

Quarterly Report No. 1

IMPROVED SOLAR CELL CONTACTING TECHNIQUES

Contract No. 952144

Prepared for:

CALIFORNIA INSTITUTE OF TECHNOLOGY
JET PROPULSION LABORATORY
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ION PHYSICS CORPORATION



A Subsidiary of High Voltage Engineering Corporation

BURLINGTON, MASSACHUSETTS

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by:

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ABSTRACT

Work is reported on aluminum and nickel contacted solar cells using high vacuum sputtering technology. Cells were fabricated with both aluminum and nickel contacts, and electrical measurements made. The effect of a temperature cycle after sputtering is reported for aluminum contacted solar cells. Aluminum contacted cells with greater than 10% AMO efficiency are reported for an uncoverslipped CeO_2 antireflected coated cell.

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SECTION 1

INTRODUCTION

Solar cell contacts have undergone little improvement over the years, the only major change being from plated Au and Ni to evaporated Ti-Ag contacts made and proven by Bell Laboratories. The advantages of Ti-Ag contacts were immediately recognized and, more recently, the disadvantages. The system is not giving the environmental stability and shelf life required.

Solder coating of the Ti-Ag contacts has retarded the degradation or at least made the problem difficult to detect. The disadvantage of solder coated cells are well-known as to the limited temperature excursion possible and the increase in weight.

This program has been designed to improve the known methods of establishing electrical contacts to silicon solar cells. The technique being used is IPC's high vacuum sputtering system. The basic system configuration is shown in Figure 1. The contact materials being investigated are Al, Ni and Cu.

In addition to development of the electrical contacts, the development of solderless interconnection techniques is also being investigated.

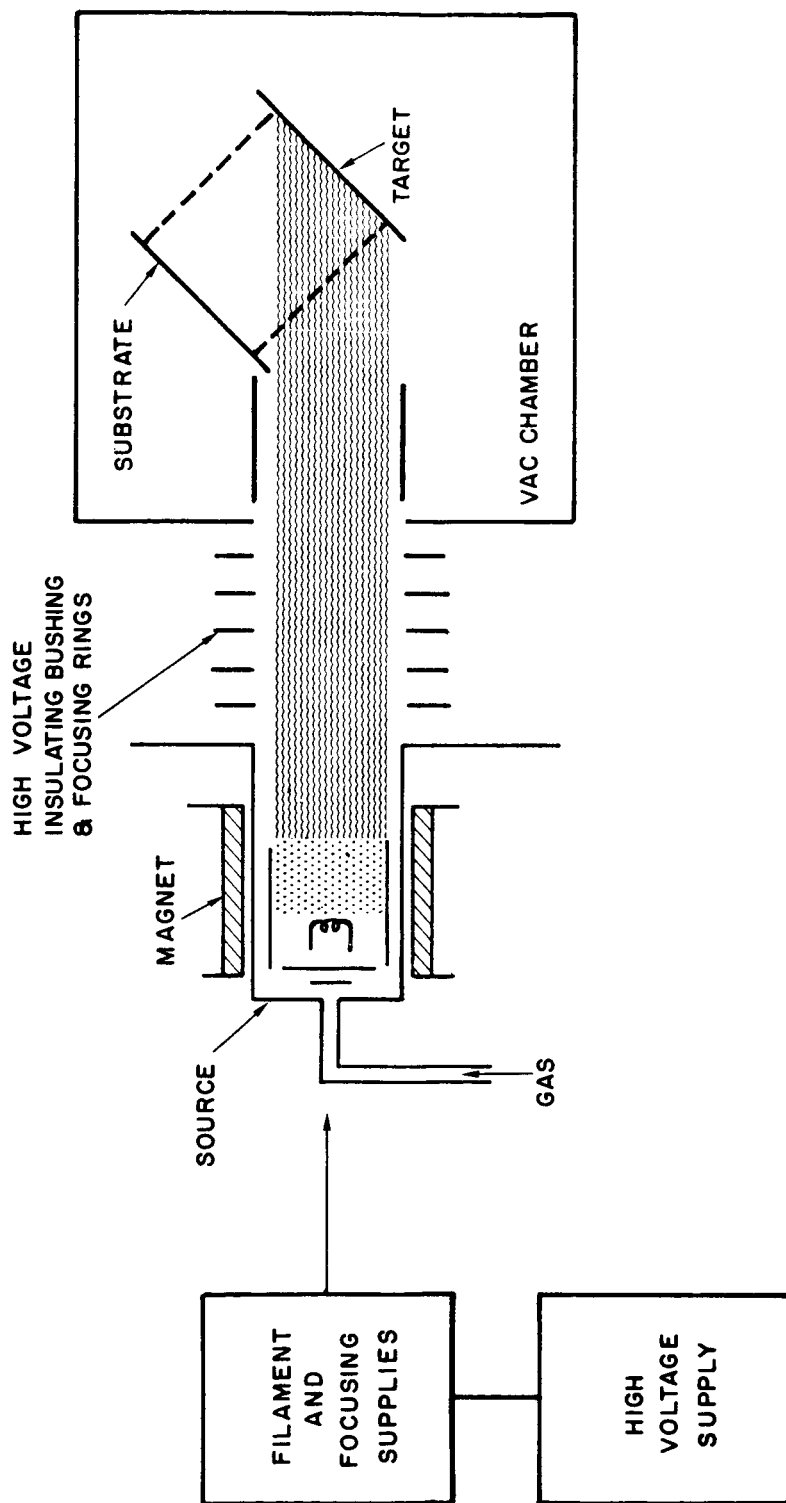


Figure 1. High Current High Vacuum Sputtering System Schematic

SECTION 2

EXPERIMENTAL WORK

2.1 Aluminum Contacts

Aluminum contacted solar cells have been fabricated utilizing high vacuum ion beam sputtering. Both Al front finger contacts and back area contacts have been applied to IPC's n-on-p silicon solar cells. For the front contacts IPC's standard 14 finger contact mask was used. The bimetallic mask was heated to 150°C which results in well defined contact fingers as shown in Figure 2. The fingers are tapered which is not indicated. The back surface contacts were deposited at room temperature.

Front contacts were applied with Al thicknesses from 1 to 5 microns. The back contact was approximately 2 microns thick. Finger resistance of front contacts is measured with an ohmmeter for approximately 2/3 of the length of the finger contact. Normal Ti-Ag cells measured by this technique are found to have finger resistances of less than 5 ohms. For the group of cells with 2 microns of Al, the finger resistance was found to be generally over 6 ohms. Another group of cells with 5 microns of Al on the front contact reduced the finger resistance to 5 ohms, but mechanical contact was poor.

Tape tests using Scotch Brand No. 810 were made of all Al contacted cells. All of the cells with 2 microns of Al passed the tape test without any noticeable removal of Al. As mentioned the cells with 5 μ of Al were susceptible to peeling. Only 4 of the 10 cells tested did not indicate any peeling. The peeling started primarily at the contact bar during scribing of the cells to size.

The electrical characteristics of the 20 cells fabricated with 2 microns of Al are indicated in Table 1. The 15 cells furnished JPL were selected from these cells. All cells had CeO₂ antireflection coatings. The table indicates results before and after a one-hour heat treatment cycle at 450°C. Initially a low open circuit voltage was found for a number of the cells which was improved for some of the cells by the temperature cycle. A threshold

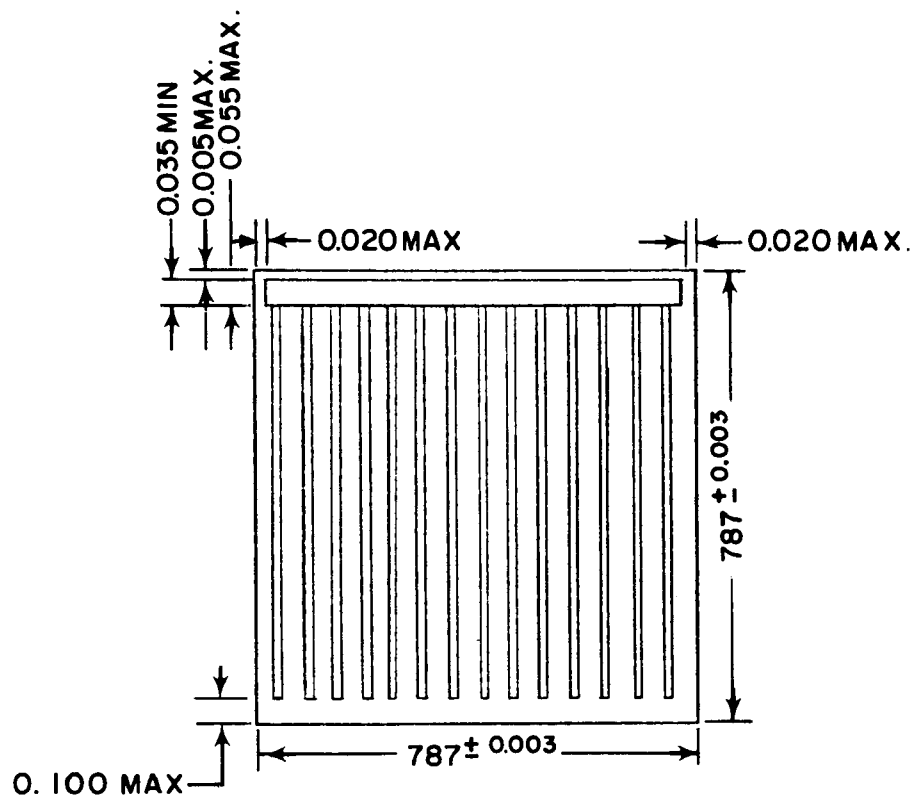


Figure 2. 14 Finger Mask

Table 1. Anti-Reflected Al Contacted Cells
(2 x 2 cm Cells)

	Before Anneal			After 450°C Anneal		
	I_{SC}	I_{43}	V_{OC}	I_{43}	V_{OC}	$\eta\%$
1	128	112	0.548	114	0.549	9.2
2	129	120	0.550	121	0.550	9.8
3	131	125	0.550	125	0.550	10.1
4	126	76	0.513	120	0.545	9.7
5	124	93	0.532	116	0.544	9.4
6	126	64	0.496	105	0.520	8.5
7	127	86	0.520	98	0.517	7.94
8	129	116	0.540	121	0.546	9.8
9	130	112	0.534	119	0.562	9.6
10	132	119	0.546	122	0.552	9.9
11	127	76	0.516	106	0.529	8.57
12	124	100	0.532	115	0.540	9.30
13	128	40	0.488	109	0.531	8.80
14	128	113	0.532	122	0.543	9.90
15	132	85	0.510	121	0.540	9.80
16	126	106	0.531	118	0.544	9.55
17	132	121	0.549	125	0.551	10.1
18	134	118	0.543	122	0.548	9.9
19	122	78	0.546	89	0.545	6.7
20	130	103	0.547	119	0.547	9.6

temperature for this improvement had been seen previously at 200°C but in this test the improvement was not noticed until approximately 400°C. No further improvement was observed at 500°C. It appears from the threshold observed, two distinct mechanisms are involved, although they are not fully understood.

Figure 3 shows the I-V characteristic curve of one of the cells. This curve as well as the tabulated data were taken on a carbon arc simulator with an electronic ratio comparator to correct the data to AMO.

The series resistance measured from the curve is found to be approximately 0.5 ohm. The curve factor of 0.735 is close to the 0.75 value often given for Ti-Ag cells. As indicated in Table 1, two of the solar cells had efficiencies exceeding 10%. The requirement has not been met for the current at 0.40 volt to be less than 2.1 ma down from the I_{SC} value. The best Al contacted cell to date was down 3.4 ma from I_{SC} at 0.40 volt. Electrical characteristics for the four 5 μ sputtered contact cells that passed tape test are indicated in Table 2 and reflect a contact problem.

Humidity chamber tests were carried out in IPC's Tenney chamber which is presently maintained at 60°C and 95% humidity. This is less than the contract requirement, but believed to be adequate for initial testing. Cells were prepared with sputtered Al front contact and regular Ti-Ag back contacts. After one week cells passed tape test with Scotch Brand No. 810 and no degradation was observed. After five weeks of testing extensive peeling of the Ti-Ag back contact resulted in a stop in testing. At that time the front Al contact passed the tape test.

Another approach to the Al contacting problem is being carried out at IPC on Contract No. F33615-68-C-1164. Al contacts are being evaporated and sintered at slightly below the 577°C Al-Si eutectic. When the eutectic is reached the alloys penetrates the junction and increased leakage degrades the cell. The firing at slightly below the eutectic does not appear to give excessive leakage, but does increase the bond strength. It has not been determined if the bond strength is adequate, but it appears to be comparable with the sputtered contacts fabricated on this program. Figure 4 is a I-V characteristic

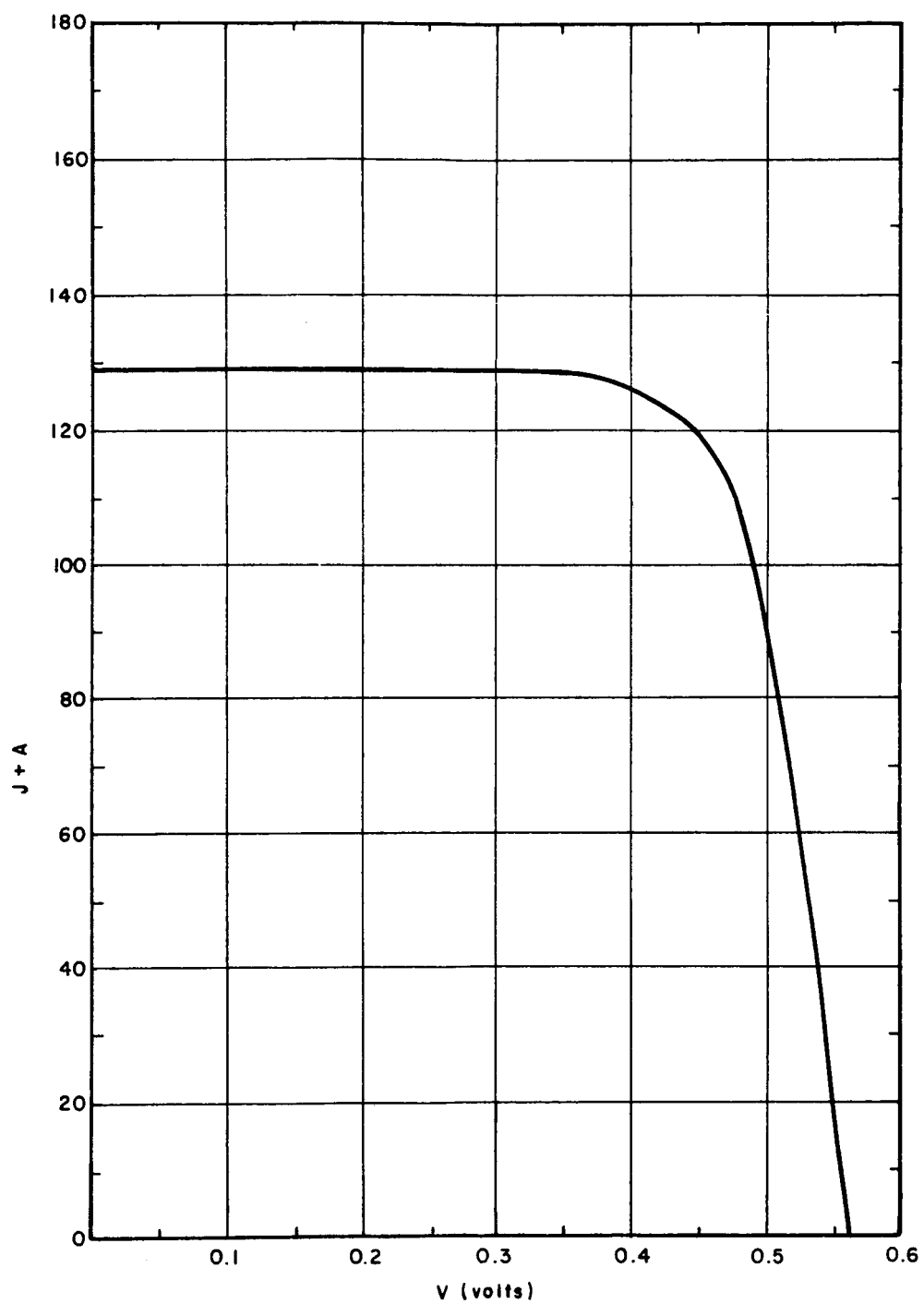


Figure 3. I-V Characteristic Curve, 2μ
Sputtered Al (2 x 2 cm)

1-2527

Table 2. 5 μ Sputtered Front Al Contacts
(No Antireflection Coating)

	I_{SC}	$I_{.43}$	V_{OC}
1	96	24	0.540
2	105	47	0.522
3	97	46	0.538
4	69	--	0.530

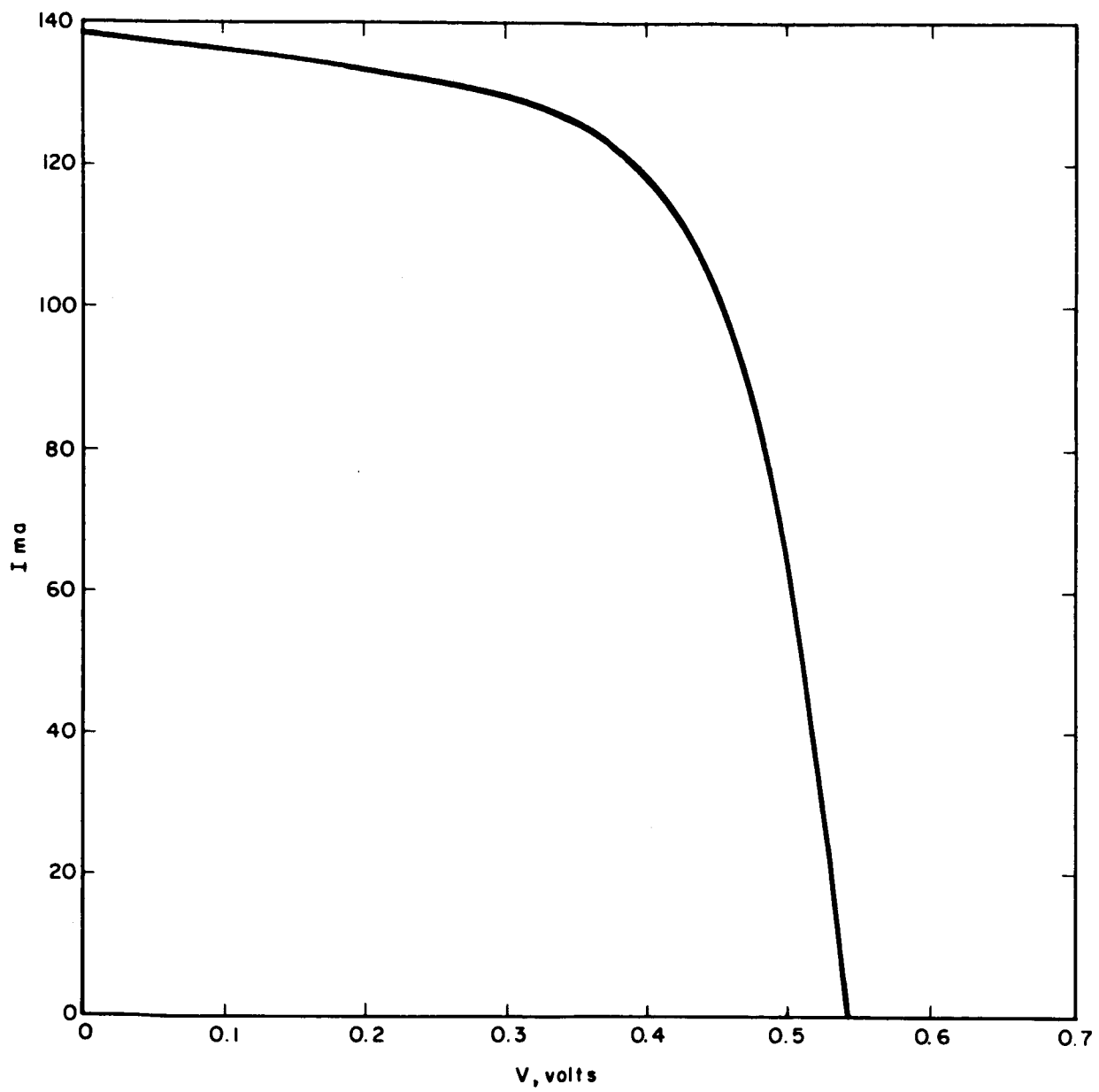


Figure 4. I-V Characteristic of Cell with 2μ
Evaporated Al after Ce-O_2

1-2615

of a cell with an evaporated Al contact and the electrical characteristics of three of the cells are given in Table 3. Prior to antireflection coating curve factors were as high as 0.75, but the antireflection coating step or the cleaning step prior to coating degraded the cells. The problem was increased edge leakage.

A 550°C sintering for 20 minutes had worked for evaporated cells, as indicated above, the same treatment was used for the 5 micron sputtered Al contacts which had indicated poor efficiencies. In this case the cells completely degraded resulting in very low open circuit voltages.

2.2 Nickel Contacts

Solar cells were fabricated with sputtered Ni contacts to both surfaces. Thick Ni contacts have indicated strain problems resulting in peeling, therefore, initial cells were made with 0.7 microns of Ni. This thickness of nickel will result in series resistance problems.

These cells were being fabricated for delivery to JPL in April. During the cleaning step prior to CeO_2 antireflection coating, damage to the contact was observed and resulted in the loss of part of the lot. The cleaning step involved ultrasonic cleaning in an alconox solution.

The electrical results for the cells are indicated in Table 4.

2.3 Interconnections

Ultrasonic bonding techniques are being utilized to form Al-to-Al interconnection. To date, experiments have been only moderately successful. Equipment problems have now been solved and the necessary tips and wire received. The work is continuing with 3 mil Si doped Al wire, with which bonds have been made. It appears the wire is being damaged during the bonding operation as it is compressed and the wiring is breaking next to the bond leaving a segment of wire bonded to the Aluminum contact pads.

Table 3. Cells with 2 μ Evaporated Al
Before and After CeO₂ Coating

	Before CeO ₂			After CeO ₂		
	I _{SC}	I _{.43}	V _{OC}	I _{SC}	I _{.43}	V _{OC}
1	101	94	0.545	133	107	0.547
2	101	95	0.544	134	109	0.547
3	104	95	0.543	136	111	0.548
4	100	94	0.547	132	100	0.548

Table 4. Ni Contact Cells
(0.7 μ Ni Both Surfaces by Sputtering)
(2 x 2 cm Cells)

	Before CeO ₂			After CeO ₂		
	I _{SC}	I ₄₃	V _{OC}	I _{SC}	I ₄₃	V _{OC}
1	97	44	0.496	117	46	0.516
2	97	50	0.514	124	56	0.521
3	87	29	0.490	101	39	0.515
4	91	50	0.516	128	59	0.525
5	97	48	0.516	130	64	0.525
6	100	52	0.509	121	76	0.513
7	96	39	0.489	112	40	0.527
8	93	37	0.496	117	54	0.541
9	98	53	0.522	127	58	0.523
10	94	32	0.492	116	52	0.529
11	97	50	0.518	124	52	0.513
12	100	47	0.517	124	52	0.517
13	96	25	0.467	124	54	0.514
Avg I_{SC} before CeO₂ = 95.6 ma Avg I_{SC} after CeO₂ = 120.5 ma Avg V_{OC} before CeO₂ = 0.503 v Avg V_{OC} after CeO₂ = 0.521 v						

SECTION 3

CONCLUSIONS AND FUTURE PLANS

Aluminum contacts for solar cells have been fabricated and the results indicate that high efficiency cells can be fabricated by this technique. The cells have shown superior results in a temperature-humidity environment when compared to Ti-Ag.

Work will continue on Al contacted cells and the requirement for less than 2.1 ma reduction from I_{SC} at 0.40 v is expected to be met.

The work on Ni contacted cells will continue as well as the Ni and Al combination. In addition, Cu contacted cells will be fabricated in the next quarter.

SECTION 4
NEW TECHNOLOGY

No reportable items of new technology have been identified on this contract to date, 10 April 1968.