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Cadmium Stannate Selective Optical Films for Solar Energy Applications

NSF Grant AER 73-07957

April 1, 1975 - March 31, 1976

$160,000

Author and Principal Investigator:

G. Haacke

American Cyanamid Company

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Abstract

Most of the work discussed in this report has been performed during the last three months of the reporting period after receipt of a renewal grant. At Cyanamid efforts concentrated on reducing the electrical sheet resistance of sputtered cadmium stannate films, installing and testing equipment for spray coating experiments, and sputter deposition of thin cadmium sulfide layers onto cadmium stannate electrodes. In addition, ahead of schedule, single crystal silicon wafers were coated with cadmium stannate. The University of Delaware continued development of the backwall CdS solar cell.

Earlier attempts at sputtering cadmium stannate films with sheet resistances R_s smaller than 1 ohm/square failed because, for thick films, R_s did not decrease proportionally to increasing film thickness. It has now been found that modified post-deposition heat treatment alleviates this problem and 0.7 ohm/square films have been prepared. Visible optical transmission values of these samples reach 80-85%. Approximately 5% of the transmission loss is attributable to a slight haziness which is expected to disappear after refinement of the heat treating procedure.

During the first phase of the spray coating development different spray nozzles were evaluated and a sonic atomizer selected for the current experiments. A substrate heater has been designed and installed which facilitates fast sample heat-up and a wide-range temperature control. Coatings properties achieved during last year's

feasibility study (~ 100 ohm/square) can now be reproduced at much lower substrate temperatures (400°C vs. 850°C).

In an effort to reduce cadmium requirements and optical absorption of backwall CdS cells thin cadmium sulfide layers (2-5 μ) were sputtered onto Cd_2SnO_4 films. A highly oriented, columnar CdS crystal growth was induced by the Cd_2SnO_4 substrates. However, micropinholes along the grain boundaries caused short circuits and low cell efficiencies. Attempts to eliminate these pinholes were only partially successful. Additional work is planned and will include surface treatment of the Cd_2SnO_4 electrodes before CdS deposition.

At the request of Innotech, Inc. n-type and p-type single crystal Si wafers were coated with Cd_2SnO_4. These experiments proved that low temperature Cd_2SnO_4 deposition (300°C) onto Si is possible. Ohmic contacts formed on n-type Si. The Cd_2SnO_4 sheet resistances were twice as high as expected indicating lower conductivities and/or the presence of a resistive interlayer.

Work at the Institute of Energy Conversion led to backwall efficiencies higher than 5% in Cd_2SnO_4/CdS/Cu_2S cells. This improvement has been achieved by advanced cell lamination techniques and lower series resistances. Heat treatment experiments at 250°C indicate that degradation in cells with Cd_2SnO_4 substrates is less severe than in standard metal substrate cells.

The following activities are planned for the next six months:

1. increase optical transmission of low sheet resistance Cd_2SnO_4 films,
2. reduce sheet resistance of spray coated Cd_2SnO_4 films to 10 ohm/square region,
3. raise backwall efficiency of Cd_2SnO_4/CdS/Cu_2S cells to 6% or higher,
4. investigate deposition of Cd_2SnO_4 onto silicon wafers.

CADMIUM STANNATE
SELECTIVE OPTICAL FILMS FOR SOLAR ENERGY APPLICATIONS

NSF GRANT AER 73-07957

AMERICAN CYANAMID COMPANY
UNIVERSITY OF DELAWARE

GRANT PERIOD: APRIL 1, 1975 – MARCH 31, 1976

AWARD: $ 160,000

PRINCIPAL INVESTIGATOR: G. HAACKE

PROJECT OBJECTIVES

- PREPARE HIGHLY TRANSPARENT, ELECTRICALLY CONDUCTING THIN COATINGS OF CADMIUM STANNATE
- DEVELOP SPRAY TECHNOLOGY FOR FABRICATION OF CADMIUM STANNATE FILMS ON TRANSPARENT SUBSTRATES
- EVALUATE PERFORMANCE OF CADMIUM STANNATE BACKWALL ELECTRODES IN CdS SOLAR CELLS
- DEPOSIT CADMIUM STANNATE FILMS ONTO SILICON SUBSTRATES AND ASSES POTENTIAL FOR FRONT ELECTRODES IN SILICON SOLAR CELLS

PLANNED ACTIVITY TO DATE

- OPTIMIZE SPUTTER CONDITIONS FOR PREPARATION OF LOW SHEET RESISTANCE (1ohm/square) CADMIUM STANNATE FILMS

- INSTALL AND TEST EQUIPMENT FOR SPRAY DEPOSITION OF CADMIUM STANNATE COATINGS

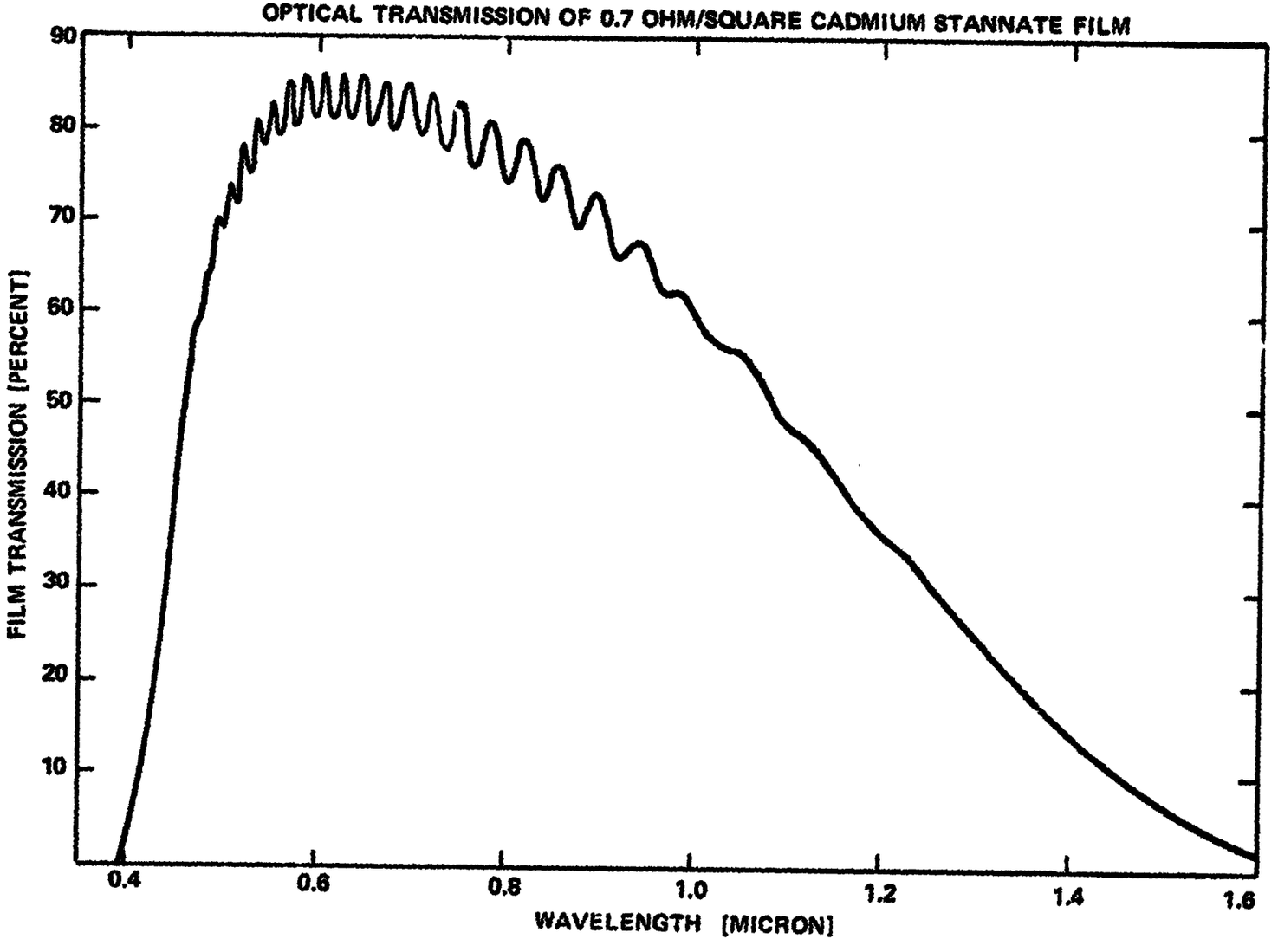
- COAT THIN CADMIUM SULFIDE LAYERS (2-5 microns) ONTO CADMIUM STANNATE ELECTRODES BY SPUTTERING

- INCREASE BACKWALL EFFICIENCY OF Cd_2SnO_4/CdS/Cu_2S SOLAR CELLS

LOW SHEET RESISTANCE FILMS
PROGRESS TO DATE

- MODIFIED POST-DEPOSITION HEAT TREATMENT LOWERS ELECTRICAL SHEET RESISTANCE

- LOWEST SHEET RESISTANCE TO DATE:
  0.[illegible] OHM/SQUARE


OPTICAL TRANSMISSION OF 0.7 OHM/SQUARE CADMIUM STANNATE FILM
FILM TRANSMISSION [PERCENT]
90
80
70
60
50
40
30
20
10
0.4
0.6
0.8
1.0
1.2
1.4
1.6
WAVELENGTH [MICRON]

SPRAY COATING DEVELOPMENT
PROGRESS TO DATE

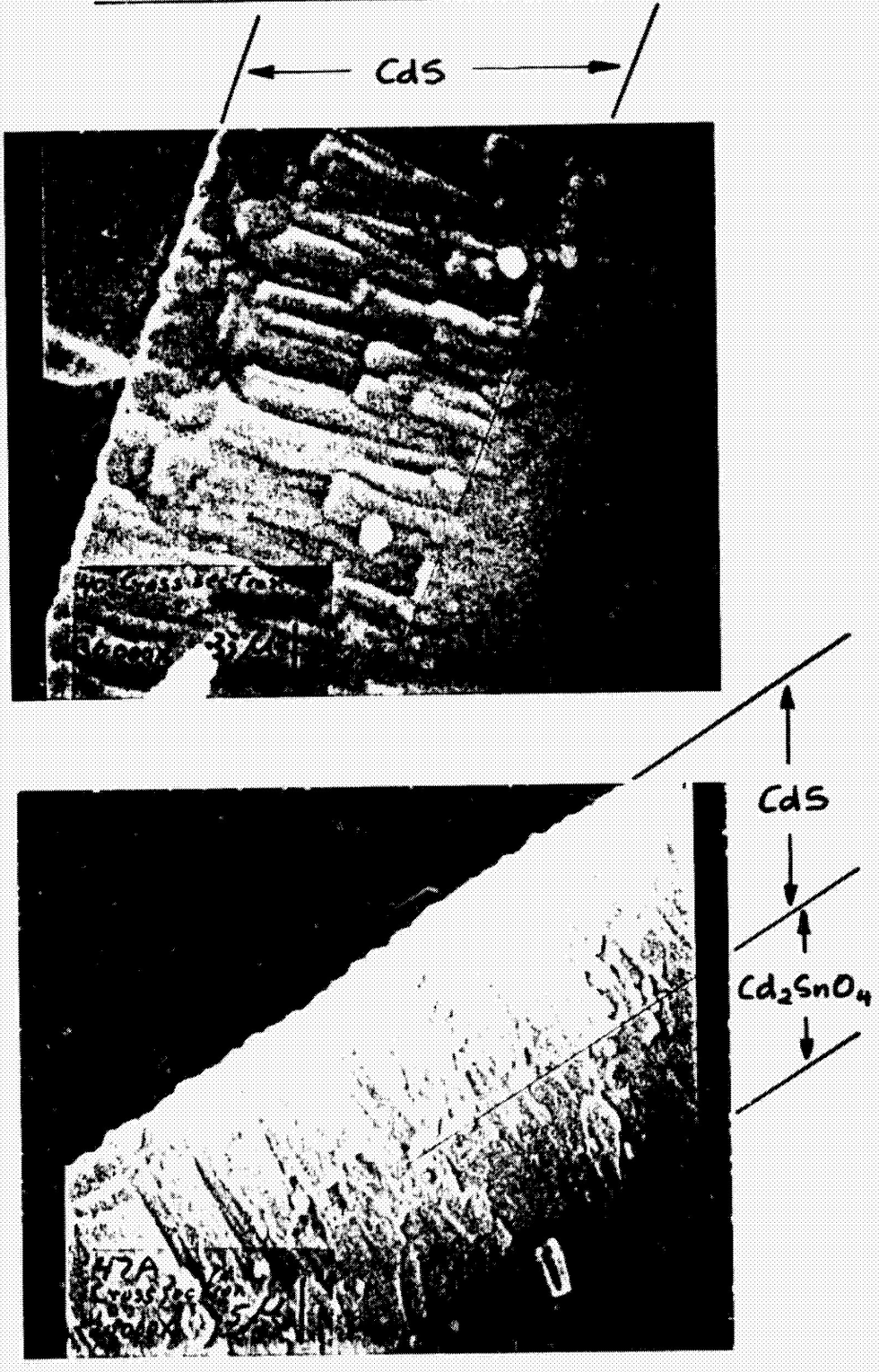
- DIFFERENT SPRAY NOZZLES EVALUATED
- CONTROLLED SUBSTRATE HEATER DEVELOPED AND INSTALLED
- PREVIOUS FILM PROPERTIES REPRODUCED AT LOWER SUBSTRATE TEMPERATURES (400°C *vs* 850°C)

SPUTTERED THIN CdS LAYERS
PROGRESS TO DATE

- HIGHLY ORIENTED CdS LAYERS GROW ON Cd_2SnO_4 SUBSTRATES

- DEPOSITION CONDITIONS ESTABLISHED WHICH MINIMIZE NUMBER OF MICRO-PINHOLES

CROSS SECTIONS OF CdS FILMS SPUTTERED ONTO Cd_2SnO_4 SUBSTRATES

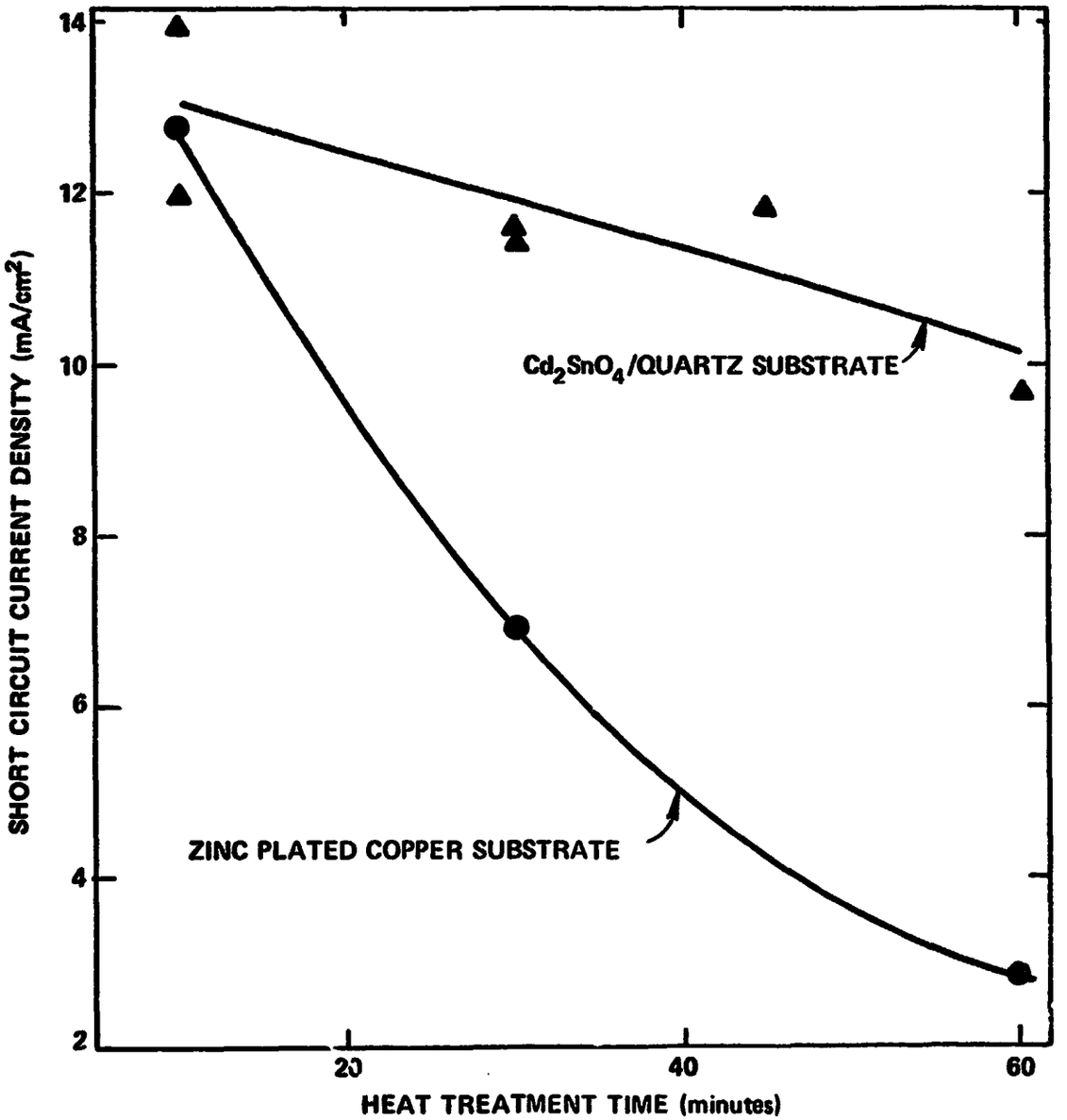


BACKWALL CdS SOLAR CELL DEVELOPMENT
PROGRESS TO DATE

- BACKWALL EFFICIENCIES EXCEED 5%

- HIGH TEMPERATURE (250°C) CELL DEGRADATION APPEARS TO BE LESS SEVERE FOR BACKWALL CELLS

DEGRADATION OF SHORT CIRCUIT CURRENT DENSITY
WITH HEAT TREATMENT TIME (AIR - 250°C) FOR
METAL AND QUARTZ SUBSTRATE CELLS



SUMMARY OF KEY RESULTS

- CADMIUM STANNATE ELECTRODES WITH SHEET RESISTANCES BELOW 1 OHM/SQUARE CAN BE PREPARED

- SPRAY COATING TECHNIQUE MODIFIED FOR LOW SUBSTRATE TEMPERATURE DEPOSITION

- BACKWALL EFFICIENCY OF $Cd_2SnO_4/CdS/Cu_2S$ SOLAR CELLS EXCEEDS 5%

- LOW TEMPERATURE COATING OF SILICON WAFERS WITH CADMIUM STANNATE POSSIBLE

MAJOR PROBLEMS

- HIGH ELECTRICAL SHEET RESISTANCE OF SPRAY COATED CADMIUM STANNATE FILMS

- LOW ELECTRICAL CONDUCTIVITY OF CADMIUM STANNATE FILMS ON SILICON SUBSTRATES

PLANNED ACTIVITY FOR NEXT SIX MONTHS

- REDUCE OPTICAL ABSORPTION OF LOW SHEET RESISTANCE CADMIUM STANNATE FILMS
- REDUCE ELECTRICAL SHEET RESISTANCE OF SPRAY COATED CADMIUM STANNATE FILMS
- IMPROVE BACKWALL RESPONSE OF CdS SOLAR CELLS
- INVESTIGATE DEPOSITION OF CADMIUM STANNATE ONTO SILICON WAFERS

ABSTRACT

Title Page

(a) Title of Paper: Thin Film Ternary Compound Solar Cells

(b) Title of Project: Ternary Compound Thin Film Solar Cells

(c) Grant Number: Pending

(d) Period of Grant: 1 September, 1975 - 31 August, 1976.

(e) Value: $34,929 (requested)

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(i) Paper presented at National Solar Photovoltaic Program Review Meeting
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