CHAPTER - 5

EXPERIMENTAL MEASUREMENTS
Experimental measurements of solar cell parameters.

Introduction.

The solar cell structure being examined is the metal-insulator-semiconductor configuration on n-GaAs, in which the thin intervening oxide layer has been grown by thermal and plasma oxidation techniques. Putting an I-layer between a metal and semiconductor can improve the photovoltaic response. At first glance, it is not expected. Obviously one would expect the current to be decreased with the introduction of the I-layer. Superficially one would expect all current to be decreased. To be definitive, in a MIS device on n-type material the diode current (Dark current) flowing conventionally from the metal to semiconductor intuitively should be reduced. The photovoltaic short circuit current flowing from semiconductor to the metal should be decreased also. Generally, a decrease in the photovoltaic short circuit current is not seen but orders of magnitude changes are seen in many systems in the dark current. As a consequence enhanced photovoltaic response performance is frequently obtained with the I-layer. Clearly the photogenerated holes created in the semiconductor (n-type material) are easily crossing the I-layer. The supply of these holes depends on the light diffusion length of the semiconductor etc. This supply is fixed and should be same for MS or MIS to first order. It is possible that the insulator is a tunnel barrier but of negligible hinderance for holes. The fact that dark current can change orders of magnitude with the inclusion of the I-layer means one of the two things: either the electrons (n-type
semiconductor) are having great difficulty crossing this I-layer or their supply has been affected.

This physical situation can be systematised into three general categories of the I-layer effects transport control, trapping on the passing of the current and also the barrier modification.

In this chapter we shall try briefly to analyse our experimental results as have been obtained on n-GaAs MIS solar cells.

Photovoltaic measurements preliminaries.

When one considers the photovoltaic testing of a candidate solar cell, the illumination intensity and also the irradiance of the light source should be precisely known. The commonly employed standard of illumination is called the Air Mass (AM1 spectrum). Briefly speaking, this corresponds to a secant of the angle of the sun to its Zenith. That is the path length that a ray of sunlight moves transverse compared to the shortest path it could take. Of course the actual sea level intensity and irradiance varies from day to day and also due to the prevailing weather conditions. The air mass (1) thus represents the sunlight at the earth's surface under optimum weather conditions and with the sun at Zenith, the total incident power for this case is 100 mW/cm².

For the purpose of an AM1 laboratory standard, a Phillips ELH Halogen lamp produces an illumination irradiance that closely approximated AM1. The total power density was set using a calibrated solar cell to 100- mW/cm². The photovoltaic current-voltage output in both the dark and under illuminated conditions
could be obtained using well established techniques. The study of I/V in dark and under illumination is a characteristic feature of any solar cell and also that it yields abundant information about the solar cell output parameters and other allied one's also.

The incorporation of a thin interfacial oxide layer in the Schottky barrier solar cells is known to increase the open circuit voltage (V_{OC}) and the efficiency (\eta) of the cells. The open circuit voltage is related to the other device parameters in the following way (Card et al., 1976):

$$V_{OC} = \frac{q}{n} \cdot \frac{kT}{\ln\left(\frac{J_{SC}}{A^*T^2}\right) + \frac{\phi_B}{kT} + c \cdot \chi^2 \cdot d}$$

Where (J_{SC}) is the short circuit current density, (\phi_B) is the barrier height, (A^*) is the Richardson constant, (n) is the ideality factor and the factor (c \cdot \chi^2 \cdot d) is related to the attenuation in the majority carrier tunneling due to oxide thickness (d). In case of Silicon, c is close to unity (Card et al., 1971), when (\chi) is expressed in ev and (d) in A. As can be seen from the equation (S.1), Voc enhancement can be related to the following effects, (a) increase in (\phi_B) due to fixed charge in the oxide or modification of interface states. (b) increase in n resulting from the potential drop across the oxide layer or increase in the number of interface states that equilibrate with the semiconductor and (c) decrease in the probability of majority carrier tunneling resulting in the suppression of the dark current.

The relative importance of the above mechanisms for enhancement of (V_{OC}) depends on the nature of the semiconductor and the interface layer and is not well understood. Charlson and Lien (1975) observed an enhancement in the barrier height in Al-Si_{2}-P Si solar cells, which was latter explained by (Pulfrey, 1976) in terms of the charge in the oxide. This mechanism is however
ruled out by (Anderson et al., 1977) who show that for cr-Si$_x$P Si solar cells, the barrier height increases because of the lowered work function of the slowly deposited cr contact. On the other hand (Card and Yang, 1976) attribute the enhancement of ($\psi_B$) in Au-Si$_x$-n Si solar cells to the suppression of the majority carrier current due to tunneling through the oxide.

Gallium Arsenide, with its high light absorption in the solar spectrum region is a material of considerable importance in solar cell technology. (Stiren and Yeh, 1977) have fabricated metal-insulator-semiconductor (MIS) GaAs solar cells with high open circuit voltage by using a native oxide grown by room temperature oxidation. High efficiency solar cells have also been reported in case of GaAs when the oxide layer is grown by electrolytic anodisation in active mode (Hasegawa et al., 1980). As in the case of Silicon, the mechanism causing the enhancement of ($V_{OC}$) is not very well understood.

However according to (Stiren and Yeh, 1977), the increase in ($V_{OC}$) is caused by two mechanisms (a) increase in the barrier height, caused either by modification of surface state or by the presence of the negative charge in the oxide, (b) an enhancement in the value of $n$ caused by modification in the majority carrier transport due to the presence of the oxide. These authors also suggest that in some cells which show high value of the open circuit voltage, the enhancement of ($V_{OC}$) is not caused by an increase in the value of ($\psi_B$) or $n$. Instead it may result from the suppression of the majority carrier current due to tunneling through the oxide. (Hasegawa et al., 1980) on the other hand show that an increase in ($V_{OC}$) is caused by enhancement in the barrier height due to the modification of the surface states caused by the oxidation process.
In order to have a satisfactory understanding of the problem, we have measured ($\phi_B$) and ($A^2\rho$) for Au thin oxide n-GaAs MIS solar cells from a Richardson plot of the dark I-V characteristics. Besides doing our measurements on MIS type of cells, we have performed the experimental measurements on MS type of samples also.

Current-voltage characteristics.

Dark current-voltage data is very informative, since it shows the solar structure functioning as a diode. I/V measurements have been taken for the solar cell before the irradiated conditions. The test setup of figure (26) was used to take all the data for the dark case. The collected I/V data is analysed by the standard current equation of the diode device. We know that

$$I = I_0 \exp \left( \frac{qV}{nkT} \right)$$

or

$$\log I = \log I_0 + \log \left[ \exp \left( \frac{qV}{nkT} \right) \right]$$

or

$$\log I = \log I_0 + \frac{1}{2.3026} \ln \exp \left( \frac{qV}{nkT} \right)$$

A plot of this equation yields a straight line, whose intercept with the current axis yields the logarithm of the saturation current ($I_0$). Also that the line has a slope of 0.43 ($\frac{qV}{nkT}$). In actual test data, Log I versus V is generally seen to be composed of several straight line segments. This is due to the additional current mechanism in the device, that are generally surface potential (hence applied potential) dependent.

The I-V data also provides a means of calculating the actual barrier height for the device. Generally speaking, barrier height ($\phi_B$) or barrier potential is defined as the
potential between the Fermi level in the metal and the majority carrier bandedge of the semiconductor at the interface. It can also be defined as the difference in the energy between the bottom of the conduction band at the boundary of the semiconductor and Fermi level in the metal. The barrier height is the most significant property of the MS and MIS devices. This barrier is also due to the the Fermi level difference in the work function of the metal and the semiconductor.

From the thermionic emission theory, we obtain for the Schottky cell the equation:

$$\phi_B = \frac{kT}{q} \ln \left( \frac{A^* T^2}{F_0} \right)$$

using the cell area and the measured ($I_0$), the experimental barrier height can be obtained for the device. For taking the dark I-V measurements, the samples were subjected to the preheat treatment in N₂ ambient between (300-350) K. Richardson plot ($\ln(I_{SC} vs \frac{1}{T})$) was used to determine ($A^*$) and also ($\phi_B$). Ideality factor was calculated from the dark I/V plot and under lighted conditions was calculated from the slope of the In ($I_{SC}$) vs ($V_{oc}$) plot (Panagolates et al., 1978).

We find that the barrier height for two samples is nearly the same, where as ($A^*$) for the MIS type is smaller than that for the MS type. We have made measurements on several samples and the values of ($\phi_B$), dark $n$ and ($A^*$) are given in the table (5.1). We find that in all cases, the MIS samples are characterised by a large diode idality factor and smaller ($A^*$) than the MS one's. The ($\phi_B$) values are however very similar.
The increase in the value for dark $n$ due to interfacial layers is well known and can be well understood in terms of the interface states, which do not equilibrate with the metal and the potential drop across the oxide. The lower value of $\phi^*_M$ for MIS samples is due to the tunneling caused by the presence of the interfacial layer as given by the equation

$$\phi^*_M = \phi^*_S \exp (-C \chi^{1/2} \delta)$$

For GaAs the theoretical value ($\phi^*_S$) (Rhoderick, 1978) is $3 \text{A/cmK}$, which is close to the experimental value shown in the table (5·1) and $C = 0.26$ (Ashok et al, 1979), where $\chi$ is expressed in ev and $\delta$ in A. From our experimental value of ($\phi^*_M$) for MIS samples, we calculate

$$\chi^{1/2} \delta = 10 \text{ev} \chi^2 A.$$  

The oxide thickness has been measured to be (45-50) A and this gives $\chi = 0.06$ ev, which is in agreement with the reported value in the literature (Ashok et al, 1979).

Our observation that values of $\phi_B$ for MS and MIS are the same implies that there is no appreciable modification in the nature of the surface states. We have also measured the open circuit voltage and the short circuit current at AM1 intensity and the lighted $n$ for our samples. The results are shown in the table (5·7). We find that $V_{oc}$ for MIS cells is much larger than for MS cells. The as prepared MIS cells showed $V_{oc}$ in the range of (620-630) mv. There was a degradation in the value of $V_{oc}$ by about (15-25)mv annealing. It is because of the fact that the prolonged optical exposure heats up the sample, the values of $V_{oc}$ are at temperatures (5-6)° C above room temperature. The room temperature values are higher ones. It is also seen from the table (5·7) that the lighted $n$ for MIS cells is slightly lower than the dark $n$. This as pointed out by (Card and Yang, 1976) may be due to the fact that on
Fig. 5: Forward characteristics for MIS (Thermally oxidized) diodes.
Fig. 5. Forward I/V characteristics of MIS (plasma oxidized) diodes.
Fig. 5: Reverse I/V characteristics of MIS diode.
shinning light, potential drop in the interfacial layer is negligibly small because of the interface states becoming more positive as a result of the communication principally with the minority carriers.

As we observe that Voc in our MIS samples is larger than in MS one's, even though $\phi_B$ values are the same, therefore it can be said that there is no enhancement of Voc through an increase in $\phi_B$ value. We have also calculated Voc from the equation (S. 1) using the measured device parameters. The value of lighted $n$ has been used for the said calculations, since the values of $n$ for the MIS samples are higher, the open circuit voltage is slightly enhanced, but this alone does not account for the high open circuit voltage. We find the excellent agreement between the theory and the experiment only when the contribution to the tunneling term is included. Neglect of this term gives the much lower value of Voc. Therefore from our experimental measurements carried out on n-GaAs MIS solar cells it can be said that enhancement in the open circuit voltage in MIS cells on GaAs with the oxide grown by thermal and plasma oxidation techniques arises mainly due to the suppression of the majority carrier dark current due to the tunneling through the oxide layer and to some extent due to the small increase in the lighted $n$

High frequency capacitance-voltage characteristics.

The study of the high frequency capacitance-voltage characteristics of the metal-insulator-semiconductor (MIS) solar cells enables us to determine a variety of parameters such as barrier height ($\phi_B$), doping concentration ($N_d$), surface state density ($N_{SS}$) and oxide charge ($\delta_{SCO}$), (Ahrenkien and Dunlavy, 1984. Rinbley and Gilbdenbalt, 1984. Datta et al, 1984. Arora et al, 1979. Sze, 1978.) In the
optimisation of the MIS devices the values of such parameters are quite beneficial. These high frequency (1MHz) C-V data can be quite useful in determining these parameters. Using the standard laboratory Boonton capacitance bridge, measurements were taken for a number of reverse bias voltages. At high frequency the parasitic effects of the surface states are absent, since they are unable to respond to such a high frequency.

Determination of numerous parameters.

(a) : Barrier height ($\phi_B$).

The barrier height is given by the expression (Sze, 1969)

$$\phi_B = V_i + \xi - \alpha \phi$$  \hspace{1cm} (5.4)

where ($V_i$) is the intercept of the plot of C vs V, $\xi = (V_n + \frac{KT}{q})$ is the degeneracy correction factor, ($V_n$) is the depth of the Fermi level below the conduction band and is given by the equation

$$V_n = - \frac{KT}{q} \ln \frac{Nc}{Nd}$$  \hspace{1cm} (5.7)

Figure (5.6) shows the plot of C vs V, the applied voltage. From the curve it is observed that the voltage intercept ($V_i$) = 0.69 V. The value of ($V_n$) was calculated from the expression (5.4) for the sample having the doping level of the order of ($10^{17}$) cm$^{-3}$. This value comes equal to -0.30 ev. The image lowering force ($\alpha \phi$) was determined to be 0.139 ev at a field of 5.66 cm$^{-1}$. By the substitution of these values in the expression (5.5), ($\phi_B$) was found to lie in the range of (0.81-0.83) ev. This value is of the same order as reported by (Ashok et al., 1979) based also on high frequency C-V measurements taken at 1MHz.
5.4.2(b): Doping concentration.

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The doping concentration has been obtained from the expression (5.8 Sze, 1969)

\[ \frac{1}{c^2} = 2 \left( \frac{v_i - v_d - \frac{K_T}{q}}{q} \right) / q \epsilon S N_d \quad \ldots \quad (5.8) \]

\[ \frac{d(C_e)}{-dV} = \frac{2}{q \epsilon S N_d} \quad \text{or} \quad N_d = 2 \frac{(-dV)}{q \epsilon S C_e} \quad \ldots \quad (5.9) \]

where \( N_d \) is the doping concentration measured in units of \( \text{cm}^{-3} \). This gives an easy method for measuring \( N_d \). We have also calculated the doping concentration by using the above expression (5.9). From the curve of the figure ( ), we get

\[ d(C_e) \sim 10^{14} \text{cm}^2 \text{F}^{-1} \quad \ldots \quad (5.10) \]

\[ dV \sim 0.2 \text{V} \]

Substitution of these values in the expression (5.9) gives us the value of \( N_d \) to be equal to \( 10^{17} \text{cm}^{-3} \). This value is closely matching with the crystal supplier (M/S Atomergic Chemetals Corporations, New York) specifications.

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5.4.3(c): Surface state density.

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Of the non-idealities the one which has the most significant impact on the performance of the MIS devices are the interface states. The presence of the interface states usually degrades the performance of the semiconductor devices. Its effect is apparent in case of C.C.D's, MIS transistors and diodes etc. The interface state density has been determined previously using experimental techniques such as differentiation method (Terman, 1962), integration method (Berglund, 1966), temperature method (Gray and Brown, 1966) and
The differentiation method is one of the earliest methods for the determination of the surface states and their distribution within the forbidden gaps. We have used the Quasi static method (Castagar, 1968; Khun, 1970) for the determination of the surface state density, because this method is very sensitive yet easy to perform. In this case a slowly varying ramp voltage is applied to the capacitor (MIS) so that it is at all times in a near-equilibrium (Quasi static condition). The interface state capacitance is given by the expression (Ahrenkiel and Dunlavy, 1984).

\[ \frac{C_{SS}}{C_{HF}} = \frac{C_{LF} - C_{HF}}{C_{LF} - C_{HF}} \]

Where \((C_{LF})\) and \((C_{HF})\) are the low frequency capacitance and the high frequency capacitance respectively. The value of \((C_{LF})\) on the thermally grown oxide layer MIS samples has been found to be of the order of \((10^8)\) Fcm\(^{-2}\). The value of \((C_{LF})\) at 1KHZ was found to be of the order of \((10^6)\) Fcm\(^{-2}\) and that of \((C_{HF})\) at 1MHZ to be of the order of \((10^5)\) Fcm\(^2\). Using these values in the equation (5.11) for \((C_{SS})\), its value comes out to be equal to \((10^8)\) Fcm\(^{-2}\). By substituting the so obtained value of \((C_{SS})\) in the expression

\[ N_{SS} = \frac{C_{SS}}{Q_A} \]

the value of \((N_{SS})\) is found to be of the order of \((10^{12})\) states cm\(^{-2}\).

This value is quite close to the value reported earlier. (Ahrenkiel and Dunlavy, 1984; Khokle et al, 1982). The interface density has also been calculated on the MIS samples containing plasma grown oxide layer on n-GaAs and its value has been found to be almost identical to the value found for thermal grown oxide layers on n-GaAs.
Charge within the insulator (oxide) are due to either mobile or fixed charges. Mobile charges are traps within the insulator that electronically interact with the semiconductor or the metal contact. They are in general similar to the surface states but with three dimensional distribution. Fixed charges on the other hand do not participate in the transfer processes across the interfaces and may be associated with ionic defects in the insulator or states located at the semiconductor-insulator interface.

We have tried to estimate the magnitude of the oxide charge in the plasma grown native oxide on n-GaAs. It has been observed that the voltage across the oxide is made up of two terms. The first term arises from the work function difference between the metal and the semiconductor (Crow et al., 1965) and the second term arises from the interface trap charge. Expressing this mathematically and assuming the oxide charge is a sheet at the oxide-semiconductor interface. One obtains

\[ \Delta = \frac{Q_{SCO}}{2\varepsilon_0} + \frac{q_{NT}}{\varepsilon_0} \]  

where \( Q_{SCO} \) is the semiconductor surface state charge at zero bias due to the work function difference and is given by (Poate et al., 1978).

\[ Q_{SCO} = \left( \frac{2e\varepsilon_0 q_N \phi_B}{\varepsilon_0} \right)^{\frac{1}{2}} \]

where \( q_N \) is the net charge interface trap density and \( \Delta \) is the voltage drop across the oxide layer. It is equal to \( \phi_B - V_C \).

We have calculated the values of \( \phi_B \) and \( V_C \) from C/V measurements. The value of \( \Delta \) as calculated from the equation (5.13) comes out to be equal to 0.10 V. The oxide capacitance for an oxide layer of thickness (45-50) Å was found to be \( (10^8) \text{ Fcm}^{-2} \).
Fig. 5. Plot of $\frac{1}{C^2} \text{ (cm}^2/\text{F}) \times 10^{14}$ vs $V$ for MIS diode (Al-oxide GaAs) at a frequency of 1 MHz.
Substitution of these values in the expression \( S'_13 \), the net charge was found to be \( 10^{11} \) charges \( cm^{-2} \) negative. This value of charge closely matches with the value reported on plasma anodised GaAs by (Chesler and Robinson, 1978). Fixed charges due to the traps in the plasma grown native oxide on n-GaAs was determined by the aforementioned methods. It was found out that the trap charge came out to be of the order of \( 10^{12} \) \( cm^{-2} \), i.e., one order of magnitude higher than what has been found in case of thermally oxidised n-GaAs MIS samples.

5.5 Spectral Response.

Gallium arsenide utilises the solar spectrum better than Silicon, because the bandgap is direct and better matched. The spectral response measurements have been performed by us at AM1 conditions using a standard electric quartz halogen lamp (1000 W). All the measurements have been done in the visible wavelength range of \( 4000-7000 \) Å. The short circuit current as a function of the incident wavelength has been measured using a current meter.

Figure (55) shows the absolute collection efficiency as a function of the wavelength for the unirradiated GaAs (MIS) solar cell and the spectral response is found to be consistent with the behaviour of the short circuit current.

5.6 Photovoltaic parameters measurements on electron irradiated n-GaAs (MIS) solar cells.

Metal-insulator-semiconductor (MIS) cells based on n-GaAs material were subjected to electron irradiation at 1 Mev using particle
FIG. 5: ABSOLUTE SPECTRAL RESPONSE OF GaAs MOS SOLAR CELLS UNDER UNIRRADIATED CONDITIONS
accelerator producing fluence between \((10^{14} - 10^{16})\) ecm\(^{-2}\). The irradiation was carried out at room temperature at TIFR, Bombay using an electron flux of \((10^2)\) e/cm\(^2\)-sec. An attempt was made to repeat all the measurements on irradiated cells using the same techniques of I/V and C/V as were used in case of unirradiated specimens. However in nearly all the measurements on the irradiated ones it was found that the values of the solar cell output parameters had lowered to values considerably below the optimum one's needed for the smooth functioning of the solar cell. This may have resulted owing to the large scale degradation suffered by the samples as a consequence of the electron irradiation. It is well known that the solar output parameters like open circuit voltage (Voc) and the short circuit current are quite radiation sensitive and hence it is obvious to expect the degradation in these values after the cell is subjected to electron irradiation, but in our case the cell degraded under the said radiation beyond expectations and therefore it was not possible for us to record and calculate the changes in the numerous solar cell output parameters. Briefly speaking, the electron irradiated GaAs (MIS) solar cells did not yield any significant information on the radiation damage mechanism observed in such cells. Another reason for our samples having undergone large scale degradation may be due to the significant charge buildup in the insulating layer on Gallium Arsenide material.
(Experimental values of various parameters under dark and lighted conditions and comparison with theoretical value.)

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<td>n</td>
</tr>
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<td>------</td>
</tr>
<tr>
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</tr>
<tr>
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<td>1.13</td>
</tr>
<tr>
<td>C</td>
<td>45-50</td>
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<thead>
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<th>Voct1 (mV)</th>
<th>Voct2 (mV)</th>
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<td>C</td>
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REFERENCES


SUMMARY OF THE PRESENT WORK AND SCOPE AND RECOMMENDATIONS FOR FUTURE WORK.

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Summary of the present work

We have been concerned with the investigation of the electron irradiation damage studies in GaAs (MIS) solar cells. In this type of device, the intervening oxide layer is thin having its thickness between 50 A. We were able to evaluate various parameters that have significant influence on the total power output of the cell and its efficiency.

The first chapter of the thesis has dealt with the knowledge about the various kind of semiconductors being used for the solar cell application and the survey of the work carried out by different workers on the radiation effects on Silicon and GaAs solar cells.

The second chapter presents the experimental techniques used in the present Ph.D programme viz; Ellipsometry, Scanning electron microscopy, metallisation, photolithography, I/V, C/V etc. for the thickness measurement, surface examination studies, contact formation, deposition of front metal contact, measurement of various solar cell output parameters, etc.

The third chapter presents valuable information about the radiation damage mechanism in thin wafers of Gallium Arsenide. Various parameters that are dependent on electron energy viz energy loss, displacement crosssection, minority carrier lifetime/diffusion length, etc. have been determined by incorporating three different values of displacement energy ($E_d$) i.e. 9.45, 17.5 and 25 ev, capture crosssection ($\xi_p$) i.e. 1E-15, 1E-16, 5E-15. We have ascertained the value of $E_d$ = 9.45 ev to be most suitable in our case, so far the question of producing a displacement in the
semiconductor is concerned.

Fourth chapter presents the computations on the degradation of the various solar cell parameters such as short circuit current, open circuit voltage etc. that have significant influence on reducing the power output of the cell in view of their radiation sensitive nature. The spectral response of the solar cell has been computed in unirradiated and irradiated conditions by incorporating three different values of the recombination velocity viz. $1E4, 1E5, 1E7$ cm sec in our numerous calculations the first value of $(S \rho)$ has been chosen because it is considered to be the optimum value for the smooth functioning of the cell and the third value i.e. $1E7$ is considered to be the least desirable value for the solar cell operation. Therefore we have selected the middle value also for use in our different calculations.

In the fifth chapter, some experimental results on $I/V$ and $C/V$ measurements have been presented. The values of the various solar cell parameters obtained under dark and illuminated conditions are as under:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>Open circuit voltage ($V_{oc}$)</td>
<td>$638$ mV</td>
</tr>
<tr>
<td>Short circuit current density ($J_{SC}$)</td>
<td>$27$ m/A cm$^{-2}$</td>
</tr>
<tr>
<td>Barrier height ($\phi_B$)</td>
<td>$0.83$ ev</td>
</tr>
<tr>
<td>Surface state density ($N_{ss}$)</td>
<td>$10^{12}$ states cm$^{-2}$</td>
</tr>
<tr>
<td>Interfacial charge ($Q_{sc0}$)</td>
<td>$10^{12}$ Charges cm$^{-2}$</td>
</tr>
<tr>
<td>Doping concentration ($Nd$)</td>
<td>$10^{17}$ cm$^{-3}$</td>
</tr>
</tbody>
</table>

Though these values are not optimum values, but they represent the magnitudes that can be improved.
From the work presented in this thesis, we conclude that the MIS configuration may not be an ideal one for the photovoltaic systems, but the fundamental understanding of the defect production and their annealing in GaAs provides a lot of useful information on the nature and role of defects in controlling power output in solar cells. Gallium Arsenide is bound to take the place of Silicon in electron devices. In this direction the present work will certainly contribute to the understanding of the nature and structure of the electron induced defects in GaAs based devices.

Scope and recommendations for the future work.

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Our main aim of the work was to optimise the various radiation sensitive parameters for the ideal operation of the solar cell in various radiation environments. Though we have been able to study only the electron irradiation damage caused in MIS configuration based on GaAs semiconductor, yet there is a need to investigate the effects of different kinds of irradiations on GaAs (MIS) solar cells to gain some insight into the radiation damage mechanism. We have not been able to compare our experimentally observed results with those computed by us in third and fourth chapters. However, a desire to establish a collective theoretical model dealing with all types of incident nuclear radiations to calculate their effect on different kinds of semiconductors surely rests with the researcher interested in exploring such an area. Moreover, some parameters like mobility etc. have not been calculated owing to the lack of any well established theoretical model for the said purpose. In our present work we have
not applied any kind of antireflection coatings on our fabricated solar cells but there is an urgent need to fabricate a solar cell having such a coating to give a clue to the role played by it in making maximum possible use of the incident radiation for the sake of energy conversion.

We have carried out all our measurements on GaAs wafers having an orientation of \langle 100 \rangle. However a need to investigate the role of different orientations such as \langle 110 \rangle and \langle 111 \rangle on the overall efficiency of the solar cell is also required. Qualitatively it could be said that the main defect produced by electron irradiation in n-GaAs is due to the Gallium vacancy which gives rise to the energy levels. But there may be other types of defects also produced by the electrons irradiations giving rise to different energy levels. The identification of the energy levels in a semiconducting compound is very significant because it exerts a significant influence on the power output of the solar cell. In our study dealing with the electron irradiation effects in n-GaAs, we could not identify all the energy levels mainly due to the non-availability of the more sophisticated techniques like DLTS with us. Therefore it can be said that with the adoption of more sophisticated techniques like ones as described above could very-well provide lots of significant information on the majority of the radiation induced defects in thin wafers of GaAs.