscopy (FESEM) exhibits an increase in grain size from 31.3 nm to 64.6 nm, which refers to an enhanced electrical property of AMZO films. Additionally, optical measurements demonstrate a tunable bandgap ranging from 3.32-3.65 eV, with respective changes in transmittance at varying AZO composition in MZO films. This wide optical window reveals the strong potential of AMZO films as high-resistance transparent (HRT) layers for optoelectronic devices (**Fig. 1b and c**). These results offer valuable insights into the design and fabrication of advanced metal oxide materials for a wide range of optoelectronic applications, including transparent conductive layers in solar cells and photodetector and sensor devices. Furthermore, the ability to tune optical properties through post-annealing makes these films highly versatile for the development of high-performance materials with tailored properties, enabling their use in a wide array of photonic and optoelectronic technologies.

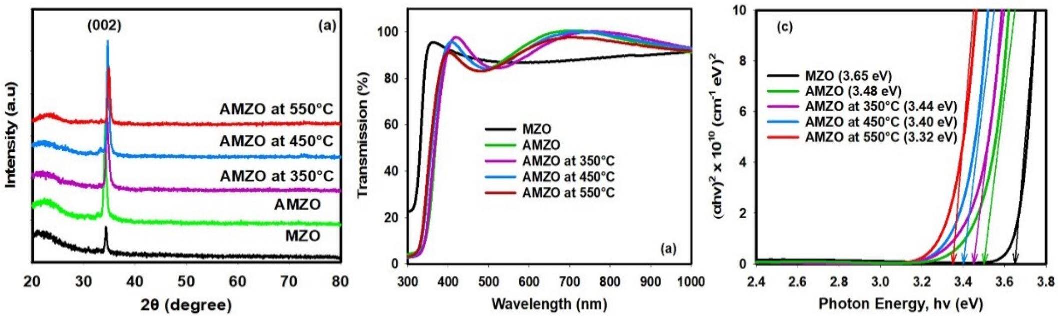

Fig. 1 (a) X-ray diffraction (XRD) spectra, (b) UV-visible (transmittance) spectra, and (c) the respective Tauc Plots (band gap, E_g) of sputtered MZO and AMZO films at varying post-annealing temperatures.

References: C Doroody et al. Results in Physics. (2023), 2) B Z Bhari et al. Physica B: Cond. Mat. (2025)