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Enhancing the Optical and Structural Properties of CdTe Thin Films via Thermal Treatments for Solar Cell Applications

DALAL N. ALHILFI [1*], ALAA S. AL-KABBI [2]

[1]polymer Research Centre, University of Basrah, Basrah, Iraq,61004

[2] Department of Physics, College of Science, University of Basrah, Basrah, Iraq,61004

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Abstract: **This study examined the optical, structural, morphological, and electrical properties of polycrystalline cadmium telluride films fabricated using electrochemical deposition in a two-electrode system. Cadmium acetate is a source of cadmium and is one of the few precursors used to prepare cadmium tellurides. CdTe films were grown on glass substrates of fluorinated tin oxide (FTO), followed by thermal annealing at 200, 300, 350, and 400 °C. In addition, chlorination treatment was conducted at 400 °C. We analyzed various physical properties using characterization techniques, such as transmittance, X-ray diffraction, scanning electron microscopy with energy-dispersive X-ray spectroscopy (EDX), and a source meter. The increase in temperature after cadmium telluride deposition increased the optical transmittance, resulting in a progressive decrease in the optical energy bandgap from 1.74 to 1.49 eV. We computed various dielectric and optical constants using the Swanepoel and Herve-Vandamme models necessary for dielectric theory. Thermal annealing improved the crystallinity of the films (cubic structure), with 111 orientations being predominant. The heat treatment also determined and examined the various crystallinity parameters in detail. Surface morphology analysis revealed that the films exhibited homogeneity, high compaction, uniformity, and the absence of crystal imperfections.**

Keywords: **CdTe, optical bandgap, refractive index, photovoltaic, absorber layer, electrochemical deposition.**

1. INTRODUCTION

The Shockley-Queisser limit can improve the conversion efficiency of cadmium-based thin-film solar cells while lowering the cost of traditional silicon solar cell technology. Cadmium telluride (CdTe), a member of the compound II-VI group, is increasingly popular in bulky photovoltaic technology because of its unique properties.[1] CdTe is a promising material because its bandgap is approximately 1.45 eV, which fits well with the solar spectrum. [2]. Other advantages of CdTe include its low cost, excellent stability, and simple deposition process. These qualities have enabled its application in thin-film solar cells, which are the advancements required to lower solar energy production costs.[3,4]

Various methods[5–8] in addition, Chemical Molecular Beam Deposition (CMBD) [9]Successive Ionic Layer Adsorption and Reaction (SILAR) [10,11], Chemical Bath Deposition (CBD) [12,13].and electrodeposition[14] Electrochemical deposition has emerged as a cost-effective and environmentally friendly method, making it ideal for the mass production of solar cells.[15]. Moreover, electrochemical deposition provides precise control over the film thickness and composition, which helps improve device performance.[16]. In this case (without a reference electrode), we employed a two-electrode electrochemical deposition method instead of a conventional three-electrode setup. Among other advantages, the two-electrode ED method can be used industrially in less time and with simpler systems. This increases efficiency and reduces metal ions from the reference electrode, lowering cost.[17,18]

Many studies have been conducted on cadmium telluride films using different types of cadmium, including cadmium chloride ($CdCl_2$) [19], cadmium nitrate $Cd(NO_3)_2$ [20], and cadmium sulfate ($CdSO_4$) [21,22]However, research on the use of cadmium acetate in cadmium telluride films is limited. Most investigations have focused on the effect of deposition agents on film properties.