NOVEL TECHNOLOGY FOR PRODUCTION OF COPPER COMPONENT AND PASTE USED IN THE PRODUCTION PROCESS OF ELECTRICAL CONTACTS OF SILICON CELLS

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Abstract

The paper presents results of research on a new type of copper component that enables the production of Cu paste. Two pastes were applied during investigations: 1 - Pv19B commercial paste manufactured by Du Pont, 2 - experimental containing more than 50 % copper. Investigations were made into electrical properties of solar cells, with front metallization made in a non-conventional way (using template/stencil) on computerized Solar-Lab positioning table and included the measurement of I-V curves of the photovoltaic solar cells. The specific contact resistance of front metallization of the solar cell was measured also onto measuring position Corescan. Using the presented results, we can reduce the cost of silicone metallization by 50%, replacing the previously used silver with cheaper copper (CuXX).

Keywords: Copper, screen-printing, photovoltaic cells, metallization, silver

1. INTRODUCTION

The aim of the work was to compare the electrical parameters of photovoltaic cells produced on the basis of two pastes: commercial and novel paste component. The paper presents results achieved in the project is to draw up and demonstrative development of metallizing paste with the use of Cu at a minimum of 50 % by weight to mark electric contacts in photovoltaic silicon cell production process. New metallizing paste (based on the patent application No. P.409794), which was created to substitute silver (Ag) with a new copper component (CuXX, XX- compound is confidential within patent application), will be a worlds novelty and enable to decrease costs of metallizing paste by 28-78 % (depending on project results and market prices of silver), which willed crease the cost of metallizing silicon cell process by 10-15 % (as in the above). It is estimated that cost of metallizing paste will decrease by 55 %, i.e. cost of silicon metallization process by 50 % [1].Two pastes were applied during investigations: 1 - Pv19B - commercial paste manufactured by Du Pont, 2 - experimental prepared that content of more than 50 % copper. Investigations were made of electrical properties of solar cells, with front metallization made non-conventional way (using template/stencil) on computerized Solar-Lab positioning table and included the measurement of I-V curves of the photovoltaic solar cells [2].

1.1. Material for testing and samples preparation

Test plates were used from single crystal silicon (Cz-Si) p-type surface area 5 x 5 cm^2, the starting crystallographic orientation of the surface (100) of thickness 160 μm and a resistivity of 1 Ω·cm [3].

- chemical cleaning of the silicon surface,
- high-temperature molding of the connector,

- removal of lateral joints and enamel washing,
- surface passivation,
- applying the anti-reflective TiO_2 layer by CVD
- electrode creation (printing and firing in the IR furnace) [4].

After contact printing, the structures were subjected to metallization in the IR furnace for three consecutive set point temperatures: 1. - 530 °C, 2. - 570 °C, 3.- in the range of 840 ÷ 960 °C at a tape speed of 200 cm/min. Solar cells were prepared in 2 series [5].

- Characteristics of solar cells in the first series: front contact electrode of PV19B paste-a new DuPont paste PV19B was used to make the front electrode.
- Characteristics of the solar cells in the second series: with the front contact electrode from the experimental paste prepared with a Cu content of more than 50 % by weight.

PV505 and PV36A pastes were used for rear contacts. After drying at 200 °C for 15 minutes, the plates were fired in an IR furnace.

1.2. Methodology of research

In order to determine the effect of the obtained electrode from two different pastes on the electrical properties of the produced photovoltaic cells, two different research stands were used.

- A computerized test stand Solar-Lab for measurement of current-voltage (I-V).
- A computerized test stand equipped with a Corescan device for measuring contact resistance and resistivity [6].

2. EXPERIMENT

Measurement of I-V characteristics was performed using Solar-Lab. Measurement allowed to determine the basic parameters of solar cells such as I_{sc} (short circuit current), V_{oc} (open circuit voltage), *FF* (fill factor) (1), E_{ff} (efficiency). The results of measurements of the electrical properties of solar cells with the front contact electrode applied from PV19B paste are shown in **Table 1**, **Figure 1**. The purpose of the experiment was to check the parameters of solar cells produced solely on the basis of commercial paste PV19B, used as the starting paste. Depending on the metallization temperature between 880-900 °C and 920-940 °C, PV19B can be used to produce a cell with a fill factor *FF* greater than 0.7 [7]. The highest value of FF obtained for the metallization temperature of 940 °C. Using only metallic dopants to PV19B paste, obtain a higher FF value is unlikely [8].The above PV19B paste was used as a base material for the production of experimental pastes with a component based on copper. Corescan device with complete operating software allowing automatic measurement of the resistance and resistivity required for optimization and control of the final stage of the photovoltaic cell manufacturing process with the possibility of immediate analysis of the photovoltaic cells [9]. Based on the results obtained in text (**Table 1**) and graphical form (**Figure 2**), it was found that at 840 °C high and non-uniform contact resistance was obtained. At 920 °C, cells with low uniform contact resistance were obtained, At 940 °C, the lowest contact resistance was obtained, but slight degradation of the samples was observed. Slight degradation of the samples was also observed at 960 °C. Based on the results obtained, it was found that the best result of resistance and resistivity was obtained at 920 °C [10, 11]. Therefore, the next stage was the production of 2 cells in the same technology process, differing in the type of paste used for applying the front electrode (**Table 2**, **Figure 3**). Research shown that the smallest value of the PV relative values of Rc (coating resistance) in series produced at the same temperature of the metallization process was obtained at a commercial paste PV19B at temperature 920 °C of 36.33 mΩ·cm^2 compared to the experimental paste (55.36 mΩ·cm^2). In the case of the commercial paste used, the cell was characterized by a uniform low contact resistance with slight degradation (**Figure 3a**), whereas in the experimental paste the cell was characterized by a greater defect (**Figure 3b**) [12-14].

Table 1 Results of measurements electrical properties of photovoltaic cells in which the front electrode was made of PV19B paste using two test stand for J = 30 mA/cm^2

			Test stand Solar-Lab						Corescan device		
LP.	Firing temperature (°C)	Symbol of the sample	I_{sc} (mA)	V_{oc} (mV)	FF (-)	E_{ff} (%)	R_s (mΩ)	R_{sh} (Ω)	U (mV)	R_{cl} (Ω·cm)	R_c (mΩ·cm^2)
1	840	D-21-1.0	515.6	545.7	0.316	3.56	536.1	1.64	441.9	132.57	1325
2		D-21-1.2	x	x	x	x	x	X	293.3	88	880
3	860	D-21-1.3	801.4	572.4	0.517	9.48	136.4	1.12	1883	56.47	565
4		D-21-1.4	783.7	577.6	0.562	10.18	111.5	7.77	94.1	27.9	279
5	880	D-21-1.5	8205	588.5	0.689	13.31	67	48.29	23.3	7	70
6		D-21-1.6	814.7	591.3	0.703	13.55	54.7	46.5	x	x	x
7	900	D-21-1.7	811	591.2	0.701	13.44	65.7	1.56	11.57	3.47	34.67
8		D-21-1.8	799.8	589.3	0.68	12.83	66.9	12.63	19.53	5.87	58.67
9	910	D-21-1.9	812.5	591.8	0.68	13.08	53.8	9.91	11.07	3.33	33.33
10		D-21-1.10	816.4	590.6	0.682	13.15	66.6	28.19	17.57	5.27	52.67
11	920	D-21-1.11	804.4	587.6	0.66	12.48	63.6	3.98	10.27	3.07	30.67
12		D-21-1.12	809.5	594	0.702	13.51	59.9	35.57	10.43	3.13	31.33
13	930	D-21-1.13	800.3	591.6	0.7	13.25	65.5	16.59	10.27	3.07	30.67
14		D-21-1.14	805.8	592.5	0.702	13.4	65.6	5.52	11.23	3.37	33.67
15	940	D-21-1.15	791	591.2	0.704	13.17	64.2	0.94	9.3	2.77	27.67
16		D-21-1.16	806.3	593.1	0.692	13.24	55.5	15.26	9.3	2.77	27.67
17	950	D-21-1.17	787	586.4	0.657	12.12	63.8	2.05	10.57	3.17	31.67
18		D-21-1.18	794.6	586.1	0.593	11.04	66.7	1.82	12.03	3.63	36.33
19	960	D-21-1.19	795.9	587.3	0.645	12.07	63.9	4.88	10.43	3.17	31.33
20		D-21-1.20	801.5	586.6	0.633	11.9	65.2	5.9	10.87	3.27	32.67

where: I_{sc} - short circuit current, V_{oc} - open circuit voltage, FF - fill factor, E_{ff} - conversion efficiency, R_s - specific series resistance, R_{sh} - specific shunt resistance, U - voltage, J - current density, R_{cl} - line contact resistance, R_c - coating resistance.

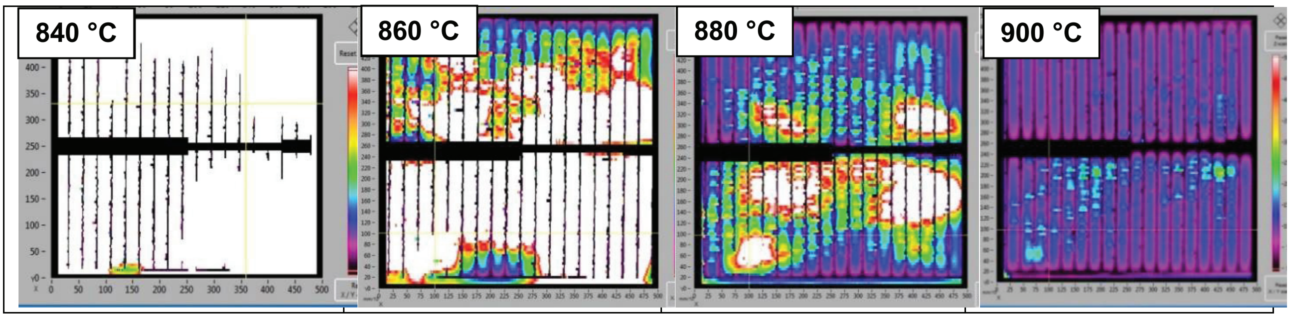

Figure 1/1 View of the "history result tab in the form of a 2D image for the front electrode made of PV19B paste, fired in the range of 840 to 960 °C

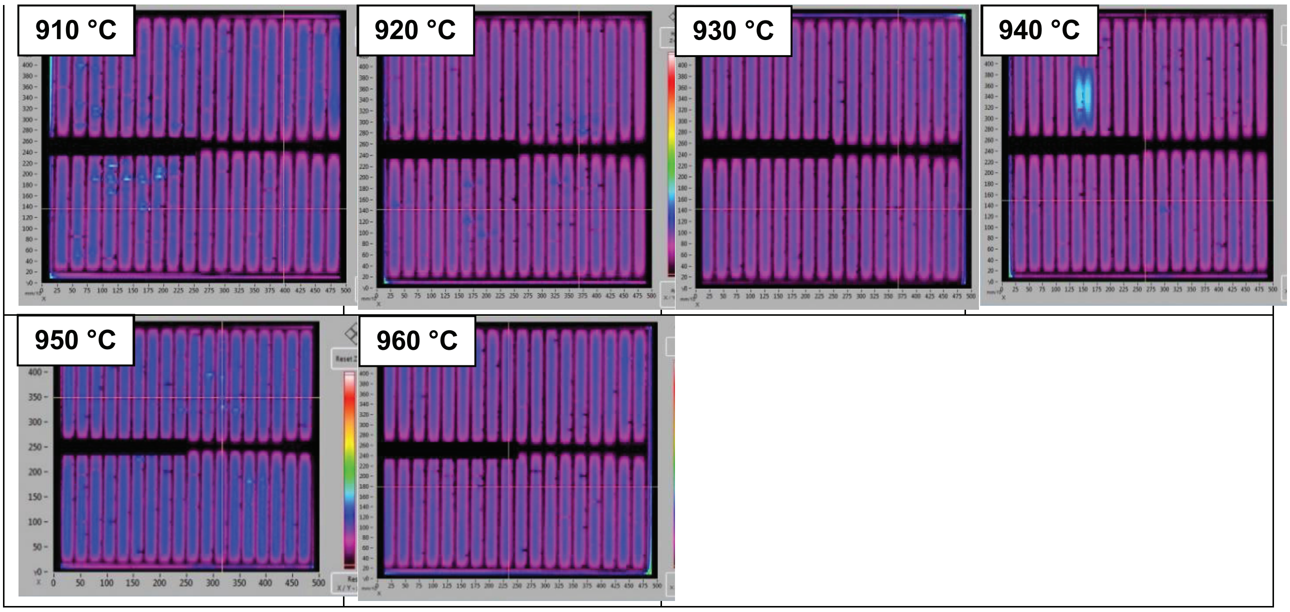

Figure 1/2 View of the "history result tab in the form of a 2D image for the front electrode made of PV19B paste, fired in the range of 840 to 960 °C

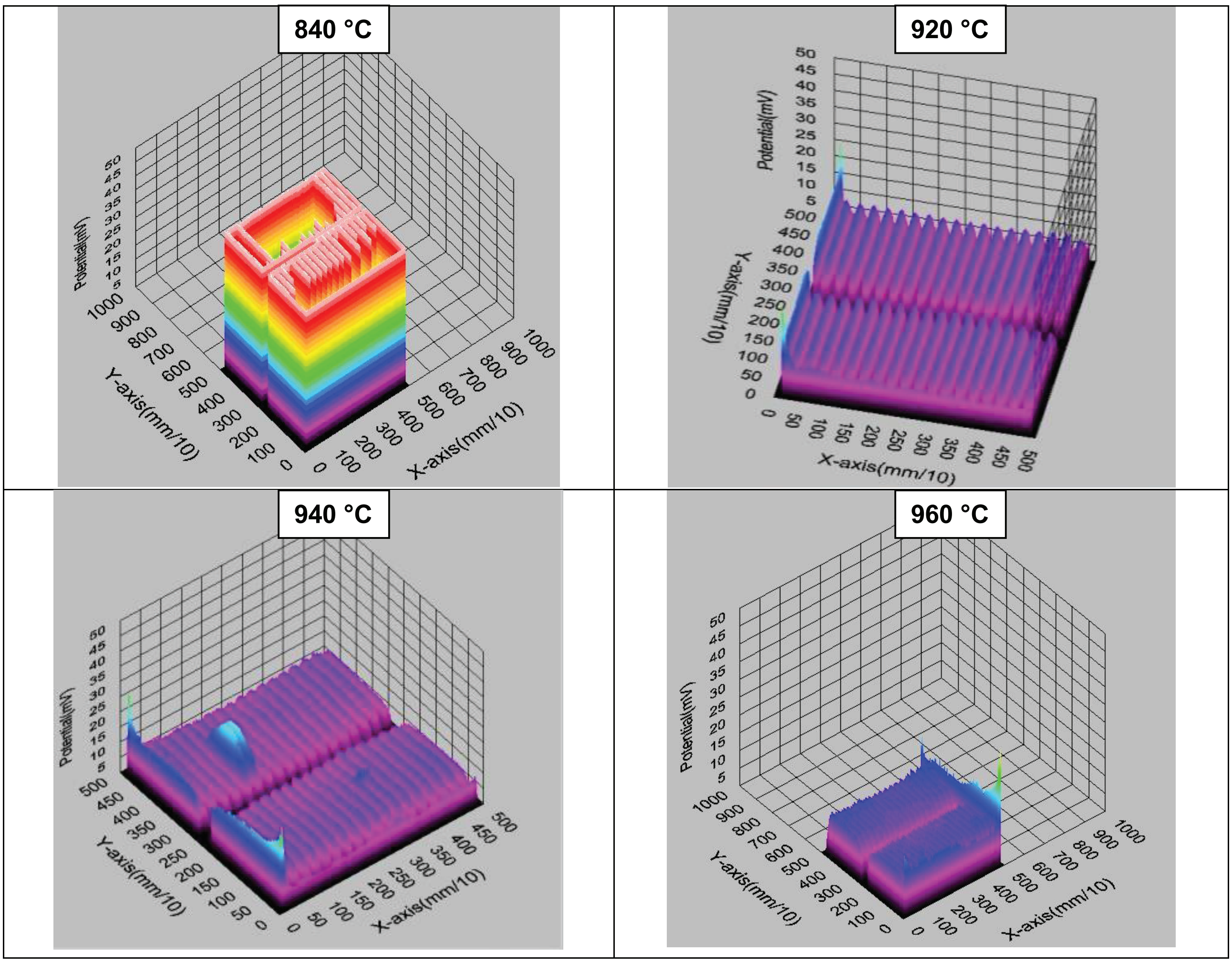

Figure 2 View of the "history result" tab as a 3D image for front electrode made of PV19B paste and fired at selected temperature range: 840, 900, 940 and 960 °C

Table 2 The results of the resistance measurements and the specific resistance of the photovoltaic cells in which the front electrode was made of 2 pastes.

				Corescan device			
LP.	Firing tempe-rature (°C)	Symbol of the sample	Type of paste	U_{AVG} (mV)	J (mA/ cm^2)	R_{cl} (Ω·cm)	R_c (mΩ·cm^2)
1	920	MM-13	PV 19B	12.03	30	3.63	36.33
2		C3-N-6	Experimental	18.4		5.53	55.33

Where: U_{AVG} - average voltage, J - current density), R_{cl} - line contact resistance, R_c - coating resistance.

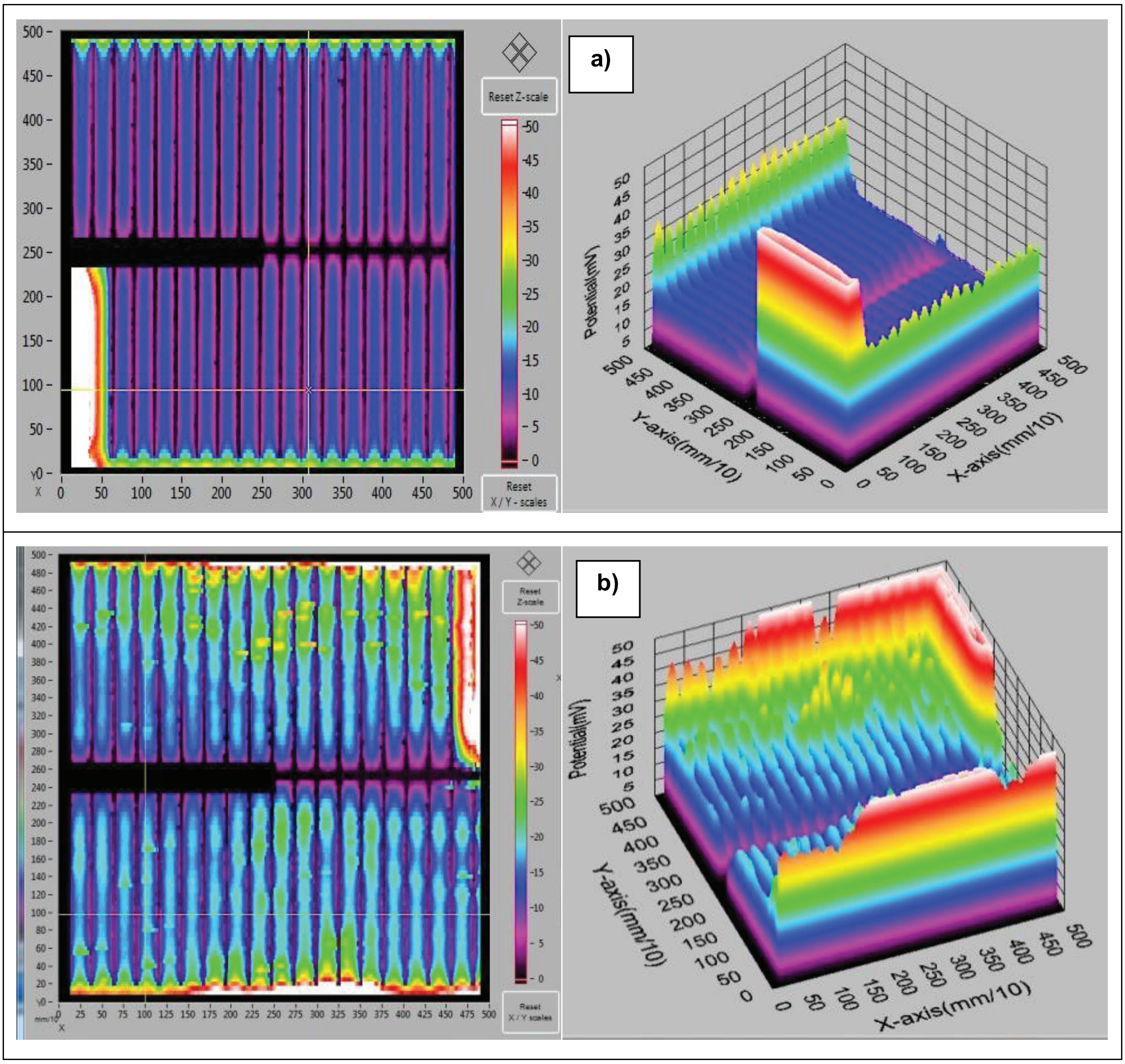

Figure 3 View of the "history of measurement results" tab in the form of 2d and 3D images for the front electrode made of a) PV19B and b) firing temperature of novel paste at 920 °C

3. CONCLUSION

1) The purpose of the experiment was to check the electrical parameters of photovoltaic cells produced on the basis of a new commercial paste No. PV19B from Du Pont, as starting material depending on the metallization temperature to produce an experimental paste prepared with a Cu content of more than 50% by weight.
2) It has been demonstrated that the Corescan device enables detailed and practical measurement of the selected photovoltaic cellular components and their presentation in two forms (graphical, textual).Detailed research results of the electrical properties of a photovoltaic cell can be used to analyze or solve problems in selected stages of its manufacturing process.
3) The electrical parameters of solar cells produced in individual series while maintaining the same temperature of the metallization process show the spread of their values, whose primary source is the lack of automatic processing line in the manufacture of photovoltaics.

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