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ScienceDirect

Energy Procedia 92 (2016) 236 – 241

Energy Procedia

6th International Conference on Silicon Photovoltaics, SiliconPV 2016

Influence of silver-aluminium alloy at solar cell rear side on series resistance and open circuit voltage

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Abstract

The rear side metallization of industrial PERC solar cells was investigated regarding the implication on the silver-aluminium-alloy formation, in particular the effect of the high resistivity alloy formation and the etching of surface passivation layer. By changing the dimensions of the printed silver-pads the size of the silver-aluminium-overlap region at the pad-aluminium interface were varied. The influence on fill factor and open circuit voltage are evaluated. For a three busbar cell design with six pads per busbar, the fill factor decreases up to 2.2 %abs, if the overlap length between aluminium and silver pad is reduced from 12.5 mm to 1 mm, whereas the open circuit voltage increases by 2.5 mV. These results are additionally confirmed by a 3D simulation which validates the measurement results and shows perspectives for reducing the series resistance effect of the silver-aluminium overlap region up to 40% by increasing the busbar count from 3 to 5.

Peer review by the scientific conference committee of SiliconPV 2016 under responsibility of PSE AG.

Keywords: AgAl alloy; overlap resistance; AgAl spiking; COMSOL simulation, PERC

1. Introduction

In solar cell manufacturing a change from BSF type solar cells to PERC like structures is visible. This change of cell concept has a significant impact on the rear side metallization. One point is the formation of a silver-aluminum (AgAl) alloy at the interface between rear side metallization and soldering pad. In contrast to BSF cells, all the current flows via the rear side metallization to the pad and soldering interconnection [1]. The resistivity of the silver-aluminum-alloy is up to 20 times higher than the resistivity of pure aluminum [2] and therefore relevant in regards to the series resistance (r_s) of the solar cell. Additionally, the formation of silver-aluminum spikes is well known [3] and therefore this interface was investigated concerning the influence on open circuit voltage (V_{oc}) due to passivation layer damaging.

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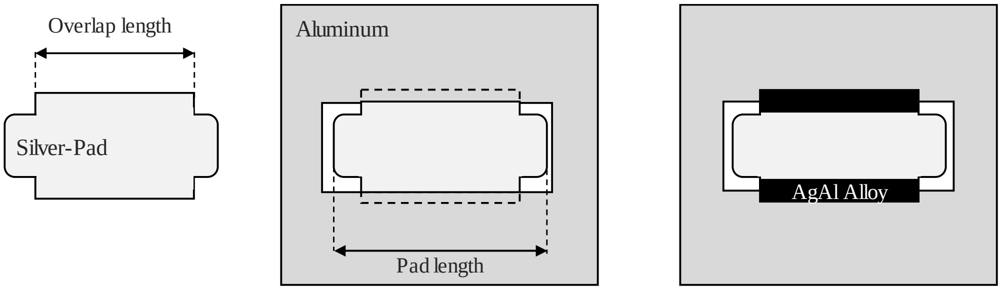
doi:10.1016/j.egypro.2016.07.065

2. Methods

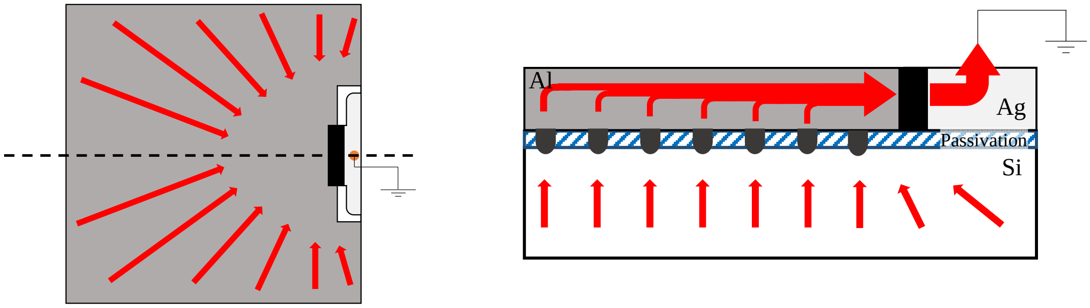
The experimental setup contains 5 different batches were as only the rear side metallization was changed. Therefore 3 busbar cz-Si-PERC solar cells with overall 18 soldering pads were used. The PERC process includes the local contact opening via laser ablation and screen printing of silver (Ag) and aluminum (Al) metallization. The rear side layout of these Ag pads was changed in 4 steps from 1 mm overlap length (*OL*) to 12.5 mm, therefore the only contact between Ag and Al metallization was changed in respect to the cross section of the AgAl alloy, see Fig. 1. The pads themselves (pad length) stays constant. As reference a 5th batch with full Al rear side metallization was used. After printing the rear side metallization the wafers were randomized to reduce the influence of the front side screen printing and were fired in an inline fast firing belt furnace which leads to the formation of the AgAl alloy at the overlap between Ag and Al, see Fig. 1.



(a) (b) (c)

Fig. 1. a) Screen printed Ag metallization pad (1st print), b) after 2nd print of aluminum metallization the overlap of both metal layers at the long side of the pad and c) after sintering in the fast firing furnace the AgAl alloy gets visible.

The IV measurement was performed with 2 different, calibrated systems. The first one was a Berger inline flasher with spring loaded contact pins at front and rear side of the solar cell. The number of pins contacting the soldering spots were 12 and 6 per busbar at front and rear side respectively. This setups enables a measurement which is very equal to the effective wiring within the module where only soldering leads to a reliable electrical contact [1]. The second setup was a sun simulator with spring loaded contacts at the front (equal to the inline flasher) and a conductive chuck for a homogenous, full area contact at the rear side.



(a) (b)

Fig. 2. a) Plan view of symmetry element with schematic current flow to the ground contact at the silver pad and b) cross section of symmetry element with homogenous current generation within the silicon.

Additionally the sheet resistance of Ag ($R_{sh\text{-}Ag}$) and Al ($R_{sh\text{-}Al}$) were determined with classical four-point probe measurement [4] and the AgAl resistance with special IV setup. Therefore an IV prober was used to execute a