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Thermally evaporated CdS/CdTe thin film solar cells: Optimization of $CdCl_2$ evaporation treatment on absorber layer

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ABSTRACT

$CdCl_2$ treatment is crucial in the fabrication of highly efficient CdS/CdTe thin-film solar cells. This study reports a comprehensive analysis of thermal evaporated CdS/CdTe thin-film solar cells when the CdTe absorber layer is $CdCl_2$ annealed at temperatures from 340 to 440 °C. Samples were characterized for structural, optical, morphological and electrical properties. The films annealed at 400 °C showed better crystallinity with a cubic zinc blende structure having large grains. Higher refractive index, optical conductivity, and absorption coefficient were recorded for the CdTe films annealed at 400 °C with $CdCl_2$. Optimum photoactive properties for CdS/CdTe thin-film solar cells were also obtained when samples were annealed at 400 °C for 20 min with $CdCl_2$, and the best device exhibited V_{OC} of 668.4 mV, J_{SC} of 13.6 mA cm^{-2}, *FF* of 53.9% and an efficiency of 4.9%.

1. Introduction

CdTe thin films are excellent light-absorbing material due to the optimal energy bandgap for PV applications and high absorption coefficient [1]. Different pre and post-deposition treatments on the CdTe absorber layer and CdS/CdTe interface play an essential role in achieving higher CdTe/CdS solar cell efficiencies and long term stability [2]. Among pre and post-deposition treatments, $CdCl_2$ treatment has been decisive in achieving the highest recorded solar to the electric conversion efficiency of 22.4% for CdS/CdTe laboratory-scale thin-film solar cells [3]. Conventionally, $CdCl_2$ treatment methods can be divided into; (a) solution treatments (b) evaporated treatments and (c) vapour treatments [4,5]. In the solution treatment methods, samples are dipped in a concentrated $CdCl_2$ solution followed by drying in an air or nitrogen environment before annealing. The $CdCl_2$ layer is deposited by evaporation of $CdCl_2$ powder using an evaporation technique in the evaporated and vapour treatment methods. However, the substrate is not heated in evaporated treatment method while it is heated during the $CdCl_2$ deposition in the vapour method [6]. When comparing $CdCl_2$ solution treatments, evaporated treatments, and vapour treatment methods, the evaporated technique is more efficient and produces uniform $CdCl_2$ layer depositions than the other methods [7].

Recombination of generated electron-hole pairs in a solar cell can be a significant cause for reducing the device performance. Since grain boundaries are considered potential recombination centres, reducing the grain boundaries is crucial for achieving higher efficiencies [8]. Increasing the grain size is one way of achieving this.

CdTe thin-film grain boundaries are known to depend on the deposition method and conditions as well as post-deposition treatments significantly [9]. It is believed that the grain sizes of primary as-deposited CdTe thin films can be improved by post-deposition $CdCl_2$ heat treatment [10]. Therefore, this study investigates the properties of post-deposition $CdCl_2$ heat-treated CdTe films and CdS/CdTe thin-film solar cells, which are entirely fabricated using the thermal evaporation technique. Characterizations were carried out using UV–visible spectrophotometry, grazing incident X-ray diffractography (GIXRD), scanning electron microscopy (SEM), and *I–V* measurements. According to the authors' best knowledge, very few studies have been carried out for CdS/CdTe solar cell fabrications and $CdCl_2$ treatments entirely using the thermal evaporation technique [11,12].

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