Ain Sahms University
Faculty of Engineering

MODELLING OF POLYCRYSTALLINE SOLAR CELLS USING SPICE

BY

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A Thesis

Submitted in partial fulfillment of the

requirments of the Degree of M.Sc

in Electrical Engineering

(ELECTRONICS AND COMMUNICATION ENGINEERING DEPARTMENT)

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1994

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STATEMENT

This dissertation is submitted to Ain Shams University for the Degree of **M. Sc.** in **Electrical** Engineering.

This work included in this thesis was carried out by the author in the Department of **Electronics** and communucation Engineering, Ain Shams University, From 9 - 11 - 1987 to - 1994

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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Acknowledgment

It is a pleasure to express my deep appreciation to Prof.Dr. HANI FIKRI RAGAIE, for his valuable guidance, helpfull suggestions and most of all for encouragment and patience during the preparation of this thesis.

I am deeply indebted to Dr.HASSAN EL-GHITANI for his great help, permanent support and continuous guidance throughout this work.

Finally, my deep thanks to all who offered me any direct or indirect assistance.

Abstract

Throughout this work, a detailed characterization of polycrystalline silicon solar cells in dark and under illumination is carried out. It is known that the efficiency of these cells is lower than that of other cells fabricated on single crystal materials.

This is due to crystallographic defects as grain boundaries and dislocations . In large grained polycrystalline silicon the mean grain size is much greater than the minority carrier diffusion length, so the influence of grain boundaries is reduced. The photovoltaic properties of such a material are mainly affected by the presence of dislocations. Both the recombination of carriers at dislocation (a mechanism which generally degrades photocurrent) and the movement of carriers along the dislocation core crossing the junction (a mechanism which increase dark current) are taken into consideration.

We have developed a model for the shunt current submitted by dislocations which is found to vary exponentially with the applied voltage.

The effect of this dislocation current on the cell performance is then simulated by the aid of a personal computer.

The particular influence of the density of dislocations and their recombination activity on the short circuit current density, open circuit voltage, Fill factor, and conversion efficiency are computed and discussed.

List of symbols

A	Cross-section area of the cell (cm^2).
AMo	Solar spectrum within the free space.
AMI	Solar spectrum when the sun is directly overhead.
$d_G = 2a$	Grain size (μm).
D_n, D_p	Electron and hole diffusion coefficent (cm^2/sec).
E_f	Fermi-Level (e.V).
E_{fp}, E_{fn}	Hole and electron quasi-fermi levels (e.V).
E_g	Forbidden gap energy of semiconductor (e.V).
FF	Fill Factor.
H	Cell thickness (μm).
I_{sc}	Short circuit current (mA).
J_o	Reverse saturation dark current density (mA/cm^2).
J_D	Dark current density (mA/cm^2).
K	Boltzman's constant (e.V/ K).
L_n, L_p	Electron and hole intra - grain diffusion length (μm).
L_{eff}	Effective electron diffusion length (μm).
n_i	Intrinsic concentration (cm^{-3}).
N_A, N_D	Acceptor and donor concentration (cm^{-3}).
N_{dis}	Density of dislocation (cm^{-2}).

Q_t	Density of trapping states per unit area (cm^{-2}) due to grain boundaries
	Density of trapping states per unit length (cm^{-1}) due to dislocations
q	Electronic charge (C).
R_{dis}	Shunt resistance due to dislocation within SCR.(Ohm)
R_s	Series resistance (Ohm).
R_{sh}	Shunt resistance (Ohm).
R	Recombinatiom rate (1/cm.s).
r	Radius of dislocation pipe (μm).
S_d	Recombination velocity at the edge space charge cylinder surrounding the dislocation line (cm/s).
S_g	Recombination velocity at the grain boundary (cm/s)
V_{oc}	Open circuit voltage (V).
VCCS	Voltage controlled current source.
V^p_{th}, V^n_{th}	Holes and electrons thermal velocities (cm/s).
W	Space charge region width. (μm)
Z_j	Junction depth (μm).
σ_p, σ_n	Hole and electron capture cross-section (cm^2).
ε	Permittivity of silicon (F/m).
τ	Carrier life time (sec).
λ_c	Critical wavelength (μm).
ϕ	Potential height of GB-material.
μ	Intrinsic mobilities (cm^2 / V.s).
η	Efficiency.

Contents

Introduction

Introduction

Direct conversion of sunlight into electrical energy is realized with the solar cell, a semiconductor device, the only photovoltaic component which presently exhibits a reasonable conversion efficiency. But it was not until 1954 that solar cells with acceptably high conversion efficiency was fabricated by G.L.Pearson, C.S.Fuller and D.M. Chapin of Bell Laboratories. Improvements since then have led to the present day solar cell devices.

Solar cells at present furnish the most important long duration power supply for satellites and space vehicles . They have also been successfully employed in small scale terrestrial applications. Solar cells are considered a major candidate for obtaining energy from the sun . To make photovoltaic solar energy conversion economically attractive, the cost of solar cells must be reduced, therefore a dramatic reduction in the cost of the material is required. To achieve this goal, silicon with higher concentration of impurities and sheets with higher degree oi crystallographic defects up to polycrystalline (PX) level are used.They contain defects such as dislocations and grain boundaries. Such defects act as sinks for photon - generated carriers. The principal problem influencing the efficiency of PX-Si solar cells is the carrier recombination which occurs at defect sites. In large grained polycrystalline silicon the mean grain size is actually greater than 1mm and the influence of grain boundaries (GBs) is neglegible compared to that of intragrain defects especially dislocations.

In this work, the effect of dislocations on large grained polycrystalline solar cells is studied taking into consideration both recombination and shunt mechanisms of dislocations with a special consideration of the shunt effect.

This thesis contains four chapters; in the first chapter, a general study of p-n junction characteristics will be given followed by explaining how this junction works as solar cell and what are its output parameters.

The second chapter contains a review for the different technological methods used for preparing the PX Si, followed by explaining the crystallographic defects such as dislocation and grain boundaries. The effect of the grain boundaries on solar cell performance is then discussed. Chapter three contains the detailed characteristic for the effect of dislocation on large grained polycrystalline solar cells.