

SUBSTRATE INFLUENCE ON CDTE THIN FILM PROPERTIES

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Cadmium telluride (CdTe) remains a prominent material in the field of thin-film semiconductors, widely utilized for the development of cost-effective and high-efficiency photovoltaic devices, particularly terrestrial thin-film solar cells. Its widespread application is primarily attributed to its near-optimal direct bandgap (~1.5 eV) for solar energy conversion under standard illumination conditions, along with a high absorption coefficient that enables efficient light harvesting with absorber layers only a few micrometers thick. Additionally, the availability of mature and resource-efficient deposition techniques for CdTe thin films has further promoted its industrial scalability. First Solar (USA) currently leads the global market in the commercial production of high-performance CdS/CdTe solar modules, with a reported cumulative module output of 2.4 GW in 2020.

Structural analysis of CdTe films deposited on glass substrates revealed the predominance of a cubic crystalline phase, whose presence intensifies with increasing substrate temperature, reaching a maximum phase fraction at 200 °C. However, X-ray diffraction (XRD) patterns display a broad halo in the 2θ range of 39°–46°, indicative of limited crystallinity and suboptimal structural ordering at lower deposition temperatures.

Elevated substrate temperatures promote enhanced texturing of the films and lead to a marked reduction in internal stresses—by approximately an order of magnitude—when the temperature is increased from 100 °C to 200 °C. Moreover, the nature of the residual stress transitions from compressive to tensile within this range. Given that the lattice constants of the hexagonal CdTe phase remain effectively invariant, the observed stress inversion likely corresponds to the nucleation and growth of the cubic phase. Upon further temperature elevation to 300 °C, the stress state again becomes compressive, which may correspond to a reduction in the hexagonal phase fraction. Notably, the lattice constant of the cubic phase was observed to exceed its reference value, suggesting the presence of significant tensile stress within this phase.

For CdTe films deposited on glass substrates coated with a transparent conductive oxide (ITO) at 200 °C, XRD analysis identified the coexistence of two hexagonal phases (designated H1 and H2) and one cubic phase (C). Similar to the observations on bare glass substrates, an increase in substrate temperature leads to an enlargement of coherent scattering domain sizes. Across all temperatures studied, the dominant H1 hexagonal phase exhibits a pronounced texture. From 100 °C to 200 °C, a slight reduction in the degree of texture is observed for the H1 phase, followed by a substantial enhancement at 300 °C. Internal stress analysis further shows that the absolute stress magnitude decreases by a factor of two between 100 °C and 200 °C. As the temperature increases beyond this point, the stress polarity reverses from tensile to compressive, accompanied by a reduction in stress magnitude by approximately two orders of magnitude.