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INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

THEORETICAL INVESTIGATION ON HETEROJUNCTION SOLAR CELL *

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ABSTRACT

The study of thin film solar cells has proved that the surface is rough. A two-dimensional method based on the integral equation technique to analyse thin film solar cells has been developed by DeMey et al. In this paper we present our analysis of a thin film solar cell using the above techniques. Variation of the minority carrier concentration, the saturation current and the junction current of the solar cell with surface roughness is presented.

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I. INTRODUCTION

The heterojunction solar cell has been the subject of extensive research interest and several workers have treated the photovoltaic properties of heterojunction in considerable detail (de Vos 1976; de Vos and Pauwels 1977; Boer 1979; Fonash 1979; 1980; Fonash and Ashok 1980). In thin film solar cells, particularly cugs/cds, the surface of the cell is very rough and the surface topography is usually made up of pyramids (G.H. Hewig et al.1979). Hence the junction interface is also highly convoluted and non planar. The actual area of the junction is therefore much larger than the corresponding geometrical flat plane area. Several workers have studied the influence of the rough shaped junction profile on the performance of these cells (DeMey et al.1977).

In heterojunction, a dislocation field, at the junction interface, arising from lattice mismatch between the two materials can counteract a space charge and act as a recombination surface. The charge state, capture cross section and density of these interface states also strongly influence the photocurrent through the junction. Most practical heterojunction solar cells also suffer from

a) surface effects owing to ionic charges causing surface depletion layers and from
b) generation and recombination of carriers in the depletion layers.

In this paper we solve the two-dimensional integral equation developed by DeMey et al.(1978), for the theoretical analysis of thin film solar cells with rough junctions.

II. INTEGRAL EQUATION

The geometry used is shown in Fig.1, only the junction is rough, while the frontside is kept flat. The roughness profile is taken to be periodic in the y direction. For a periodic structure, one can consider the area AA'BB'. The equations and the boundary conditions have been found (DeMey 1978) as follows:

$$D_1 \nabla^2 n - \frac{(n-n_0)}{\tau_n} = g(\bar{r}) = I_0 e^{-\alpha x}$$
$$n = n_0 ; \quad \vec{r} \in A'B' \tag{1}$$

$$\nabla n \cdot u_n = 0 ; \quad \bar{r} \in AA';BB'$$
$$n = n_0 e^{qV/kT} ; \quad \vec{r} \in AB \tag{2}$$

where n is the minority carrier concentration in the cu_2s layer, D diffusion constant, τ carrier lifetime, V voltage across the cell and n_0 the equilibrium concentration.

The solution of Eq.(1) can be written as an integral equation,

$$n(\vec{r}) = n_0 + n_1(\vec{r}) + \oint_c \rho(\vec{r}') \, G(\vec{r}/\vec{r}') \, dc' \tag{3}$$

where the C is the boundary and $\rho(\bar{r}')$ is an unknown source function defined on c. $n_1(\bar{r})$ is a particular solution of Eq.(1).

$$n_1(\vec{r}) = \frac{I_0 \tau}{\alpha^2 L^2 - 1} e^{-\alpha x} ; \quad L = \sqrt{D\tau} \tag{4}$$

$G(\bar{r}/\bar{r}')$ is the Green's function of Eq.(1)

$$G(\bar{r}/\bar{r}') = K_0\left(\frac{|\bar{r} - \bar{r}'|}{L}\right)$$

and it satisfies the differential equation

$$\nabla^2 G - \frac{G}{L^2} = \delta(\bar{r} - \bar{r}') \tag{5}$$

where $\delta(\bar{r}-\bar{r}')$ is the Dirac delta function, $\rho(\bar{r})$ is found by imposing the boundary conditions (2) on the proposed solution of Eq.(3). As a result we obtain a set of four equations:

$$\oint_c \rho(\bar{r}) \, G(\bar{r}|\bar{r}') \, dc' = -n_1(\bar{r}') + n_0 ; \quad \bar{r} \in A'B'$$
$$= n_0\left(e^{qV/kT} - 1\right) ; \quad \bar{r} \in AB \tag{6}$$

$$\pi \rho(\bar{r}') + \oint_c \rho(\bar{r}') \, \nabla G(\bar{r}|\bar{r}') \cdot u_n \, dc'$$
$$= -\nabla n_1(\bar{r}) \cdot u_n ; \quad \bar{r} \in AA';BB' \tag{7}$$

Eqs. (6) and (7) constitute an integral equation in the unknown source function $\rho(\bar{r})$.

These two equations are reduced to a form of a set of linear simultaneous equations by writing the integrals on the left as summations. This set of equations is written in its matrix form as

$$A\rho = B \ .$$

The numerical values of the source functions at different points on the boundary are computed using the SIMQ subroutine available in DECIO.

Minority carrier concentration n(r) at different points and the junction current

$$I = D_n \int_{AB} \nabla n \cdot u_n \, dc \tag{8}$$

are calculated using Eqs.(3) and (8).

III. DISCUSSION OF THE RESULTS

Fig.2 shows the saturation current I_S and the light current I_L as functions of the roughness parameter γ. Both currents have been normalized at their values at $\gamma = 0$. It is observed that the normalized currents I_S increase with the roughness parameter γ and I_L reaches a maximum at a certain value of γ. The variation of normalized current at AB, with γ, is shown in Fig.3, which indicates the influence of the roughness on the current. The carrier concentration has been estimated at different distances from the junction. Figs.4(a,b,c) show the variation of the concentration for different voltages at different points from the junction. It has been observed that when the point is nearer to the junction, the concentration of carrier increases and the concentration is found to increase with the voltage developed across the cell.

IV. CONCLUSION

It has been found that the integral equation technique is useful in evaluating the behaviour of the heterojunction solar cells. The calculations performed for the solar cell indicate that the saturation current increases more than the light current with the roughness of the junction. The effect of roughness on the conversion efficiency of the cell is being evaluated. This work is being continued for cells made of different materials.

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FIGURE CAPTIONS

Fig.1	Geometry of Heterojunction.
Fig.2	Plot of Saturation current and light current against junction roughness.
Fig.3	Variation of normalized total current with tan $\frac{\lambda}{2}$.
Fig.4	Variations of carrier concentration with γ at different points at (a) 0.1 volt, (b) 0.2 volt and (c) 0.3 volt.

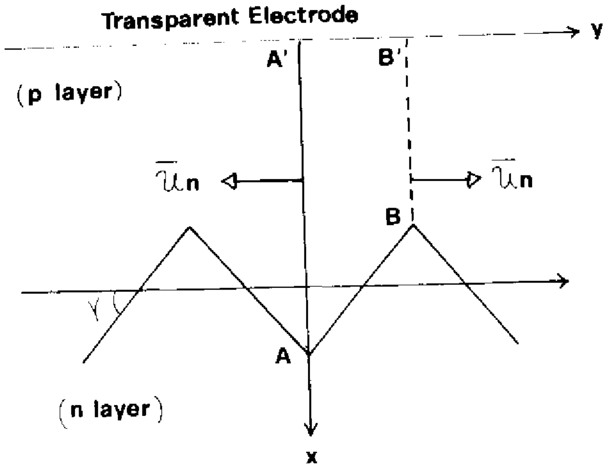

Fig.1

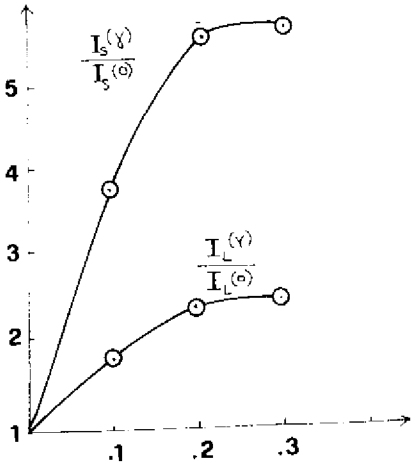

Fig.2

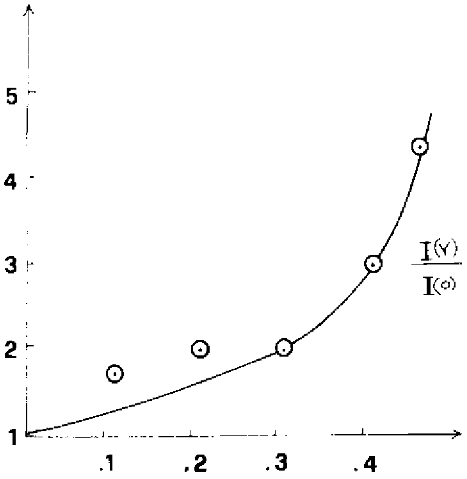

Fig.3

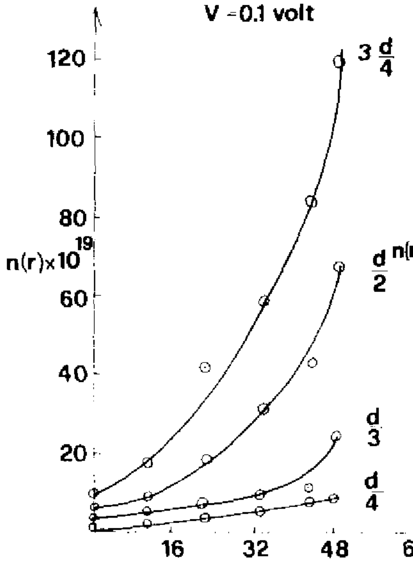

Fig.4a

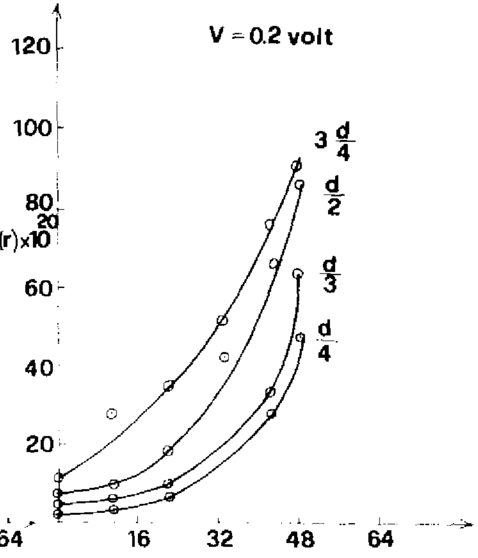

Fig.4b

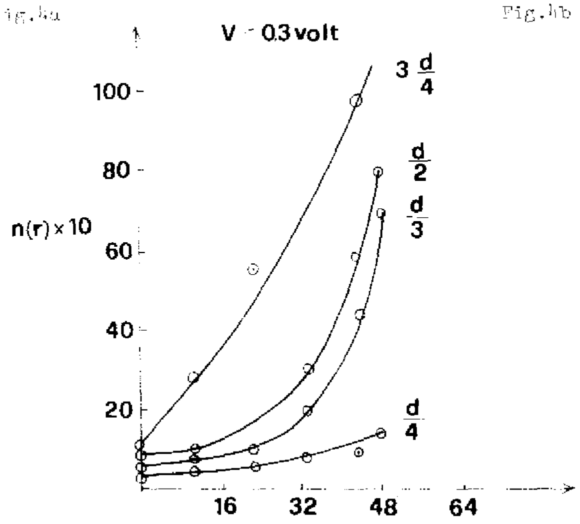

Fig.4c