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HIGH EFFICIENCY THIN FILM CdTe SOLAR CELLS

Second Quarterly Progress Report for June 19–September 18, 1979

By
H. B. Serreze
G. Entine
R. B. Goldner

October 1979

Work Performed Under Contract No. AC04-79ET23012

Radiation Monitoring Devices, Inc.
Watertown, Massachusetts

MASTER

U.S. Department of Energy

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I. ABSTRACT

During the second quarter of this program primary emphasis was put into depositing and evaluating both n and p-type CdTe films on a variety of conducting and non-conducting substrates. Improvements in the deposition apparatus permitted preparation of a large number of CdTe films and numerous analytic techniques available at Tufts University were utilized to examine these films. It was found that the introduction of a thin ($100 \text{ \AA}$) In layer between the ITO and the CdTe significantly reduced the previously observed barrier present at the ITO/n-CdTe interface without adversely reducing optical transmission. While the resistivity of the films is still rather high, very recent results show that proper changes in procedure are capable of markedly lowering the resistivity. Preliminary Schottky barrier devices have been made which show promising photovoltaic characteristics.

II. DESCRIPTION OF PROJECT

A program is being pursued to develop high efficiency thin-film CdTe solar cells. By combining the expertise now available from recent CdTe work in nuclear detectors, heterojunction cells, and homojunction cells, a novel cell structure has been conceived which should overcome present cell limitations.

The proposed solar cell will consist of a thin-film CdTe homojunction vapor deposited on commercially available indium-tin-oxide coated glass substrates. The required long lifetimes of the CdTe layers will be obtained by chlorine-iodine compensation, a process based on similar techniques which provide nuclear grade CdTe with lifetimes of over 10^{-6} sec (almost 10 times that needed for the solar cells). The indium-tin-oxide layer will provide both a low sheet resistance contact layer for the n-type CdTe plus a good anti-reflection coating. Finally, a layer of HgSe between the back metal contact and the p-type CdTe will provide a good ohmic contact.

Materials characterization, which is being performed at Tufts University, will involve measurement of various physical, optical, and electrical parameters. Interpretation of these results will assist in reaching our objective.

III. PROGRESS DURING PAST QUARTER

A. Materials Growth - During the second quarter, a number of improvements and modifications were made to the vacuum deposition apparatus. The principal addition was the installation of a quartz crystal thickness/rate monitor which greatly improved our ability to control the reproducibility of the deposition runs. In addition, the shutter was repositioned closer to the substrate holder so that the thickness monitor would be able to see the source regardless of the shutter position. In this way, we were able to determine when the desired evaporation rate had been reached before exposing the samples to the evaporant stream. Evaporation rates on the order of 10 Å/sec corresponding to boat temperatures of approximately 650°C were used since previous work had shown that low rate, low temperature evaporations tend to produce films with better optical properties⁽¹⁾.

Typically, eight 25 mm by 25 mm substrates were included in a single run. At least one substrate was uncoated glass upon which a 20 mm diameter area was deposited with CdTe. These samples were used primarily for optical evaluation with a visible-NIR spectrophotometer in order to determine film thickness, refractive index, and general behavior near the absorption edge. The substrates for these samples were cut from either glass microscope slides (Fisher brand) or from the same glass used for the ITO-coated glass substrates (either PPG "Nesatron" or Corning "EC") with the ITO removed using a 1:1 H₂O:HCl etchant. Prior to loading into the evaporator, all the substrates were typically cleaned by first scrubbing with a cotton ball saturated with hot "Ivory Liquid" water solution, rinsing with distilled water, then methanol, and finally immersing several times in hot trichloroethylene vapor. After loading into the sample holder, the final step prior to evacuation was a dry nitrogen blow to remove any dust particles.

Depending on the purpose of the run, the remaining samples were either full area (20 mm diameter) depositions onto various conductive glass substrates or were depositions of a "Hall bar pattern" onto uncoated glass substrates. These 20 mm

by 2 mm Hall patterns having six side arms were deposited to permit fast and accurate determination of four-terminal resistivity and Hall mobility of either the as-deposited films or, by annealing these samples, of annealed films. By utilizing a properly registered evaporation mask, In (for n-samples) or Au (for p-samples) contacts were evaporated over the Hall samples prior to measurement.

In the case of the full area samples, Schottky barriers were fabricated by evaporating an array of either In or Au dots over the ITO/CdTe structure. In some cases, due to not knowing a priori whether a barrier would be present at the ITO/CdTe interface, both In and Au dots were deposited onto the same sample.

A summary of the runs performed during this quarter appears in Table I. Most of the runs were halogen-doped, n-type since this will be the film adjacent to the ITO contact in the final structure. A variety of experiments are included in these runs. These include variations in dopant concentration, Cd or Te excess, substrate temperature, substrate cleaning procedure, and ITO pre-deposition treatment. In addition, a number of samples were prepared for post-anneal studies or for optical absorption coefficient measurement.

Table I. Summary of CdTe evaporations

RUN NO.	TYPE	DOPANT	DOPANT CONC. (mole %)	EXCESS Cd or Te	SUBST. T (°C)	REMARKS
18F9-1	N	In	1.0	Cd	200	new substrate heater
19F9-1		I+C1	0.1			new boat
19F9-2						
19F9-3						
25F9-1						
26F9-1						
29F9-1	✓	✓	✓	✓	✓	
2G9-1	N	I+C1	0.1	Cd	200	
9G9-1						new boat thermocouple
12G9-1						first run with thickness monitor
13G9-1						thickness calibration
13G9-2						" "
16G9-1						substrate cleaning experiment
17G9-1						" " "
18G9-1					✓	" " "
19G9-1					28	" " " (low T)
20G9-1		✓	✓	✓	315	" " " (high T)
25G9-1		In	1.0	Stoich	28	cleaning experiment (ITO)
25G9-2		In	1.0		200	" " "
26G9-1		I+C1	0.1		200	" " "
30G9-1					28	new shutter & boat - clean system
30G9-2					200	same - 200°
31G9-1			1.0	✓	200	same - 10% dopant
1 H9-1	N	I+C1	0.1	Stoich	28	2 μm thick run
3 H9-1	-	None	-		200	undoped run
7 H9-1	N	I+C1	1.0		28	duplicate of 31G9-1
8 H9-1			1.0	✓	150	same - 150°
8 H9-2			0.1	Cd	28	use p-CdTe bulk substrates
13H9-1				Stoich	150	" " " "
14H9-1					28	50 Å In flash on ITO
15H9-1					150	In-on-glass substrates
21H9-1						
22H9-1						
23H9-1	✓	✓	✓	✓	✓	100 Å In flash on ITO
5I9-1	P	P	1.0	Te	28	p-type film
6I9-2	P	P	1.0	Te	28	p-n junction thin film
6I9-1	N	I+C1	0.1	Stoich	100	50 Å In flash on ITO
5I9-2					28	" " " " "
12I9-1						variable thickness
13I9-1						for anneal study
13I9-2						variable thickness for α study
14I9-1		✓	✓	✓		" " " " "
14I9-2	P	P	1.0	Te		for anneal study
17I9-1	-	None	-	Stoich		" " "
17I9-2	N	I+C1	1.0		✓	" " "
17I9-3			0.1		200	" " "
18I9-2	✓	✓	1.0	✓	200	" " "

B. Materials Characterization - During the second quarter of this program, two major goals were addressed. These two major goals have been to:

1. Determine the feasibility of obtaining low enough resistivity ($10^2 \Omega\text{-cm}$), high enough mobility ($\gtrsim 10 \text{ cm}^2/\text{V-sec}$) and large enough minority carrier diffusion lengths ($\gtrsim 0.5 \mu\text{m}$) in n- and p-type vacuum-deposited thin films of CdTe; and
2. Determine the feasibility of obtaining low resistance ohmic contacts to the CdTe films without adversely altering the charge transport properties of the films.

To achieve these and other goals, measurement efforts have been initiated which include the following:

1. Lateral film resistivity.
2. Optical transmission as a function of wave length.
3. Crystal structure by X-ray diffraction.
4. Refractive indices in the infrared and visible
5. Current-voltage characteristics of Schottky-type device structures under dark and illuminated conditions.
6. Capacitance-voltage characteristics as a function of frequency on Schottky-type diodes.
7. Hall mobility.
8. Carrier concentration and type by thermopower techniques (and with resistivity measurements, a determination of the resistivity, or drift, mobility).
9. Diffusion length.
10. Barrier characteristics at electrode contact/film interfaces.

In summary, the following results have been obtained on the deposited films.

1. Except for one sample which showed an anomalously low resistivity, ($\sim 10^2 \Omega\text{-cm}$, probably due to surface contamination), the lateral resistivities of the films have been greater than $5 \times 10^3 \text{ ohm-cm}$, with the lowest resistivities ($\sim 10^4\text{-}10^5 \Omega\text{-cm}$)

generally occurring for indium doped films.

2. Frequently, there are a large number of pin-holes which particularly hamper I-V and C-V evaluations.

3. Hall and thermopower determinations of mobility for the same sample differ by more than one order of magnitude $[(\mu_{\text{Hall}}/\mu_{\text{Thermopower}}) > 20]$ strongly suggesting small crystallites ($< 1 \mu\text{m}$); $\mu_{\text{Hall}} \simeq 0.9 \text{ cm}^2/\text{V-s}$, $\mu_{\text{Thermopower}} \simeq 0.04 \text{ cm}^2/\text{V-s}$]

4. Hole diffusion lengths (L_D) in Cl_2 and I_2 doped films are less than $0.5 \mu\text{m}$ and L_D appears to decrease with increased dopant concentration of the starting material - [for 0.1 mole % I_2 and Cl_2 , $L_D \simeq 0.5 \mu\text{m}$; and for 1.0 mole % I_2 and Cl_2 , $L_D \simeq 0.2 \mu\text{m}$];

5. Preliminary optical absorption coefficient measurements in the wave length range 0.6 to $0.8 \mu\text{m}$ yield values greater than $3 \times 10^4 \text{ cm}^{-1}$ which is in rough agreement with the results of Mitchell⁽²⁾, and Brown and Brodie⁽³⁾. The purpose of these absorption coefficient measurements is to enable us to obtain more precise values of diffusion length from constant short-circuit current measurements using the technique of Stokes and Chu⁽⁴⁾;

6. From I-V measurements it is apparent that a barrier occurs at the ITO/CdTe interface. The other interface was CdTe/In , which appeared to be ohmic. From $I_{\text{SC}}(\lambda)$ measurements the barrier height was determined to be in the range $1.2 - 1.3 \text{ eV}$.

The precise origins of the observed relatively high resistivities and high concentrations of pinholes remains a puzzle. It is possible that the films are being too heavily doped, are being deposited under uncontrolled Cd and Te vapor pressure conditions. The excess dopants would be providing excess scattering/trapping/recombination centers, without contributing free carriers, because they are associating with vacancies (most likely Cd vacancies) and/or are precipitating into relatively large clusters of a phase different from CdTe (e.g., CdCl_2 , CdI_2).

In addition to increased scattering from electrically inactive dopants, increased scattering from grain boundaries is probably also a cause of the observed high lateral resistivities. This view is confirmed by the high ratio (>20) of Hall to drift mobilities. This result suggests that crystallite sizes are quite small (less than the mean free path of the charge carriers). The Hall mobility is expected to be less sensitive to grain size than is the drift mobility.

In addition, we have been concerned largely with the ITO/n-CdTe contact. Our initial assumption based on Fermi-level reasoning (using for electron affinities, $\chi_{\text{ITO}} \simeq 4.3\text{eV}$, $\chi_{\text{CdTe}} \simeq 4.78\text{ eV}$), was that ITO should form an ohmic contact for electrons to the CdTe. However, the experimental results indicate that a potential barrier forms when the CdTe films are deposited on commercially-sprayed ITO layers on glass substrates. From short circuit vs. wave length measurements, the barrier height is approximately 1.25 eV. Because the CdTe resistivity is too high, C-V measurements can not yet yield a unique barrier width. However, when a top gold contact was used, the C-V measurements clearly did indicate that there was a double barrier. Following a suggestion by K. Mitchell, a thin layer of indium was deposited on the ITO prior to the CdTe deposition. This strikingly reduced the effective barrier. At present, we are attempting to have Auger analysis done to chemically characterize the ITO/CdTe and ITO/In/CdTe interfaces. The results of some very preliminary Auger scans appear in Fig. 1. Due to relatively fast etch rates ($\sim 50\text{ \AA/min}$), details of what is precisely happening at the ITO/CdTe interface are not yet known. In addition, we are also awaiting the results of Auger analysis of films sent to SERI. It should be noted that Bube et al.⁽⁵⁾ have recently reported that a buried homojunction seems to form in CdTe when ITO is sputter-deposited onto p-type CdTe. While our process is the reverse of this (i.e., we are depositing CdTe onto ITO), there may be some relevancy between this observation and ours.

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Fig. 1. Auger scan of CdTe on ITO sample number 14H9-1-1. Sputter etch rate was approximately 50 Å/min.

It should also be noted that ITO/n-CdTe/In structures which we have fabricated behave as Schottky solar cells, with the photovoltaic quadrant occurring for ITO (+). Because ITO/n-CdTe forms a barrier, such a structure has allowed us to measure hole diffusion lengths in the CdTe using the Stokes-Chu method⁽⁴⁾. (c.f. Appendix B).

C. Device Fabrication and Characterization - Two types of devices were fabricated during this past quarter. The first was a number of preliminary Schottky diode devices which were utilized primarily to allow study of (1) the TlO/CdTe interface, (2) any pin holes in the films, and (3) the diffusion lengths in the films. These results of these studies have already been discussed. In addition, however, a limited number of I-V measurements under very approximate AM 1 illumination conditions were also obtained. One such result appears in Fig. 2. This result, however, is severely limited by the high resistivity of the film.

In addition, an attempt was also made to fabricate an all-thin film structure (see run 6I9-2 in Table I). Due to pin holes in either or both the n and p layers, these devices were totally shorted and not at all photovoltaic. However, had the pin hole problem not dominated, the performance would very likely have been controlled by the high resistivity of the films and the contact to the p - CdTe.

Fig. 2. Light and Dark I-V curves
for ITO-CdTe-In device no. 30C9-2-1
($\approx$ AM 1 microscope illuminator)
Junction area $\approx 1.8 \text{ mm}^2$

IV. CONCLUSIONS AND PLANS FOR NEXT QUARTER

In the vacuum evaporation of many compound materials including CdTe, incongruent vaporization occurs; that is, the CdTe solid molecule breaks up into gaseous Cd and Te:

This can lead to the composition of the vapor being different from that of the source due to the difference in vapor pressure between Cd and Te. This can be further complicated by differences in "sticking coefficients" between Cd and Te at the substrate, particularly at the elevated substrate temperatures preferred for large grain growth. These basic facts have contributed to the results seen in the past for vacuum evaporated CdTe films. For example, Glang et al.⁽⁶⁾, using simple evaporation of In-doped CdTe, obtained resistivities consistently in excess of 10^7 ohm-cm. Annealing up to 575°C was incapable of lowering their resistivity below 10^3 ohm-cm. Attempts on our part to anneal in forming gas a number of undoped and both p and n-type doped samples up to 400°C in temperature produced similar results (see Table II). We were unable to lower the resistivity below about 10^4 ohm-cm and even these figures are somewhat suspect due to limited statistics.

This inability to produce low resistivity CdTe films as an apparent result of the higher Cd vapor pressure which produces Cd vacancies in the final film was precisely one of the reasons for investigating double-halogen doped, single-source evaporated CdTe. However, as appears to be indicated by the high resistivity of the n-type films regardless of dopant concentration, constituent excess, substrate temperature, or annealing temperature, this approach does not seem to yet produce CdTe of adequately low resistivity. Furthermore, an apparent barrier at the ITO/CdTe interface whose origin is still unclear is both complicating materials analysis and hindering device performance.

There are, however, other approaches to vacuum deposited CdTe which have or should produce high-quality, low resistivity films. Recent work by Lopez-Otero using the Hot Wall Epitaxy (HWE) process has resulted in films having excellent electrical properties^(7,8,9). Films deposited on BaF₂ substrates at temperatures of approximately 500°C have produced low resistivity films having mobilities of

TABLE II

Summary of Resistivity Results on Various Annealed CdTe Thin Films

SAMPLE	DOPANT TYPE	DOPANT CONC. (mole %)	SUBSTRATE T (°C)	ANNEAL T (°C)	RESISTIVITY (Ω - cm)
17I9-1.8 17I9-1.7 17I9-1.6 17I9-1.5	Undoped	-	28°C	- 100 200 400	3×10^4 3×10^4 3×10^4 -
13I9-1.8 13I9-1.2 13I9-1.4 13I9-1.6	N (Cl+I)	0.1	28°C	- 100 300 400	- $\sim 10^7$ 2.1×10^6 2×10^6
17I9-3.8 17I9-3.5 17I9-3.6 17I9-3.7			200°C	- 300 350 400	$> 10^6$ 1.2×10^4 $> 10^6$ $> 6 \times 10^5$
17I9-2.8 17I9-2.7 17I9-2.6 17I9-2.5		1.0	28°C	- 100 200 400	$> 10^6$ $> 10^6$ - 2×10^4
18I9-2.8 18I9-2.5 18I9-2.6 18I9-2.7			200°C	- 300 350 400	$\sim 10^5$ $\sim 10^4$ $> 10^6$ $> 10^6$
14I9-2.8 14I9-2.5 14I9-2.3 14I9-2.1		0.1	28°C	- 100 200 400	$> 10^6$ $> 10^6$ $> 10^7$ 6×10^5

480 cm²/V-sec and grain sizes of 50 μ m⁽¹⁰⁾. Even at temperatures as low as 400°C, respectable properties can still be obtained.

Another technique which has been shown useful for materials having components with widely different vapor pressures is the flash-evaporation process⁽⁷⁾. Very recent work on CdS and CdS_xSe_{1-x} films has demonstrated the potential of this technique for II-VI compounds.⁽¹¹⁾ Some very recent results here at RMD using this process have produced low resistivity films (< 0.1 ohm-cm) with good mobility (> 20 cm²/V-sec). Furthermore, there is indication that the barrier at the ITO interface may be markedly reduced, possibly as a result of the shift in the Fermi level in the low resistivity films.

Based on ~~these~~ recent experiments, plans for the third quarter will emphasize approaches which tend to circumvent the problems brought about by the basic evaporation mechanisms of CdTe. We will actively pursue the flash evaporation process for both p and n material and, if the ITO barrier is indeed reduced, we will investigate both Schottky barrier and p-n junction devices.

V. APPENDIX

A. Carrier Concentration From Thermopower Measurements - As pointed out by Kwok and Bube, carrier concentration can be determined from thermoelectric power measurements⁽¹²⁾. In particular, one can write

$$\left[\alpha_{\text{Thermopower}}^{e,h} = \frac{k}{q} \left[A + \ln \left(\frac{N_{c,v}}{n,p} \right) \right] \right] \quad \text{V/}^{\circ}\text{K}$$

where: e refers to electrons.

h refers to holes

k = Boltzmann's constant

q = electronic charge

A = a factor which is temperature dependent and determined by scattering mechanism(s) and is approximately 2 at 300°K for II-VI compounds.⁽¹³⁾

N_c = effective density of states for conduction band (electrons)

N_v = effective density of states for valence band (holes)

n = density of electrons in conduction band

p = density of holes in valence band

To measure α , the circuit of Fig. 3 was utilized.

To determine α , it is necessary to eliminate any strain or other extraneously introduced voltage. This is done by plotting V_2 of Fig. 3 versus V_1 . The voltage V_1 yields ΔT , the temperature difference between the two electrodes ($V_1 / \Delta T \approx 40 \mu\text{V/}^{\circ}\text{K}$ at 300°K for a copper vs. constantan thermocouple.) The slope of V_2 vs ΔT yields the desired thermopower α . Typical values seen for the CdTe films are approximately $400 \mu\text{V/}^{\circ}\text{K}$ for samples with a resistivity of about 10^4 ohm-cm.

Switch in position 1, V gives ΔT

Switch in position 2, V gives ΔV sample

Fig. 3. Thermopower Measuring Circuit

B. Comments on the Stokes-Chu Technique for Diffusion Length Measurements -

The technique is quite useful for the case where the sample thickness is larger than both the diffusion length and optical absorption depth, and for which the depletion width is small compared to the absorption depth and is very close to the illuminated surface. For our samples of thickness $1\ \mu\text{m}$ this requires an absorption depth less than $1\ \mu\text{m}$, a diffusion length less than $1\ \mu\text{m}$, and a depletion width much less than $1\ \mu\text{m}$. In at least one sample, based upon the short circuit current measurements, one or more of these conditions were probably violated, and hence the Stokes-Chu technique is not universally applicable, even to our samples.

VI. REFERENCES

1. R.O. Bell, H.B. Serreze, and F. V. Wald, 11th Photovoltaic Specialists Conference Record, IEEE, New York, p. 497 (1975).
2. K.W. Mitchell, "Evaluation of the CdS/CdTe Heterojunction Solar Cell", Garland Publishing, Inc. N.Y. (1979).
3. H. M. Brown & D.E. Brodie, "The Optical Properties of Amorphous ZnTe and CdTe," Can.J. Phys. 50, 2502 (1972).
4. E.D. Stokes and T.L. Chu, "Diffusion Lengths in Solar Cells from Short-Circuit Current Measurements ", Appl. Phys. Lett. 30, 425 (1977).
5. R.H.Bube, et al, "Oxide/Semiconductor Photovoltaic Heterojunctions Based on CdTe or InP," p. 432 of Proc. of 2nd European Community Photovoltaic Solar Energy Conference (W.Berlin, 23-26 April 1979), D. Reidel Publishing Co., Boston, 1979, edited by R. Van Overstraeten and W. Palz .
6. R. Glang, J. G. Kren, and W. J. Patrick, J. Electrochem. Soc. 110, 407 (1963)
7. A. Lopez-Otero, Thin Solid Films 49, 3 (1978).
8. A. Lopez-Otero and W. Huber, J. Cryst. Growth 45, 214 (1978).
9. W. Huber and A. Lopez-Otero, Thin Solid Films 58, 21 (1979).
10. A. Lopez-Otero, private communication, August 1979.
11. T. H. Weng, J. Electrochem Soc. (126), 1820 (1979).
12. H. B. Kwok and R. H. Bube, J. Appl. Phys. 44, 138 (1973).
13. S. S. Devlin, "Physics and Chemistry of II-VI Compounds," (M. Aven and J. Prener, eds), Wiley, N.Y., 1967, p.561.