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Low-temperature interconnection of PVD-Aluminium metallization

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Abstract

Aluminium, thermally evaporated with physical vapor deposition (PVD), is considered a cost efficient rear metallization for crystalline silicon heterojunction or tunnel oxide passivated solar cells. Owing to the temperature-sensitivity of the solar cell structure, potential routes of low temperature interconnection methods for PV module integration are assessed. Textured wafers with a full area 2 μm PVD-Al metallization are divided into two groups: The first is capped with sputtered 100 nm Ti and 400 nm Ag for testing solderability. The second is capped with 400 nm Ag for electrically conductive adhesive (ECA) interconnection. Low temperature soldering with Sn43Bi57 and Sn41Bi57Ag2 coated ribbons and ribbon interconnection with two ECAs are evaluated in terms of peel strength, contact resistivity and accelerated aging properties. It is found that peel strength of soldered interconnections on the Al/Ti/Ag achieve between 1.5 $N\,mm^{-1}$ to 2 $N\,mm^{-1}$ whereas glued interconnections on Al/Ag between 0.5 $N\,mm^{-1}$ to 1 $N\,mm^{-1}$. The contact resistivity is $2.6 \times 10^{-3}\,m\Omega\,cm^2$ to $3.6 \times 10^{-3}\,m\Omega\,cm^2$ for both interconnection technologies. Soldered samples show a stable contact resistivity when tested in 1000 h in damp heat conditions or 200 thermal cycles. The contact resistivity of glued interconnections increases to 1 $m\Omega\,cm^2$ to 10 $m\Omega\,cm^2$ along with an observed disintegration of the Al-layer and an ablation of the Ag-capping from the Al-layer.

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1. Motivation and goals

A mono-facial, wafer-based 6” solar cell technology comprising an amorphous silicon/crystalline silicon heterojunction [1] and/or tunnel oxide passivation [2] and a full area, thermally evaporated aluminium metallization deposited on the rear side [3] with an efficiency potential of more than 25 % is presently under development. For PV module integration this cell concept demands an interconnection technology with process temperatures below 200 °C that

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achieves highly conductive and mechanically strong bonds. Furthermore, they have to be reliable and long-term stable during outdoor exposure of the PV module and accelerated aging tests.

It is, however, very challenging to achieve proper electrical interconnections on Al due to the presence of an insulating native oxide layer that prevents common solders or ECAs from wetting and interacting with the Al base material. Thus, several approaches have previously been developed to tackle this problem [4, 5, 6, 7]. One of the possible solutions is the formation of a solderable stack, consisting of 100 nm TiN, 20 nm Ti and 150 nm Ag on top of the 2 μm Al metallization [8]. The use of TiN is to prevent Al diffusion through the stack during thermal annealing for 1 min to 10 min at 300 °C to 350 °C, which would else deteriorate solderability on the stack. Thermal annealing is necessary to achieve sufficiently low contact resistivity of Al to Si [9]. The Ti-layer promotes adhesion of Ag to TiN. Solderability and electrical stability during accelerated aging tests have been demonstrated using standard ribbon soldering technology with Sn62Pb36Ag2 solder coatings [8].

The goals of our work are to demonstrate the capability to interconnect this type of metallization with alternative, low-temperature interconnection methods. We chose to evaluate ribbon soldering with Sn43Bi57, Sn41Bi57Ag2, as well as ECA ribbon interconnection. Since the above mentioned solar cell concept requires process temperatures below 200 °C, the TiN diffusion barrier is omitted. Thus, the viability of a further simplification of the metallization stack is to be investigated.

Nomenclature

d_{n_n+1}	Distance between adjacent terminals of contact resistance samples
I_{n_n+1}	Current through terminals n and $n+1$
l	Contact length
m	Slope of the linear fit of front resistances over the distances between the terminals
n	Terminal n of the contact resistance sample
$R_{e,\,n\_n+1}$	End resistance between terminals n and $n+1$
R_e	Mean end resistance of all individual end resistance values
$R_{f,\,n\_n+1}$	Front resistance between terminals n and $n+1$
R_{sh}	Sheet resistance of the metallization
ρ_c	Specific contact resistance (contact resistivity)
V_{n_n+1}	Voltage between terminals n and $n+1$
V_{n+1_n+2}	Voltage between terminals $n+1$ and $n+2$
w	Contact width

2. Experimental

2.1. Approach

Textured and metallized wafers are subject to a sequence of interconnection tests.

1. 90° peel tests to evaluate the mechanical strength of the interconnection
2. Contact resistivity measurements to evaluate the electrical properties of the contact using the contact end resistance method [10]
3. Accelerated aging tests (damp heat 1000 and thermal cycling 200) to assess the long-term stability of the interconnection in laminates

Two different technological routes are investigated: Ribbon soldering with Sn43Bi57 and Sn41Bi57Ag2 solder alloy coatings and conductive glueing with two kinds of ECA. The results of the test sequence are used to compare the two interconnection approaches with regard to their feasibility to interconnect PVD-Al.