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Progress Report No. 2

PREPARATION AND PROPERTIES OF EVAPORATED CdTe FILMS

COMPARED WITH SINGLE CRYSTAL CdTe

February 1 - April 30, 1981

Subcontract No. XW-1-9330-1

Solar Energy Research Institute
Department of Energy
Golden, Colorado

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ABSTRACT

The design, construction and testing of the hot-wall vacuum evaporation system is proceeding on schedule. The vacuum system, a Varian 3118 diffusion pump system, has been installed and tested. The present schedule calls for first trial deposition with the completed apparatus by the end of August.

A calculation of the optimum possible efficiency for an n-p CdTe homojunction using the parameters measured and reported in Progress Report No. 1 indicates a value of 14%.

A complete background is given on the growth of over fifty CdTe single crystals at Stanford, the last four of which were grown as part of this program. Use of crystal regrowth and vibration during growth both increase crystal quality. Higher electrical activity of phosphorus acceptors in CdTe is achieved when 0.1% excess Te is used in place of 0.5% excess Te. These results are in general agreement with the careful study of Selim and Kröger on the P-doping of CdTe crystals. Careful characterization of boules grown for this program are underway, using Hall effect or capacitance-voltage data on selected samples.

Initial investigation of the properties of grain boundaries in p-type CdTe:P crystals indicates a grain boundary height of 0.44 eV unaffected by illumination. These results suggest that grain boundaries are more strongly pinned in p-type than in n-type CdTe.

EVAPORATED CdTe FILMSHot-Wall Vacuum Deposition System

This quarter has concentrated on fabrication of the deposition cell and installation of the vacuum system. The vacuum system, a Varian 3118 diffusion pump system, has been installed and tested. It reached a short-pumping-time ultimate vacuum of 3×10^{-8} Torr without bakeout. A Construction Schedule for the hot-wall vacuum deposition system is given in Table I.

The first deposition cell section furnace was assembled and tested to above its intended temperature. It behaved very well, reaching about 650°C with only about 90 watts of electrical input. A plot of input power vs temperature follows the T^4 relationship and has enabled us to predict rough power input vs. temperature relations for the remainder of the furnace sections. While the remaining sections for the deposition cell are being fabricated, experiments are being run to compare the temperatures inside a dummy quartz liner (at the position of the CdTe evaporant) with those between the furnace interior and the quartz liner. A thermocouple will be inserted into the CdTe evaporant charge in this dummy liner for these experiments. This will also give qualitative information on the thermal coupling between the furnace sections and the evaporant charges and enable us to evaluate the response time of the furnace/evaporant system. These thermal transport considerations are important with regard to the control of the substrate temperature as well, since, for example, a CdTe substrate would be transparent to most of the thermal input at this temperature. In this example, a susceptor of carbon may be used to absorb the thermal energy and communicate it to the substrate by conduction.

TABLE I.

HOT-WALL VACUUM EVAPORATION CONSTRUCTION SCHEDULE

Completed to date:	Rough configuration design
	Rough thermal design
	Order vacuum system
	Retort design
	Obtain quotes on graphite parts
	Final design of first retort section
	Rough layout of power supply
	Layout of laboratory space
	Order temperature controllers
May 1	Rearrange laboratory space
8	Install vacuum system
	Order feedthroughs
	Order graphite parts
	Order CdTe, dopants
	Order stainless steel for top-plate
	Baseline vacuum system trial
15	Construct first retort section
	First furnace section trial
22	Order suction collar and blower
27	Complete thermal analysis
29	Final retort design
June 3	Order blank substrates
	Rough fixturing design
	Order vacuum system cylinder
	Order source bottles
	Final power supply design
	Order transformers
12	Construct power supplies
15	Order residual gas analyzer
26	Complete fixturing design
	Layout baseplate holes and drill
	Order spares for vacuum system
July 1	First complete retort constructed
7	First complete retort trial
10	Construct fixturing
15	Layout and construct top-plate
20	Construct Meissner trap
August 7	Assemble complete system with one retort
15	Baseline date before deposition
20	First trial deposition

EBIC Measurements

EBIC measurements at 10 kV electron beam were compared with the results reported for the n-p CdTe junction in Progress Report No. 1 using a 20 kV electron beam. Equivalent diffusion lengths were inferred from the measurements with the two electron energies.

Cell

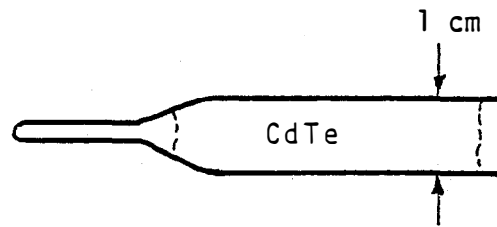
Using the parameters reported for the n-p CdTe junctions in Progress Report No. 1, a calculation was made to estimate possible maximum efficiency. A value of 14% was obtained.

SINGLE CRYSTAL CADMIUM TELLURIDEHistorical Perspective on CdTe Crystal Growth

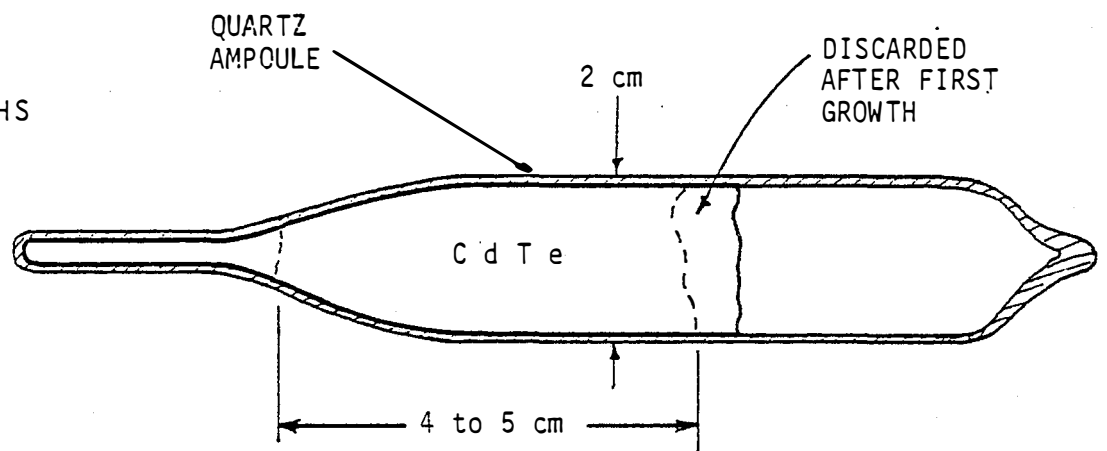
For about eight years the Center for Materials Research Crystal Growth Laboratory at Stanford University has been growing CdTe crystals for research projects carried out by our group. Most of these CdTe crystals were used as absorber components for heterojunction solar cells together with various larger bandgap n-type semiconductor "windows" such as CdS, ITO, and ZnO. The CdTe served as a single crystal substrate on which the "window" material was deposited in the form of a polycrystalline thin film (sometimes epitaxial). These CdTe crystals were grown using the vertical Bridgman technique and have been doped with In, Au, Au + P, Ni, Li, Sb, As, and P. Early crystals (up to No. 23 - the CdTe boules have been numbered consecutively from No. 1 to the current one No. 57, although some numbers are not used in order to reconcile differences between CMR and our numbering systems) incorporated about 0.5 wt.% excess Te to reduce pressure within the growth ampoule; for later growths the excess Te was reduced to 0.1 wt.%, in order to reduce the probability of Te inclusions and to reduce deviation from stoichiometry. In the early growth runs the synthesis (from elemental Cd and Te) was combined with the crystal growth. For later runs (including No. 33 onward, except for Nos. 36, 53, and 54), two growth steps were used: the first to synthesize and zone refine the CdTe, and the second to incorporate the dopant and grow more perfect crystals.

Early growth runs produced crystals about 1 cm in diameter by 3 to 4 cm long; in later growths the diameter was increased to about 2 cm and the length to 4 to 5 cm, to obtain more useful material for photovoltaic experiments. The growth geometry is shown in Figure 1.

a) EARLY GROWTHS



b) LATER GROWTHS



TYPICAL WEIGHT AFTER FIRST GROWTH: 100 g.

" " " SECOND " : 85 g.

Fig. 1. Outlines of typical CdTe boules. (a) Early growths of small boules (up to and including #17). (b) Large boules (#17 and later), showing quartz ampoule and portions discarded to effect zoning purification (both start and finish ends).

In current practice, typical growth runs start with 6N purity Cd and Te. A typical analysis is shown in Table II. The Cd is etched in HF/HNO₃ (1 part conc. HF to 9 parts conc. HNO₃ by volume) and washed in DIH₂O and finally MeOH to remove oxide, while the Te is broken from the large zone refined ingot received from the supplier, with no cleaning before crystal growth. A quartz ampoule is coated internally with a layer of pyrolytic graphite by decomposition of acetone. The ampoule is then evacuated to 10⁻⁶ Torr, and baked out at 1000°C for 1 hr. The Cd and Te are then loaded and the ampoule is pumped for 1 hr and finally sealed off at 10⁻⁶ Torr. Synthesis is performed by holding the Cd and Te at 650°C, which distills the Cd onto the Te where the reaction takes place. The reaction is complete in about 30 hours. The CdTe is then melted (1130°C) and dropped through a temperature gradient at about 1 mm/hr as shown in Figure 2. Growth is complete in about 200 hours. The crystal is cooled slowly (about 40°C/hr). The ampoule is broken open and the start and finish ends of the boule are discarded by breaking as shown in Figure 1b. Approximately 15% of the crystal is discarded, thus completing a single zone refining step.

The CdTe, broken into 3-5 mm pieces, is then loaded into a fresh, pyrolytic-graphite-lined, vacuum-baked, quartz ampoule on top of the dopant and sealed under vacuum. The CdTe is melted and the "regrown" crystal is grown. The resulting crystal is sandblasted to exhibit the grain boundary structure at its surface and then it is electrically characterized and used.

Boules are typically large grain polycrystals with grain sizes of 2 to 5 mm and up to 8 to 10 mm in a few cases. In citing these grain sizes, twin boundaries (which are in most cases electrically inactive)

TABLE II.

SPECTROGRAPHIC ANALYSIS OF TYPICAL Cd AND Te STARTING MATERIALS
 (as supplied by the manufacturer)

<u>TELLURIUM</u>	Al	0.1 ppm	
	Ca	0.1	
	Cu	0.1	
	Fe	0.1	
	Si	0.1	
 <u>CADMIUM</u>	Mg	Ca	} All < 0.00001 wt.%
	Al	Si	
	Bi	Ag	
	Fe		
	Cu		

(Note that if all the Cu and Ag in the Cd and Te were electrically active, that alone would produce some $1.2 \times 10^{16} \text{ cm}^{-3}$ acceptors.)

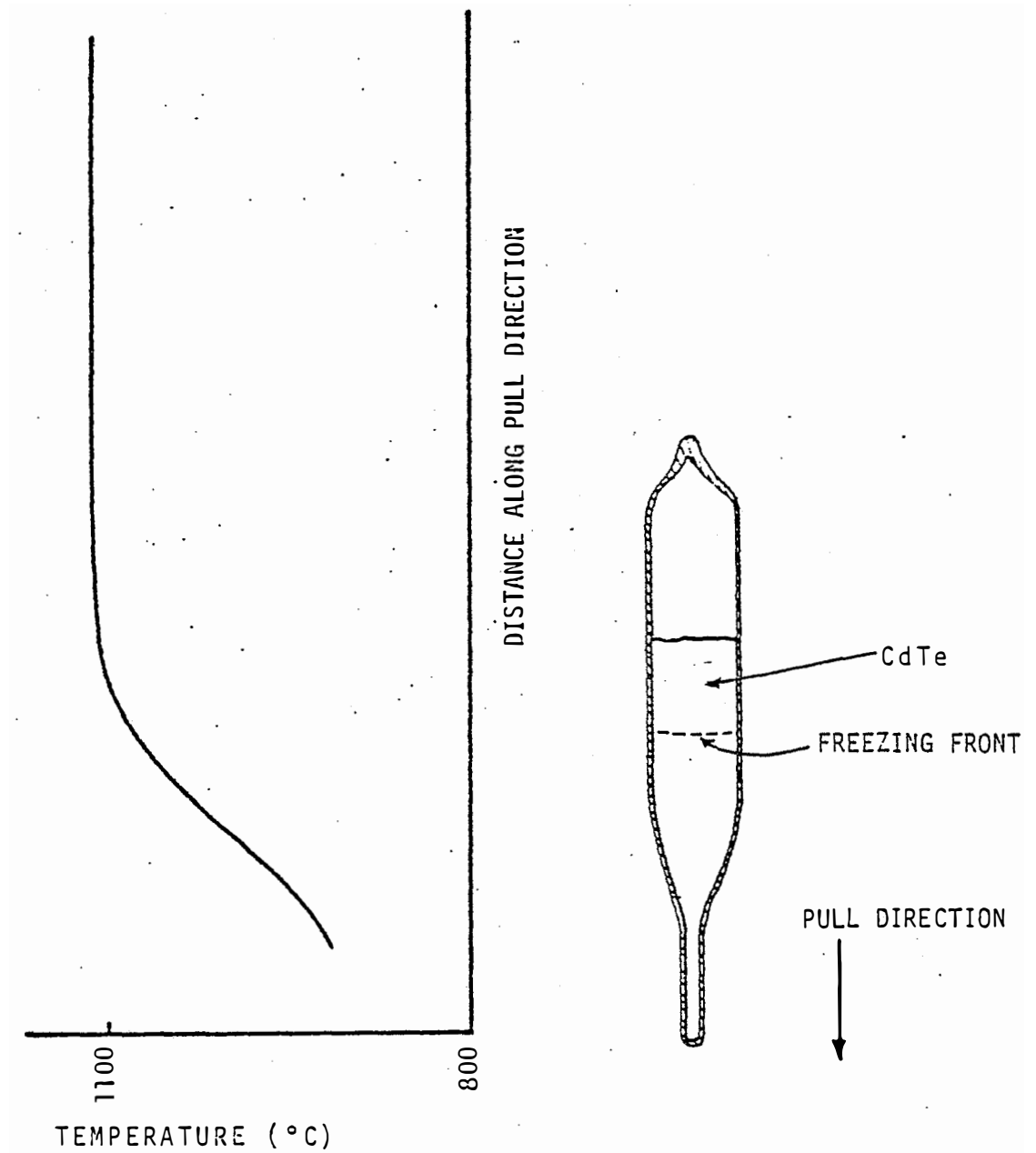


Fig. 2. Temperature profile during growth of CdTe boule. Temperature values are approximate.

are not included (i.e., boundaries with surface intersections indicating that they are planes are not counted as grain boundaries). Qualitatively it appears that grain size has been increased by (1) reduction in excess Te, (2) reduction in the amount of dopant used, and (3) regrowth, in the later boules.

Vibration of the ampoule during growth (to be described later) appears also to substantially increase grain size. Indeed a few crystals grown with vibration were essentially single grain with only a few grain boundaries near the ends.

Observation before and after slicing and polishing and under low power magnification shows a decrease in general quality of the boules toward the final end, with increasing density of grain boundaries, occasional voids, and inclusions. Reduction of excess Te and/or regrowth appears to have substantially decreased the occurrence of voids.

The various dopants used and the resulting crystal properties are summarized in Table III. Most of the recent boules have used P as the dopant, and these crystals have been used mainly for solar cell substrates (typically 3.5 x 5 mm dices and occasionally approximately 1 cm diameter slices). Some 50 small single crystal substrates can be obtained from one boule, the number depending strongly on the grain size. If crystallographic orientation is required, the number is reduced considerably.

In an effort to increase grain size, a new growth method developed by Dr. R. S. Feigelson of the CMR Crystal Growth Laboratory has been used on the last six boules (including four boules grown on the present SERI contract). In this method, a small amplitude vibration, along the growth axis at about 60 Hz, is applied during crystal growth. The expected results are (1) increased grain size, (2) more uniform growth, and (3) a possible increase in the distribution coefficient of dopants and

TABLE III.

DOPANTS USED FOR CdTe CRYSTAL GROWTH

		ρ , ohm-cm
Au	Two early boules, small grains, numerous voids	<u>3000</u>
Au + P	Five boules, poor control of resistivity (even with the same dopant density for four boules), some small voids	$11 < \rho < 7000$
Sb	One boule	70,000
Ni	One boule, crystal appears porous	100,000
Li	One boule, good quality	1.5
In	Three boules	$0.05 < \rho < 1$
As	One boule, very good crystal quality	14
None	Nine boules	100,000 No. 22 100
P	Nineteen boules, grown with excess Te	$0.8 < \rho < 40^a$

^a Eight of these had ρ between 2 and 4 ohm-cm.

impurities because of stirring at the growth interface. Although the sample is small at present, grain sizes do appear to be considerably larger with vibration in most cases, and in one or two cases essentially single crystals of CdTe:P have been grown.

Phosphorus Doping of CdTe

Phosphorus is a substitutional doping impurity in CdTe, located on a Te site, given the proper stoichiometric conditions. The P impurity level is shallow, only about 0.04 eV from the valence band edge. Perhaps the authoritative reference here is that of Selim and Kröger,¹ a comprehensive investigation including data from well-characterized crystal growth and doping experiments, as well as extensive theoretical development on the defect equilibria for CdTe:P.

These authors incorporated P during the growth of CdTe by unidirectional solidification of the melt (no mention is made of excess Te). The P content was determined by spectrographic and mass spectrographic analysis. The crystals were sliced and then annealed in various partial pressures of Cd. Representative hole density (as determined by Hall and resistivity measurements) vs Cd partial pressure data are shown in Figure 3. The increase in hole density on annealing CdTe:P in Cd vapor has been reported by several workers and has been associated with a large degree of self-compensation for high P densities. Using a "standard anneal" ($p_{\text{Cd}} = 0.01$ atmos. at 700°C), data from a number of crystals, with various proportions of P incorporated during growth, were collected. The resulting relation between hole density p and the density of P actually in the CdTe:P is shown in Figure 4 (and repeated in Figure 5). Presumably the electrical activity of the dopant is near unity until $p = 6 \times 10^{16} \text{ cm}^{-3}$ is reached (corresponding to about 2 ohm-cm material). Then compensation occurs, limiting p to about 10^{17} cm^{-3} .

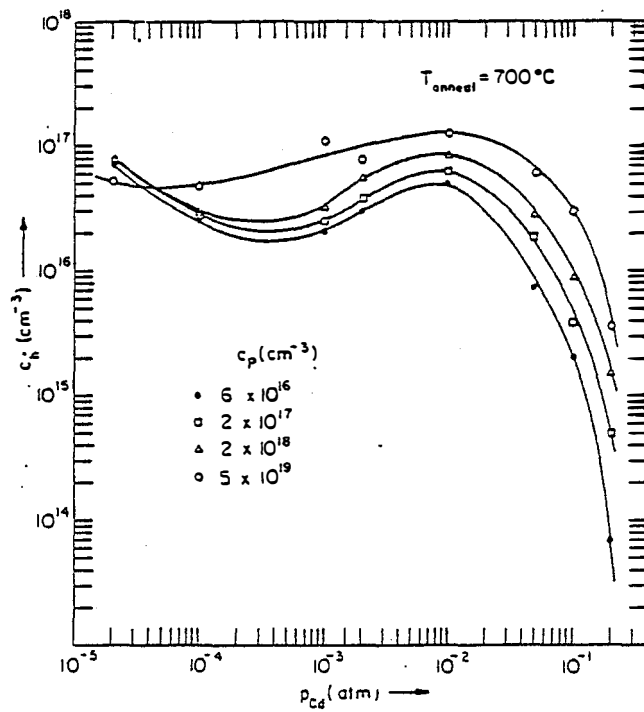


Fig. 3. Hole concentration in CdTe with various P dopant densities for crystals cooled after annealing at 700°C under different Cd pressures. After Selim and Kröger. (Hole density is denoted by c_h , here).

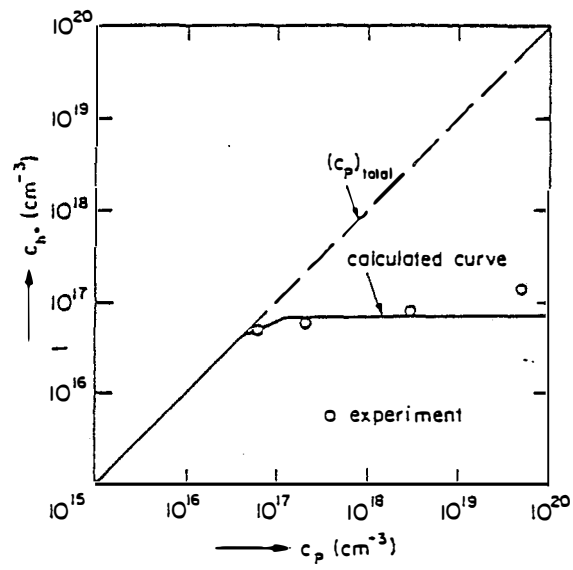


Fig. 4. Hole concentrations for CdTe with various P concentrations cooled after annealing at 700°C at $p_{\text{Cd}} = 10^{-2}$ atm. After Selim and Kröger.

Selim and Kröger suggest that the increase in hole density in Figure 3 toward the lowest Cd pressures is due to an increasing density of Cd vacancies that act as shallow, double acceptors with energy level about 0.06 eV above the valence band. The defect isotherms are accounted for on the basis of a model in which P acts as a substitutional (singly charged) acceptor P_{Te} and/or a singly or multiply charged interstitial acceptor P_i , for high Cd anneal pressures. At low Cd pressures as well as at high P concentrations, P acts as a triply substitutional donor P_{Cd} , forming complexes such as $P_{Cd}P_i$ that may be charged or neutral. At still over Cd pressures Cd vacancies V_{Cd} and Te interstitials Te_i predominate. The defect equilibrium diagram is very complex. In general, however, as long as a moderate proportion of P is incorporated, the CdTe will always be p-type no matter what the Cd (or Te) pressure during annealing. At very low Cd pressures the hole density arises from native defects; at high Cd pressures during annealing, the hole density arises from the P impurity.

Early efforts at Stanford in connection with our research on photovoltaics were not well organized, and frequently high densities of P were used in an effort to obtain high-conductivity p-type CdTe. Although doping levels as high as $5 \times 10^{19} \text{ cm}^{-3}$ were used, carrier densities p remained in the low 10^{16} cm^{-3} range or below with considerable variation in p from boule to boule. Indeed, reduction in the P doping density gave values of p as high or higher. For example, boules No. 8 and No. 15 with $4 \times 10^{19} \text{ cm}^{-3}$ P incorporated gave p of the order of 10^{16} cm^{-3} , whereas No. 36 with $2 \times 10^{17} \text{ cm}^{-3}$ P also gave an equivalent hole density. Later results (including boule No. 53 grown on the current SERI contract) are summarized in Figure 5, where the hole density p near the starting end of the boule (as calculated from measured resistivity assuming a hole mobility of $80 \text{ cm}^2/\text{V-sec}$) is plotted against the

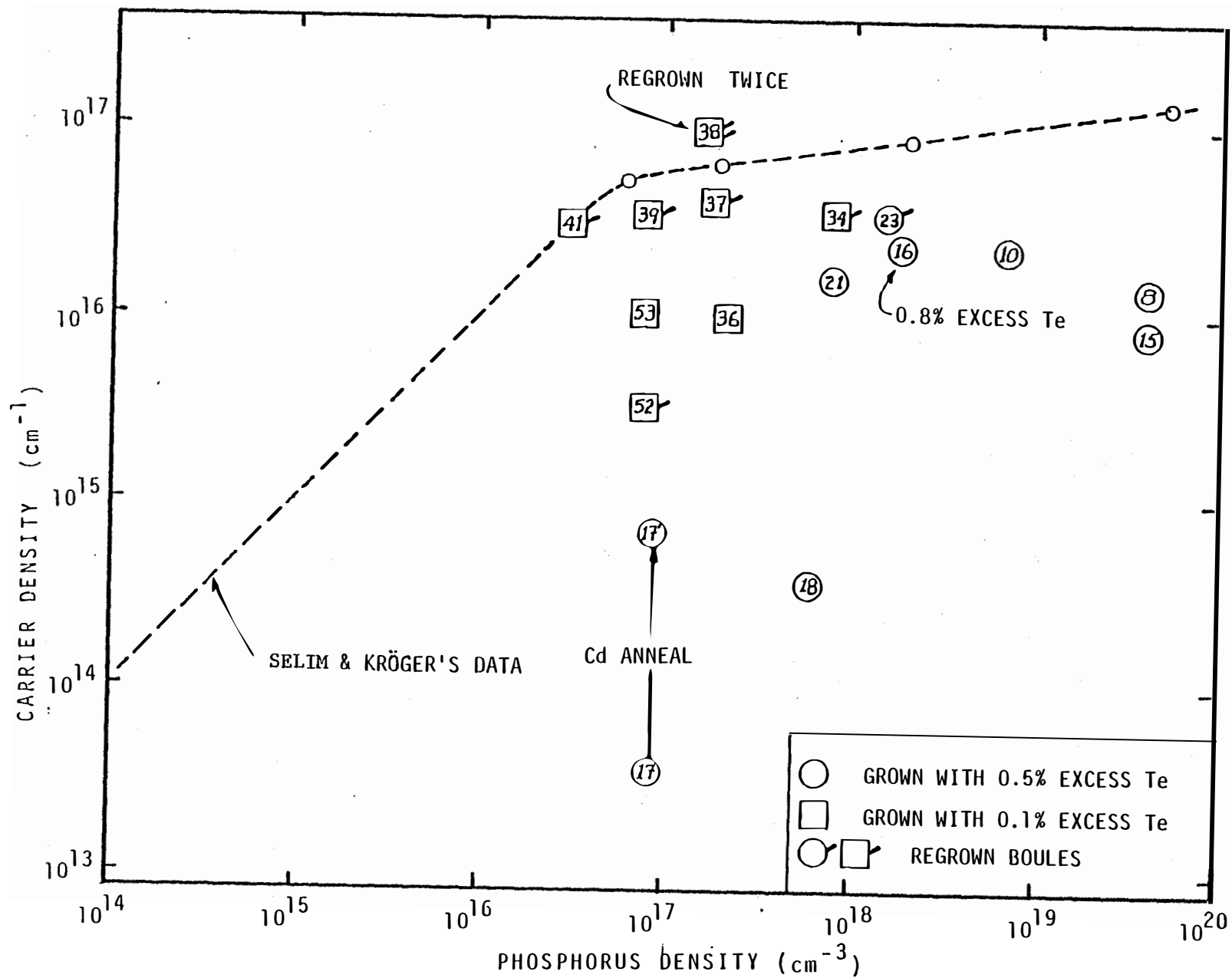


Fig. 5. Hole density versus P density as calculated from input to growth ampoule.

proportion of P put into the ampoule prior to growth. It is quite apparent that all of the samples with 0.1% excess Te have higher electrical activity of the P than those grown with 0.5% excess Te. The data also strongly suggest that regrowth is beneficial. In particular, boule No. 38, which was regrown twice, has the highest hole density p and the next to highest electrical activity of any of the boules grown to date.

Selim and Kröger's data for hole density vs P density were taken using mass spectrographic analysis of the CdTe crystal after it was grown and thus they represent the actual proportion of P incorporated in the CdTe:P (denoted by $[P]$ here). Our data, plotted in Figure 5 represent the proportion of P put in the ampoule before final crystal growth $[P]_0$. Thus, to obtain the P density theoretically in the grown crystal, we must adjust the density by the distribution coefficient, given by Selim and Kröger as $k_0 = 0.1$. For the start of the boule we should then have

$$p \sim [P] \sim k_0 [P]_0 \quad (1)$$

Six of our samples (Figure 5) have values exceeding the theoretical result given by Eq. (1), some by a factor of 10.

Our results for CdTe:P may not be strictly comparable to those of Selim and Kröger since their growths were followed by a Cd anneal while ours were not (except for the case of No. 17 that showed a 20-fold increase in p on annealing in Cd vapor). The growth stoichiometry conditions for our regrown crystals might approximate those of Selim and Kröger (apparently stoichiometric) since most of the excess Te is zoned out by the pre-growth. Nevertheless some qualitative considerations can be inferred from the comparison of their data with ours: The distribution coefficient for our growth process is > 0.1 and/or acceptor doping is predominantly by some other entity such as Cu or

Ag (from the starting material), or a complex involving Te_i or V_{Cd} . Certainly our experience with growth (using excess Te) of undoped CdTe resulting in resistivities greater than 10^5 ohm-cm suggests that P is playing a major role in determining carrier density.

Experiments are under way that should resolve these questions. Two crystals have been grown (but not yet characterized) for which the [P] was reduced to the 10^{15} to 10^{16} cm^{-3} range. A crystal has also been grown with excess Cd. Annealing a few slices of selected boules in Cd vapor may be tried as well in order to establish a firmer connection with Selim and Kröger's data.

Electrical Measurements on CdTe Boules

Early electrical measurements (before boule No. 52, ca. January 1981) consisted primarily of resistivity measurements, in some cases along the length of the boule. Measurements of resistivity were often hampered by the presence of grain boundary potential barriers that can electrically partition the boule in undetermined ways. In addition low-resistance ohmic contacts to p-CdTe are difficult to make, so that a four-point geometry and deposited contacts must always be used. Carrier density was then calculated by assuming a hole mobility of $80 \text{ cm}^2/V\text{-sec}$. A few independent carrier densities obtained from junction capacitance vs V measurements on $3 \times 5 \text{ mm}^2$ samples verified that the acceptor density for these samples was within about 50% of the values calculated from the assumed mobility.

Even with these rather crude profiling measurements a pattern emerged. The resistivity usually first decreased, then increased from the start to the finish end of the boule, with a minimum somewhere near the midpoint. This in turn suggests a maximum in p near the midpoint. The explanation proposed is that of the combined effects on the

distribution coefficient, increasing the density of incorporated [P] from start to finish (the theoretical shape of the [P] variation for $k_0 = 0.1$ is shown in Figure 6 for reference), and on the other impurities, that were assumed to compensate the P acceptors once their density had been increased to high enough levels by zoning. Excess Te being zoned out may play an important role here too. The resistivity profiling experiments also seem to indicate that the acceptor density is different from grain to grain within each boule, perhaps due to a dependence of k_0 on crystallographic orientation.

In connection with the SERI program on CdTe, more thorough characterization is clearly needed. For the recent boules, both resistivity and Hall mobility data were taken on small dice samples chosen from at least three positions along the length of the boule. The careful selection of small samples eliminates the presence of grain boundaries and should yield much better accuracy than before. In the future the Hall measurements will probably be supplanted by Schottky diode junction capacitance measurements, since these allow probing much smaller volumes and require much less sample preparation time. In addition, the capacitance measurement apparatus is automated, saving considerable data reduction time. Shown in Appendix 1 is a data sheet that represents the usual minimum data to be taken for each boule.

Current CdTe Growth and Characterization

Four p-type CdTe boules were grown (using vibration) and partially characterized during this quarter. Results for two of them are summarized in Figure 6. Boule No. 52 was regrown while No. 53 was not. The first growth of No. 52 was without dopant, and was used primarily to remove impurities. This was accomplished by zoning the impurities out to one end and then discarding that end of the boule (about 0.5 cm)

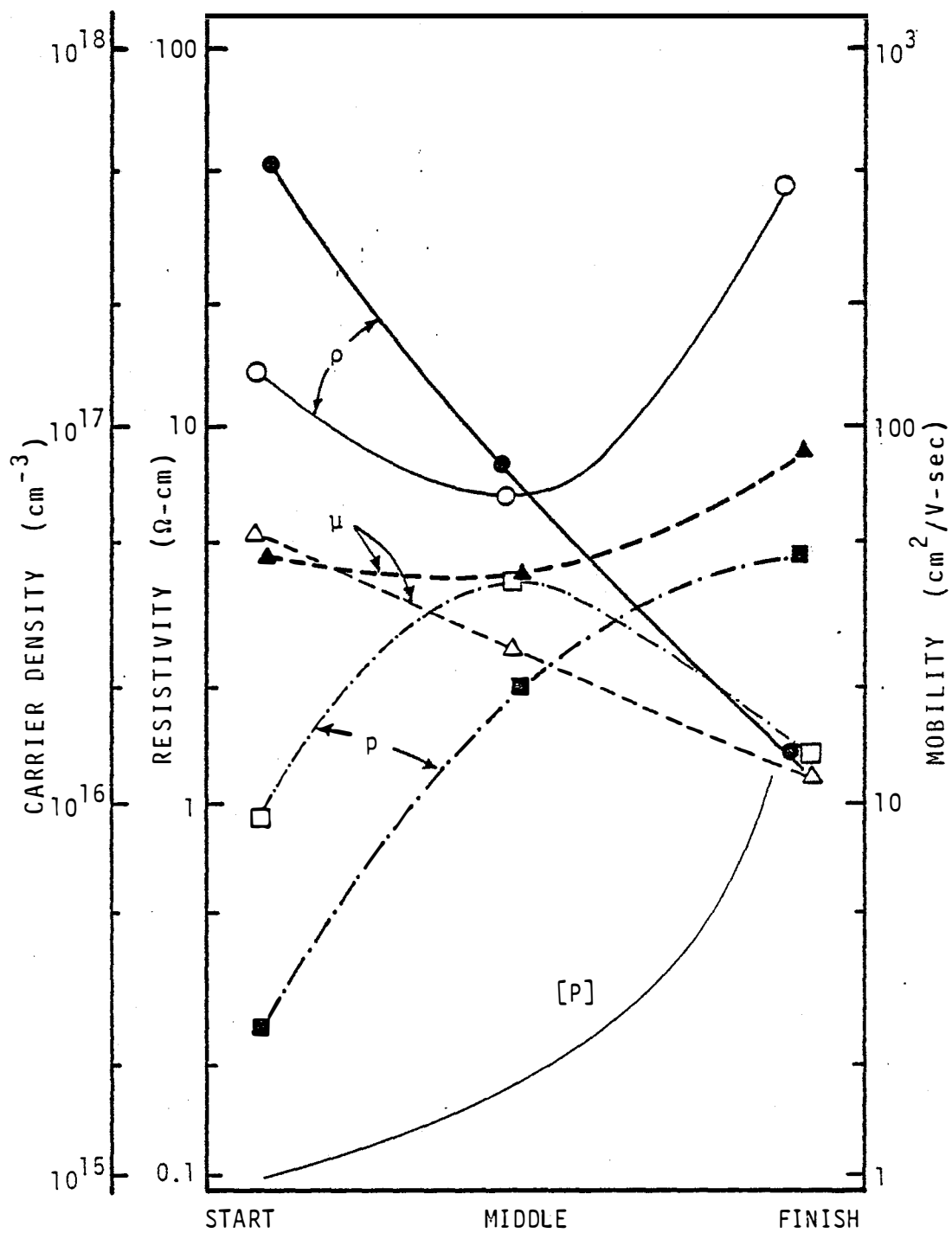


Fig. 6. Hole density p , Hall mobility μ , and resistivity ρ , versus distance along the boule for #53 (light curves) and #52 (bold curves). Also shown is a [P] distribution for $k_0 = 0.1$ (theoretical)

before regrowth. The dopant, in the form of Cd_3P_2 , was introduced during the second growth (regrowth), with an intended carrier density of $7.8 \times 10^{15} \text{ cm}^{-3}$ (accounting for a distribution coefficient of $k_0 = 0.1$). As can be seen from the resistivity profile of this boule, regrowth has essentially eliminated the rise in resistivity at the impure end that appears to be characteristic of once-grown crystals. For comparison, the profile of the once-grown boule, No. 53, whose growth conditions were otherwise identical to No. 52, is shown. A much smaller portion of No. 53 boule is low resistivity and thus usable for solar cells. All subsequent boules will be regrown as a result of these findings.

In addition, Hall measurements were made on small samples taken from along the length of each boule. The Van der Pauw method was used at room temperature. Carrier density along the boule qualitatively matches the conductivity profile. The mobility rises by a factor of two toward the finish end of No. 52, but falls by a factor of five for No. 53, suggesting that mobility-decreasing impurities (or defects) are being removed by regrowth.

The data suggest that the compensation effect is stronger in boule No. 53 (i.e., p decreases more toward the finish in No. 53 than it does in No. 52). In addition the mobility decreases toward the finish rather than increasing in No. 53. This may be due to an increased involvement of impurities other than P in the charged impurity scattering.

In the next quarter, growth of additional CdTe boules will be made, at first concentrating on the dopants, As, Sb, and Cs, that appear to be the most promising. All succeeding crystals will be grown with the same techniques, including vibration.

Grain Boundary Investigations

The initial investigation of single grain boundaries reported for n-type CdTe crystals in Progress Report No. 1 was extended to p-type

CdTe:P material. Samples were cut from the boules characterized as above. The contact surface was lapped with 1200 grit abrasive and then etched in 5% Br in MeOH for approximately 3 min to remove the damaged layer. A CuAu alloy (15% Cu by volume) was evaporated onto the surface to provide electrical contacts. There was no subsequent annealing. Four-point contacts were made on each side of the grain boundary, as shown in Figure 7, providing for the measurement of bulk resistivity on either side of the boundary as well as the I-V curve of the boundary itself. A typical sample cut from near the middle of the regrown boule No. 52 yielded bulk resistivity of 1 ohm-cm and a grain boundary resistivity of 2×10^5 ohm-cm² at room temperature. The slope of the grain boundary resistivity vs 1/T plot yielded an activation energy of 0.44 eV, considerably larger than the barrier heights observed for the n-type CdTe samples.

Samples were illuminated with white light with intensities up to 30 mW/cm². A negligible decrease in grain boundary resistivity was observed (less than 5%). This is in marked contrast to the n-type CdTe grain boundaries, where changes in excess of 50% were observed and spectral response data could be measured.

Although these data are of a preliminary nature, they suggest that the grain boundary potential barriers are much more strongly pinned in p-type than in n-type CdTe. Photocapacitance and EBIC measurements of both n- and p-type grain boundary samples will be made in the next quarter.

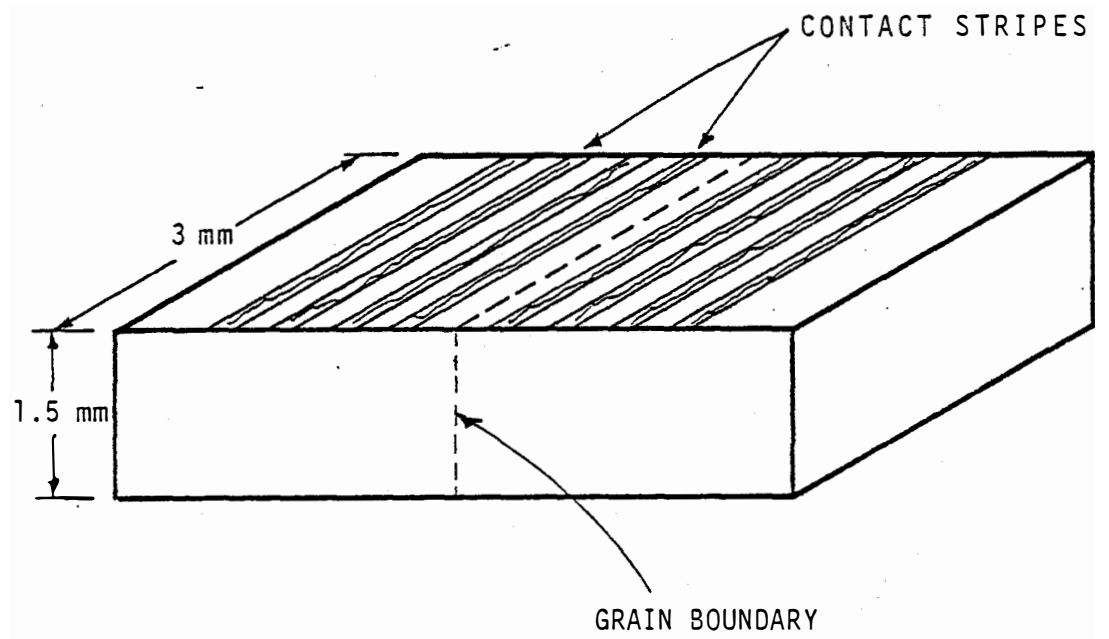


Fig. 7. Grain boundary analysis sample fo CdTe.

REFERENCE

1. F.A.Selim and F.A.Kröger, J. Electrochem. Soc. 124, 401 (1977)

APPENDIX 1

BULK CRYSTAL GROWTH

PREGROWTH CALCULATIONS

Desired resistivity _____ Ω -cm
 Assumed mobility _____ $\text{cm}^2/\text{V-sec}$
 Desired carrier density _____ $\times 10 \text{ cm}^{-3}$
 Assumed electrical activity _____ %
 Assumed distribution coef. _____
 Desired dopant elemental density input to growth ampoule _____ $\times 10 \text{ cm}^{-3}$
 Dopant compound _____ Source _____
 Desired weight of dopant compound input per gram of crystal _____ g/g

Material _____
 CMR Number _____
 PV Group Number _____
 Growth Date _____
 Contract 2 DHZ _____

STARTING MATERIALS

Material 1 _____ Purity _____ ns, Source _____ Batch _____ Weight _____ g.
 Material 2 _____ Purity _____ ns, Source _____ Batch _____ Weight _____ g.
 Dopant _____ Weight _____ g, Weight fraction* _____ $\times 10 \text{ g/g}$, Number density** _____ $\times 10 \text{ cm}^{-3}$
 Excess _____ Weight _____ g, Weight percent _____ %, Number density _____ $\times 10^{-3}$
 *of dopant compound **of doping element atoms

Treatment of starting materials: TOTAL WEIGHT _____ g.

#1 _____
 #2 _____

Carbon coated ampoule? _____ Vacuum bakeout _____

Details _____

FIRST GROWTH

Growth method _____ Temperature _____ $^{\circ}\text{C}$

Excess component incorporated when? _____

Vibration _____ Intensity _____

Details _____

SECOND GROWTH

Weight cut off finish end _____ g

Total weight regrown _____ g

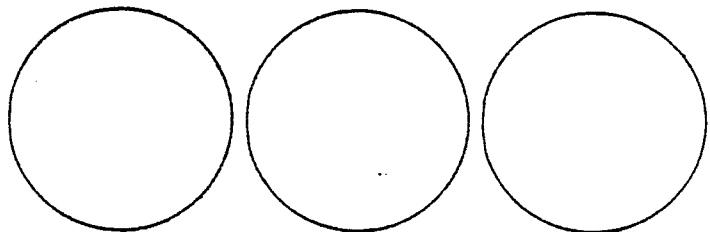
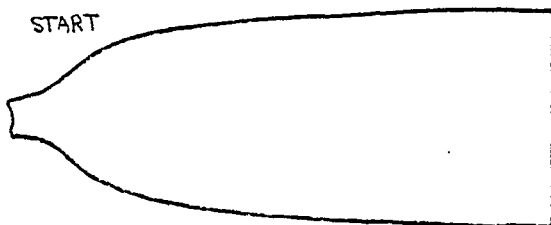
Dopant incorporated when? _____

Vibration _____ Intensity _____

Details _____

CRYSTAL QUALITY

CROSS SECTIONS



DISPOSITION OF BOULE

Name Date Use Portion of Boule Measured Carrier Density

ELECTRICAL PROPERTIES

	START	MIDDLE	FINISH
<u>Resistivity</u>			
Method _____			
Experimenter _____			
Values, Ω -cm.....			
Assumed mobility _____ $\text{cm}^2/\text{V-sec}$			
Calculated carrier density, cm^{-3} ...			
<u>Carrier density</u>			
Method _____			
Experimenter _____			
Values, cm^{-3}			
<u>Mobility</u>			
Method _____			
Experimenter _____			
Values, $\text{cm}^2/\text{V-sec}$			
<u>Minority Carrier Diffusion Length</u>			
Method _____			
Experimenter _____			
Values, μm			
<u>Other Measurements</u>			
Method _____			
Experimenter _____			
Values,			

Electrical Activity of Dopant

Using assumed distribution coefficient _____ and carrier density _____ $\times 10^{-3} \text{ cm}^{-3}$
 from _____ measurement.

Values, %.....

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