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Fire-through contacts—a new approach to contact the rear side of passivated silicon solar cells

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ABSTRACT

In this work, we present a novel fire-through contact (FTC) approach for the formation of local rear contacts for rear surface passivated silicon solar cells. The FTC approach aims at an easy integration of rear surface passivation into typical production lines. Besides rear surface passivation, no new technology is required as FTC only relies on common printing equipment. In this work, different FTC contact geometries and printing approaches are investigated using lifetime and resistance measurements. A PC1D model is implemented to allow for a comparison of different FTC configurations on cell level. Finally, the integration of the FTC approach into metal wrap through solar cells is presented.

1. Introduction

Along with the strongly increasing interest in solar cells with passivated rear surface, industrially feasible rear contacting methods gain importance. Usually, the fabrication of PERC-type cells (passivated emitter and rear cell, [1]) requires laser processing or other structuring process steps for the creation of local rear contacts. Currently, laser processing is the most dominant approach for industrial application, either applied before metallisation [2–4] (i-PERC) or after contact firing [5,6] (laser fired contacts, LFC).

In this paper we present an easily scalable technology for contacting the rear side of PERC-type cells using solely printing technology. Analogous to the contact formation on the front side [7], local penetration of the dielectric layer during contact firing is the key aspect of this approach. For this purpose, a fire-through paste is printed locally on the top of the rear dielectric layer with a defined geometry. In a second step, a non-fire-through aluminium paste is printed on top, thus interconnecting the previously applied fire-through areas. Subsequently a high temperature process realises the contact formation.

With this novel FTC approach, one additional screen printing step substitutes local laser contact formation. This is beneficial for retrofitting of existing industrial Al-BSF-based production lines, as the printing based FTC method depends on a smaller number of technologies and does not require laser expertise. Compared to previous fire-through approaches [8], an additional benefit of the FTC technology is the decoupling of contact formation and lateral conductivity, thus providing the possibility to manipulate the paste for local BSF formation or the contact geometry without affecting the properties of the overlying Al layer. Furthermore, the rear contact is established during the common contact firing process, thus – in contrast to previous approaches [9] – no high temperature process is necessary after application of the fire-through paste.

2. Experimental

2.1. Approach

The FTC approach is applicable to solar cell structures that comprise a rear surface passivation and a large-area p-type rear contact. For the deposition of the FTC structure as well as the overlying large-area metallisation, various technologies may be utilised. This work focuses on stencil and screen printing of the fire-through paste and screen printed large-area Al layers. Fig. 1 shows the intended process sequence for the FTC approach integrated into a typical PERC process sequence.

The following sections present a detailed investigation of fire-through structures regarding contact resistance and recombination using special test structures.

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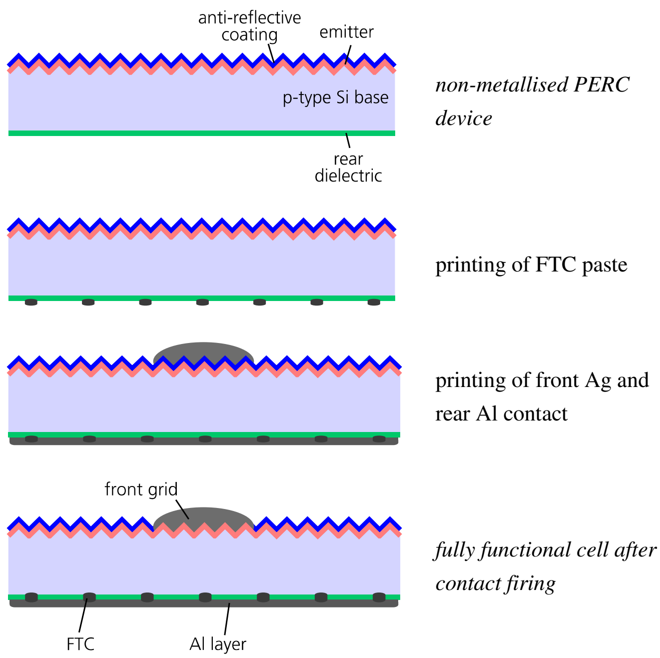

Fig. 1. Process sequence for the fabrication of PERC devices with fire-through contacts (FTC).

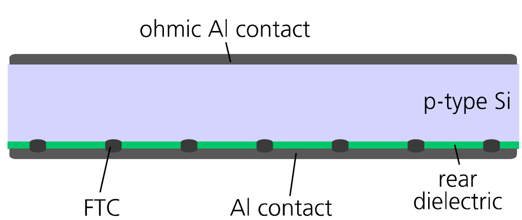

Fig. 2. Resistance test structure for FTC resistance measurements.

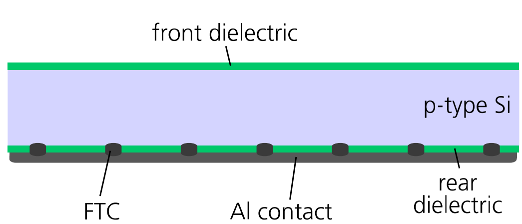

Fig. 3. Carrier lifetime test structure used for evaluation of the recombination rate at the fire-through contacts.

2.2. Sample preparation

To investigate the relevant properties of the fire-through contacts – contact resistance and the influence of the fire-through process on the passivation quality – both resistance and carrier lifetime test structures (see Figs. 2 and 3) are fabricated from monocrystalline p-type silicon wafers with a thickness of 200 μm and an edge length of 125 mm. The resistance samples are made of float-zone silicon (FZ-Si) with a base resistivity of $\rho = 1\,\Omega\,\text{cm}$ passivated by a stack of 100 nm thermally grown SiO_2 and 100 nm PECVD SiN_x on the rear side. The lifetime samples are made of Czochralski-grown silicon (Cz–Si) with a base resistivity of $\rho \approx 6\,\Omega\,\text{cm}$ and the same SiO_2/SiN_x passivation layer stack on both sides.

A fire-through Al paste is printed on the rear side of the samples with the test layout depicted in Fig. 4 using both stencil and screen printing. The design of this test structure with nine separated areas enables an investigation of various contact geometries on a single wafer. Afterwards, a full area non-fire-through aluminium layer is printed on top. After contact firing in an industrial belt furnace, the resistance samples are equipped with an ohmic full-area PVD-Al contact on the front side whereas the lifetime samples are treated with HCl/H_2O_2 in order to fully remove the rear Al structure and thus enable a QSSPC [10] measurement.

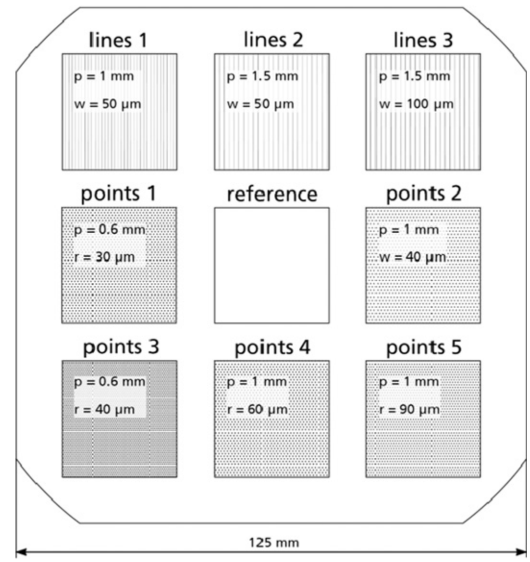

Fig. 4. Test structure with different contact geometries (*p*: pitch, *w*: width and *r*: radius).

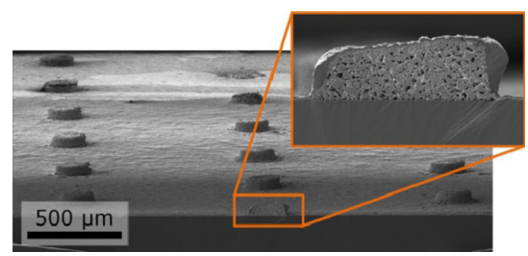

Fig. 5. SEM micrograph of a stencil printed FTC Al dot after firing (structure "points 4"). The dots are covered by evaporated Al.

3. Results and discussion

3.1. Printing of fire-through structures

The desired fire-through areas only cover a small area fraction of the solar cell's rear side, thus especially stencil printing is a highly suitable technology for fast creation of well-defined FTC structures. The test layout depicted in Fig. 4 is printed with a nickel stencil as well as a reference screen printing process. The individual contact geometries evaluated with the test structure represent different pre-optimised point- and line-shaped structures with feature sizes in the range of typical LFC and i-PERC contacts. Fig. 5 displays an SEM cross section micrograph of dots printed with a stencil showing a high aspect ratio and sharp edges.

Printablility tests for the evaluation of a suitable fire-through paste were carried out. Fig. 6 shows the average height profile of FTC line structures measured using confocal microscopy for four different pastes. Paste 1 is a special fire-through aluminium paste and shows the highest aspect ratio and the narrowest line width and is therefore selected as the most suitable FTC paste. This paste