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Solar Energy Materials & Solar Cells 90 (2006) 3624–3632
Solar Energy Materials & Solar Cells
www.elsevier.com/locate/solmat

$CuInSe_2$ thin films deposited by UV laser ablation

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Received 13 August 2005; received in revised form 10 May 2006; accepted 13 June 2006
Available online 17 August 2006

Abstract

Application of pulsed laser ablation method for deposition of $CuInSe_2$ films was studied. The special time–temperature regime was developed. The homogeneous amorphous and polycrystalline $CuInSe_2$ films were prepared and investigated with XRD, SEM-EDS and optical spectroscopy.

Keywords: $CuInSe_2$; Solar materials; Pulsed laser deposition; CIS films

1. Introduction

$CuInSe_2$ is one of the most promising materials for creation of high-efficiency polycrystalline thin film solar cells. It is due to the very high absorption coefficient of $CuInSe_2$ ($\alpha \sim 10^5\,cm^{-1}$), although the rather low fundamental optical band gap of 1.04 eV [1] is too small for optimal conversion efficiency (but this parameter can be improved by modification of chemical composition). Several methods have been tested for preparation of $CuInSe_2$ films. Ordinary thermal deposition technique is not successful because of large difference of vapor pressure of selenium and other elements. In order to overcome this problem, additional selenization of the deposited film [2] or deposition of alternate layers of pure elements with subsequent thermal treatment [3] have been reported, which make the procedure of preparation of $CuInSe_2$ films quite complicated. Other techniques such as

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0927-0248/$ - see front matter
doi:10.1016/j.solmat.2006.06.057

electrodeposition [4], close-spaced vapor transport (CSVT) [5], RF-sputtering [6], magnetron sputtering [7] and pulsed laser deposition [8] have also been proposed. The last method has the advantage because in contrast with other mentioned methods at the pulsed UV laser ablation the part of sample irradiated by one laser pulse is fully evaporated so that the composition of vapor and film should be the same as the composition of source bulk sample.

This work is aimed at adaptation of UV laser ablation method for the deposition of $CuInSe_2$ thin films for subsequent solar cell application.

2. Experimental

Electrical properties of $CuInSe_2$-based polycrystals strongly depend on composition [9–11]. For investigations we selected the following compositions of target for film deposition: stoichiometric $CuInSe_2$ ($Cu_{25}In_{25}Se_{50}$); sample with surplus of Se ($Cu_{21}In_{21}Se_{58}$) for compensation possible loss of Se at film deposition and sample $Cu_{23}In_{25}Se_{52}$. The last composition was chosen in order to try to prepare film with composition inside the region of homogeneity of $CuInSe_2$ chalcopyrite structure and with n-type conductivity. $CuInSe_2$ has p-type conductivity, but some deficiency of Cu and Se results in transition to n-type conductivity [12].

Samples of composition $CuInSe_2$, $Cu_{21}In_{21}Se_{58}$ and $Cu_{23}In_{25}Se_{52}$ were synthesized from pure elements by melting in vacuum-sealed quartz ampoules at 1150 °C for 5 h with subsequent cooling at a rate of about 100 grad h^{-1}. Chemical and phase compositions of synthesized samples were controlled with EDS and X-ray diffraction.

The $CuInSe_2$ target was ablated with XeCl excimer laser operating at the wavelength 308 nm with 20 ns pulse length and pulse energy of 0.01–0.04 J $pulse^{-1}$. Specially cleaned microscope glass slides with 0.3 mm thickness were used as substrates. The substrate was rotated at frequency of 6000 rpm and could be heated up. Various geometry of the pulse laser deposition experimental setup was tested. Previous testing revealed that the most uniform film profile was achieved with the scheme of setup shown in Fig. 1a [13]. During the film deposition the target was periodically shifted in the 3 mm range to avoid a deep damage. We also tested the new configuration of target where target was designed as a crown with 12 platforms, which were orientated under different angles and on which plane-parallel samples were fixed (see Fig. 1b) [14]. This crown was rotated during

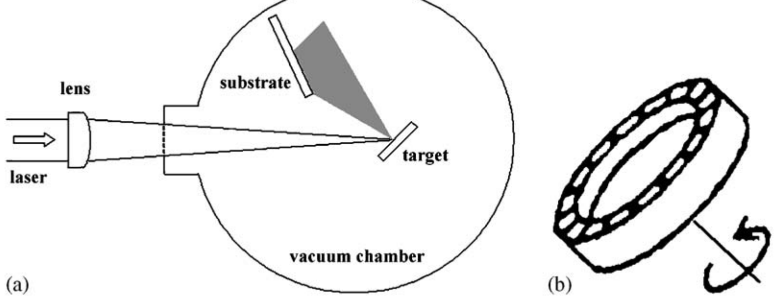

Fig. 1. Scheme of laser deposition experimental setup (a) and alternative construction of target for laser deposition (b).