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Long-term stable encapsulated solder joints on an Al/Ni:V/Ag metallization for silicon solar cells

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Abstract

Evaporated Al as metallization for silicon solar cells may be profitable as it requires less Al material than the common screen-printed Al/Ag-paste combinations and forms contacts with a lower contact resistivity. To achieve solderability a sputter deposited Ni:V and an Ag layer are deposited onto the evaporated Al layer. Tin-coated Cu-connectors with a lead-free and a lead-containing solder are employed in combination with two halogen-free no-clean fluxes with varying solid contents. The long-term solderability of the metallization stack is demonstrated by comparing 180° peel forces (DIN EN 50461) of Cu-connectors soldered onto the metallization stack directly after preparation, after accelerated storing following IPC J-STD-003B and after storing for half a year at room temperature. The long-term stability of the solder joints is verified by measuring the normalized contact resistivity and by a visual inspection of encapsulated samples during a damp heat test (DIN EN 61215). For encapsulation an EVA foil and a silicone elastomer are used as encapsulation materials. As the lead-containing solder does not adhere sufficiently after accelerated aging, the flux with high contend of solids may accelerate corrosion and the EVA laminates exhibit adhesion problems between the samples and the lamination foil. The lead-free solder and the flux with the lower solid content in a silicone elastomer based laminate emerge to be the most promising candidates for a long term stable interconnection of Al/Ni:V/Ag metallized solar cells.

Keywords: crystalline silicon; solar cell; metallization; long-term stable; solder joint; laminate; evaporation; sputtering;

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1. Introduction

Aluminum is a well known metallization for silicon solar cells. For standard screen printed solar cells

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it is introduced as porous Al paste and combined with solder pads consisting of a solderable Ag paste [1]. Related to the Al weight, evaporated Al requires only about 10% of the amount of screen printed Al paste and may thus be more profitable [2-4]. To obtain a solderable surface a sputtered Ni:V layer and a subsequently sputtered Ag layer are deposited on the evaporated Al layer [5]. This metallization stack is adapted from microelectronics, known there as under bump metallization (UBM) [6-8]. Fig. 1 shows a SEM cross section of an Al/Ni:V/Ag metallization stack on a Si wafer.

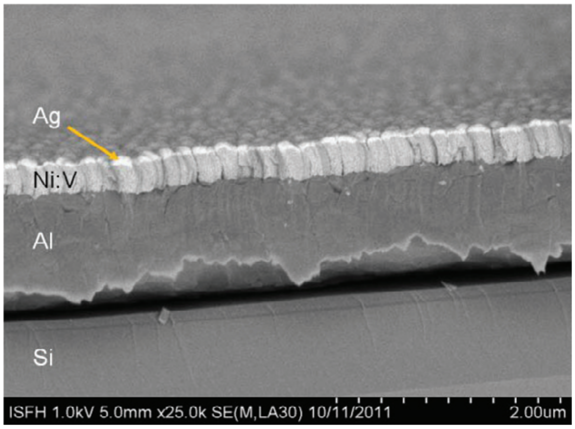

Fig. 1. Metallization stack on silicon wafer: 1 µm evaporated Al (dark grey with breaking edge in the bottom of the layer), 250 nm sputtered Ni:V (light grey) and 25 nm sputtered Ag (white)

For the preparation of a PV module the solar cells need to be interconnected and encapsulated in a laminate. In a standard PV module ethylen vinyl acetate (EVA) and a Tedlar based foil are the common encapsulation foil and back sheet [9]. For the interconnection of the solar cells a solder and a flux need to be selected. As the three metal layers Al, Ni:V and Ag are vacuum deposited on top of each other, the resulting surface is much more flat and less oxidized compared to the surface of a screen printed and fired Al and Ag paste. Consequently all materials and processes belonging to the module preparation need to be tested in combination with the vacuum deposited metallization. The aim of this work is to demonstrate the long-term solderability of a vacuum deposited Al/Ni:V/Ag metallization. Secondly, the best working combination of a solder, a flux and an encapsulation material for the preparation of PV modules based on this metallization is determined and the long-term stability of encapsulated solder joints is verified.

2. Experimental

After cleaning, the test wafers (125 × 125 mm² Cz-grown Si) are metallized in an in-line high-rate metallization system (ATON from Applied Materials) [3]. The metallization stack consisting of 2 µm evaporated Al and 200 nm sputtered Ni:V as well as 25 nm sputtered Ag is deposited. All deposition steps are carried out without vacuum break.

2.1. Setup of storage test

The storage test was realized with 12 samples, split up in three groups with four different solder/flux combinations in each group. The first group, shown in Fig. 2 as “3.a Direct processing” was soldered directly after metallization, simulating an integrated industrial production process of wafers and modules.