ENHANCING PLASMONIC PHOTOVOLTAIC USING EMBEDDED METAL NANOPARTICLES

By

Marina Medhat Rassmi Melek

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfilment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
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Title of Thesis:

Enhancing Plasmonic Photovoltaic Using Embedded Metal Nanoparticles

Key Words:
Photovoltaic; Plasmonic; Metal Nanoparticles; Nanoantennas; Plasmonic Solarcells

Summary:
Plasmonic Photovoltaic is a promising way to enhance the thin film photovoltaic (PV) efficiency. Gear shape nanoparticles are introduced to enhance the PV efficiency via increasing the power absorbed by the PV semiconductor in the visible and near infrared ranges. The modes of the gear nanoparticles are investigated. A parametric study is performed that demonstrates how the design parameters of the proposed nanoparticles can be engineered for best power absorption within Si. A Figure of Merit (FoM) is defined that consider all objectives. An optimization process is carried out and the optimum gear's dimensions, penetration depth, and periodicity are obtained for the maximum FoM. Then, a model for PIN-PV with embedded gear nanoparticles is presented for 1D and 2D structures. The enhancement of the embedded gear nanoparticles on the J-V characteristics of the PV is studied, and J-V characteristics corresponding to maximum FoM is presented.

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Marina Medhat

To my family and all my friends

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List of Symbols and Abbreviations

a-si	Amorphous silicon.
AlGaAs	Aluminum Galium Arsenide.
c-si	Crystalline silicon.
GaN	Galium nitride.
InGaAs	Indium Galium Arsenide.
InGaP	Indium Galium Phosphide.
ϵ	Dielectric constant.
Γ	collision frequency.
λ	Optical wavelength.
$\mu_{\mathbf{n}}$	Average Electron mobility .
$\mu_{\mathbf{p}}$	Average Hole mobility .
$\omega_{\mathbf{p}}$	plasma frequency of the free electron gas.
ω	Angular frequency.
$\phi_{\mathbf{n}}$	N-type semiconductor work function.
$\phi_{\mathbf{p}}$	P-type semiconductor work function.
Φ	Work function.
ψ	Potential.
ρ	Charge density.
$\tau_{\mathbf{n}}$	Electrons life time.
$\tau_{\mathbf{p}}$	Holes lifetime.
$\boldsymbol{c}$	Speed of light.
$\boldsymbol{D}_{\mathbf{n}}$	Electrons diffusion constant.
$\boldsymbol{D}_{\mathbf{p}}$	Holes diffusion constant.

e, q	Electron charge.
$\boldsymbol{E}_{\mathbf{f}}$	Fermi level.
E	Electric field.
G	Generation rate.
H	Magnetic field.
h	Planks constant.
K	Boltzmann constant.
m	Mass of electrons.
$\boldsymbol{N}_{\mathbf{a}}$	Acceptor doping concentration.
$\boldsymbol{N}_{\mathbf{d}}$	Donner doping Concentration.
$\boldsymbol{n}_{\mathbf{i}}$	Intrinsic carrier concentration.
N	number of electrons per unit volume.
n	Electron Concentration.
$\boldsymbol{P}_{\mathbf{abs}}$	Absorped Power in Si.
$\boldsymbol{P}_{\mathbf{L}}$	Absorped Power.
p	Holes Concentration.
R	Shockley Read Hall recombination rate.
$\boldsymbol{S}_{\mathbf{11}}$	Power reflected.
$\boldsymbol{S}_{\mathbf{21}}$	Power transmited.
S	Solar spectrum irradiace for AM1.5 .
T	Temperature in Kelvin scale.
θ	Gear arm angle.
$\boldsymbol{D}_{\mathbf{1}}$	Inner diameter.
$\boldsymbol{D}_{\mathbf{2}}$	Outer diameter.
d	Nanoparticle depth from Si surface.
P	Structure periodicity.
$\boldsymbol{S}_{\mathbf{g}}$	Global scattering matrix.
$\boldsymbol{T}_{\mathbf{Si}}$	Silicon thickness.
AD	anno Domini.

NanoHUB	In-browser simulation tools geared toward nanotechnology, electrical engineering, chemistry, and semiconductor education.
NR	Newton- Raphson algorithm.
PV	Photovoltaic.
SOI	silicon on insulator.
THz	Terahertz.
TW	terawatts.