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An effective method of Cu incorporation in CdTe solar cells for improved stability

S. Erra, C. Shivakumar, H. Zhao, K. Barri, D.L. Morel, C.S. Ferekides *

Clean Energy Research Center, Department of Electrical Engineering, University of South Florida, Tampa, FL 33620, USA

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Abstract

Thin film CdTe solar cells of the superstrate configuration have been fabricated in order to study the effect of Cu on device stability. The study focused on two distinct sets of solar cells: in one set of devices Cu was introduced during the formation of the back contact, by sputtering a small thickness of Cu onto the CdTe surface prior to the application of a graphite electrode; for the second set of devices Cu was introduced in CdS by briefly immersing the CdS films in a CuCl solution prior to the deposition of CdTe with the back contact electrode being sputtered Mo. The solar cells were light soaked under approximately AM1.5 conditions for nearly 700 h during 4 h ON/4 h OFF cycles. Device degradation correlated well with the amount of Cu for the devices with Cu in the back contact. Cells with larger amounts of Cu exhibited larger degradation, suggesting that the amount of Cu utilized during the back contact formation must be minimized. On the other hand, a number of devices fabricated without any Cu in the back contact, but with Cu in the CdS, exhibited nearly no degradation during the light soaking process suggesting that in addition to the amount of Cu used for the fabrication of CdTe cells, the method of incorporating this element is also critical in achieving long term device stability.

Keywords: CdTe; Solar cells; Stability

1. Introduction

Thin film CdTe-based solar cells continue to be one of the better alternatives for low cost PV technologies. Although performance can be further improved, with module efficiencies around 10.0% and small area efficiencies over 16.0%, another important device aspect that needs to be addressed is stability. In most cases the fabrication of CdTe solar cells incorporates Cu during the final stages of the process in order to achieve an effective back contact [1–3]. Due to the high diffusivity of Cu in CdTe, and the apparent instability of the Cu_2Te compound, this element is suspected to be responsible for changes in device performance and characteristics with exposure to light. It has also been shown that as a result of stressing, Cu seems to accumulate at the CdTe/CdS interface with no significant changes at the Cu levels in the CdTe thin film [4]. Other stress related changes include the conversion of Cu_2Te to CuTe believed to be responsible for the degradation of the back contact [5]. Additional information on the role of Cu on device stability can also be found elsewhere [6]. Since this particular element plays a key role in device performance and stability, it is important to demonstrate that it can be utilized to optimize/maximize both of these. The main objective of this work is to study the effect of Cu on device stability. Specifically, the effect of “back contact” Cu, i.e. Cu utilized to form the back contact, and “interfacial” Cu, i.e. Cu introduced onto the CdS surface. Devices with these characteristics were fabricated, and their performance was monitored over a light soaking period of approximately 700 h.

2. Experimental

Thin film CdTe solar cells have been fabricated using various deposition methods. The substrate for all devices discussed in this work, consisted of a bi-layer SnO_2 deposited on borosilicate glass (glass/SnO_2:F/SnO_2) by chemical vapor deposition (CVD). The devices with “back contact” Cu were fabricated

* Corresponding author. University of South Florida, Department of Electrical Engineering, ENB 118 4202 East Fowler Ave Tampa, FL 33620, USA. Tel.: +1 813 974 4818; fax: +1 813 974 5250.
E-mail address: ferekide@eng.usf.edu (C.S. Ferekides).

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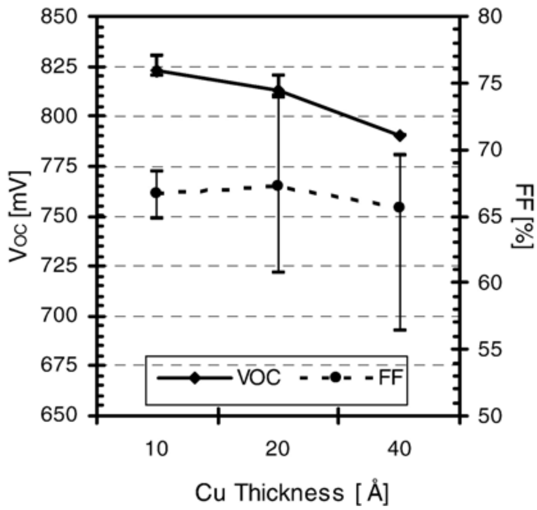

Fig. 1. The initial performance of CdTe cells with “back contact” Cu.

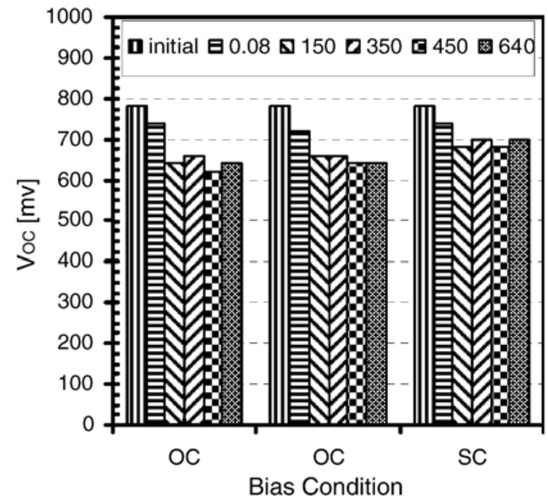

Fig. 2. The V_{OC} for cells contacted with 10 Å Cu over 650 h of light soaking.

by the successive depositions of CdS by chemical bath deposition (CBD) and CdTe by close-spaced sublimation (CSS). Following the heat treatment of the structures in $CdCl_2$, the CdTe surface was etched in a bromine/methanol solution (0.01% vol.). A thin film of Cu was then deposited to a thickness in the range of 10–40 Å. Following the application of graphite paste the devices were heat-treated in inert ambient at a temperature of 240 °C. The devices with “interfacial” Cu were fabricated using the CSS process for both semiconductors. However, prior to the deposition of CdTe, the structures (glass/SnO_2:F/SnO_2/CdS-CSS) were immersed in warm (80 °C) CuCl solution to introduce Cu at the surface of CdS. More details on the optimization of this process and its effect on device performance can be found elsewhere [7]. The other key difference in fabrication between the two sets of devices is in the back contact formation, where instead of graphite paste, sputtered Mo (0.8–1.3 μm) was used as the back electrode (for the “interfacial” Cu cells). All devices were light soaked in a vacuum oven which was evacuated and backfilled with inert gas. The cells were placed on a water-cooled plate to keep their temperature from exceeding 65–70 °C. Light soaking was carried out during 4 h ON/4 h OFF cycles; the light intensity was near AM1.5. Silver epoxy was used to attach wires to the cells and connect them to a source/measurement unit via a bank of computer-controlled relays, in order to measure their current–voltage (*J–V*) characteristics. The devices with “back contact” Cu were light soaked at open-circuit (OC) and short-circuit (SC) conditions, while the devices with interfacial Cu were light soaked only at OC.

3. Results and discussion

3.1. “Back contact” Cu devices

The initial performance for the cells with “back contact” Cu is shown in Fig. 1. As the data indicates optimum performance is achieved for a 10 Å Cu thickness; smaller thicknesses did not lead to further performance improvements, and were in general avoided due to the greater uncertainty in controlling the Cu thickness at such small amounts. The FF losses and in particular the significant scatter observed (for the two larger thicknesses in Fig. 1) are due to collection losses (no significant light shunting). Each thickness point in Fig. 1 represents data from four cells, two of which were light soaked at OC and two at SC; the *J–V* characteristics for these devices were monitored during a 650-hour light soaking process, with the devices operating at 65–70 °C.

The light soaking results can be summarized as follows: In general cell performance decreased in all cases; however, there were distinct differences among the three sets of devices (with different Cu thickness) as well as between the two bias conditions. The V_{OC} of the devices with the smallest amount of Cu decreased slightly more for the devices held at OC (vs. SC) but the difference was small, and due to the size of the data set it should be considered statistically insignificant. As the thickness of Cu increased two distinct features were evident in the behavior of V_{OC}: (a) there was an initial and significant loss in

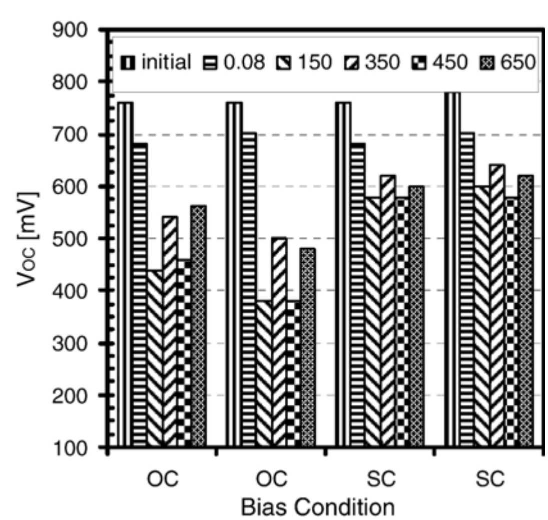

Fig. 3. The V_{OC} for cells contacted with 40 Å Cu over 650 h of light soaking.