APPLICATION OF SCREEN PRINTING IN PHOTOVOLTAIC

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ABSTRACT

The screen printing is used in the photovoltaic for the realization of solar cells´s contacts. The screen printing is divided on this one of the front side and that one of the back side. Ag paste is used as the filling for screen printing. The drying of the spread paste follows after the screen printing of the silicon wafer. The higher stability of the print and the elimination of humidity before the firing are the purpose of this drying. The firing is founded on Ag diffusion from the contact to the desired depth in the silicon wafer.

1 INTRODUCTION

The temperature of firing is oscillating from 600 °C to 900 °C by the common thick films layers. These temperatures are high enough to change the silicon under the contact. The optimal print of the front side is 60 μm wide and 10-15 μm high. It is necessary to control the print during the screen printing because it can occur to the print´s defects (irregular width, bad resolution, …). These defects can be caused by the damaged membrane of screen, by the unsuitable speed or the wrong angle of spreading paste by a spatula.

2 THE TEST PATTERN

The test pattern was made for measure :

- Sheet Resistivity of Diffused Layer r_S [Ω/sq]
- Contact Resistance R_C [$\Omega.cm^2$]
- Line Resistance r_{Line} [Ω/squ]
- Junction Characteristics

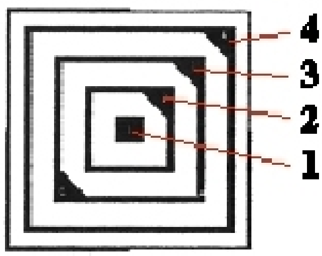

Fig. 1: *The test pattern*

By measure sheet resistivity of diffused layer (test1), the current source is connected to pads 1 and 4, the voltage is measured on terminals 2 and 3. The voltage measured is the result of current flowing through the silicon surface layer for a length L of approximately 0,017 inch and over width W of approximately 4 x 0,064 inch. The quotient R_S indicated by ohmmeter is the resistance of the surface layer:

$$R_S = r_S \frac{L}{W} \qquad (1)$$

This equation can serve to calculate the sheet resistivity of the silicon.

$$r_S = \frac{W}{L} R_S \qquad (2)$$

When a very high contact resistance exists between pads and silicon, the voltage measured is lower than the voltage drop in the silicon due to the meter current flowing across the contact resistance. The silicon appears to have a low resistance. A meaningful measurement of the silicon sheet resistivity is only possible once ohmic contact has been made to the silicon.

By moving the current source terminals to the same pads that are connected to the voltmeter, the sum of contact resistance and diffused layer resistance is being measured. Three different probe positions are possible for the contact resistance test (test 2, 3, 4). Using all these tests and comparing the results increases the confidence in the measurement. Assuming that the current is evenly distributed over the contact area, the normalized contact resistance can be calculated from the resistance readings of Tests 2 – 4.

With current and voltage terminals of the ohmmeter contacting the same terminal pad in opposite corners, the line resistance can be measured (test 5). The line resistivity of less than 0,01 Ω/sq that is comon for thick film material compares to a value of greater than 10 Ω/sq for the diffused layer. This means that the effect of the parallel current path through the diffused layer is usually negligible. The limit of the line resistivity depends on the maximum lenght of a collectro line. The cell design with collector lines exceeding 1 cm length, a line resistivity of less than 12,5 mΩ/sq is required. Since resistivities of less than 3 mΩ/sq are difficult to achieve with thick film inks, the line resistance is one of the limiting factors for large thick film cells and a low line resistance is one of the important criteria for paste used on the diffused side.

Fig. 2: *Contact probe station*

3 RESULTS

8 types of Ag pastes were selected for print test paterns on the front side of the tested sollar cell. The measurement followed after drying and firing. The results of these measurements are in table 1.

Paste	Process	r_S[Ω/sq]	r_{C2}[mΩ.cm^2]	r_{C3}[mΩ.cm^2]	r_{Line}[mΩ/sq]
2	D8	56,77	1,05	4,77	28,46
2	D8 + G3	45,80	1,24	3,30	26,44
3	D8	55,65	0,86	6,67	15,80
3	D8 + G3	41,49	0,91	3,60	17,30
4	D8	49,17	2,24	4,38	24,41
4	D8 + G3	42,41	1,43	2,35	22,54
6	D8	99,92	1,83	37,40	20,77
6	D8 + G3	57,90	1,22	7,55	22,38
7	D8	98,76	2,04	48,57	33,38
7	D8 + G3	54,16	2,07	5,04	32,40

Tab.1: *Measurement´s results of different type of paste*

The results of the pastes 1, 5 and 8 are not mentioned in the table 1. These pastes had very poor printing properites. Proces G3 means galvanical strengthened layer. The paste no.3 (even with galvanical strengthened layer) reached the best line resistance. The second was the paste 2 fired in infrared furnace. Galvanical metalization does not suit to the paste 3 and the paste 6.

4 firing profiles were tested :

- 400-500-600-650-700-750
- 400-500-600-700-750-825
- 400-500-600-750-820-875
- 400-600-750-820-870-920

Profil	Proces	r_S[Ω/sq]	r_{C2}[mΩ.cm^2]	r_{C3}[mΩ.cm^2]	r_{Line}[mΩ/sq]
1.	D8	38,57	55,33	57,46	17,18
2.	D8	35,54	4,07	2,97	18,11
3.	D8	27,94	16,41	15,14	18,43
4.	D8	29,19	17,92	24,96	16,28

Tab.2: *Measured values in dependence on firing profile*

The results of measurements of the paste 2 by air circulation 50-100-100-60-100 are in table 2.

The whole solar cells were fired with the same profiles. On the solar cell´s characteristics is well seen, that the most suitable profile is the firing profile no.3. V-A chrarkteristics are shown on the figure 3.

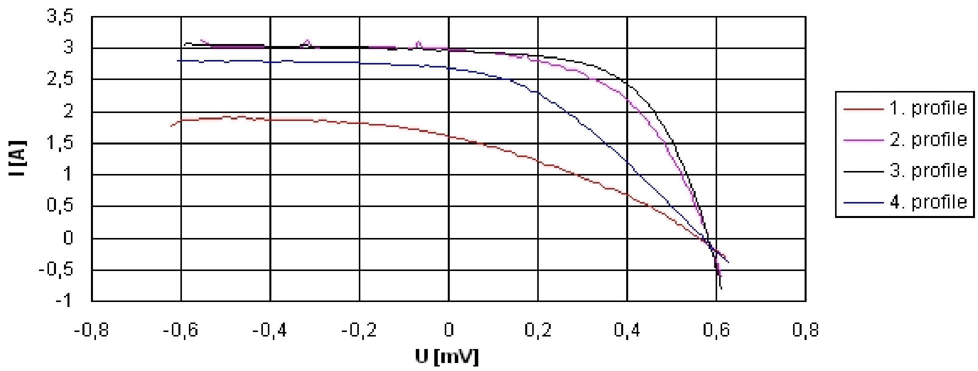

Fig. 3: *V-A characteristic of solar cell by different firing profiles*

The screen through plastic fibers was chosen for create the screen printing pattern at first (figure 4), but it was ascertained inconvenient as shown in figure 5. Pastes No. 1, 5 and 8 had poor properties for the used screen. The poor quality of print was caused by larger diameter of Ag grains and their higher viscosity. The best results were achieved by stainless screen as shown in figure 6. Optimizing of printing process is one of main topics of this paper.

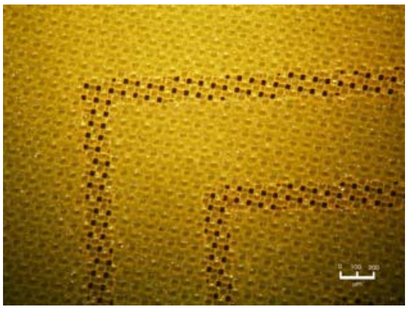

Fig. 3: *Screen printing pattern*

Fig. 4: *Inequality of print*

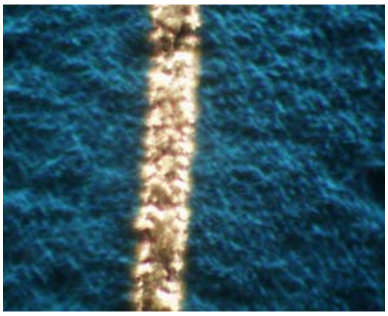

Fig. 5: *Detail of Ag paste*

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