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Final Report

for

Cadmium Sulfide Photoconductor Cells

Sept 1964 to Sept 1965

Contract No. NAS5-5884

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Prepared by

E. Hill

Crystal-Solid State Division

The Harshaw Chemical Company

1945 E. 97th Street

Cleveland, Ohio

for

Goddard Space Flight Center

Greenbelt, Maryland

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SUMMARY

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Two general types of photoconductors have been made, each of which can meet the requirements of the contract. One type uses a film of CdS deposited onto glass with light incident to the glass surface. A second uses a film of CdS deposited onto a metal foil with a high transparency metal grid overlaying the CdS. This is packaged in clear plastic with the light passing through the plastic and screen openings to the CdS. The second method is preferred for weight reduction and mechanical integrity. Samples of each type have been prepared, tested, and submitted. It is felt that the cell on metal foil is sufficiently flexible in design to meet any future requirements for large area, low density detectors.

Butler

INTRODUCTION

The goal of this program is the development of a light weight large area photoconductor which is stable at sea level environment for periods of the order of a month. In operation, the cell will be covered with an opaque layer of aluminized plastic and the sensitivity of the device is to be such that in direct sunlight, a detectable change in cell resistance shall occur when the film is pierced to form a one mil diameter hole.

METHODS OF APPROACH

Two general cell configurations can be used, and these are shown in Figures 1 and 2. In Figure 1, the photoconductor is fabricated on a piece of glass which has been coated with a conducting layer of tin oxide. CdS is deposited onto the tin oxide, treated, and a metal layer deposited onto the CdS for an electrode. The tin oxide and metal layer are the two terminals. A layer of SiO is then deposited over the metal to seal the cell from the atmosphere. In Figure 2, the CdS layer is deposited onto a sheet of molybdenum foil and heat treated. A very fine screen grid of gold is then placed onto the CdS and the whole cell laminated between two sheets of Kel-F plastic. Electrical connections are made to the molybdenum and gold foil by silver foil tabs extending out past the plastic film.

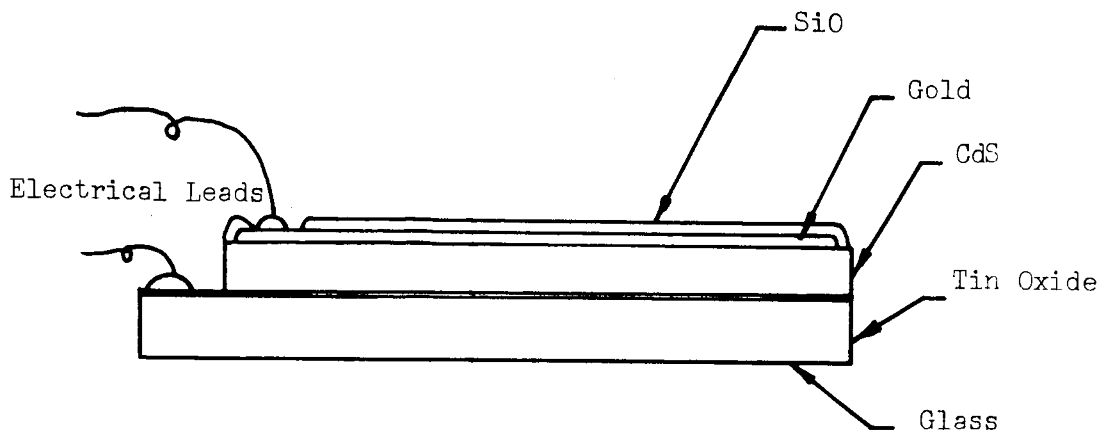

Figure 1

Photoconductor built on glass base

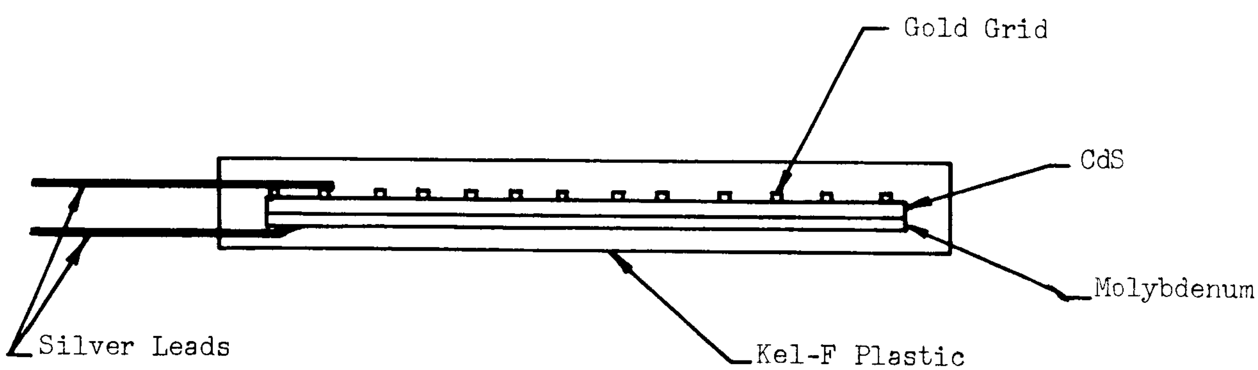

Figure 2

Photoconductor built on molybdenum foil

In principle, either of these approaches will produce a device to satisfy the requirements. The choice is to be made on the basis of mechanical and material considerations. To determine which was the more feasible method, cells were made from both processes.

CONSTRUCTION

Specifically, the construction processes are as follows. For the glass cell, pyrex is coated with a conducting layer of tin oxide on one surface. This is accomplished by the well known pyrolysis of $SnCl_4$ in air at about 500°C on glass. The resulting layer has a resistance of about 100 ohms per square and a visible transmission of about 80%. A water suspension is made from 1 part CdS powder, 10% by weight $CdCl_2 \cdot 2\frac{1}{2}H_2O$ and 0.1% CuCl. The CdS powder is General Electric Electronic Chemical Cadmium Sulfide 118-8-2 with particle size in the range of 1 to 2 micron diameter. All other chemicals are reagent grade.

The glass substrate is heated to 100°C and the suspension sprayed onto the glass with an air brush. The material is applied in layers with enough pause between layers for the water to evaporate. The sprayed layer is never wet enough to run or level itself. A layer about 100 microns total thickness is applied which should result in hole-free structure. The entire device is then heated to 600°C in air for 5 minutes and cooled. To eliminate shorts through pinholes in the CdS layer, silicone varnish is squeegeed over the sintered CdS. A stripe of tin oxide on glass is left exposed for one electrical contact and a 1000 Å layer of gold evaporated onto the CdS for the other contact. To protect the cell from the atmosphere, 3000 Å of SiO are evaporated onto the CdS-gold surface with one spot masked for the electrode contact.

The procedure for making the metal backed cell is quite similar. The substrate is a sheet of molybdenum 2 mils thick which has been cleaned and etched. The molybdenum is 2 mils thick and is purchased from Fansteel Corporation. For cleaning, the metal is scrubbed in a hot solution of trisodium phosphate to remove any oil. It is then etched in 1:1 HNO_3 to water solution for 3 to 5 seconds, rinsed in cold running water, and quickly dipped into concentrated HCl for one minute and again rinsed in cold running water. The chemicals are reagent grade. The water suspension of CdS, $CdCl_2$ and CuCl described previously is sprayed onto the molybdenum heated to 100°C. The same air brush technique is used again to obtain the 100 micron thick layer. Care is taken to insure that the sprayed layer does not flow, since this will cause the more soluble chemicals to concentrate in the area which dries last. The substrate and CdS are then heated in air to 600°C for 5 minutes. After cooling, the metal mesh is laid on the CdS surface and silver foil tabs attached to the mesh and molybdenum. The entire structure is then sandwiched between two layers of 5 mil thick KEL-F plastic.

This secures the electrical connections and seals the cell from the atmosphere. For more stringent environmental specifications, the plastic can be made thicker. The metal mesh electrode is made of gold and has a square mesh configuration of 1 mil by 1 mil wires with 85% opening. It is made by an electroforming process by the Buckbee Mears Corporation.

RESULTS

Cells were fabricated by both processes and treated. The first prototype delivered was made on a 1 x 3 inch pyrex plate 1/16" thick. The sensitivity was satisfactory and no detectable degradation was observed due to atmospheric humidity. Since the ultimate goal was a device about 1/32" thick, later efforts were concentrated on the metal backed cell. This was necessary since the process for forming tin oxide on glass generates high stresses in the glass. Our experience has been that a 30 mil sheet of pyrex 2 to 3 inches in diameter is likely to crack after the conductive coating is applied. Commercial suppliers do not offer tin oxide coated pyrex in thicknesses less than 1/16 inch.

The metal backed cells also produced satisfactory sensitivites and no detectable atmospheric degradation. The mass of a 2 inch diameter cell is 3 grams, or a surface density of about 0.15 grams/cm^2. The contemplated configuration of a

$4\frac{1}{2}$ inch diameter disc would then have a mass of about 15 grams. The sensitivity was measured as follows. The cell was covered except for a 1 cm^2 area on which light was incident. A tungsten lamp with a filament temperature of 2850°K provided the illumination. The intensity was varied by inserting 1/3 transmission screens in the beam. The intensity was measured by a calibrated silicon solar cell. All three photoconductors gave essentially identical results and the performance of one is shown in Figure 3. The abscissa is intensity in equivalent sea level runs and the ordinate is the resistance of the cell with 3 volts bias. The slope of 0.83 decades change in resistance per decade change of intensity is that observed in commercial photoconductors. This test is conservative in that the change in resistance is larger as the same total light flux is concentrated in a smaller area. Also, the CdS is more sensitive in the blue end of the spectrum and the silicon cell is uniformly sensitive over the visible and near infrared regions. No detectable change in sensitivity was observed over the entire cell surface. The change in resistance of the cell is less than 75% over the range from 20°C to 60°C for light levels of 10^{-2} suns and less. Cycling from room temperature to 100°C produced no permanent change.

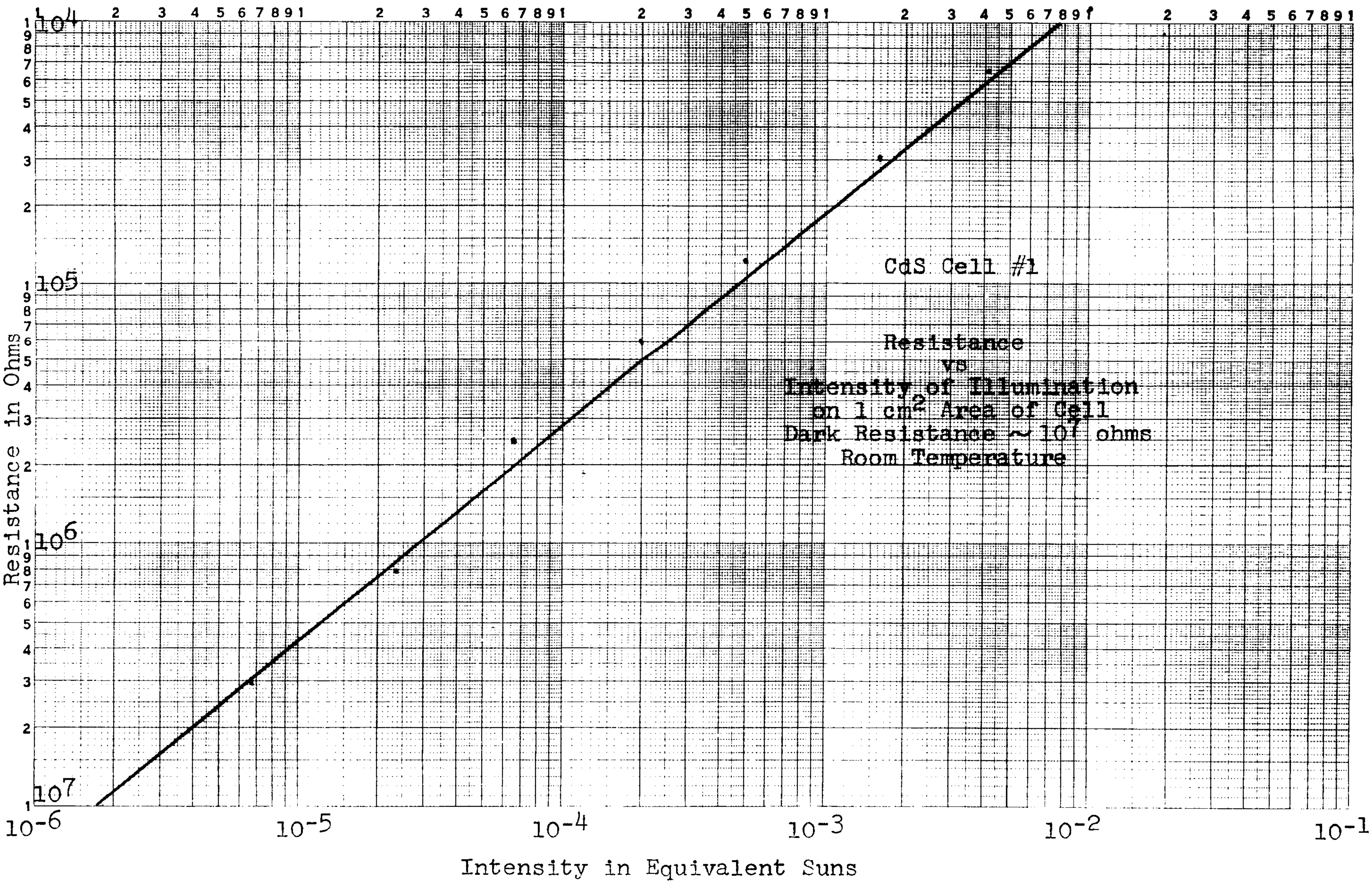
CdS Cell #1
Resistance
vs
Intensity of Illumination
on 1 cm2 Area of Cell
Dark Resistance ~ 107 ohms
Room Temperature
Resistance in Ohms
10^4
10^5
10^6
10^7
10^-6
10^-5
10^-4
10^-3
10^-2
10^-1
Intensity in Equivalent Suns

Figure 3