STUDY OF DRIFT-FIELD SOLAR CELLS DAMAGED BY LOW-ENERGY PROTONS

Contract NAS 5-9627

Report Covering Period of October 15 to November 19, 1965

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CONTENTS

1. OBJECTIVE

The objective is to conduct an irradiation study of drift-field solar cells (supplied by NASA) with low-energy protons. The experimental data are to consist of I-V curves and spectral response curves. The data are to be analyzed with the aid of a solar-cell model.

2. WORK SUMMARY

The irradiation was performed and reported in the previous monthly report (Ref. 1). The solar cells were mounted on Disks 13, 15, 16, 14,10, and 17 and irradiated at 2.53 Mev, 1.04 Mev, 1.04, 470 kev, 221 kev, and 221 kev, respectively. A typical I-V curve or spectral response curve is coded by three numbers, the first giving the disk number, the second, the irradiation run number, and the third, the cell position number. For an example, the code number, 13-4-5, refers to Disk 13, Run 4, and Cell-Position 5. Run 0 is a pre-irradiation run, Runs 1-6 are runs in which the cells were all irradiated to a particular proton fluence, and Runs 7 and 8 are runs to check on annealing.

Table 1 of the previous monthly report correlates cell-position numbers for each disk with the cell designation supplied by the manufacturer. Table 2 of that report gives the proton fluences corresponding to the code numbers. The values of these fluences are presently being re-examined as a result of comparing the damage obtained for uniform cells irradiated in the experiment of September 27-30, 1965 with the damage obtained for uniform cells in earlier experiments (Ref. 2-4). The experimental work this month was the measurement of the I-V curves of all irradiated cells to check on annealing effects (Run 8), the measurement of the spectral responses of three unirradiated control cells used to check stability of the O.C.L.I. sun simulator, the measurement of the spectral response of the cells on Disk 14, to check on annealing effects (Run 8), and the measurement of the effect of cleaning the filters in the filter-wheel spectrometer.

The computer program used to calculate the spectral response of a solar cell was modified to include two auxiliary computer programs. These programs calculate the number of layers and the width of each layer in the base of the n-layer solar cell model and the average values of the input parameters for each layer in such a way that the variations of the parameters over each layer are less than 10%. The first auxiliary program, called the "E" program, is used for uniform solar cells damaged by protons of energy, E. The second auxiliary program, called the "N" program, is used for unirradiated drift-field cells having a range of impurity atom densities, $N_1 \leq N \leq N_2$. A third auxiliary program, called the "N+E" program, is being developed to combine the "E" and "N" auxiliary programs for use with irradiated drift-field solar cells.

3. CONFORMANCE OR NON-CONFORMANCE WITH THE WORK SCHEDULE

The analysis of the data is proceeding satisfactorily and is considered to be on schedule.

4. ANALYSIS OF THE WORK

All the I-V curves were fitted to a modified diode equation to yield two parameters, R_s, the series resistance, and N, the coefficient of the kT term. These results are expected to be meaningful for the uniform cells but are not interpretable for the drift-field cells because of the negative values of R_s which frequently appear. However, because the fits are quite close, the results of the curve fitting serve to check irregularities in the data and to present the results in a compact form. Tables 1-12 give the results of the curve fitting. The "cell" column gives the code numbers of the cells.

The code numbers for each cell are grouped and the grouping identified by the manufacturer's designation for that cell. During the I-V measurements with the O.C.L.I. simulator the cells were cooled with an air blower and held to a room temperature estimated to be 298°K. The fourth column gives the short-circuit current, I_{sc}. The fifth column gives the open-circuit voltage, V_{oc}.

The fifth and sixth columns give R_s and N. The seventh, eighth, and ninth columns give the values of the maximum power and the coordinates of the maximum power.

For Disk 13 the drift-field cells are E-33-1A, E-33-2C, H-105, 72, and 82 while the uniform cells are located in cell positions 7, 8, and 9. The high value of N belonging to code number 13-6-9 is not a fault of the analysis but is thought to be caused by an electrical switching error during the measurements. Note that R_3 is positive for the three uniform cells except for the one coded 13-6-9.

For Disk 15, the drift-field cells are E-34-2D, E-35-4A, H-98, H-106, 76, and 85 while the uniform cells are located in the positions 7, 8, and 9. Note that R_s is positive for the three uniform cells.

For Disk 16, the drift-field cells are TI-3-2 (25μ) and TI-4-2 (12μ) while the uniform cells are located in the positions 4 and 5. Note that R_s is positive for the two uniform cells.

For Disk 14, the drift-field cells are H-61, 56, TI-3-3(25), TI-4-1(12), and E-54-8a while the uniform cells are located in the positions 3 and 4. Note that R_s is positive for the cell, H-10 Ω cm, in position 3 but is negative for the cell, H-1 Ω cm, in position 4.

For Disk 10, the drift-field cells are E-33-3A, E-33-2A, H-68, H-75, 62 and 64 while the uniform cells are at positions 7 and 9. Note that R_s is partly positive and partly negative for the uniform cells in positions 7 and 9.

For Disk 17, the drift-field cells are TI-3-1(25μ), TI-4-3(12μ) and E-55-1c while the uniform cells are at positions 5 and 6. For the most part, the values of R_s for the uniform cells are positive.

No explanation is offered at present for the negative values of R_s which occasionally are shown for the uniform cells.

The drift-field solar cell, No. 82 (Texas Instruments, Inc.), was chosen as a test case in comparing a measured spectral response with a spectral response calculated from the n-layer solar cell model (Ref. 5). This particular choice was made because information concerning this cell is given in Table VII of the Technical Summary Report (Ref. 6) published by the Texas Instruments, Inc.

The parameter on which several other parameters depend in calculating the spectral response of a drift-field cell from the solar cell model is the impurity (acceptor) atom density, N, which is a function of the distance, x, below the junction. Figure 1 depicts the different layers in the construction of a drift-field solar cell. Initially, the epitaxial and substrate layers have the uniform impurity atom densities, N_1 and N_2. Diffusion causes a new distribution of impurity atom densities to be produced when the two layers are raised to an elevated temperature for a time, t. After this process is completed an N/P junction is produced in the epitaxial layer at a distance, d_o, below its surface. The new distribution of impurity atom densities is assumed to have the form

$$N(x) = a + b\ \mathrm{erf}\left(\frac{x-c}{d}\right) \qquad \ldots (1)$$

where

$$a = \frac{N_1 + N_2}{2}\ , \qquad \ldots (2)$$

$$b = \frac{N_2 - N_1}{2}\ , \qquad \ldots (3)$$

$$c = w - d_o\ , \qquad \ldots (4)$$

and

$$d = 4D_B t \qquad \ldots (5)$$

In the last formula the diffusion coefficient, D_B, is evaluated for boron in silicon for the elevated temperature at which the diffusion process takes place. Numerical values which are pertinent to drift-field cell, No.82, are

$N_1 = 10^{15}$ atoms/cm^3, corresponding to a resistivity of 13 ohm cm, from Irvin's data (Ref. 7)

$N_2 = 1.6 \times 10^{17}$ atoms/cm^3, corresponding to a resistivity of 0.2 ohm cm, from Irvin's data (Ref. 7)

$d_o = 0.3\mu$,

$w = 25.9\mu$,

$D_B = 2 \times 10^{-12}$ cm^2/sec,

and

$t = 1.836 \times 10^5$ sec,

and are used in the calculation of a, b, c, and d as given by Eq's. (2-5). Finally, N(x) is calculated from Eq. (1).

The parameters which must be calculated for the solar cell model and which pertain to the minority carriers (electrons) in silicon are the mobility, $\mu(N)$, the lifetime, $\tau(N)$, the diffusion coefficient, D(N), and the diffusion length, L(N). Also, the strength of the drift electrical field, E(N), must be calculated. Since all these parameters are dependent on N they vary with the distance, x, as measured from the junction of the solar cell. The mobility, $\mu(N)$, was obtained as a function of N by fitting the experimental data (Fig. 6 of Ref. 6) to an equation of the form

$$\mu(N) = \mu_o + \mu_1 \log N + \mu_2(\log N)^2 + \mu_3 (\log N)^3 \qquad \ldots (6)$$

The lifetime, $\tau(N)$, was calculated by generalizing Eq. (3-5) of Ref. 6 into the form,

$$\tau = \tau_1 \left(\frac{N}{10^{15}} \right)^{-m} \qquad \ldots (7)$$

where the two new parameters, τ_1 and m, must be determined from the spectral response data. The diffusion coefficient, D(N), is calculated from the mobility, $\mu(N)$, according to

$$D = \frac{\mu kT}{e} . \qquad \ldots (8)$$

The diffusion length, L(N), is given by

$$L = D\tau . \qquad \ldots (9)$$

Finally, the drift electrical field, E(N), is calculated from

$$E = - \frac{kT}{e} \frac{d}{dx} \log N. \qquad \ldots (10)$$

Table 13 shows some of the output information given by the "N" computer program for the drift-field solar cell, No. 82, with values of the two parameters controlling the lifetime selected to be $\tau_1 = 0.3$ μsec and m = 0.4. The units in which the quantities are tabulated are given in order from left to right as cm^2/volt-sec for μ, ev/cm for eE, cm for L, cm for x (D), cm for Δx(DD), atoms of boron/cm^3 for N(FN), and cm^2/sec for D. The symbols appearing in Table 13 are part of the FORTRAN language required in the computer program.

Figure 2 shows graphs of the results of the calculations for the drift-field solar cell, No. 82, and of the measurements obtained with the filter wheel spectrometer. The ordinate gives the relative yield of the short-circuit current per photon while the ordinate gives the wavelength in microns. The data are all normalized to unity at $\lambda = 0.803\mu$. Twelve different combinations of τ_1 and m were tried before choosing the best three combinations shown in Fig. 2: m = 0.2 with τ_1 = 0.1, 0.3, 1, and 3 μsec; m = 0.4 with τ_1 = 0.1, 0.3, 1 and 3 μsec; m = 0.6 with τ_1 = 0.1, 0.3, 1, and 3 μsec. The best fit seems to be m = 0.4 and τ_1 = 0.3 μsec.

5. RELIABILITY PROCEDURES

A search is being made to find the reason for the lack of agreement between the present experimental data and three previous sets of data regarding proton fluences required to reduce relative short circuit currents to different prescribes values for 1-ohm-cm and 10-ohm-cm uniform solar cells at the same proton energies. The first set of data (Ref. 2) was obtained during October 1962 for 1- and 3- Mev protons. The second set of data (Ref. 3) was obtained during December 1963 for 0.1-, 0.2-, 0.3- and 0.5-Mev protons. The third set of data (Ref. 4) was obtained during November 1964 for 0.5-, 1.0-, and 2.7- Mev protons. The fourth or present set of data (Ref. 1) was obtained during September 1965 for 0.221-, 0.470-, 1.04-, and 2.53- Mev protons. The indications are that the present set of data give proton fluences about twice as large as they should be except for the 2.53- Mev data which are in good agreement with the other data.

6. ADEQUACY OF FUNDS

The funds provided by the contract are adequate to last at the present rate of expenditure, until December 15, the termination date of the contract.

7. CHANGE IN PERSONNEL

Participating personnel have been

J. De Pangher	Staff Scientist
D. L. Crowther	Research Scientist
W. H. Harless	Senior Scientist
E. A. Lodi	Senior Scientist
G. D. Jones	Research Laboratory Analyst
G. N. Biren	Research Laboratory Analyst

8. FUTURE WORK

The "N + E" computer-program arrangement for dividing the base region into layers is to be completed to enable comparisons to be made between theory (Ref.8)

and experiment for drift-field cells damaged by low-energy protons. An explanation is being sought for the discrepancies observed in the measured values of the proton fluences.

9. REFERENCES

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7. Irvin, J C., "Resistivity of Bulk Silicon and of Diffused Layers in Silicon," Bell System Tech. Jour. 41, 387-410 (1962).

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LIST OF TABLES

Table 1

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 2.53-Mev Protons (13-0-1 to 13-8-5)

	CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
E33-1A	13-0-1	298.	44.6000	0.4880	2.8695	0.9361	11.9895	35.8309	0.3346
	13-1-1	298.	44.0000	0.4880	2.7686	1.0732	11.8223	35.4630	0.3334
	13-2-1	298.	43.6000	0.4860	2.7226	1.1752	11.6453	35.2636	0.3302
	13-3-1	298.	41.9000	0.4790	2.6388	1.2663	10.9797	33.7870	0.3250
	13-4-1	298.	38.9000	0.4680	2.5224	1.3489	10.0177	31.4959	0.3181
	13-5-1	298.	36.5000	0.4590	2.4438	1.4384	9.2320	29.6020	0.3119
	13-6-1	298.	28.9000	0.4350	2.5086	1.2328	7.0033	23.3518	0.2999
	13-7-1	298.	29.4500	0.4450	2.4791	1.7357	7.1073	23.6486	0.3005
	13-8-1	298.	31.3000	0.4370	2.6582	1.2951	7.3805	24.8785	0.2967
E33-2C	13-0-2	298.	41.9000	0.5440	14.5864	-8.5454	10.4860	26.1869	0.4004
	13-1-2	298.	41.4000	0.5400	13.1384	-7.4051	10.3753	26.3241	0.3941
	13-2-2	298.	41.2000	0.5330	12.5133	-7.0579	10.3057	26.4519	0.3896
	13-3-2	298.	39.2000	0.5190	12.3996	-7.3466	9.4840	25.0354	0.3788
	13-4-2	298.	36.2000	0.4920	11.1525	-6.9514	8.3527	23.3453	0.3578
	13-5-2	298.	33.8000	0.4750	10.7181	-6.9058	7.4244	21.6782	0.3425
	13-6-2	298.	27.0000	0.4310	8.2289	-5.0084	5.2140	17.4513	0.2988
	13-7-2	298.	27.3000	0.4330	8.3592	-5.8073	5.5151	17.9425	0.3074
	13-8-2	298.	29.1000	0.4440	10.4047	-6.9999	5.6252	18.0714	0.3113
H-105	13-0-4	298.	48.6000	0.5610	3.2774	-1.1557	18.5540	41.5345	0.4467
	13-1-4	298.	48.1000	0.5520	3.3129	-1.3258	18.1882	41.0736	0.4428
	13-2-4	298.	47.7000	0.5370	3.1879	-1.3820	17.7531	40.8811	0.4343
	13-3-4	298.	45.6000	0.5130	2.9206	-1.2751	16.2965	39.2680	0.4150
	13-4-4	298.	42.2000	0.4860	2.7461	-1.2115	14.2022	36.3145	0.3911
	13-5-4	298.	39.5000	0.4710	2.5254	-0.9905	12.8127	34.1002	0.3757
	13-6-4	298.	32.1000	0.4400	2.7568	-1.5634	9.5057	27.1911	0.3496
	13-7-4	298.	32.5000	0.4400	3.3091	-2.2558	9.4498	26.9387	0.3508
	13-8-4	298.	35.1000	0.4460	2.8650	-1.5706	10.5419	29.6693	0.3553
72	13-0-5	298.	52.8000	0.5780	5.6995	-2.3687	18.7039	41.6649	0.4489
	13-1-5	298.	51.7000	0.5740	6.0395	-2.7943	18.2237	40.5326	0.4496
	13-2-5	298.	50.8000	0.5660	5.9814	-2.9518	17.8507	39.9397	0.4469
	13-3-5	298.	47.0000	0.5500	5.6047	-2.8349	15.9906	37.0597	0.4315
	13-4-5	298.	41.7000	0.5270	4.9839	-2.5521	13.5523	33.1165	0.4092
	13-5-5	298.	38.0000	0.5140	5.0279	-2.8962	11.9917	30.0243	0.3993
	13-6-5	298.	29.1000	0.4810	4.8439	-3.5012	8.4475	22.8019	0.3705
	13-7-5	298.	29.6000	0.4800	4.0297	-2.4409	8.7927	23.8281	0.3690
	13-8-5	298.	31.3000	0.4840	4.4380	-2.4867	9.0907	24.7316	0.3676

Table 2

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 2.53-Mev Protons (13-0-6 to 13-8-9)

CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
13-0-6	298.	59.2000	0.5870	2.0466	-0.3406	25.7992	53.5691	0.4816
13-1-6	298.	56.1000	0.5770	2.0563	-0.4025	24.0225	50.6853	0.4739
13-2-6	298.	54.1000	0.5660	1.9520	-0.3509	22.7763	49.0039	0.4648
13-3-6	298.	50.1000	0.5480	1.7464	-0.1813	20.4377	45.6169	0.4480
13-4-6	298.	45.7000	0.5240	1.6301	-0.0857	17.7485	41.6441	0.4262
13-5-6	298.	42.8000	0.5110	1.7443	-0.2943	16.1509	38.7473	0.4168
13-6-6	298.	34.2000	0.4790	1.7080	-0.5429	12.1507	30.8956	0.3933
13-7-6	298.	34.7000	0.4780	1.5988	-0.2524	12.2253	31.4459	0.3888
13-8-6	298.	37.1000	0.4830	1.8596	-0.3778	12.8810	33.1528	0.3885
13-0-7	298.	68.1000	0.5540	1.5407	0.1713	27.7791	62.4154	0.4451
13-1-7	298.	64.8000	0.5410	1.4361	0.3366	25.5049	59.4416	0.4291
13-2-7	298.	61.6000	0.5150	1.3683	0.2445	23.3717	56.5144	0.4128
13-3-7	298.	54.6000	0.4960	1.4039	0.2113	19.8128	49.9385	0.3967
13-4-7	298.	49.0000	0.4810	1.3669	0.3705	16.9429	44.6754	0.3792
13-5-7	298.	46.4000	0.4660	1.3692	0.1994	15.7468	42.3105	0.3722
13-6-7	298.	39.5000	0.4490	1.4981	1.1187	11.4463	34.9411	0.3276
13-7-7	298.	39.6500	0.4475	1.4291	1.0584	11.6154	35.2291	0.3297
13-8-7	298.	42.2000	0.4520	1.5069	0.8018	12.6377	37.4785	0.3372
13-0-8	298.	49.9000	0.5410	2.3815	-0.1752	18.4034	43.6748	0.4214
13-1-8	298.	45.5000	0.5340	2.3710	-0.2716	16.6502	39.8422	0.4179
13-2-8	298.	42.7000	0.5250	2.2479	-0.1632	15.3594	37.4946	0.4096
13-3-8	298.	37.7000	0.5160	2.2987	-0.4059	13.4146	33.0480	0.4059
13-4-8	298.	33.8000	0.5030	2.2880	-0.5054	11.7051	29.5707	0.3958
13-5-8	298.	31.5000	0.4970	2.1746	-0.3313	10.7501	27.6266	0.3891
13-6-8	298.	25.7000	0.4760	1.9564	-0.2776	8.4990	22.7037	0.3743
13-7-8	298.	25.8500	0.4750	2.2039	-0.6675	8.4240	22.5628	0.3734
13-8-8	298.	27.3000	0.4750	2.2245	-0.3769	8.7266	23.7081	0.3681
13-0-9	298.	66.3000	0.5410	1.3422	0.1955	26.9681	61.3544	0.4395
13-1-9	298.	63.5000	0.5300	1.3308	0.2715	24.9959	58.6202	0.4264
13-2-9	298.	60.7000	0.5220	1.2624	0.5053	23.0034	55.9611	0.4111
13-3-9	298.	54.3000	0.5030	1.2028	0.6123	19.7033	50.0432	0.3937
13-4-9	298.	48.6000	0.4750	1.2489	0.3581	16.9011	44.6504	0.3785
13-5-9	298.	45.9000	0.4720	1.2522	0.5565	15.5129	41.9973	0.3694
13-6-9	298.	28.9000	0.4460	6.3133	-1.6451	5.7727	19.3761	0.2979
13-7-9	298.	39.0000	0.4400	2.8084	1.0211	9.1201	30.6804	0.2973
13-8-9	298.	41.6000	0.4440	1.5586	1.3401	11.3587	36.1545	0.3142

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H-10 ohm cm

H-1 ohm cm

H-110

Table 3

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 1.04-Mev Protons (15-0-1 to 15-8-3)

	CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
E34-2D	15-0-1	298.	43.1000	0.4420	1.2862	0.0890	14.0820	39.4196	0.3572
	15-1-1	298.	43.0000	0.4350	1.3464	0.0305	13.7175	39.1283	0.3506
	15-2-1	298.	44.4000	0.4400	1.2860	0.1361	14.3441	40.5539	0.3537
	15-3-1	298.	44.3000	0.4340	1.3820	-0.0282	14.0974	40.2377	0.3504
	15-4-1	298.	41.0000	0.4260	1.3776	0.0987	12.5813	37.0900	0.3392
	15-5-1	298.	37.6000	0.4160	1.5003	0.0525	11.0180	33.6254	0.3277
	15-6-1	298.	34.4000	0.3900	1.6809	0.5311	8.5629	29.6973	0.2883
	15-7-1	298.	32.4000	0.3915	1.7438	0.2414	8.2697	28.0421	0.2949
	15-8-1	298.	34.6000	0.3940	1.5904	0.3921	8.9980	30.2689	0.2973
E35-4A	15-0-2	298.	54.0000	0.5280	2.4274	-0.3795	19.6710	47.2248	0.4165
	15-1-2	298.	53.2000	0.5100	2.4710	-0.5670	18.8284	46.3895	0.4059
	15-2-2	298.	55.1000	0.5060	2.3309	-0.4689	19.4855	48.3121	0.4033
	15-3-2	298.	53.0000	0.4810	2.3879	-0.6064	17.7001	46.1295	0.3837
	15-4-2	298.	46.0000	0.4520	2.4823	-0.9770	14.4535	39.7145	0.3639
	15-5-2	298.	39.7000	0.4330	2.2344	-0.6306	11.6678	34.2697	0.3405
	15-6-2	298.	34.6000	0.4010	1.8415	0.0219	9.1480	29.9527	0.3054
	15-7-2	298.	33.1000	0.4050	2.1889	-0.5330	8.8171	28.2475	0.3121
	15-8-2	298.	35.5000	0.4070	2.2447	-0.5372	9.4709	30.2169	0.3134
H-98	15-0-3	298.	51.2000	0.5590	2.8746	-0.8678	19.9144	44.4557	0.4480
	15-1-3	298.	50.6000	0.5380	2.7520	-0.8654	19.0142	43.9903	0.4322
	15-2-3	298.	52.1000	0.5270	2.3139	-0.5168	19.4734	45.9897	0.4234
	15-3-3	298.	49.6000	0.4940	2.3938	-0.8249	17.4464	43.4846	0.4012
	15-4-3	298.	43.3000	0.4700	2.4186	-0.9894	14.3364	37.6946	0.3803
	15-5-3	298.	38.0000	0.4510	2.3212	-0.9217	11.8976	32.9757	0.3608
	15-6-3	298.	33.2000	0.4230	2.1811	-0.7163	9.5180	28.6509	0.3322
	15-7-3	298.	31.7000	0.4260	3.1023	-1.9745	8.8615	26.3092	0.3368
	15-8-3	298.	34.0000	0.4300	3.4787	-2.7119	9.8282	28.1055	0.3497

Table 4

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 1.04-Mev Protons (15-0-4 to 15-8-6)

CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
15-0-4	298.	52.3000	0.5110	2.9949	-0.6130	17.4441	44.2304	0.3944
15-1-4	298.	51.5000	0.5000	3.0470	-0.7633	16.8570	43.4334	0.3881
15-2-4	298.	53.0000	0.4990	3.0069	-0.7894	17.4847	44.8552	0.3898
15-3-4	298.	50.3000	0.4790	2.9180	-0.9180	16.0807	42.6296	0.3772
15-4-4	298.	44.1000	0.4610	2.7478	-0.9151	13.5490	37.4338	0.3619
15-5-4	298.	39.0000	0.4460	2.7087	-0.9629	11.4703	32.9623	0.3480
15-6-4	298.	34.0000	0.4200	2.1179	-0.3037	9.4141	29.2048	0.3223
15-7-4	298.	32.4000	0.4220	2.8802	-1.4643	8.8835	26.9858	0.3292
15-8-4	298.	34.7000	0.4260	2.9348	-1.3081	9.5085	28.7998	0.3302
15-0-5	298.	42.3000	0.5920	3.1077	-1.2188	17.4464	36.6761	0.4757
15-1-5	298.	41.4000	0.5830	2.8820	-1.1361	17.0358	36.1724	0.4710
15-2-5	298.	42.6000	0.5820	2.8413	-1.0499	17.4978	37.2572	0.4696
15-3-5	298.	40.5000	0.5620	3.2538	-1.6102	15.8065	34.8013	0.4542
15-4-5	298.	36.4000	0.5410	2.6180	-1.0052	13.7983	31.8089	0.4338
15-5-5	298.	33.0000	0.5240	2.4571	-0.9440	12.1294	28.9164	0.4195
15-6-5	298.	28.2000	0.4930	2.3346	-1.0521	9.7295	24.6793	0.3942
15-7-5	298.	27.0000	0.4970	2.3017	-0.9344	9.3597	23.6539	0.3957
15-8-5	298.	28.7000	0.4970	2.3277	-0.8319	9.8844	25.0861	0.3940
15-0-6	298.	62.0000	0.5850	1.9556	-0.1746	26.7420	56.1998	0.4759
15-1-6	298.	60.4000	0.5670	1.7702	0.0067	25.1286	54.9365	0.4574
15-2-6	298.	61.0000	0.5550	1.7217	-0.0337	25.0029	55.5637	0.4500
15-3-6	298.	54.6000	0.5300	1.5470	0.1253	21.2738	49.8844	0.4265
15-4-6	298.	45.8000	0.5050	1.5221	0.0884	16.9719	41.7494	0.4065
15-5-6	298.	40.3000	0.4900	1.5062	0.0703	14.4600	36.6732	0.3942
15-6-6	298.	34.3000	0.4600	1.5423	-0.0424	11.4265	30.9845	0.3688
15-7-6	298.	32.8500	0.4610	1.5876	-0.1783	11.0105	29.6425	0.3714
15-8-6	298.	35.2000	0.4560	1.8876	-0.2938	11.5365	31.2073	0.3697

Table 5

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 1.04-Mev Protons (15-0-7 to 15-8-9)

	CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
H-10 ohm cm	15-0-7	298.	66.6000	0.5540	1.6319	0.1515	26.9048	60.7333	0.4430
	15-1-7	298.	65.4000	0.5400	1.5448	0.3262	25.2978	59.5692	0.4247
	15-2-7	298.	67.7000	0.5350	1.4415	0.4975	25.5811	61.7423	0.4143
	15-3-7	298.	62.8000	0.5000	1.5163	0.3792	21.9839	56.7589	0.3873
	15-4-7	298.	53.2000	0.4740	1.4977	0.3855	17.5715	47.9099	0.3668
	15-5-7	298.	45.6000	0.4550	1.5193	0.2986	14.4843	40.9271	0.3539
	15-6-7	298.	38.8000	0.4230	1.6179	0.3225	11.0597	34.2402	0.3230
	15-7-7	298.	36.7000	0.4270	1.7907	0.0961	10.5425	32.1492	0.3279
	15-8-7	298.	39.3000	0.4310	1.8456	0.1649	11.2379	34.2627	0.3280
H-1 ohm cm	15-0-8	298.	66.1000	0.5490	1.6111	0.4456	25.4217	59.8748	0.4246
	15-1-8	298.	65.0000	0.5370	1.5017	0.6085	24.1445	58.9233	0.4098
	15-2-8	298.	64.9000	0.5290	1.4993	0.6494	23.5078	58.6702	0.4007
	15-3-8	298.	61.0000	0.5000	1.3809	0.7456	20.7226	55.1549	0.3757
	15-4-8	298.	50.6000	0.4730	1.3820	0.6897	16.3896	45.6535	0.3590
	15-5-8	298.	42.4000	0.4570	1.4455	0.6785	13.1909	38.0088	0.3470
	15-6-8	298.	35.2000	0.4270	1.5317	0.6663	10.0054	31.1284	0.3214
	15-7-8	298.	33.5500	0.4300	1.6098	0.6347	9.5545	29.5420	0.3234
	15-8-8	298.	36.0000	0.4340	1.7351	0.5589	10.1984	31.4358	0.3244
RCA 10 ohm cm	15-0-9	298.	69.9000	0.5520	1.5526	0.4333	27.2523	63.5800	0.4286
	15-1-9	298.	68.3000	0.5400	1.4295	0.5383	25.9904	62.3326	0.4170
	15-2-9	298.	69.7000	0.5300	1.4975	0.4330	26.0018	63.3418	0.4105
	15-3-9	298.	64.4000	0.5100	1.3757	0.6273	22.7491	58.5265	0.3887
	15-4-9	298.	55.4000	0.4810	1.3696	0.6055	18.4437	50.1688	0.3676
	15-5-9	298.	45.7000	0.4650	1.4502	0.5291	15.0055	42.0260	0.3571
	15-6-9	298.	39.0000	0.4380	1.4381	0.6565	11.5837	34.8437	0.3324
	15-7-9	298.	37.4000	0.4390	1.4812	0.6221	11.1291	33.3477	0.3337
	15-8-9	298.	39.6000	0.4420	1.6826	0.4382	11.7347	35.0574	0.3347

Table 6

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 1.04-Mev Protons (16-0-1 to 16-8-5)

	CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
TI 3-2 (25μ)	16-0-1	298.	59.8300	0.5898	2.1875	-0.3987	25.9504	53.8262	0.4821
	16-1-1	298.	58.4700	0.5794	2.0892	-0.2442	24.6658	52.6107	0.4688
	16-2-1	298.	55.8000	0.5684	1.9857	-0.2104	23.1805	50.3493	0.4604
	16-3-1	298.	50.9200	0.5487	1.8695	-0.2393	20.5865	46.0865	0.4467
	16-4-1	298.	44.2000	0.5243	1.6604	-0.0513	17.0421	40.1805	0.4241
	16-5-1	298.	39.9300	0.5083	1.5351	0.0229	14.9912	36.4327	0.4115
	16-6-1	298.	33.2700	0.4789	1.5165	0.0543	11.6110	30.1985	0.3845
	16-7-1	298.	32.0500	0.4750	1.5088	-0.0369	11.1643	29.1163	0.3834
	16-8-1	298.	34.7000	0.4830	1.8408	-0.2849	11.9668	30.9911	0.3861
TI 4-2 (12 μ)	16-0-2	298.	46.3700	0.5860	2.3583	-0.4377	19.4131	41.2568	0.4705
	16-1-2	298.	45.3000	0.5815	2.3474	-0.3024	18.5724	40.1918	0.4621
	16-2-2	298.	44.7200	0.5780	2.3389	-0.3102	18.2211	39.6687	0.4593
	16-3-2	298.	42.7300	0.5664	2.1792	-0.2855	17.2563	38.1259	0.4526
	16-4-2	298.	38.7500	0.5480	2.0731	-0.2861	15.1888	34.6380	0.4385
	16-5-2	298.	35.6500	0.5327	1.8624	-0.1153	13.6774	32.0822	0.4263
	16-6-2	298.	29.4000	0.5037	1.8582	-0.2534	10.5997	26.3301	0.4026
	16-7-2	298.	28.7500	0.5000	1.8543	-0.5417	10.4635	25.8180	0.4053
	16-8-2	298.	30.7000	0.5040	1.8903	-0.2562	11.0355	27.4442	0.4021
RCA 10 ohm cm	16-0-4	298.	69.5200	0.5579	1.3969	0.2181	29.0000	64.2504	0.4514
	16-1-4	298.	68.9200	0.5483	1.3085	0.4289	27.6634	63.6666	0.4345
	16-2-4	298.	66.4300	0.5355	1.3059	0.4689	25.8004	61.2056	0.4215
	16-3-4	298.	61.1700	0.5104	1.3123	0.4534	22.4984	56.1311	0.4008
	16-4-4	298.	51.5800	0.4842	1.3917	0.3753	17.8615	46.9548	0.3804
	16-5-4	298.	44.3700	0.4670	1.4256	0.3150	14.7847	40.2215	0.3676
	16-6-4	298.	36.6400	0.4447	1.6172	0.7344	10.7363	32.2959	0.3324
	16-7-4	298.	36.1600	0.4390	1.5748	0.4177	10.8232	32.1403	0.3367
	16-8-4	298.	39.3000	0.4430	1.6488	0.4535	11.6745	34.7150	0.3363
HOFF 10 ohm cm	16-0-5	298.	71.5300	0.5442	1.9119	0.0726	27.4585	64.1026	0.4284
	16-1-5	298.	71.2000	0.5343	1.7258	0.3221	26.3775	63.9649	0.4124
	16-2-5	298.	69.2500	0.5235	1.7837	0.3316	24.7751	61.8072	0.4008
	16-3-5	298.	64.9000	0.5000	1.6771	0.4249	21.9728	57.8795	0.3796
	16-4-5	298.	56.0000	0.4719	1.5921	0.4479	17.9098	49.9308	0.3587
	16-5-5	298.	47.9200	0.4537	1.6695	0.3398	14.6978	42.4387	0.3463
	16-6-5	298.	39.7500	0.4250	1.7055	0.4799	11.0344	34.7955	0.3179
	16-7-5	298.	33.9300	0.4210	1.7323	0.2020	10.3696	34.1479	0.3212
	16-8-5	298.	42.0000	0.4260	1.9999	0.1206	11.5830	34.1323	0.3206

Table 7

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 470-kev Protons (14-0-1 to 14-8-4)

H-61 56 H-10 ohm cm ii-1 ohm cm

CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
14-0-1	298.	56.9300	0.5167	1.8651	0.0282	20.7543	50.9247	0.4075
14-1-1	298.	56.7300	0.5189	1.7673	0.0320	21.0699	51.0855	0.4124
14-2-1	298.	56.4700	0.5122	1.6527	0.1339	20.7214	51.0427	0.4060
14-3-1	298.	55.9000	0.4942	1.6008	0.0497	19.9791	50.5947	0.3949
14-4-1	298.	51.3400	0.4660	1.7787	-0.1573	17.0154	45.8135	0.3714
14-5-1	298.	47.0300	0.4411	2.0088	-0.4918	14.5714	41.3165	0.3527
14-6-1	298.	40.3000	0.3974	2.8027	-1.1837	10.3516	33.4160	0.3098
14-7-1	298.	38.1000	0.4000	2.4848	-0.7395	9.8171	31.9421	0.3073
14-8-1	298.	40.6000	0.4070	2.7592	-0.9924	10.6116	33.7333	0.3146
14-0-2	298.	53.6000	0.5482	2.9994	-0.6959	19.7694	45.9451	0.4303
14-1-2	298.	51.9300	0.5330	2.5294	-0.4907	19.0958	45.2999	0.4215
14-2-2	298.	50.9300	0.5122	2.4751	-0.4004	17.7363	44.2196	0.4011
14-3-2	298.	47.0000	0.4745	2.4356	-0.5975	15.1870	40.6197	0.3739
14-4-2	298.	39.5300	0.4412	2.9878	-1.0556	11.1517	32.8093	0.3399
14-5-2	298.	34.4500	0.4132	3.6579	-2.1495	8.8544	27.6215	0.3206
14-6-2	298.	26.5300	0.3645	4.4672	-3.2075	5.3593	19.7574	0.2713
14-7-2	298.	26.5000	0.3680	4.2416	-2.8415	5.4357	19.9169	0.2729
14-8-2	298.	31.0000	0.3700	4.0002	-1.7706	6.2490	23.2785	0.2684
14-0-3	298.	65.6500	0.5482	1.9012	0.2258	24.9662	58.6965	0.4253
14-1-3	298.	64.4500	0.5445	1.9404	0.2363	24.1471	57.4200	0.4205
14-2-3	298.	64.4200	0.5317	1.7471	0.4581	23.3033	57.5898	0.4046
14-3-3	298.	63.8900	0.5020	1.6208	0.5722	21.4716	56.9964	0.3767
14-4-3	298.	59.0700	0.4680	1.7794	0.4839	17.9857	51.7411	0.3476
14-5-3	298.	55.4500	0.4387	2.1423	0.1862	15.3451	47.2309	0.3249
14-6-3	298.	52.4700	0.3857	2.5050	0.1818	11.5256	42.2295	0.2729
14-7-3	298.	50.0000	0.3900	2.5264	0.0236	11.3932	40.5878	0.2807
14-8-3	298.	52.4000	0.3980	2.4794	0.1900	12.0631	42.5598	0.2834
14-0-4	298.	62.7500	0.5608	2.3130	-0.2142	24.6704	55.5220	0.4443
14-1-4	298.	61.5500	0.5576	2.4348	-0.3635	24.0886	54.2392	0.4441
14-2-4	298.	61.3200	0.5487	2.2640	-0.1977	23.5358	54.2308	0.4340
14-3-4	298.	57.0000	0.5272	2.1518	-0.1946	21.0617	50.4711	0.4173
14-4-4	298.	49.8600	0.5033	2.3000	-0.3861	17.3349	43.6367	0.3973
14-5-4	298.	43.4000	0.4867	1.9492	-0.3047	14.9867	38.5760	0.3885
14-6-4	298.	30.2300	0.4510	2.1079	-0.6959	9.4393	26.4226	0.3572
14-7-4	298.	27.2000	0.4515	1.8772	-0.4766	8.6350	24.0668	0.3588
14-8-4	298.	30.3000	0.4580	2.0940	-0.4633	9.5042	26.4677	0.3591

Table 8

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 470-kev Protons (14-0-5 to 14-8-7)

	CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
TI 3-3 (25μ)	14-0-5	298.	57.8500	0.5920	2.2315	-0.3460	24.8929	51.8783	0.4798
	14-1-5	298.	56.9200	0.5805	1.9175	-0.0914	24.1757	51.5597	0.4689
	14-2-5	298.	57.1300	0.5645	1.8146	0.0467	23.3907	51.7637	0.4519
	14-3-5	298.	54.4200	0.5314	1.7140	0.0342	20.9865	49.3023	0.4257
	14-4-5	298.	49.0000	0.5033	1.8187	-0.0476	17.5480	43.8983	0.3997
	14-5-5	298.	43.6700	0.4834	1.5827	-0.0416	15.3890	39.5555	0.3890
	14-6-5	298.	31.0800	0.4440	1.6580	-0.1898	9.8284	27.7850	0.3537
	14-7-5	298.	27.8000	0.4440	1.7028	-0.0844	8.6493	24.7274	0.3498
	14-8-5	298.	30.2000	0.4510	2.9489	-0.1701	8.0587	24.5900	0.3277
TI 4-1 (12μ)	14-0-6	298.	44.5200	0.5813	2.5407	-0.5584	18.2121	39.2502	0.4640
	14-1-6	298.	43.5000	0.5815	2.4788	-0.4468	17.7493	38.4011	0.4622
	14-2-6	298.	43.2700	0.5725	2.3007	-0.3479	17.5418	38.4363	0.4564
	14-3-6	298.	40.0800	0.5525	2.3049	-0.5998	15.8123	35.5629	0.4446
	14-4-6	298.	35.0300	0.5279	2.1102	-0.4353	13.1526	31.1556	0.4222
	14-5-6	298.	32.0300	0.5126	2.0458	-0.5794	11.7780	28.5375	0.4127
	14-6-6	298.	27.3400	0.4837	1.9792	-0.4729	9.3210	24.2313	0.3847
	14-7-6	298.	24.3000	0.4840	2.0255	-0.9416	8.4254	21.5699	0.3906
	14-8-6	298.	25.7000	0.4880	1.9236	-0.2561	8.8025	22.8212	0.3857
E54-8a	14-0-7	298.	40.2200	0.5752	1.2007	0.4549	17.8186	37.6720	0.4730
	14-1-7	298.	39.1500	0.5715	1.1956	0.4794	17.2060	36.6588	0.4694
	14-2-7	298.	38.9700	0.5615	1.1980	0.4922	16.7429	36.4321	0.4595
	14-3-7	298.	35.3800	0.5352	1.2538	0.2959	14.4725	32.9152	0.4397
	14-4-7	298.	29.9500	0.5107	1.3067	0.3335	11.4847	27.6634	0.4152
	14-5-7	298.	25.8900	0.4935	1.2011	0.3446	9.7083	24.0190	0.4042
	14-6-7	298.	19.0500	0.4605	1.4548	-0.0705	6.4449	17.3174	0.3722
	14-7-7	298.	17.4000	0.4610	1.4474	-0.5043	6.0091	15.8738	0.3786
	14-8-7	298.	18.7000	0.4670	1.3004	0.5204	6.4299	17.1376	0.3752

Table 9

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 221-kev Protons (10-0-1 to 10-8-4)

	CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
E33-3A	10-0-1	298.	32.2000	0.5320	5.0412	-1.2780	9.2637	24.4709	0.3786
	10-1-1	298.	31.6000	0.5270	5.3469	-1.7551	8.9652	23.7945	0.3768
	10-2-1	298.	30.2000	0.5200	5.1967	-1.5864	8.4022	22.7263	0.3697
	10-3-1	298.	27.0000	0.5120	4.6368	-1.1781	7.5165	20.6619	0.3638
	10-4-1	298.	23.3000	0.4950	4.1750	-0.7268	6.2881	17.9844	0.3496
	10-6-1	298.	16.0000	0.4390	3.7594	-0.5172	3.7547	12.2405	0.3067
	10-7-1	298.	14.9000	0.4330	3.5790	-0.4822	3.4817	11.4824	0.3032
	10-8-1	298.	15.9000	0.4390	3.7237	-0.0403	3.6619	12.0897	0.3029
E33-2A	10-0-2	298.	29.4000	0.3960	2.9708	0.9207	5.9563	22.4201	0.2657
	10-1-2	298.	28.8000	0.3930	2.6841	1.3581	5.8010	22.1886	0.2614
	10-2-2	298.	27.5000	0.3890	3.1844	0.8713	5.3148	20.5324	0.2588
	10-3-2	298.	24.0000	0.3800	2.9041	0.6926	4.7607	18.4135	0.2585
	10-4-2	298.	20.2000	0.3630	2.4688	1.6489	3.7983	15.6355	0.2429
	10-6-2	298.	13.4000	0.3180	3.0016	-0.5114	2.1742	9.9621	0.2182
	10-7-2	298.	12.5000	0.3140	2.6721	0.4474	2.0128	9.4166	0.2138
	10-8-2	298.	13.4000	0.3200	2.0786	3.4020	2.1305	10.2427	0.2080
H-68	10-0-3	298.	49.3000	0.5510	1.8745	-0.1380	19.8037	44.5433	0.4446
	10-1-3	298.	49.2000	0.5430	1.4939	0.1883	19.8073	45.1706	0.4385
	10-2-3	298.	49.6000	0.5210	1.7392	-0.1155	18.9006	44.8954	0.4210
	10-3-3	298.	49.0000	0.5000	1.8480	-0.2610	17.7400	43.9713	0.4034
	10-4-3	298.	48.9000	0.4680	1.8209	-0.0546	15.9801	43.4192	0.3680
	10-6-3	298.	48.7000	0.3960	1.7185	0.2260	12.5586	42.2270	0.2974
	10-7-3	298.	44.8500	0.3990	2.0297	-0.0722	11.5474	38.2923	0.3016
	10-8-3	298.	46.4000	0.4070	1.9824	0.0922	12.1018	39.6925	0.3049
H-75	10-0-4	298.	42.7000	0.5120	1.5162	0.0201	16.2239	39.0354	0.4156
	10-1-4	298.	43.0000	0.5080	1.5366	-0.0638	16.0165	39.0277	0.4104
	10-2-4	298.	43.0000	0.4980	1.6868	-0.1050	15.5716	38.8452	0.4009
	10-3-4	298.	42.7000	0.4860	1.6044	-0.1163	15.2071	38.6905	0.3930
	10-4-4	298.	42.3000	0.4580	1.7109	-0.1505	13.8065	37.8188	0.3651
	10-6-4	298.	41.8000	0.3930	1.8471	0.0133	10.7587	36.0588	0.2984
	10-7-4	298.	38.5000	0.3940	1.8890	-0.1135	10.0125	33.2199	0.3014
	10-8-4	298.	40.0000	0.4030	1.7857	0.2137	10.5111	34.6359	0.3035

Table 10

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 221-kev Protons (10-0-5 to 10-8-9)

	CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
62	10-0-5	298.	49.3000	0.5530	1.6621	0.0396	20.1199	44.9894	0.4472
	10-1-5	298.	49.7000	0.5430	1.8503	0.1048	19.1854	44.6978	0.4292
	10-2-5	298.	48.8000	0.5200	1.5927	0.3678	17.9963	44.1799	0.4073
	10-3-5	298.	46.7000	0.4920	1.5582	0.2709	16.3295	42.2029	0.3869
	10-4-5	298.	44.2000	0.4640	1.6423	0.2233	14.2466	39.4727	0.3609
	10-6-5	298.	37.3000	0.4030	2.1634	-0.2340	9.6710	31.6738	0.3053
	10-7-5	298.	34.7000	0.4060	2.4652	-0.4959	8.8752	28.9788	0.3063
	10-8-5	298.	37.5000	0.4070	2.7144	-0.6873	9.4910	30.9298	0.3069
64	10-0-6	298.	50.4000	0.5280	1.5825	0.1600	19.3920	45.9059	0.4224
	10-1-6	298.	49.5500	0.5220	1.6196	0.1856	18.6456	44.9508	0.4148
	10-2-6	298.	50.0500	0.5150	1.5650	0.2734	18.4824	45.4228	0.4069
	10-3-6	298.	49.3000	0.4910	1.5383	0.2448	17.2712	44.6155	0.3871
	10-4-6	298.	49.8500	0.4625	1.8597	0.1867	15.4883	43.7962	0.3536
	10-6-6	298.	49.6500	0.3940	2.1760	0.0791	12.0250	41.5402	0.2895
	10-7-6	298.	45.4500	0.3990	1.9641	0.2931	11.2809	38.5423	0.2927
	10-8-6	298.	47.3000	0.4040	2.0396	0.2953	11.7731	39.9169	0.2949
H-1 ohm cm	10-0-7	298.	67.2000	0.5570	1.9151	0.0487	26.6610	60.4211	0.4413
	10-1-7	298.	66.0000	0.5520	1.8838	0.0869	25.8664	59.3369	0.4359
	10-2-7	298.	65.6500	0.5485	1.9533	0.0573	25.3884	58.7725	0.4320
	10-3-7	298.	64.4000	0.5300	1.6756	0.1755	24.3909	58.2624	0.4186
	10-4-7	298.	61.4000	0.5060	1.8858	-0.0427	21.9389	54.8084	0.4003
	10-6-7	298.	54.0000	0.4260	3.1546	-0.7880	14.2590	44.0460	0.3237
	10-7-7	298.	50.4500	0.4280	3.0562	-0.8579	13.6075	41.4931	0.3279
	10-8-7	298.	53.8000	0.4370	2.5116	-0.2965	15.0139	45.3211	0.3313
H-109	10-0-9	298.	69.2000	0.5340	1.6717	-0.0069	27.1457	62.9418	0.4313
	10-1-9	298.	68.3000	0.5290	1.5665	0.1441	26.3023	62.2463	0.4226
	10-2-9	298.	68.1000	0.5220	1.5448	0.2739	25.3784	61.8611	0.4102
	10-3-9	298.	67.6000	0.5010	1.5119	0.4388	23.4187	60.9751	0.3841
	10-4-9	298.	66.7000	0.4685	1.7306	0.4581	20.3907	58.5928	0.3480
	10-6-9	298.	67.1000	0.3980	2.0287	0.3425	15.9656	56.0916	0.2846
	10-7-9	298.	62.7000	0.4010	1.8496	0.4308	15.3460	53.1890	0.2885
	10-8-9	298.	64.1000	0.4080	1.9860	0.4313	15.6858	53.8538	0.2913

Table 11

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 221-kev Protons (17-0-1 to 17-8-4)

	CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
TI 3-1 (25μ)	17-0-1	298.	63.3000	0.5815	2.4729	-0.2413	25.6416	55.8072	0.4595
	17-1-1	298.	62.1200	0.5735	2.3908	-0.1755	24.7606	54.8234	0.4516
	17-2-1	298.	62.1500	0.5620	2.1754	-0.0691	24.4781	55.2449	0.4431
	17-3-1	298.	59.9800	0.5402	1.9069	-0.0021	23.0820	53.8339	0.4288
	17-4-1	298.	59.6800	0.5030	2.0068	-0.0853	20.9186	52.8716	0.3956
	17-6-1	298.	35.2800	0.4290	3.1279	-1.3148	9.8289	29.7955	0.3299
	17-7-1	298.	33.0000	0.4265	2.7716	-1.3803	9.2680	27.7092	0.3345
	17-8-1	298.	37.6000	0.4330	2.2158	-0.3137	10.7127	32.2420	0.3323
TI 4-3 (12μ)	17-0-2	298.	46.5900	0.5818	3.3484	-1.0808	18.2772	39.7822	0.4594
	17-1-2	298.	45.5000	0.5769	3.0174	-0.7398	17.7463	39.1962	0.4528
	17-2-2	298.	45.5200	0.5695	2.5472	-0.4403	17.9252	39.9234	0.4490
	17-3-2	298.	43.5600	0.5482	2.3216	-0.3303	16.6547	38.4254	0.4334
	17-4-2	298.	43.0500	0.5155	2.4510	-0.4303	15.1018	37.4343	0.4034
	17-6-2	298.	28.6500	0.4512	2.5253	-0.9534	8.5577	24.4147	0.3505
	17-7-2	298.	25.5000	0.4480	2.4837	-1.3148	7.7075	21.8479	0.3528
	17-8-2	298.	27.3000	0.4520	2.1938	-0.0459	8.0371	23.4559	0.3426
E55-1c	17-0-4	298.	44.1100	0.5278	1.1062	0.4422	17.8133	41.2737	0.4316
	17-1-4	298.	43.5500	0.5242	1.2184	0.2141	17.5104	40.5517	0.4318
	17-2-4	298.	43.8500	0.5193	1.1931	0.2386	17.4587	40.8531	0.4274
	17-3-4	298.	42.9600	0.5052	1.2237	0.2467	16.4527	39.8527	0.4128
	17-4-4	298.	44.2300	0.4642	1.5361	0.2694	14.4361	39.7757	0.3629
	17-6-4	298.	43.5500	0.3892	2.1992	-0.0696	10.5454	36.4842	0.2890
	17-7-4	298.	40.2000	0.3900	2.0010	0.0704	9.9134	34.1169	0.2906
	17-8-4	298.	42.2000	0.3960	1.9754	0.2131	10.4787	35.8219	0.2925

Table 12

Computer Analysis of I-V Data Obtained for Solar Cells, Irradiated by 221-kev Protons (17-0-5 to 17-8-6)

	CELL	TEMP	ISC(MA)	VOC(V)	N	RS(OHMS)	PMAX(MW)	IMAX(MA)	VMAX(V)
HOFF 10 ohm cm	17-0-5	298.	71.0200	0.5475	2.4043	-0.2672	27.0805	62.4569	0.4336
	17-1-5	298.	69.6000	0.5437	2.3977	-0.2548	26.2617	61.1426	0.4295
	17-2-5	298.	70.3000	0.5387	2.0791	0.0481	26.1460	62.3144	0.4196
	17-3-5	298.	69.1300	0.5186	1.8899	0.1768	24.6475	61.4803	0.4009
	17-4-5	298.	71.1000	0.4817	1.7975	0.5037	22.0470	62.2115	0.3544
	17-6-5	298.	69.7300	0.4050	1.9098	0.5764	16.4823	58.2678	0.2829
	17-7-5	298.	64.3000	0.4050	1.9417	0.5143	15.4397	53.9093	0.2864
	17-8-5	298.	65.8000	0.4120	1.9046	0.6084	15.9598	55.2249	0.2890
HOFF 10 ohm cm	17-0-6	298.	72.5400	0.5455	2.6263	-0.3120	26.9862	63.0441	0.4281
	17-1-6	298.	71.2300	0.5415	2.6841	-0.2908	25.9644	61.5756	0.4217
	17-2-6	298.	71.8500	0.5368	2.4671	-0.0886	25.8224	62.4181	0.4137
	17-3-6	298.	70.6800	0.5203	2.1184	0.1962	24.4322	61.8834	0.3948
	17-4-6	298.	72.7000	0.4784	2.0159	0.4202	21.9054	62.6648	0.3496
	17-6-6	298.	71.2500	0.4050	2.0185	0.5556	16.5772	58.9519	0.2812
	17-7-6	298.	65.7500	0.4055	1.9534	0.5584	15.6175	54.9004	0.2845
	17-8-6	298.	67.5000	0.4110	2.0633	0.5479	16.0470	55.9347	0.2869

Table 13

Output of the "N" Computer Program for Drift-Field Solar Cell, No.82, for Values of the Parameters, τ_1 = 0.3 μsec and m = 0.4

MOBILITY (MU)	ELECT FIELD (E)	DIFF LENGTH (L)	DIST FR JUNCT (D)	THICKNESS (DD)	IMP CONC (FN)	DIFF COEFF (D)
1319.5430	-20.8635	0.3046E-02	0.1063E-03	0.1063E-03	0.1224E 16	34.1102
1318.0020	-31.0131	0.2934E-02	0.3462E-03	0.2399E-03	0.1334E 16	34.0704
1310.7217	-43.0132	0.2762E-02	0.5192E-03	0.1730E-03	0.1778E 16	33.8822
1296.2402	-50.2760	0.2593E-02	0.6672E-03	0.1480E-03	0.2371E 16	33.5078
1275.0723	-54.3664	0.2428E-02	0.8040E-03	0.1369E-03	0.3162E 16	32.9606
1247.7520	-56.2092	0.2268E-02	0.9364E-03	0.1324E-03	0.4217E 16	32.2544
1214.8047	-56.4163	0.2113E-02	0.1068E-02	0.1319E-03	0.5623E 16	31.4027
1176.7598	-55.4044	0.1963E-02	0.1203E-02	0.1343E-03	0.7499E 16	30.4192
1134.1494	-53.4583	0.1819E-02	0.1342E-02	0.1392E-03	0.1000E 17	29.3178
1087.4922	-50.7679	0.1682E-02	0.1488E-02	0.1466E-03	0.1334E 17	28.1117
1037.3125	-47.4533	0.1551E-02	0.1645E-02	0.1568E-03	0.1778E 17	26.8145
984.1475	-43.5784	0.1426E-02	0.1816E-02	0.1707E-03	0.2371E 17	25.4402
928.5264	-39.1558	0.1308E-02	0.2006E-02	0.1900E-03	0.3162E 17	24.0024
870.9697	-34.1444	0.1196E-02	0.2224E-02	0.2179E-03	0.4217E 17	22.5146
812.0029	-28.4262	0.1090E-02	0.2485E-02	0.2617E-03	0.5623E 17	20.9903
752.1533	-21.7361	0.9903E-03	0.2828E-02	0.3423E-03	0.7499E 17	19.4432
691.9541	-13.3303	0.8968E-03	0.3386E-02	0.5581E-03	0.1000E 18	17.8870
623.8848	-0.1561	0.7971E-03	0.3356E-01	0.3017E-01	0.1334E 18	16.1274

LIST OF FIGURES

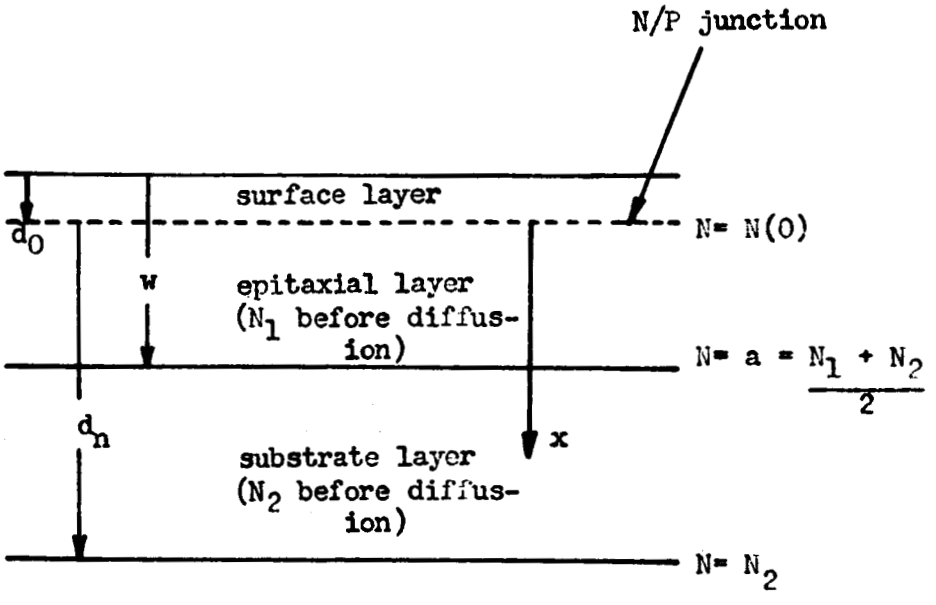
N/P junction
surface layer
d_0
N= N(O)
w
epitaxial layer
(N_1 before diffus-
ion)
N= a = $\frac{N_1 + N_2}{2}$
d_n
x
substrate layer
(N_2 before diffus-
ion)
N= N_2

FIGURE 1

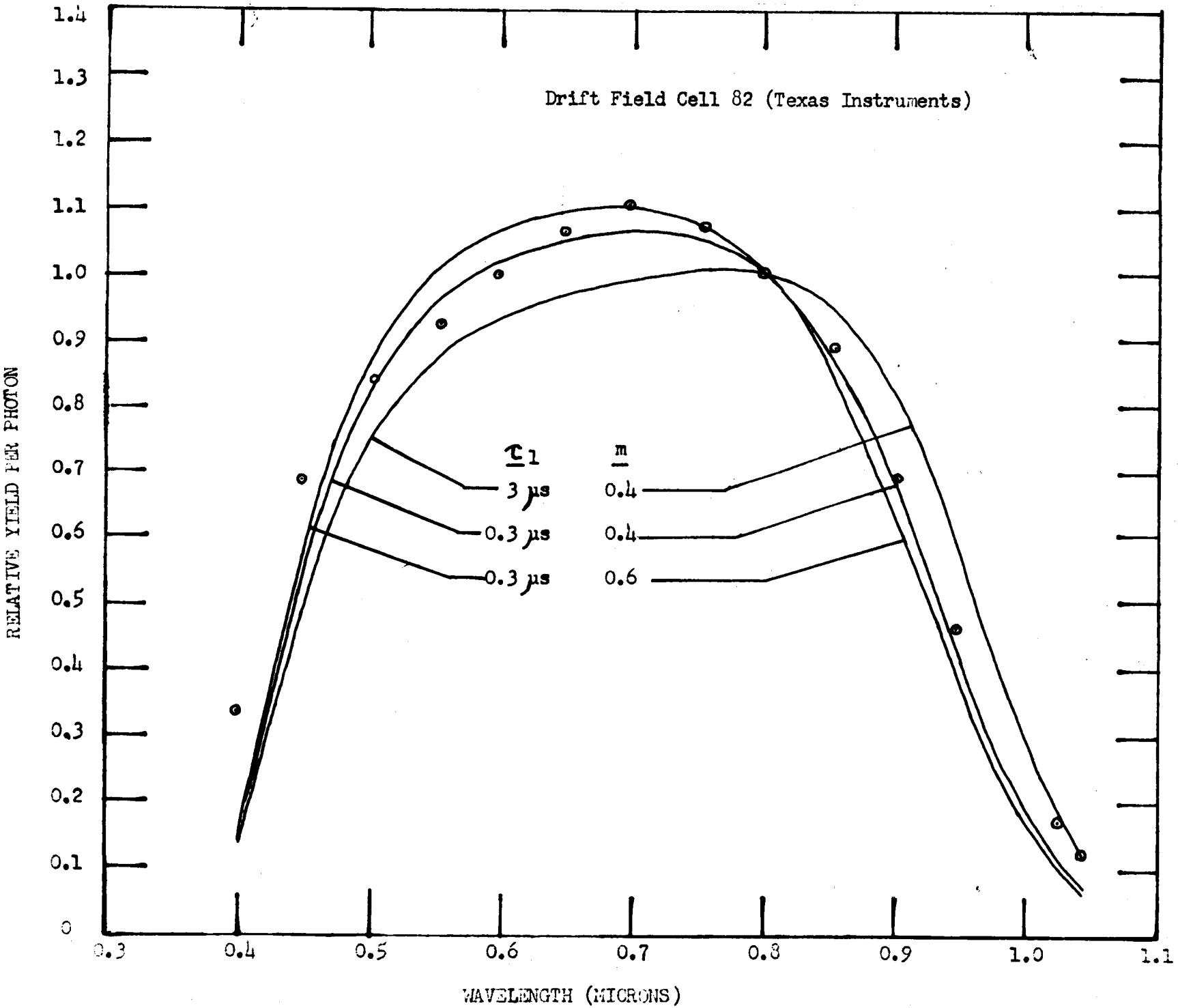
Drift Field Cell 82 (Texas Instruments)
RELATIVE YIELD PER PHOTON
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
WAVELENGTH (MICRONS)
τ1
m
3 μs
0.4
0.3 μs
0.4
0.3 μs
0.6

FIGURE 2