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REACTIVELY SPUTTERED THIN FILM PHOTOVOLTAIC DEVICES

GRANT APPLICATION

GRANT REQUESTED: ONE YEAR
265 K

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<u>Abstract</u>

REACTIVELY SPUTTERED THIN FILM PHOTOVOLTAIC DEVICES

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The overall objective of our project is to apply thin film sputtering techniques to form low cost thin film photovoltaic devices from materials with direct bandgap absorption characteristics used in existing single crystal solar cells. Also, the sputtering approach will be used to improve the performance characteristics of polycrystalline solar cells. Our immediate objective is to develop a stable, high efficiency thin film CdS-Cu_2S cell by reactive sputtering techniques.

There has been a small internally supported R&D effort at LLL on CdS-Cu_2S solar cells during the last two years. Over the last few months cells have been made by the RF reactive sputtering of Cu in a hydrogen-sulfide and argon atmosphere to form Cu_2S layers on thermally evaporated CdS films. A significant characteristic of this reactive sputtering approach is that there is no dependence on an ion exchange reaction with CdS to form the Cu_2S layer. The major findings so far are:

1. <u>Yield</u>

   We have made over 40 cells by this new process; each exhibited a photovoltaic effect. Even though the evaporation and sputtering parameters of CdS and Cu_2S, respectively, were varied intentionally to examine the latitudes of the new process, no adverse effect on yield has been observed.

2. <u>Efficiency</u>

   The best observed efficiency so far, measured in sunlight, was slightly over 4%. During the short investigation period our aim was primarily to learn more of the new heterojunction-formation process. There was little effort to optimize grid design and other parameters. We observed that open circuit voltage (OCV)

can be influenced by sputtering parameters related to formation of the Cu_2S. We measured OCV as high as 0.53 volts in some cells irradiated by 100 mW/cm^2 simulated sunlight. We expect even higher OCV when the process parameters are more thoroughly investigated.

3. Long Term Stability

Within this short period of testing, the new process cells were stable. Since our cells were not encapsulated no long term life test was conducted at this time. In comparison with the wet-dip process for p-n junction formation, the sputtering process minimizes the diffusion of Cu into CdS, and Cd into Cu_2S, and should result in a more stable interface. Also, the solid-state deposition of Cu_2S reduces the chance of formation of shunting paths along the grain boundaries, cracks and pin holes in the CdS substrate and, thus, prevents the start of open circuit degradation.

In the short run, we propose to exploit the additional degrees of freedom made available by the new process to optimize the efficiency of CdS cells. We plan to emphasize Cu_2S identification techniques and specification of the sputtering parameters needed to obtain stoichiometric chalcocite layers. Optimization of evaporated CdS films, including recrystallization and doping, would be a part of the effort. Also, accelerated life tests are planned to verify the cell's long term stability. In the long run, we would like to use reactive sputtering to form both films of the solar cell in a multiple station system, with a closer similarity to a production process. Finally, our sputtering approach would be used in parallel to do some fabrication of other compound semiconductor thin films, such as InP and $CuInSe_2$, for use with CdS.

We have proven in this study the feasibility of a reactively sputtered thin film CdS - Cu_2S solar cell. Identification of the reactively sputtered Cu_2S film was made by x-ray diffractometer and spectro-transmission measurements. Because of its simplicity, economical use of material, and high yield, the reactive sputtering process promises to be a low cost method for producing CdS - Cu_2S solar cells.

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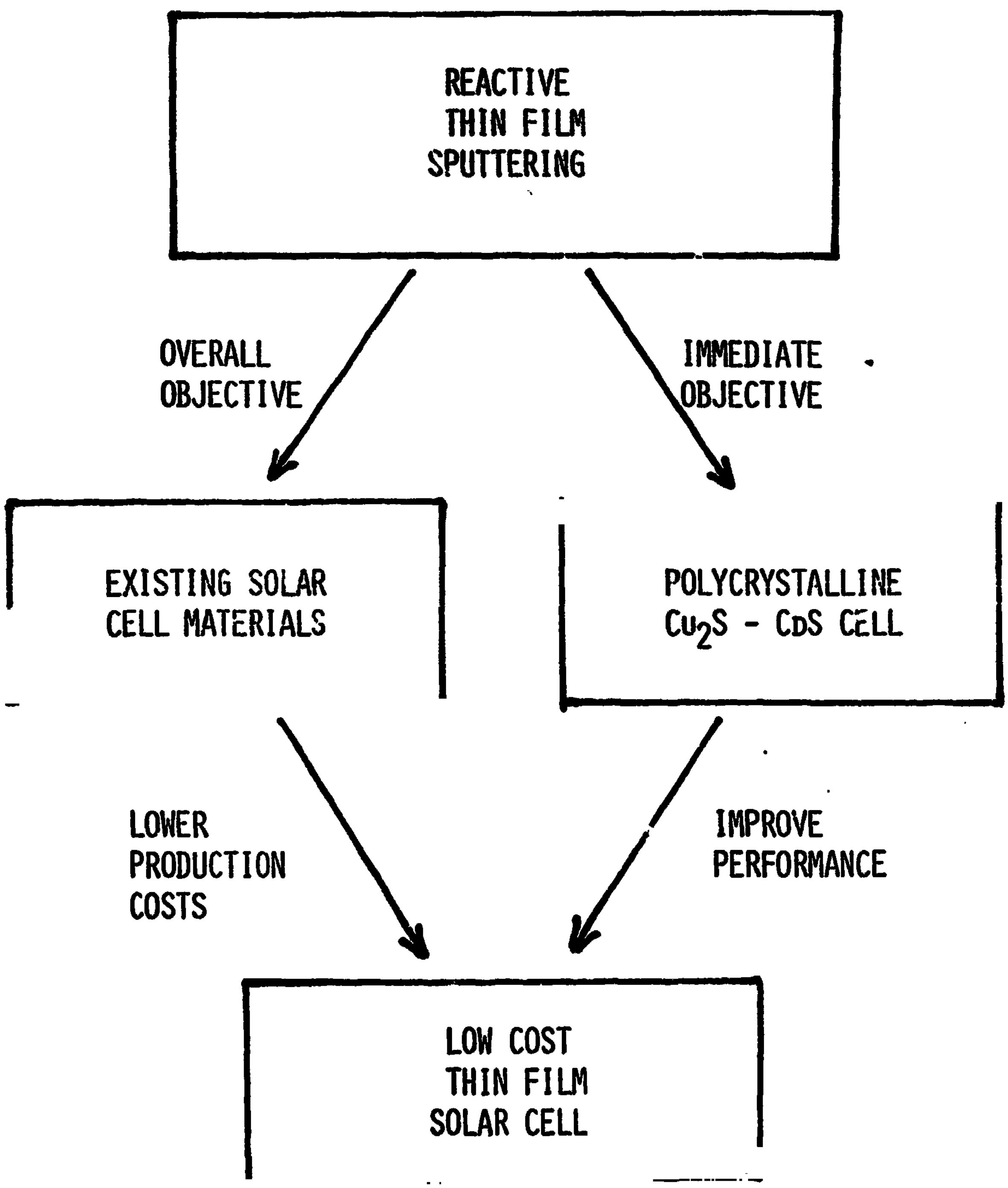
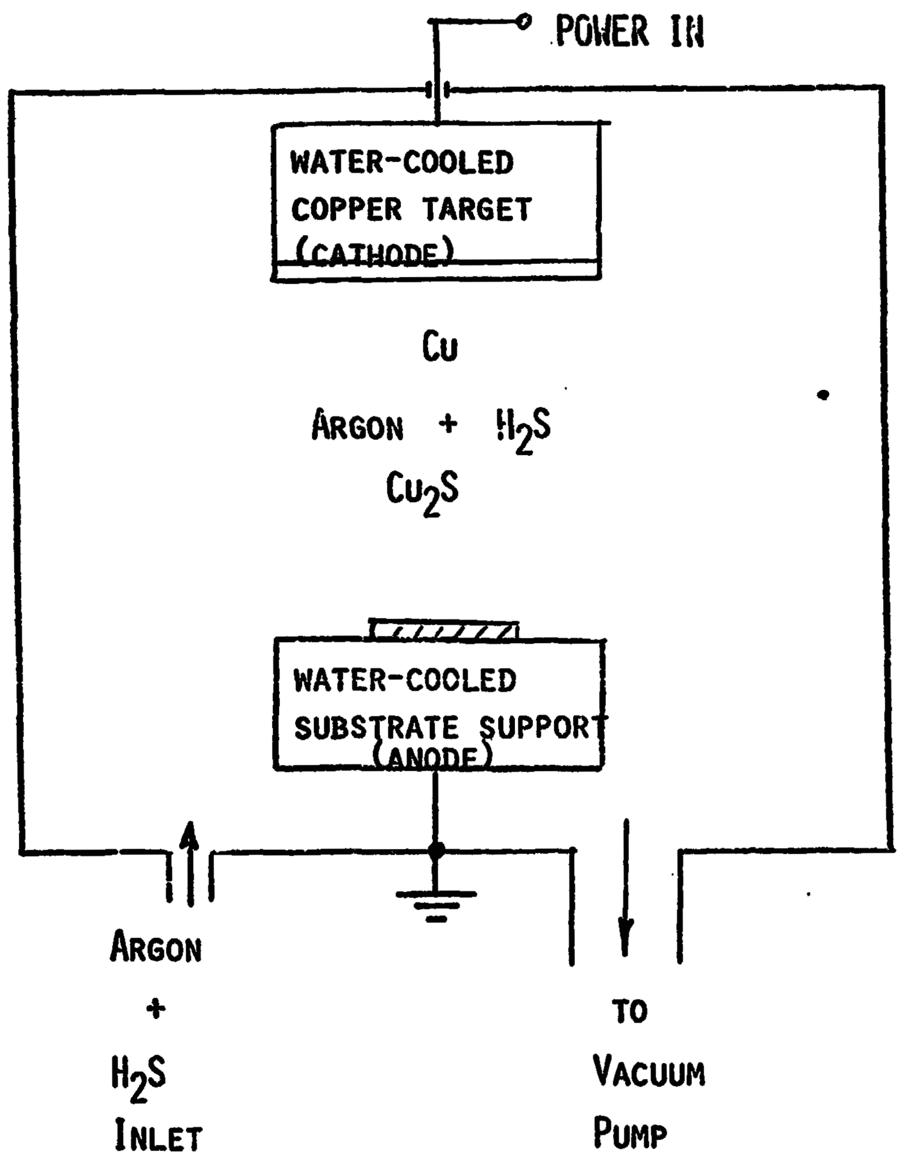
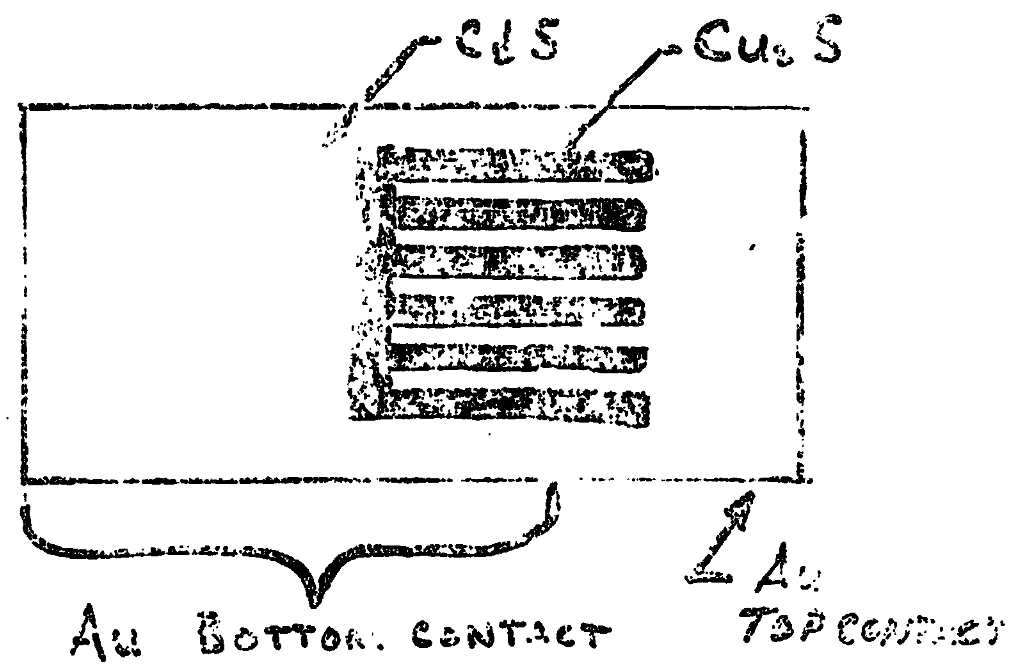
OBJECTIVE OF PROJECT



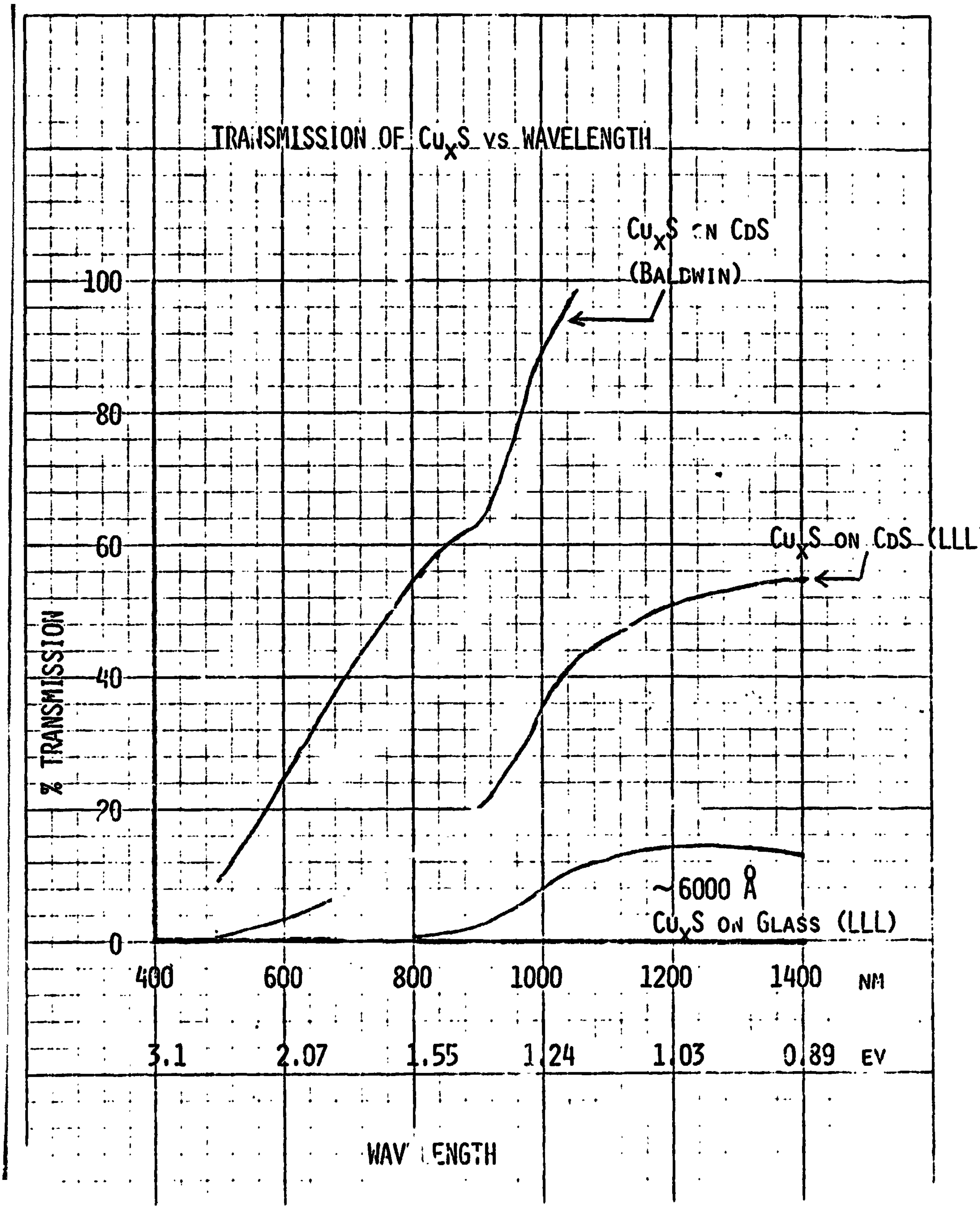
REACTIVE SPUTTERING GIVES COMPOUND FILMS FROM SIMPLE METALS

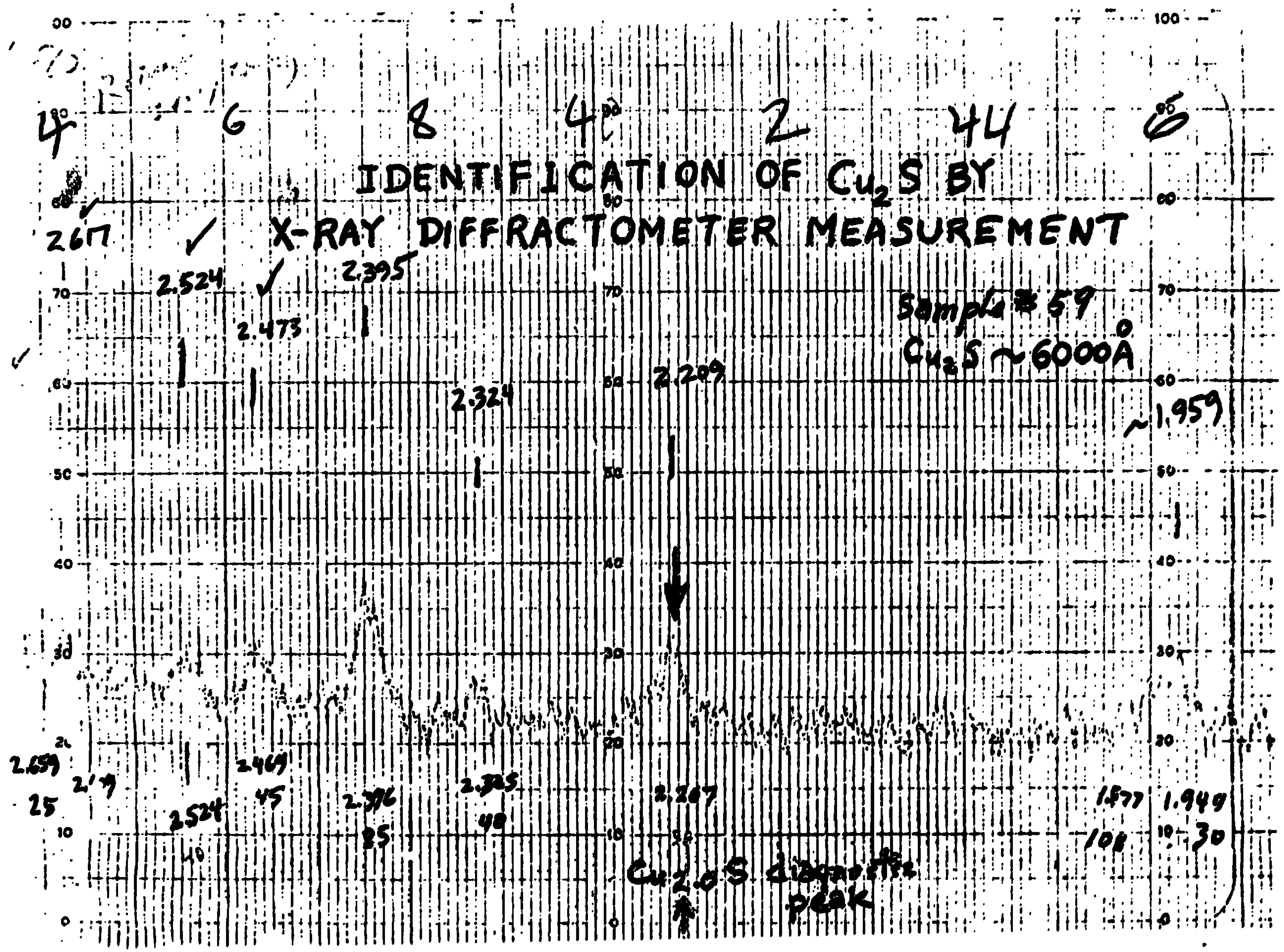


INITIAL SPUTTERED THIN FILM
CdS-Cu_2S CELL CONFIGURATION



1. Cu_2S THICKNESS ~ 800 Å - 3000 Å
2. CdS THICKNESS ~ 2-5 μ
3. BEST MEASURED EFF IN SUNLIGHT ~ 4%
4. 100% YIELD OVER 40 DEVICES MADE SO FAR


TRANSMISSION OF CuxS vs WAVELENGTH
CuxS ON CdS
(BALDWIN)
CuxS ON CdS (LLL
~6000 Å
CuxS ON GLASS (LLL)
% TRANSMISSION
100
80
60
40
20
0
400
600
800
1000
1200
1400
NM
3.1
2.07
1.55
1.24
1.03
0.89
EV
WAVELENGTH



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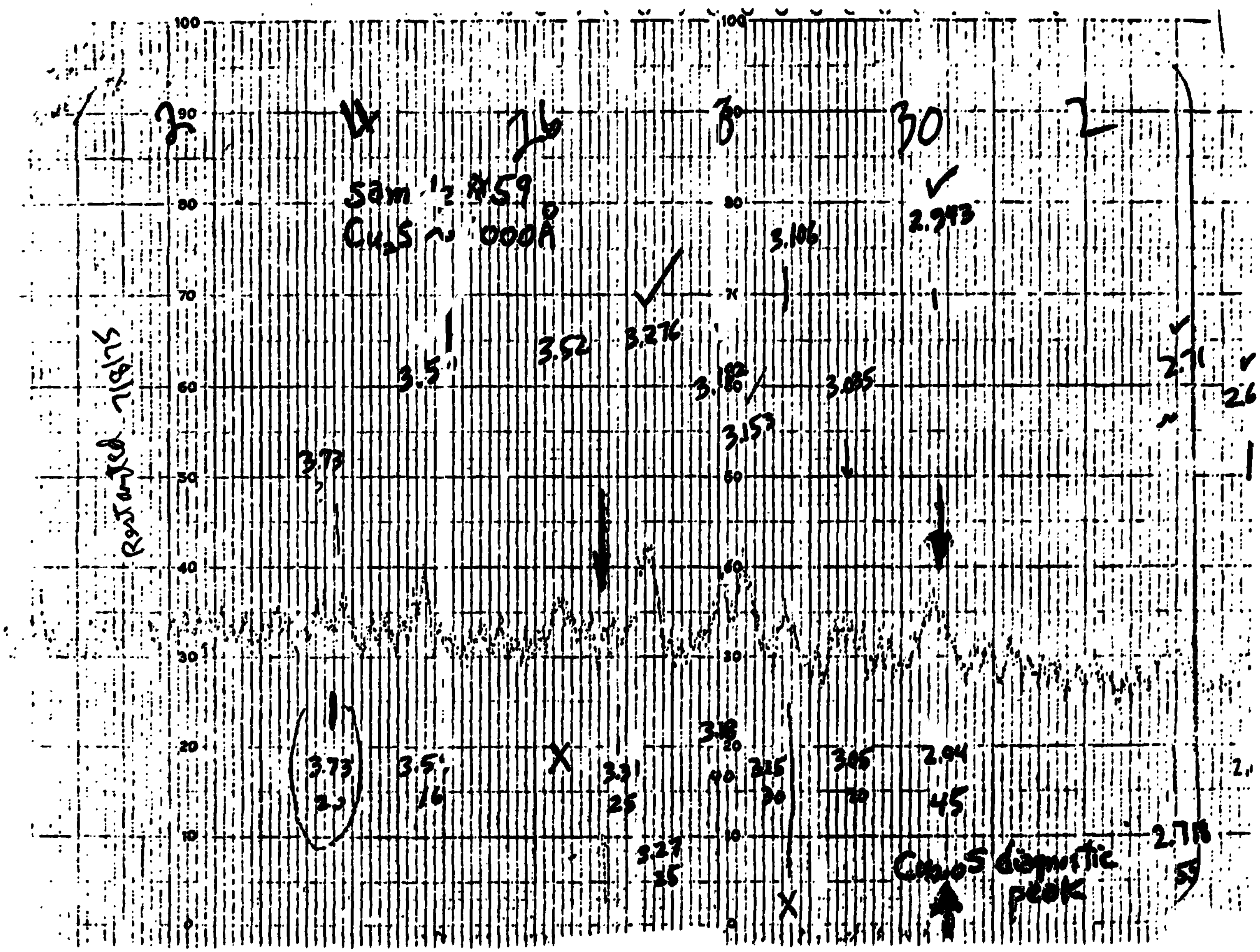
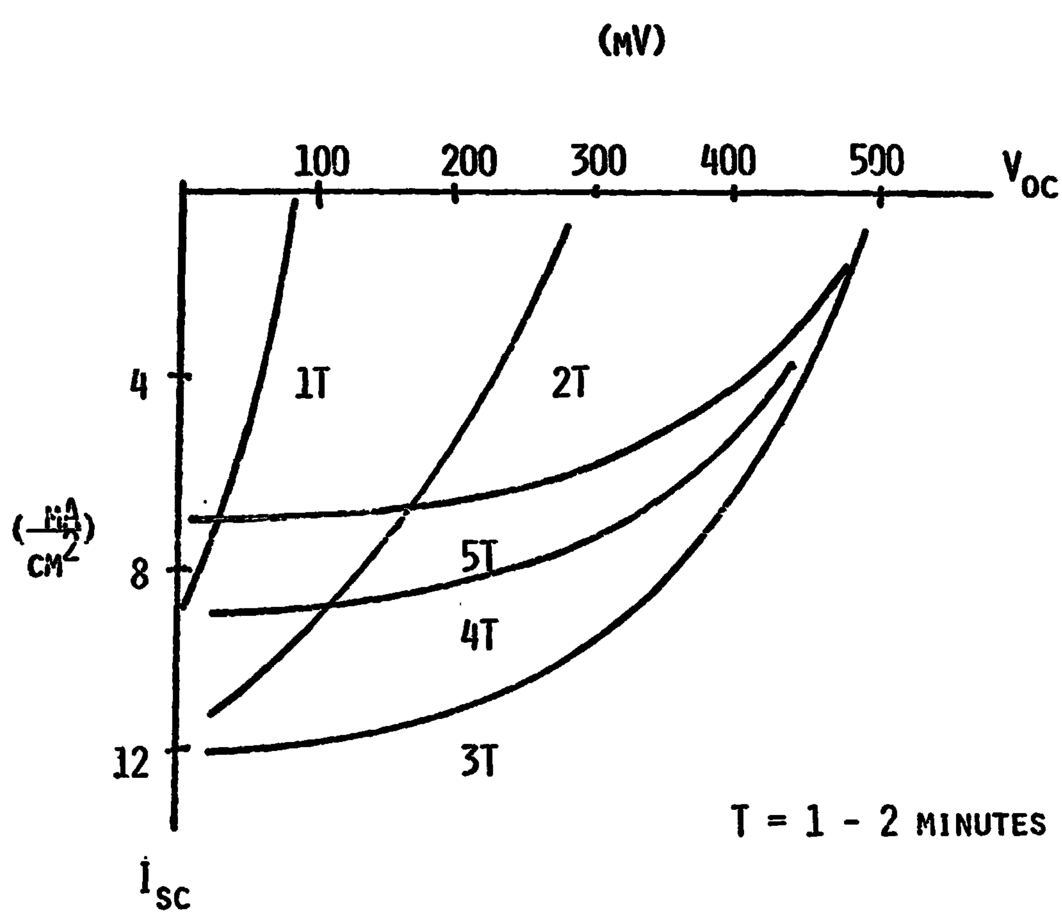
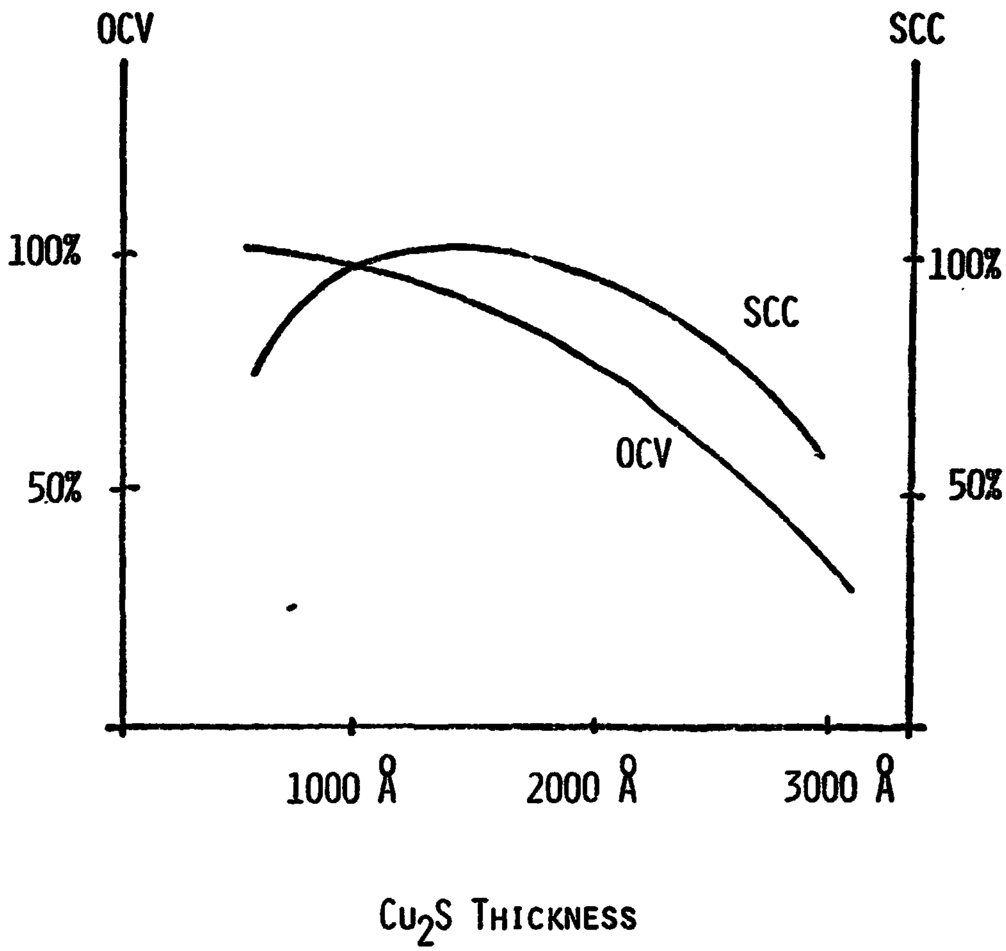


I-V CHARACTERISTICS ARE OPTIMIZED BY HEAT TREATMENT IN AIR



T = 1 - 2 MINUTES AT 200° C

OCV & SCC OPTIMIZATION DEPENDS ON Cu_2S THICKNESS



SUMMARY OF KEY RESULTS

1. PROVED FEASIBILITY OF REACTIVELY SPUTTERED CdS-Cu_2S CELL.
   - A. OVER 4% EFFICIENCY MEASURED IN SUNLIGHT
   - B. ALL CELLS MADE SHOWED PHOTOVOLTAIC EFFECT
2. ACQUIRED CAPABILITY TO IDENTIFY THE REACTIVELY SPUTTERED $Cu_{2.0}S$ FILMS.
3. PRELIMINARY CHARACTERIZATION OF THE REACTIVELY SPUTTERED CdS-Cu_2S CELL.
   - A. HEAT TREATMENTS OPTIMIZE CELL PERFORMANCE.
   - B. Cu_2S THICKNESS INFLUENCES OCV & SCC
   - C. THINNER CdS LAYER CAN BE USED.

ACTIVITY FOR NEXT 6 MONTHS

1. ASSEMBLE NEEDED EQUIPMENT AND MATERIAL.

2. IMPROVE CdS CELL EFFICIENCY ABOVE 4% BY

   A. IMPROVING CELL DESIGN

   B. IMPROVING STOICHIOMETRY OF SPUTTERED Cu_2S FILM

   C. DOPING OF CdS (WITH ZnS)

3. START PRODUCING CdS CELLS FOR STABILITY EVALUATION.

4. LITERATURE SEARCH FOR OTHER THIN FILM PHOTOVOLTAIC MATERIALS.