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Development of spin-coated copper iodide on silicon for use in hole-selective contacts

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Abstract

We studied on surface morphology, optical properties and passivation performance of copper iodide (CuI) on crystalline silicon (c-Si) deposited by spin-coating for application to hole-selective contacts to realize high performance and low-cost c-Si solar cells. Absorbance was increased by depositing CuI on c-Si owing to absorption and antireflection effect of CuI. From surface images by scanning electron microscope measurements, discontinuous layer was observed for CuI deposited Si. Effective lifetime was characterized for c-Si with ultra-thin oxide covered by CuI both sides by using a microwave photoconductive decay. The lifetime increased from 2 μs to order of 10 μs by introducing CuI layer possibly due to large conduction band offset.

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Keywords: carrier-selective contacts; copper iodide; spin-coating

1. Introduction

Passivated carrier-selective contacts have been intensively studied for high performance silicon solar cells. Passivation of surface and carrier selection are essential to achieve high efficiency of crystalline Si (c-Si) solar cells [1,2]. Heterojunction c-Si solar cells using hydrogenated amorphous silicon (a-Si:H) showed extremely high efficiency exceeding 25% owing to intrinsic a-Si:H as a passivation layer and doped a-Si:H as a carrier-selective layer [3,4]. Recently, the tunnel oxide passivated contact solar cells shows high efficiency of 24.9%, which employs

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ultra-thin oxide and partially crystallized Si for passivation layer and carrier-selective contact, respectively [5]. The ultra-thin silicon oxide layer less than about 2 nm function as passivation layer and carrier extraction by utilizing the tunneling effect. Thus, full-area contact with low recombination current is realized [6]. Meanwhile, transition metallic oxides such as MoO_x [7-10], WO_x [9,10], V_2O_x [10], NiO_x [11,12] are utilized as hole-selective contacts owing to their high work functions larger than about 5 eV [13], which widens material candidates as carrier-selective contacts.

Copper iodide (CuI) is p-type semiconductor with large bandgap energy of 3.1 eV [14,15]. In addition, the band alignment of CuI/c-Si is almost ideal for hole-selection since CuI possesses the ionization energy and electron affinity of 5.2 and 2.1 eV, respectively, which results in small valence band offset of about 0.1 eV and large conduction band offset of ~2 eV [16]. Furthermore, band-bending would be induced at the interface of CuI/c-Si (n-type) heterojunction, which enhances hole-selectivity. Therefore, holes can move from Si to CuI efficiently, while electrons are not able to pass CuI and repelled to c-Si. This suggests that CuI is a promising candidate as hole-selective contacts. Moreover, it is possible to deposit CuI by liquid phase method such as doctor blading method [17], leading to lowering cost of solar cells fabrication. In this paper, we report on structural and optical properties of CuI on c-Si with ultra-thin oxides at the interface and its passivation performance.

2. Experiments

Double sides mirror-polished, floating zone grown c-Si(100) substrates with resistivity of about 2 Ω･cm were used for all samples. A 0.1 mol/L CuI solution was prepared by dissolving CuI into 1:39 di-n-propyl sulfide to chlorobenzene, respectively. After cleaning the Si substrates, silicon oxide was removed by immersing into diluted HF. Then, some of them were dipped into ozonized, deionized water (DI-O_3) to form ultra-thin SiO_2 of about 1.2 nm. The layer thickness of SiO_2 was measured by an ellipsometer. CuI was deposited on the Si substrates by spin-coating at room temperature. The dropped solution amount and rotational speed were change from 20 to 80 μL and 1000 to 4000 rotational per minutes (rpm), respectively. Subsequently, the samples were heated on hot plate at 80 ºC for drying. For lifetime characterization, CuI was deposited on c-Si both front and rear sides. Schematic structures of fabricated samples are illustrated in Fig. 1.

Surface morphology and optical properties of CuI on c-Si were characterized by a scanning electron microscope (SEM) and a spectrophotometer, respectively. The effective lifetime of c-Si deposited CuI on the both sides is characterized by microwave photoconductivity decay (μ-PCD) method. The wavelength of pulsed light and frequency of microwave were 904 nm and 10 GHz, respectively.

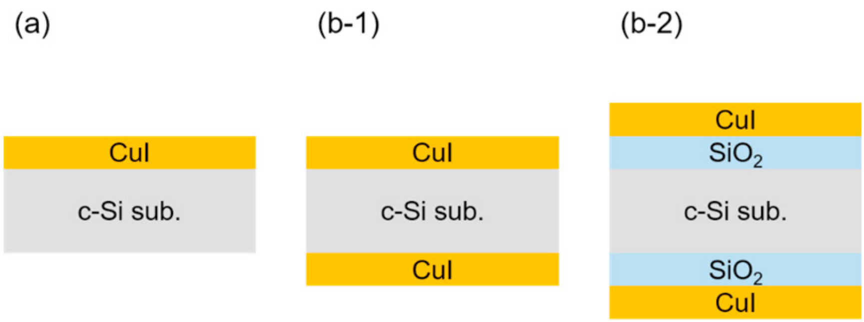

Fig. 1. Schematic illustration of (a) CuI/c-Si for surface and optical measurements, (b-1) CuI/c-Si/CuI and (b-2) CuI/SiO_2/c-Si/SiO_2/CuI for carrier lifetime measurements.