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Back Contact Materials for Superstrate $CuInS_2$ Solar Cells

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Abstract

$CuInS_2$ (CIS) solar cells were fabricated by spray pyrolysis method with different back contact electrodes of Al, Cu, Mo, Au, and C (carbon). The best conversion efficiencies of $CuInS_2$ cells using Al, Cu, Mo, Au, and C back contacts were 1.96%, 2.17%, 2.08%, 1.87%, and 2.35%, respectively. The conversion efficiency of the cells using Al and Cu back contacts significantly deteriorated after one month keeping devices in air ambience. The device performance of the CIS cells using Au, Mo and Carbon is quite stable after one month. The effect of back contact on each photovoltaic parameter has been confirmed by impedance measurements. Carbon films were crack- free and showed adequate adhesion with the $CuInS_2$ absorber layer. The annealing temperature for carbon films is in the range of 125-240 °C. The cell parameters of the CIS cells using carbon back contact are Jsc = 10.36 mA/cm^2, V_{oc} = 0.50 V, fill factor = 0.44 and conversion efficiency = 2.35 %. The resulting CIS solar cells, fabricated by spray-pyrolysis depositions for CIS layers and screen printings for carbon layers, are recognized as full non-vacuum fabricated solar cells.

Keywords: $CuInS_2$ solar cells; screen print; carbon paste; back contact; spray pyrolisys

1. Introduction

In present, molybdenum (Mo) have been well-known as the best back contact electrode for applications in $CuInS_2$ (CIS), $CuInSe_2$ and $Cu(In,Ga)Se_2$ substrate-structured solar cells because Mo satisfies a requirement for back contact electrode as inertness under highly corrosive ambience during the absorber layer deposition [1-5]. On the other hand, Goosense and Hofhuis have investigated superstrate-

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structured CIS solar cells [6]. On the top of the CIS layers, Au back contacts have been deposited for finishing the devises. This process does not deteriorate the back-contact electrode by corrosion and can select another material. Hence, the investigation of back contacts, excepting Mo, for applications in solar cells is necessary. Moreover, although the investigation by Goosens and Hofhuis was about spray-deposited CIS layer, the Au back contacts have been deposited by vacuum deposition [6]. The Mo back contact electrodes also have been deposited by vacuum methods such as sputtering or electron beam evaporation [5, 7]. However, the vacuum methods are slow process speed because it needs a long time for pumping high vacuum. Hence, if back contact materials can be fabricated by non-vacuum method, it will be very advantageous for fabricating solar cells.

In this paper, we concentrate on the investigation of CIS solar cells deposited by spray pyrolysis using various back contacts of Al, Cu, Mo, Au, and C (carbon). Among these back contacts, Mo, Au and C showed better conversion efficiencies and durability. Especially, the achievement of significant cell performance with carbon back contact is very interesting in the application of full non-vacuum fabricated solar cells. Hence, fabrication process of carbon paste, microstructure, and electrical properties of carbon back contact were thoroughly investigated.

Experimental

Carbon powder (Printex L6, Evonik Company) was used for making paste. The liquids such as water and ethanol were injected drop by drop into an alumina mortar. Most process was carried out at room temperature in air ambient. In this experimental, 0.5 g TiO_2 was added to improve the adhesion of the carbon paste after screen-printing on CIS films. The process of fabricating carbon paste is mostly similar to that of the reported TiO_2 paste [8]. The structure of superstrate solar cells is back contact electrode/CIS/In_2S_3/TiO_2/FTO/glass. The fabrication processes of spray-deposited CIS solar cells were described in our previous manuscript [9].

Cu, Al, Mo back contacts were deposited by rf-magnetron sputtering at room temperature with a pressure of 0.5 Pa in argon ambience. These back contacts are the same thickness, around 500 nm. In the case of Au, 15 nm-Au back contacts were deposited by evaporation method in vacuum ambience with pressure of 2×10^{-5}torr. Carbon back contacts were coated on CIS absorber layer by screen-printing method, and kept in a clean box for 3 min with ethanol for reducing the surface irregularity, and then died at 125 °C for 6 min. The thickness of carbon for one time screen printing is around 5-10 μm. For the carbon back contact being thicker than 10 μm, this process is repeated to obtain the desired thickness. The area of all cells with different back contacts is 25 mm^2 (= 5 mm × 5 mm).

The surface morphology and cross-section of carbon back contact were viewed by scanning electron microscopy (SEM; JSM-6510, JEOL, Japan). Sheet resistance was measured by four-probe system (Moresta-EP MCP-J360, Mistubishi chemical). The impedance spectra were analyzed by an electrochemical analyzer (SP-150, Bio-logic SAS). Photovoltaic measurements employed an AM 1.5 solar simulator equipped with a xenon lamp (Yamashita Denso, Japan). The power of the simulated light was calibrated to 100 mW/cm^2 by a reference Si photodiode (Bunkou Keiki, Japan). I–V curves were obtained by applying an external bias to the cell and measuring the generated photocurrent with an APCMT Japan 6240 DC voltage current source.

Results and discussion

In order to compare the effect of alternative back contact materials on photovoltaic properties of CIS solar cells, the superstrate CIS solar cells with different back contact materials such as Au, Al, Cu, Mo, and C (carbon) were prepared. Figure 1 shows the photocurrent density-voltage curves of solar cells using different back contact materials. From the results, CIS solar cells with carbon back contact showed the best photovoltaic properties, namely, higher photocurrent density (J_{sc}) in comparison with another.