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DEVELOPMENT OF METALLIZATION PROCESS: FSA PROJECT,
CELL AND MODULE FORMATION RESEARCH AREA

Quarterly Technical Progress Report for the Period Ending December 31, 1983

By
Alexander Garcia III

February 1984

Work Performed Under Contract No. NAS-7-100-956205

Spectrolab, Inc.
Sylmar, California

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Quarterly Technical Progress Report

No. 6329-21

on the

DEVELOPMENT OF METALLIZATION PROCESS

FSA Project, Cell and Module Formation Research Area

For the Period Ending

December 31, 1983

Contract 956205

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February, 1984

The JPL Flat Plate Solar Array Project is sponsored by the U.S. Department of Energy and forms part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory, California Institute of Technology by agreement between NASA and DOE.

ABSTRACT/SUMMARY

New pastes were evaluated that contained additives to aid in the silicon-to-metallization contact. None were completely successful, however, inks containing silver-organic compounds showed promise.

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
	ABSTRACT/SUMMARY	i
1.0	INTRODUCTION	1
2.0	TECHNICAL DISCUSSION	2
3.0	CONCLUSIONS AND RECOMMENDATIONS	16
4.0	ACTIVITIES PROJECTION	16

Section 1.0

INTRODUCTION

The objective of this contract is the optimization, evaluation, and demonstration of a novel metallization applied by a screen printing process. The process will be evaluated on both CZ and non-CZ silicon wafers.

Section 2.0

TECHNICAL DISCUSSION

JPL took several SEM micrographs of various sintered cells to investigate changes that have been made in sintering process parameters. These analyses make it clear that most cells were not being sufficiently sintered. Changes were then made in the hydrogen delivery system for the sintering furnace to allow the flow of H_2 to be increased 7 fold to 2.5 l/min.

Repetitions of earlier runs were made using Pastes E, I, J, and L. Cells were sintered for 5 or 10 minutes at $600^{\circ}C$ in hydrogen. Paste I showed no better results than previous experiments. Cells with fairly good curve shapes were made using Pastes E, J, and L. The curves with the best shape are shown in Figures 1, 2, and 3. Figure 4 shows a silver control cell for comparison. Electrical characteristics follow:

<u>Cell</u>	I_{SC} <u>mA</u>	V_{OC} <u>mV</u>	I_{500}	<u>EFF (if AR)</u>
Ag	644	574	574	10.2% (13.5)
76	652	569	524	9.6% (12.8)
70	620	579	320	7.6% (10.1)
88	606	580	255	6.6% (8.7)

Loss of efficiency was caused by high resistance of the metallization in all cases. Shunt resistance was higher than

Figure 1

Figure 2

Figure 3

Figure 4

of the silver control. Spectrolab has acquired a JEOL JSM-T300 scanning electron microscope. Special sample holders were machined which will allow the non-destructive mounting of whole solar cells for analysis. Figures 5 and 6 are SEM micrographs of an L paste cell at 500 and 2000 magnifications. These micrographs are typical of all the pastes. Sintering particle to particle is good. Where the Mo/Sn cell differs from the silver cell is in the wetting and contact to the silicon surface. Soldering of these cells confirmed this hypothesis in that a solder pull test removed the metallization in one piece leaving behind an unmarred silicon surface.

Three new pastes were manufactured by Electrink. Paste M uses MoO_3 in place of Mo metal, a titanium resinate, and a slightly different vehicle. Pastes N and O have borane-pyridine added to a non-fritted paste. The formulations are shown in Tables 1, 2 and 3.

A typical electrical curve of a cell produced using Paste M is shown in Figure 7. The cells are fairly good electrically but not as good as the E, J, and L cells. Solder results were equally poor. More work will be done using this paste to attempt to duplicate earlier successful research.

Pastes N and O had borane-pyridine added to the non-fritted ink in 5% and 1% amounts. This was an attempt to produce a borosilicate frit in situ. The attempt was unsuccessful. All cells produced showed little or no electrical output due to extremely high series resistance.

Figure 5

Figure 6

Table 1

PASTE M, ELECTRINK #F-82

FORMULATION

<u>Item</u>	<u>% by Weight</u>
Molybdenum Oxide (MoO_3)	17.572
Tin Metal Powder	64.907
Titanium Resinate	.002
Vehicle V-44	17.519

VEHICLE V-44

α -terpineol	70.54
Carbitol Acetate	4.17
Trichloroethylene	19.20
Ethyl Cellulose	6.09

Table 2

PASTE N, ELECTRINK #F-80

FORMULATION

<u>Item</u>	<u>% by Weight</u>
Titanium Hydride (TiH_2)	.45
Molybdenum Metal Powder	16.06
Tin Metal Powder	64.24
Borane Pyridine	5.00
Vehicle V-38	14.25

VEHICLE V-38

α -Terpineol	43.62
Butyl Carbitol Acetate	43.62
Ethyl Cellulose N-14	9.76
Thixatrol ST	3.00

Table 3

PASTE O, ELECTRINK #F-81

FORMULATION

<u>Item</u>	<u>% by Weight</u>
Titanium Hydride (TiH_2)	0.47
Molybdenum Metal Powder	16.73
Tin Metal Powder	66.92
Borane Pyridine	1.04
Vehicle V-38	14.84

VEHICLE V-38

α -Terpineol	43.62
Butyl (Arbitol Acetate)	43.62
Ethyl Cellulose N-14	9.76
Thixatrol ST	3.00

Figure 7

Additional cells were made using a modification of Paste E. JPL supplied a solution of silver neodecanoate in xylene. The solution was 15% silver by weight. 4.3% of this solution was added to Paste E. Wafers were screen printed and then either dried or prefired using the IR belt furnace. The cells were then fired in H_2 for 5 or 10 minutes. Figures 8 and 9 show cells made with and without the addition of the silver neodecanoate. The additive improved the curve shape but still did not impart adequate conductivity.

Figure 8

Figure 9

Section 3.0

CONCLUSIONS AND RECOMMENDATIONS

There are no conclusions or recommendations to report for the period.

Section 4.0

ACTIVITIES PROJECTION

During the next quarter additional pastes will be evaluated that contain silver neodecanoate.