ELECTRONIC PROCESSES MODELLING IN POLYSILICON SOLAR CELLS

A THESIS

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BY

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APPROVAL SHEET

THIS THESIS

ON

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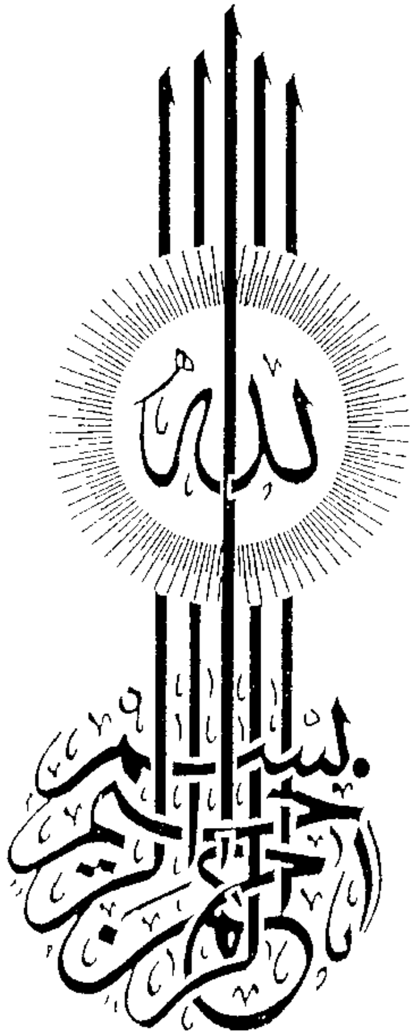
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ABSTRACT

To make the photovoltaic solar energy conversion economically attractive,the cost of polysilicon solar cells must be reduced to more than one order of magnitude below the present cost of producing single crystal cells.

Silicon with higher concentration of impurities, so called solar-grade silicon(SoG-Si), is the major candidate to achieve this goal.

The different technologies to produce this solar-grade silicon are discussed in detail besides the other methods for polysilicon production like sheet casting or ribbon technique .

Grain boundaries and crystal defects are the main drawbacks of polysilicon materials . The different models describing the conduction in polysilicon are also presented.

The optical and electrical properties of solar cells fabricated from polysilicon materials are described.

A numerical model characterizing the polysilicon solar cells is devolped .In this model, the grains are assumed to have a cylindrical shape. Assuming symmetry about the rotational axis, the three dimensional continuity equation is reduced to a two dimensional one.

The solar cell output parameters are computed using the proposed model. The results are analyzed and the optimum design structures are then proposed . Furthermore, based on the above mentioned model, a new approach to the

real polysilicon solar cell modeling is presented. In this model, the real distribution of the grains in the polycrystalline materials is taken into consideration . For the first time,a quatitative agreement has been found between measured and calculated results. More important, we have deduced that the origin of the low open circuit voltage in semicrystalline solar cells is the presence of fine grains taking the shape of sharp needles. In spite of the small overall area of these small grains, they lower the open circuit voltage of the cell and consequently its conversion efficiency.

LIST OF SYMBOLS

AMO	solar spectrum within free space(135.3 mW/cm^2)
C	velocity of light in vacuum(2.998×10^8 m/sec)
d_G	grain size(μm)
D_n	diffusion coefficient for electrons(cm^2/sec)
Dp	diffusion coefficient for holes(cm^2/sec)
E_c	conduction band edge energy(eV)
E_F	Fermi level energy(eV)
E_i	intrinsic Fermi level energy(eV)
E_g	bandgap energy(eV)
E_p	phonon energy(eV)
E_r	electric drift field in the radial direction(v/cm)
E_v	energy of the valence band edge(eV)
E_x	electric drift field in the longtudinal direction (v/cm)
FF	fill factor
G	generation rate due to incident light(cm^{-3}/sec)
GB	grain boundary
h	Plank's constant(6.625×10^{-34}J.sec)
J_d	dark current density(mA/cm^2)
J_{dr}	depletion region current density(mA/cm^2)
J_{mp}	current density at the maximum power point(mA/cm^2)
J_n	electron current density in the P-type mat.(mA/cm^2)
J_{od}	reverse saturation current density due to diffusion(mA/cm^2)
J_{or}	reverse saturation current density due to reccombination(mA/cm^2)
J_p	hole current density in the P-type mat.(mA/cm^2)

J_r	radial component of the current density(mA/cm^2)
J_{rec}	recombination current density(mA/cm^2)
J_{sc}	short circuit current density(mA/cm^2)
J_x	longitudinal component of the current density(mA/cm^2)
k	Boltzman's constant($1.386x10^{-23}$ $J/^oK$)
L_n	diffusion length for electrons(μm)
L_p	diffusion length for holes(μm)
MG	metalurgical grade
n_i	intrinsic carrier concentration(cm^{-3})
n_o	index of refraction in air
n_1	index of refraction in the antireflection coating
n_2	index of refraction in the semiconductor
N_a	acceptor concentration(cm^{-3})
N_d	donor concentration(cm^{-3})
n_p	electron concentration in the P-type material(cm^{-3})
n_{po}	thermal equilibrium electron concentration(cm^{-3})
P_{in}	input incident power density(mW/cm^2)
P_{max}	maximum power delivered from the cell(mW/cm^2)
P_n	hole concentration in the N-type material(cm^{-3})
P_{no}	thermal equilibrium hole concentration(cm^{-3})
q	electronic charge($1.6x10^{-19}$Coulomb)
Q_t	trapping state density(cm^{-2})
R	reflected part of light(%)
R_L	load resistance(Ω)
R_s	series resistance(Ω)
R_{sh}	shunt resistance(Ω)
SeG	semiconductor grade

SoG	solar grade
S_n	surface recombination velocity for electrons(cm/sec)
S_p	surface recombination velocity for holes(cm/sec)
S_g	grain boundary recombination velocity(cm/sec)
SR	spectral response(mA/mW)
T	absolute temperature(^oK)
V_j	junction voltage(volts)
V_{mp}	voltage at the maximum power point(volts)
V_{oc}	open circuit voltage(volts)
V_T	thermal voltage(kT/q)(volts)
W_{dr}	depletion region width(μm)
X_j	junction depth(μm)
X_L	cell thickness(μm)
α	absorption coefficient(cm^{-1})
ε	material permittivity(F/cm)
η	solar cell efficiency(%)
λ	wavelength(μm)
Φ	photon flux($cm^{-2}sec^{-1}$)
τ_n	electron lifetime(sec)
τ_p	hole lifetime(sec)
μ_n	electron mobility(cm^2/v/sec)
μ_p	hole mobility(cm^2/v/sec)
ν	photon frequency(Hz)
θ_n	phase thickness of optical coating
$\sum_{i=1}^{n}$	mathematical sum from i=1 to i=n

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Introduction

Energy in various forms, has played an increasingly important role in worldwide progress and industrialization. Abundant and inexpensive energy supplies have transformed many nations from subsistence level into highly developed economics. Despite the fact that per capita energy use varies for every nation around the world, increasing energy availability is now a key goal of every society.

Energy resources used today are mostly fossil-based fuels, with limited availability. With this limitation in mind, newer resources have been developed to replace the older resources and add to the total energy available.

Alternative energy resources are only a small part of the world's energy mix, but they are the key to the future.

Newer energy resources, such as wind generators and PHOTOVOLTAICS (PV), can generate electricity directly with out going through an intermediate thermal cycle. Electricity generated from such systems will play a major role in contributing to the overall energy supply, thus becoming a significant energy source for the worldwide industrialization.

PHOTOVOLTAIC systems use solar cells to convert daylight into electric energy. These cells are usually made from silicon, one of the most common elements on the earth crust.

Solar cells work silently, cleanly and without harmful waste products. In addition, they can operate for many years