Quarterly Technical Progress Report

No. 6329-27

on the

DEVELOPMENT OF METALLIZATION PROCESS
FSA Project, Cell and Module Formation Research Area

For the Period Ending
June 30, 1984

Contract 956205

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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.
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ABSTRACT/SUMMARY

New pastes were evaluated that contained additives to aid in the silicon-to-metallization contact. None were completely successful. A reevaluation of the molybdenum oxide paste and the two-step screen printing process was done. The oxide paste did not show promise. The two-step process enabled soldering of the cells but the cells still had a high series resistance. Pastes are on order from a different manufacturer.
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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.
Based upon the SEM work done on the heated stage at Mircoscopy Research Laboratories, Inc. a set of experiments was done using the L paste and sintering for long periods of time at lower temperatures without drying. It was hoped that the nonwetting of the molten tin particles was caused by an oxide which would be broken down in time by reaction with hydrogen. Cells were printed, dried and placed in the sintering furnace under H$_2$ at 400°C. After 4 hours in the furnace cells did not show signs of sintering. Two new pastes were procured from Electrink. Table 1 shows the formulations. These formulations were based on experience at Electrink on silver inks. Paste S is similar to Paste J with silver flake added and Paste T has bismith added. The printed cells were sintered at temperatures of up to 650°C but did not show good curve shape. Typical light and dark curves are shown in Figures 1 and 2. Higher temperatures and longer times produced low shunt resistances. Both S and T behaved in a similar fashion.

More experimentation was done on the molybdenum oxide paste (Paste M). Sintering temperatures up to 825°C under H$_2$ were used. The best cell IV curves are shown in Figures 3 and 4. Cells fired at higher temperatures showed severe shunts. The low short circuit current is difficult to explain and may be due to an opaquing layer forming on the cell surface. Cells fired at temperatures of 825 and 850°C showed metallic-like
Table 1

PRODUCT INFORMATION

Formulation % by Weight

<table>
<thead>
<tr>
<th>Item</th>
<th>F-86</th>
<th>F-87</th>
</tr>
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<tbody>
<tr>
<td>Titanium Hydride (TiH₂)</td>
<td>.55</td>
<td>.55</td>
</tr>
<tr>
<td>Molybdenum Powder</td>
<td>14.40</td>
<td>14.40</td>
</tr>
<tr>
<td>Tin Powder</td>
<td>57.60</td>
<td>57.60</td>
</tr>
<tr>
<td>Frit Ll571A</td>
<td>4.45</td>
<td>4.45</td>
</tr>
<tr>
<td>Silver Flake Type C</td>
<td>8.00</td>
<td>-</td>
</tr>
<tr>
<td>Bismuth Powder</td>
<td>-</td>
<td>8.00</td>
</tr>
<tr>
<td>Vehicle V-38</td>
<td>15.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Identification</td>
<td>S</td>
<td>T</td>
</tr>
</tbody>
</table>

Vehicle Formulation

<table>
<thead>
<tr>
<th>Item</th>
<th>V-38</th>
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<tbody>
<tr>
<td>α-terpineol</td>
<td>43.62</td>
</tr>
<tr>
<td>Butyl Carbitol Acetate</td>
<td>43.62</td>
</tr>
<tr>
<td>Ethyl Cellulose N-14</td>
<td>9.76</td>
</tr>
<tr>
<td>Thixatrol ST</td>
<td>3.00</td>
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### Table 1 (continued)

#### Frit Composition - % by Weight

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<thead>
<tr>
<th>Item</th>
<th>Frit L1571A</th>
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<tbody>
<tr>
<td>PbO</td>
<td>60</td>
</tr>
<tr>
<td>B₂O₃</td>
<td>30</td>
</tr>
<tr>
<td>SiO₂</td>
<td>10</td>
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</tbody>
</table>

#### Materials Sources

<table>
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<tr>
<th>Material</th>
<th>Designation</th>
<th>Source</th>
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<tbody>
<tr>
<td>Titanium Hydride (TiH₂)</td>
<td>77113</td>
<td>Alfa-Ventron, Danvers, MA</td>
</tr>
<tr>
<td>Silver Flake</td>
<td>C</td>
<td>Metz Metalurgical, Plainfield, NJ</td>
</tr>
<tr>
<td>Molybdenum Powder</td>
<td>280/325</td>
<td>GTE Sylvania, Towanda, PA</td>
</tr>
<tr>
<td>Tin Power 325 Mesh</td>
<td>00352</td>
<td>Alfa-Ventron, Danvers, MA</td>
</tr>
<tr>
<td>a-terpineol</td>
<td>TX 75</td>
<td>MCB Chem. Cincinnati, OH</td>
</tr>
<tr>
<td>Butyl Carbitol Acetate</td>
<td>BX 1722</td>
<td>MCB Chem. Cincinnati, OH</td>
</tr>
<tr>
<td>Ethyl Cellulose</td>
<td>N-14</td>
<td>Hercules, Wilmington, DE</td>
</tr>
<tr>
<td>Thixatrol (thickener)</td>
<td>ST</td>
<td>NL Industries, Hightstown, NJ</td>
</tr>
<tr>
<td>Elvacite (acrylic resin)</td>
<td>2042</td>
<td>Dupont, Wilmington, DE</td>
</tr>
<tr>
<td>Bismuth Powder</td>
<td>00046</td>
<td>Alfa-Ventron, Danvers, MA</td>
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SOLAR CONVERTER E I CURVE

SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 5-7-84

PROJECT: Proc 5

SERIAL NO.: 5475-50

□ CELL □ MODULE □ PANEL DESIGNATION: 6511

SOURCE: □ SUN □ TUNGSTEN □ XENON

□ COLLIMATED □ UNCOLLIMATED

TEST TEMP.: _______ °C. _______ °F

TEST NO. ___ PROC. NO. ___

Isc = _______ Voc = _______

Pmp = _______ BY = _______

CURRENT (MA.) X 10

VOLTAGE (VOLTS X 100)

100
90
80
70
60
50
40
30
20
10
0

0.1
0.2
0.3
0.4
0.5
0.6
0.7
Figure 3

SOLAR CONVERTER I-V CURVE

SPECTROLAB
SYLMAR, CALIFORNIA
DATE: 5-19-85

PROJECT: M Route 41484-7
SERIAL NO.: 780*6 5-5-1-5

SOURCE: □ SUN □ TUNGSTEN □ XENON
□ COLLIMATED □ UNCOLLIMATED

TEST TEMP.: __________°C. __________°F
TEST NO. __________ PROC. NO. __________
Isc= __________ Voc= __________

Pmp= __________ BY
Figure 4

SOLAR CONVERTER E I CURVE

SPECTROLAB QC FORM 3001
SYLMAR, CALIFORNIA DATE: 5/5/74

PROJECT: M-204L-1 1+8Y-77
SERIAL NO.: 760-5 5-5-1-6

SOURCE: [ ] SUN [ ] TUNGSTEN [ ] XENON
[ ] COLLIMATED [ ] UNCOLLIMATED

TEST TEMP: ___________________ °C ___________________ °F
TEST NO.: ___________________ PROC. NO.: ___________________
Isc = ___________________ Voc = ___________________
Pmp = ___________________ BY ___________________
grid patterns which were solderable. However, none of the solderable cells had measurable IV curves. Spectrolab has been unable to reproduce earlier research done on this paste system.

The use of a two-step screen printing sequence was reexamined. Cells were first printed with J and E pastes, and prefired at 600°C. The pattern left the soldering pad bare. Silver paste was then printed over the solder pad area overlapping onto the Mo/Sn metallization. The cell was then fired in air at 750°C (48"/min., 24" zone at 400°C and 18" zone at 750°C). The cells were sintered in H₂ for 5-30 min. at 600-650°C. The best cell is shown in Figures 5 and 6. There is good continuity between the ohmic pad and the rest of the metallization but series resistance is too high.

The problems of this experiment may be due to the paste used. Earlier work was done using Thick Film Systems' Paste F-503. The two pastes used here are Electrink equivalents. To ensure reproducibility an order has been placed for the Thick Film Systems' F-503 paste. Paste F-503 will be used exclusively in further work on the two-step process.
Figure 5

SOLAR CONVERTER E I CURVE

SPECTROLAB QC FORM 3001
SYLMAR, CALIFORNIA DATE: 5-31-84
PROJECT: 50076 8489-9
SERIAL NO. 1460-04
CELL MODULE PANEL DESIGNATION:

SOURCE: SUN TUNGSTEN XENON
COLLIMATED UNCOLLIMATED
TEST TEMP.: _______ °C _______ °F
TEST NO. __________ PROC. NO. __________
Isc = __________ Voc = __________
PMP = __________ BY __________

CURRENT (MA. X 10) vs. VOLTAGE (VOLTS X 10)
Figure 6

SOLAR CONVERTER I-V CURVE

SPECTROLAB QC FORM 3001
SYLMAR, CALIFORNIA DATE: 5-31-84

PROJECT: J-Part 21487-3

TEST TEMP.: °C °F

SOURCE: SUN TUNGSTEN XENON

COLLIMATED UNCOLLIMATED

CURRENT (mA) VOLTAGE (VOLTS X 0.5)

Isc= Voc=
Pn= BY
Section 3.0

CONCLUSION 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. Work on the two-step process will continue with the new paste. Economic analyses of the processes will be done using an IPEG analysis. The program will be concluded in this quarter.