SOME THEORETICAL INVESTIGATIONS IN p-n JUNCTION AND Au-GaAs SCHOTTKY BARRIER SOLAR CELLS

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THESIS
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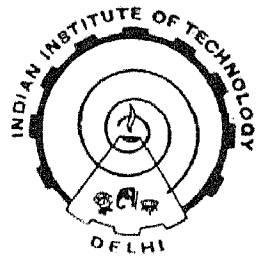

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CERTIFICATE

This is to certify that the thesis entitled "SOME THEORETICAL INVESTIGATIONS IN p-n JUNCTION AND Au-GaAs SCHOTTKY BARRIER SOLAR CELLS" by Mr.D.Vijay Kumar, submitted to the Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy, is a record of bonafide research work carried out by him under my supervision and guidance. The work in this thesis, in my opinion, has reached the standard fulfilling the requirements for the award of the degree of Doctor of Philosophy. The research reports and results presented in this thesis have not been submitted in part or in full to any other University or Institute, for the award of any degree or diploma.

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PREFACE

The present global energy crisis has given impetus to study of alternative sources of energy. Of the various energy alternatives, solar energy has the very desirable property of being essentially limitless and without having the problems of pollution or physical danger. The solar cell is a device which converts sunlight directly to electricity. Solar cells are also capable of making a significant impact on terrestrial energy needs.

The advantages of solar cells lie in their ability to provide nearly permanent, uninterrupted power at no operating cost with only heat as a waste product. They also have a high power/weight ratio compared to other power sources. Their chief disadvantages lie in their high cost, the low power/unit area of sunlight, their relatively low efficiency, etc.

Solar cell behaviour can be conveniently examined through three main parameters:

1. The open circuit voltage (V_{oc}), which is the voltage output when the load impedance is much greater than the device impedance.
2. The short circuit current (I_{sc}), which is the current output when the load impedance is much smaller than the device impedance.

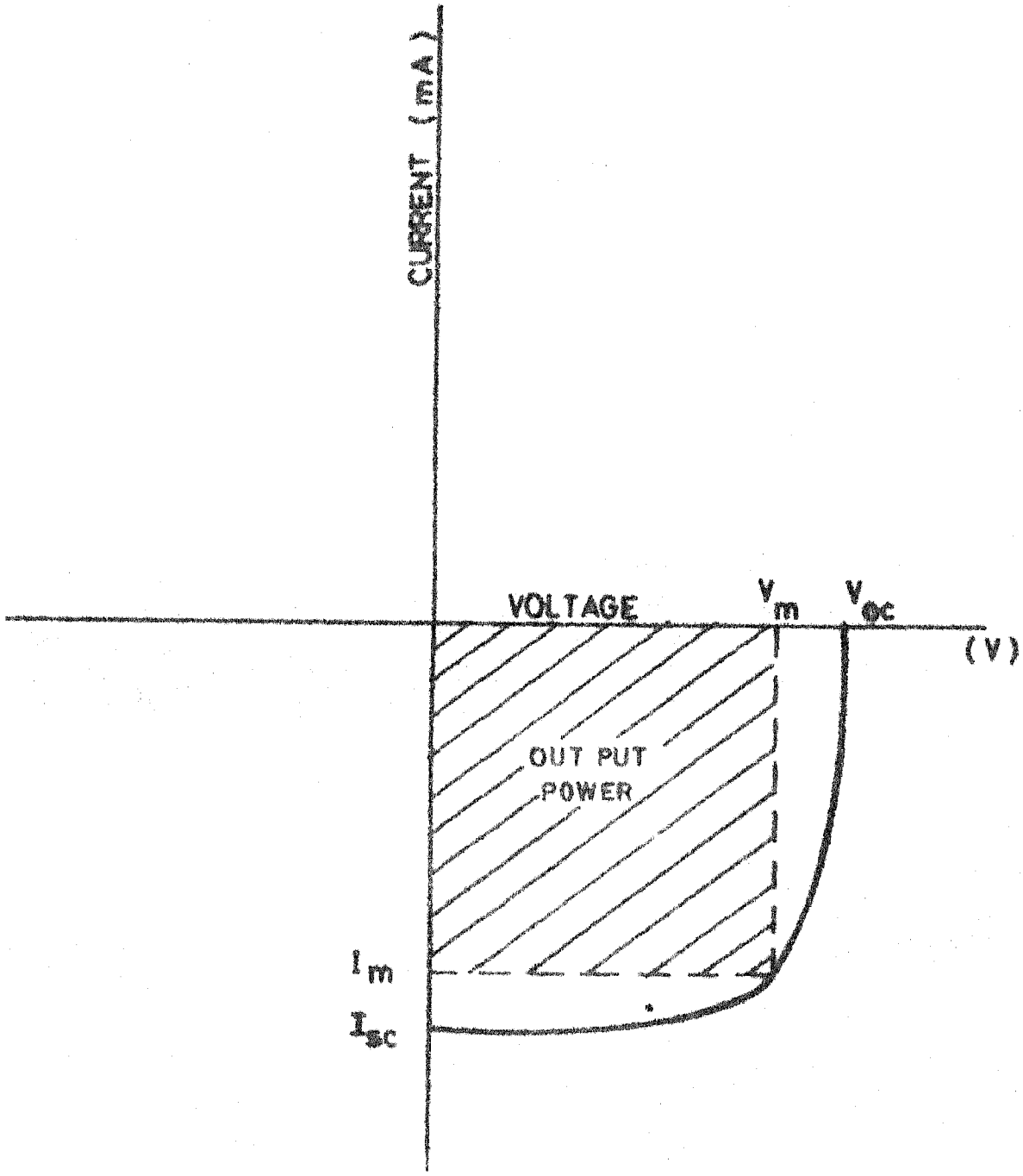

Fig. 1. Voltage and Current output from an illuminated Solar cell.

3. The fill factor (FF), the ratio of maximum power output to the product of V_{oc} and I_{sc} (the voltage and current for maximum output are known as V_m and I_m, respectively).

These three parameters determine the efficiency and the circuit conditions of the solar cell as shown in Fig.1 .

A sizeable number of papers have been published on the theory of open circuit photovoltage generated in a heavily doped p-n junction semiconductor. However, all these papers[1-6] are based on the following assumptions:

1. That the diffusion coefficient and mobility of carriers are related through Einstein relation i.e. $(D/\mu = \frac{kT}{e})$.
2. That the density of states is parabolic or in other words, the effect of impurity energy band tails is unimportant.

However, in degenerate p-n junction both of these assumptions are violated. Thus, at very high doping levels D/μ becomes a function of chemical potential[7], E_f/kT and the carrier energy levels exist within the energy gap which have non-parabolic density of states.[8,9]

In the present thesis, the author has developed a theory for open circuit voltage (V_{oc}) in arbitrarily degenerate p-n junction. Explicit expressions for V_{oc} have been obtained for low and intermediate levels of illumination in degenerate p-n junctions. The author has also investigated the effect of impurity band tails[8,9] on the open circuit voltage in degenerate p-n junction. An

expression for V_{oc} in non-degenerate p-n junction in the high injection limit has also been obtained.

The author has also investigated the effect of taking into account the non-ideality factor on the efficiency of GaAs Schottky barrier solar cell (SBSC), using the concept of excess temperature as first proposed by Padovani and Summer.[10,11]

The present thesis has been divided into four chapters, brief summaries of which are as follows:

Chapter - I: Theory of Open Circuit Photovoltage in Degenerate p-n Junction at Low Injection Levels

In this chapter, the author gives a theory for the generation of photovoltage across a degenerate p-n junction. Using Landsberg's[7] generalized diffusivity mobility relation valid for arbitrary degeneracy, the general expression for the photovoltage has been derived. The explicit expressions are, however, obtained only for intermediate and low injection levels. Numerical calculations of V_{oc} as a function of $(PN)_o^{1/2}$ (P,N being the concentration of hole and electron respectively at the junction) has been presented.

Chapter - II: Effect of Impurity Band Tails on the Open Circuit Photovoltage

In this chapter, the author has developed the theory of open-circuit photovoltage by taking into account the effect of impurity band tails. The effect of impurity

band tails has been incorporated following the work of Halperin and Lax.[8] The calculations show that the inclusion of the effect of impurity band tails results in the increase of the value of V_{oc}.

Chapter - III: Theory of Open Circuit Photovoltage in Non-Degenerate p-n Junction at High Injection Levels

The author has also given a comprehensive theory of open circuit voltage (V_{oc}) in non-degenerate p-n junction for the case of very high injection levels. Recently Parrot[12], Dhariwal et al.[13] and Fossum and Lindholm[14] have given theories for the saturated V_{oc} in Si and GaAs Solar cells. However, all of these theories assume that even at very high injection levels, the electron/hole gas in two neutral regions remains non-degenerate. This assumption is open to question since at very intense levels of illumination the excess carrier concentrations far exceed the equilibrium concentrations i.e. $\Delta N_e >> N_e$ and $\Delta N_p >> N_p$. Since N_e and N_p in a typical nondegenerate n^+p or p^+n junction are of the order $10^{18}/cm^3$, the ΔN_e or ΔN_p should be $\geq 3 \times 10^{19} cm^{-3}$ for the high injection limit to be satisfied. Thus, in high injection limit even in a non-degenerate p-n junction it is wrong to use Einstein's D-μ relation. The author has derived an expression for V_{oc} for the high injection case using Landsberg relation. Comparison between the results and the corresponding results using Parrot[12] theory which is based on Einstein relation, shows

that the inclusion of appropriate D-μ relation decreases the V_{oc} considerably.

Chapter - IV: Conversion Efficiency of Au-GaAs Schottky Barrier Solar Cell by Taking into Account of Excess Temperature

In this chapter, the author has investigated the effect of non-ideality factor on the efficiency of GaAs Schottky barrier solar cell using the concept of excess temperature following Padovani and Summer[10,11] work. This is in contrast to the calculations of Pulfrey and McQuat[15] (who have not taken into account the non-ideality factor). The calculations show that inclusion of non-ideality factor through excess temperature lowers the efficiency; this is in contradiction to the prediction of Pulfrey and McQuat that the conversion efficiency should increase with the inclusion of non-ideality factor.

The above work has resulted in the following publications/communications:

1. "Theory of Open Circuit Photovoltage in Degenerate Abrupt p-n Junction", Solid State Electronics, Vol. 25,12,1161-1164,Dec.1982.
2. "Effect of Impurity Band Tails on the Open-Circuit Photovoltage" (Communicated).
3. "Theory of Open Circuit Photo-voltage in Abrupt p-n Junctions at Very High Injection Levels (Communicated).

4. "Effect of Excess Temperature on the Efficiency of Au-GaAs Schottky Barrier Solar Cell", Solid-State Electronics, Vol. 24, 91, 1981).

5. "Effect of Various Parameters on the Efficiency of Au-GaAs Schottky Barrier Solar Cell", Indian Journal of Pure and Applied Physics, Vol. 20, pp. 224-225, 1982.

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