Presented at the 28th European Photovoltaic Solar Energy Conference and Exhibition; Paris, 30 Sept – 04 Oct. 2013

LASER-BASED FOIL METALLIZATION FOR INDUSTRIAL PERC SOLAR CELLS

J. Nekarda[1A], M. Graf[1], A. Rodofili[1], R. Preu[1], R. Böhme[2], D. Sontag[3]
[1]Fraunhofer Institute for Solar Energy Systems, Heidenhofstrasse 2, 79110 Freiburg im Breisgau, Germany
[2]Innolas Systems GmbH, Robert-Stirling-Ring 2, 82152 Krailling, Germany
[3]Roth & Rau AG, An der Baumschule 6-8, 09337 Hohenstein-Ernstthal, Germany

APhone: +49 761 4588 5563, e-mail: jan.nekarda@ise.fraunhofer.de

ABSTRACT: In this contribution we present different results of our investigations regarding the use of aluminium foil as rear side metallization for solar cells with dielectric passivation and laser fired contacts (LFC). We benchmark this metallization technology against more state of the art approaches like local contact opening (LCO) or laser fired contact– both in combination with screen printed and fired aluminum paste. Therefore we compare the IV-data from solar cells, processed on industrial pilot line equipment. Thereby we report an efficiency of 20.5 % on industrially sized wafers (A=238 cm^2) outperforming the state of the art technologies.

Keywords: Laser Processing, Manufacturing and Processing, Metallization, Contacting

1 INTRODUCTION

To make solar energy competitive in the long run, the price per watt-peak has to decline. Therefore, new cell concepts, with higher efficiency and cost saving potential have to be introduced into the market. Laser firing of local contacts (LFC) [1] is a promising technique which allows the use of dielectrically passivated rear sides as introduced by Blakers et al. with the passivated emitter and rear cell (PERC) already more than 20 years ago [2]. In this approach, the aluminum is contacted with the silicon through the dielectric passivation by means of single laser pulses. The company Hanwha Qcells runs this technology in mass production since the beginning of 2012. From field test of their modules they recently demonstrated a specific energy yield gain of 1.7% relative compared to state of the art aluminum back surface field solar cell modules due to improved low light performance [3]. As the metallization is the main cost driver in cell production, the LFC approach features high saving potential since it enables the use of aluminum foil as rear side metallization [4]. The foil is fused to the wafer during the contacting process and thereby replaces conventional metallization processes, such as screen printing or physical vapor deposition (PVD). Besides the cost saving potential, it yields other advantages like minimum thermal and mechanical impact, the possibility to use new interconnection approaches and beneficial optical properties [5].

In this paper we present first results on large area Czochalski grown silicon wafer, which were processed on pilot line equipment. In the same batch we benchmarked this approach against the state of the art technologies LFC and Local Contact Opening (LCO).

2 EXPERIMENTAL DETAILS

To compare all three technologies, we used precursor-wafer from the pilot line of our partner Roth & Rau. The LCO reference group was fully processed at their facility. The precursors are made of 156×156 mm^2 large magnetically grown Czochralski silicon wafer (MCz) with a base resistivity of ρ=1.0 Ωcm. The front side covers an emitter with a sheet resistance of approximately 80 Ω/□, passivated by a plasma enhanced chemical vapour deposited (PECVD) SiN_x layer. For lower reflection properties additionally a second layer was deposited on top of the SiN_x. The front side features state of the art screen printed and fired contacts. The rear side was wet chemically polished and passivated by an Al_2O_3/SiN_x-stack, deposited by PECVD. Group one (LCO) features 39 cells, which were processed according to the well-known and established LCO approach and therefore act as the reference. The rear passivation stack was locally opened by laser ablation. Afterwards the rear and front contacts were screen printed and fired. For group two (LFC) the same paste and printing process as for the LCO group was used on 14 wafers, but the paste was deposited on the fully passivated surface. Then the wafers were shipped to Fraunhofer ISE and received the laser fired contact process. Group three (Foil) consists of 24 cells, which also received the same front side metallization but no screen printing was performed on the rear side. Thus the firing process was carried out at a 20 °C lower peak temperature. Afterwards the wafers were shipped to Fraunhofer ISE and received the foil metallization process. No final annealing step was carried out before I-V-measurement. The process flow of the back end processes is shown in Figure 1.

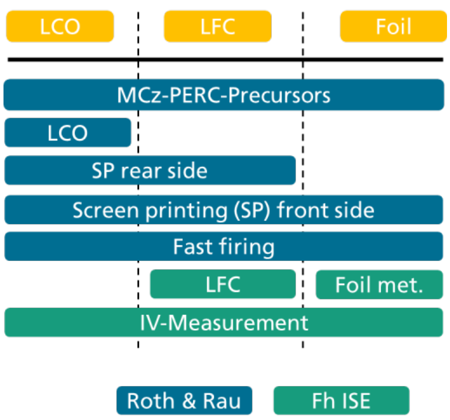

Figure 1: Process flow of the back end processes.

3 RESULTS AND DISCUSSION

As can be seen in Figure 2, with all technologies very high efficiencies well above 20% could be achieved. The deviation of the LFC group is significantly smaller, pointing out the stability of this process. The Foil metallized group achieves the highest mean value (20.3%) as well as the highest value for the best cell (20.5%), as shown additionally in Table 1. The lower fillfactor (FF) of the Foil and LFC group are most likely caused by the significantly lower contact fraction of the rear side compared to LCO. Since equal contact fraction was chosen for LFC and Foil group the lower *FF* of the Foil group indicates a higher series resistance contribution from the front contacts due to the different firing conditions required by the Foil cells. Due to the decreased contact fraction the LFC group features a higher short circuit current j_{sc} compared to LCO, since internal reflection is significantly reduced in the contacted areas. The additional, remarkable increase in j_{sc} of the foil metallized cells is caused by an improved internal reflection and thus higher internal quantum efficiency in the long wavelength range. Despite the higher contact fraction, the LCO group features slightly higher open circuit voltage V_{oc} compared to LFC, indicating an improved local back surface field in the contacted areas. However the foil metallization again achieves the highest values, pointing out, that the passivation layer is less affected by this approach, since again the quality of the local back surface field is assumed to be lower than with LCO.

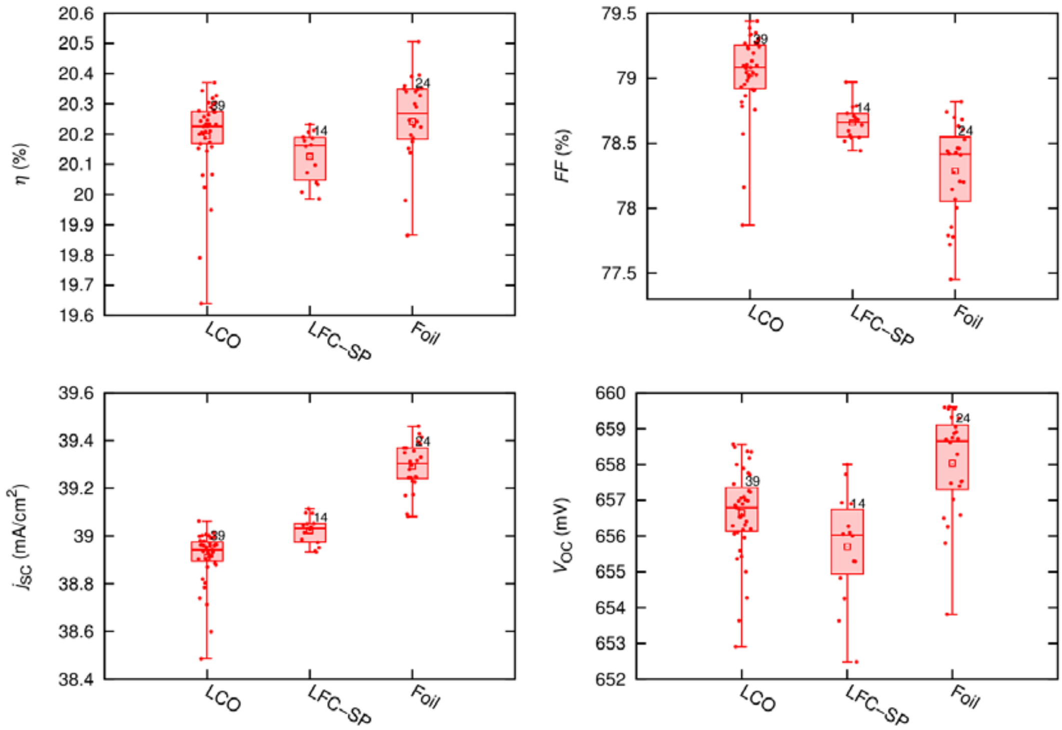

Figure 2: I-V-measurement results of 156×156 mm^2 sized, MCz PERC cells with identically processed front side featuring LCO, LFC and foil metallization technology on the rear side

Table 1: Mean values of the groups as well as I-V-measurement results of the best PERC cells with identically processed front side featuring LCO, LFC and foil metallization technology on the rear side.

Process		V_{OC} [mV]	j_{SC} [mA/cm²]	FF [%]	η [%]
LCO	Mean	657	38.9	79.1	20.2
	Best cell	659	39.1	79.4	20.4
LFC	Mean	656	39.0	79	20.2
	Best cell	658	39.1	78.7	20.2
Foil	Mean	659	39.3	78.4	20.3
	Best cell	660	39.5	78.8	20.5

4 CONCLUSIONS

In this paper we demonstrate that the simple and low cost foil metallization approach features even higher efficiency potential than the well-established LFC and LCO technology. Main advantages are higher V_{oc} potential due to the less harmful metal deposition compared to fired screen printing paste as well as remarkably higher j_{sc} potential due to improved internal reflection properties. Finally we report an efficiency of 20.5 % on large area, pilot line processed solar cells with this approach.

5 ACKNOWLEDMENTS

The German Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) is gratefully acknowledged for financially supporting this work within the project: FolMet (contract number 0325574A). The authors also would like to thank all colleagues at Fraunhofer ISE who have contributed to this paper in general and the Roth & Rau team for providing excellent precursors as well as the LCO reference cells.

6 REFERENCES

[1] E. Schneiderlöchner, R. Preu, R. Lüdemann *et al.*, *Progress in Photovoltaics: Research and Applications* **10** (2002) 29.
[2] A. W. Blakers, A. Wang, A. M. Milne *et al.*, *Applied Physics Letters* **55** (1989) 1363.
[3] B. Klöter, P. Kowalzik; H-C. Ploigt *et al.*, *Proceedings of the 28th European Photovoltaic Solar Energy Conference and Exhibition; Paris, (2013)*
[4] J. Nekarda, A. Grohe, O. Schultz *et al.*, *Proceedings of the 22nd European Photovoltaic Solar Energy Conference* (2007) 1499.
[5] J. Nekarda, M. Graf, A. Rodofili, *et al.*, *Proceedings of the SPIE Optics and Photonics* 8473 (2012) 847307 -14.