NASA TECHNICAL MEMORANDUM

NASA TM X-1687

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GPO PRICE $ ______

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Hard copy (HC) ______

Microfiche (MF) ______

ff 653 July 65

FACILITY FORM 602

(ACCESSION NUMBER) ______ (THRU) ______

(PAGES) ______ (CODE) /

(NASA CR OR TMX OR AD NUMBER) ______ (CATEGORY) ______

COMPARISON BETWEEN CEMENTED AND SOLDERED COVER GLASS FOR SILICON SOLAR CELLS

by Jacob D. Broder

Lewis Research Center

Cleveland, Ohio

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • NOVEMBER 1968

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ABSTRACT

A comparison was made of the spectral response of cemented and soldered cover glass on a current commercial silicon solar cell. Cover glass transmission factors were determined in the range of 0.4 to 0.95 micron with a filter-wheel solar simulator. Soldered and cemented cell short circuit current spectral response was calculated as a function of the effectiveness of the cover-glass radiation protection, for a bombardment dose of 10^{16} 1-MeV electrons per square centimeter.

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SUMMARY

Silicon solar cells are subject to particulate radiation when flown on Earth-orbit missions. Cover glasses, cemented to the cell, are used to provide protection from radiation damage. Since the cement darkens when exposed to ultraviolet radiation, an ultraviolet filter is placed on the glass to protect the cement. However, accompanying the use of the filter is a reduction in the blue response of the cell. An alternate method of affixing a protective glass to the solar cell is to solder the glass directly to the metallic grids of the cell, which eliminates both cement and filter.

To compare the spectral response of soldered and cemented cells the transmission factors for the cover glasses were determined in the spectral range from 0.4 to 0.95 micron, by using a filter-wheel solar simulator. These factors were used to calculate solar-cell response. For unbombarded cells or for cells with cover glass that provides 100-percent-effective radiation protection there is a 5 percent higher calculated short-circuit current response for the soldered glass than for the cemented glass on a typical commercial cell. With a cover glass that is 50 percent effective in reducing the radiation damage of 10^{16} 1-MeV electrons per square centimeter, the improvement is 6 percent.

INTRODUCTION

Radiation damage is one of the problems encountered in the use of silicon solar cells for Earth-orbit missions. Several methods can be applied to minimize the damage due to high-energy electron and proton bombardment. One approach is to shield the solar cell by means of a transparent cover, such as a quartz-glass window. Another method is to increase the blue response of the cell, since the response to the 0.4 to 0.5 micron range of the spectrum is independent of radiation damage (ref. 1). The present method of mounting the cover glass on the cell relies on the use of an adhesive which degrades on exposure to ultraviolet radiation. To protect the adhesive, an ultraviolet filter is deposited on the cover glass. An accompanying feature of the ultraviolet filter is a reduction in blue light transmission to the cell (ref. 2). In order to retain solar-cell blue response another method of attachment would be desirable. A method presently being investigated at this laboratory involves soldering the cover glass to the solar cell at the grid contacts, thereby eliminating the cement and the ultraviolet filter entirely.

In this report, for the purpose of evaluating the gain in response of cells with soldered covers, a comparison is made of the calculated spectral response of a state-of-the-art commercial silicon solar cell with cemented and with soldered covers. The spectral response of the uncovered solar cell and the absorption of the cover glass were determined by means of a filter-wheel solar simulator. Additionally, the spectral response for a high-blue-response experimental cell with cemented and soldered covers was estimated.

ANALYSIS

The evaluation of cover-glass - cell combinations is based on the comparison of the transmission factors of the cover-glass systems. The transmission factor is defined as the ratio of the short-circuit current of the solar cell with a cover glass to the short-circuit current of the uncovered cell. To obtain the solar-cell short-circuit current output, the Lewis filter-wheel solar simulator (ref. 3) is used, in which the spectral response in the wavelength region from 0.4 to 0.95 micron is measured. The performance of any solar cell in combination with any cover-glass system can then be calculated by multiplying the solar-cell response by the appropriate cover-glass factors.

Solar Cell and Covers

A current commercial solar cell with an antireflection coating is used as the basis for comparison of the cemented and soldered cover glasses. An exploded view of the cell, adhesive, and cover glass is shown in figure 1. The adhesive is Furane 15-E epoxy cement. The cover glass is drawn microsheet (Corning 0211), 6 mils (152.4 μm) thick. The cemented cover glass is coated on the top with an antireflection coating and on the bottom with an ultraviolet filter, designated herein as type 1 coating.

Construction of the soldered cover-glass system is shown in figure 2. The cover glass has a magnesium fluoride antireflection coating on both sides, designated herein as type 2 coating. Soldered cover glasses have been prepared by evaporation of ceriumsilver contacts on the glasses through the same mask used to put contacts on silicon solar cells (ref. 4). This ensures the matching of the grid patterns when solder-dipped contacted glass and cell are placed together and heated.

Spectral Response Measurements

The effect of a type 2 coating cover glass on the response of the cell was measured by placing the cover glass without the grid pattern on the cell, holding it down at an edge with tape, and measuring the spectral response of the combination. The spectral response of the uncovered cell was also measured. Shown in table I are the transmission factors for type 1 and 2 coatings on 0211 microsheet glass. Factors for 0211 microsheet glass with type 1 coating and Furane 15-E epoxy adhesive were calculated from the data of reference 2.

RESULTS AND DISCUSSION

The comparison between the cover-glass systems, before irradiation, is shown in table II. The results shown for the cemented microsheet can also be expected to hold for the currently used, 6-mil- (15.4-μm-) thick, quartz (Corning 7940) cover glass with Dow XR63488 silicone cement, since in the region from 0.6 to 0.95 micron the response appears to be independent of the type of glass and cement used. Losses in the cemented configuration may be ascribed almost entirely to reduction in blue-light transmission by the ultraviolet filter, as indicated in the lower currents obtained in the 0.4- to 0.5-micron range. No losses due to ultraviolet degradation of the cement are included, since the ultraviolet filter has been found to be effective in preventing this type of degradation (private communication from W. Cherry of Goddard Space Flight Center). With the cover glass soldered to a silicon solar cell, the short-circuit current response is calculated to be about 3.6 milliamperes, or 5 percent, higher than that of the cemented configuration.

Examining the case of a cell exposed to high-energy radiation, a cell with no protection will suffer about 27 percent degradation of total short-circuit current when subject to bombardment by a total flux of 10^{16} 1-MeV electrons per square centimeter (equivalent to about 3 years in a radiation belt) (ref. 1). All of the current loss in this case is in the 0.6- to 0.95-micron region of the spectral response and represents 34 percent of the current in this region. If the cover glass only succeeds in reducing the radiation damage to one half of the unprotected case, the soldered cell will have a 6-percent current advantage over the cemented cell. A plot of response advantage of soldered over cemented cells against the effectiveness of radiation protection is given in figure 3.

Applying the same cover-glass analysis to an experimental cell with a much higher blue (0.4 to 0.5 μm) response (ref. 1), but with about the same total response as a commercial cell, indicates that this cell with a soldered cover glass would have about 7 percent better response than with a cemented cover glass. With a cover glass that is 50-percent effective, the advantage is 8 percent. The response advantage plot for the high-blue cell is shown in figure 3.

SUMMARY OF RESULTS

A comparison of silicon solar cells with soldered and cemented glass covers indicates that the ultraviolet filter coating on the cemented cover glasses (to protect the cement from ultraviolet degradation) lowers cell current response significantly in the 0.4- to 0.5-micron range. Since an ultraviolet filter coating is not needed for soldered covers, the soldered covers produce the following estimated short-circuit current advantages:

1. A 5 percent higher total response with present commercial silicon solar cells
2. A 7 percent higher total response with an experimental high-blue-response cell
3. A 6 percent higher response with the commercial cell, after bombardment by 10^{16} 1-MeV electrons per square centimeter with a cover glass that offers 50 percent radiation protection
4. An 8 percent higher response with an experimental high-blue-response cell, for the condition of item 3 above

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, May 27, 1968,
120-33-01-09-22.

REFERENCES

1. Mandelkorn, Joseph: Improved N on P Silicon Solar Cells. Proceedings of the Nineteenth Annual Power Sources Conference. PSC Publ. Committee, May 1965, pp. 174-177.

2. Campbell, F. J.; and Lambert, R. J.: Effects of Shielding on Electron Damage to Solar Cells. Proceedings of the 4th Photovoltaic Specialists Conference, Vol. 1. Rep. PIC-SOL-209/5, Pennsylvania Univ. (NASA CR 58680), Aug. 1964, fig. 5.

3. Mandelkorn, Joseph; Broder, Jacob D.; and Ulman, Robert P.: Filter-Wheel Solar Simulator. NASA TN D-2562, 1965.

4. Mandelkorn, Joseph: A New Glass Covered Silicon Solar Cell for Space Application. Paper presented at the 20th Annual Power Sources Conference, U.S. Army Electronic Command, Fort Monmouth, N.J., May 24-26, 1966.

TABLE I. - TRANSMISSION FACTORS OF SOLAR-CELL COVERS[a]

Wavelength, μm	Transmission factor	
	For type 2 coating on soldered cover glass (b)	For type 1 coating on cemented cover glass (c)
0.95	0.98	0.97
.9	.97	.99
.8	.97	.94
.7	.98	.93
.6	.98	.98
.5	.97	.92
.45	.96	.75
.4	.95	.50

[a]Cover glass is Corning 0211 drawn microsheet.
[b]Data calculated from filter-wheel simulator data.
[c]Data from reference 2.

TABLE II. - SOLAR-CELL SPECTRAL RESPONSE

Wave-length, μm	Measured response of uncovered cell, mA	Calculated response of cell with type 2 coating on soldered cover glass,[a] mA	Calculated response of cell with type 1 coating on cemented cover glass,[a] mA
0.95	5.43	5.3	5.3
.9	12.13	11.8	12.0
.8	13.90	13.5	13.1
.7	13.82	13.5	12.9
.6	11.05	10.8	10.8
.5	6.40	6.2	5.9
.45	4.31	4.1	3.2
.4	3.55	3.4	1.8
Total response	70.59	68.6	65.0

[a]Cover glass is Corning 0211 drawn microsheet.

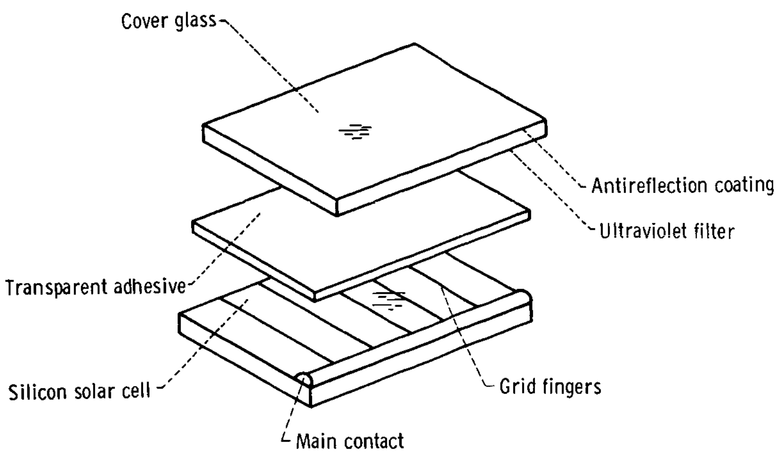

Figure 1. - Cemented-cover-glass cell.

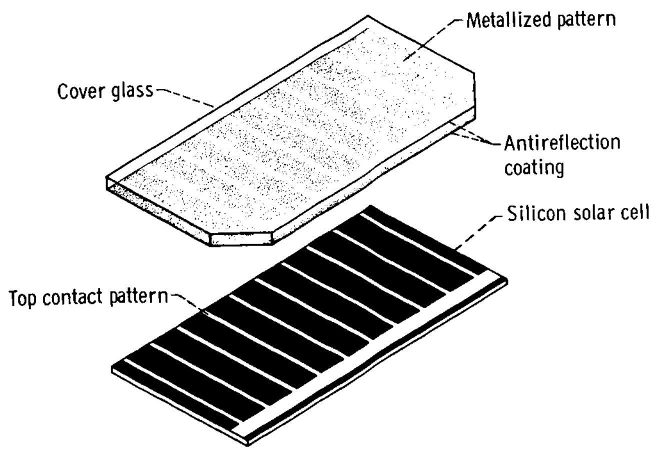

Figure 2. - Soldered-cover-glass cell.

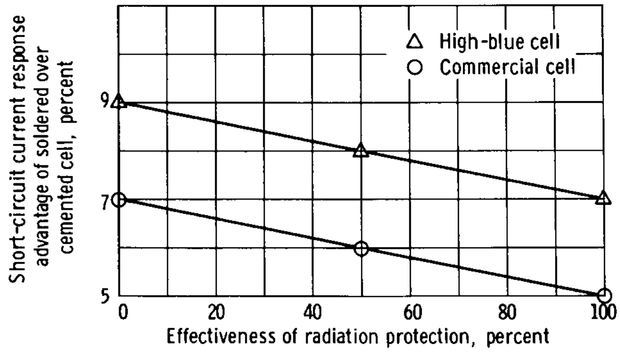

Figure 3. - Current response as function of radiation protection.

NASA-Langley, 1968 — 3 E-4486