

CONTENTS

Forwarding Certificate	i
Certificate of Approval	ii
Declaration	iii
Acknowledgement	viii
Abstract	ix
List of Table	x
List of Figure	xiii
Nomenclature	xvi
1. Introduction	1-10
1.1 Introduction	1
1.2 The Sun and Its Spectrum	2
1.2 Status of solar Power	4
1.3 Solar Cell Efficiency and Some Related Issues	6
1.4 Layout of Report	9
2. Literature Review	11-35
2.1 Introduction	11
2.2 Solar Cell and Its Resistive Losses	13
2.3 Front Side Metallization of c-Si Solar Cells	17
2.3.1 Screen Printing	18
2.3.2 Laser Micro-sintering	21
2.3.3 Light Induced Plating	23
2.3.4 Ni/Cu Metallization	24
2.3.5 Evaporated Ti/Pd/Ag Contact	28
2.3.6 Metal Aerosol Jet Printing	31
2.4 Effect of Light on Electroless Plating	33
2.5 Objective of the Work	35

3.	Experimental Work	36-39
	3.1 Preparation of Sample	36
	3.2 Set up for light and dark Condition	37
	3.3 Bath Preparation and Experimental Procedure	39
4.	Results and Discussion	41-60
	4.1 SEM and EDS	41
	4.1.1 Surface Morphology of Without Deposited Sample	42
	4.1.2 Effect of Light Intensity for Time of Deposition 60 Second	43-47
	4.1.2.1 Deposition at Light Intensity 3500±100 LUX	43
	4.1.2.2 Deposition at Light Intensity 2400±100 LUX	44
	4.1.2.3 Deposition at Light Intensity 1800±100 LUX	45
	4.1.2.4 Deposition at Light Intensity 450±100 LUX	46
	4.1.2.5 Deposition at Light Intensity 0 LUX (Dark)	47
	4.1.3 Effect of Light Intensity for Time of Deposition 60 Second	48-51
	4.1.3.1 Deposition at Light Intensity 3500±100 LUX	48
	4.1.3.2 Deposition at Light Intensity 2400±100 LUX	49
	4.1.3.3 Deposition at Light Intensity 1800±100 LUX	50
	4.1.3.4 Deposition at Light Intensity 450±100 LUX	51
	4.1.3.5 Deposition at Light Intensity 0 LUX(Dark)	51
	4.2 Mechanism for Suppressed Deposition under Light Condition	52
	4.3 Experimental Proof	53
	4.4.1 Deposition without Reducing Agent	53
	4.4.2 Initial Stage of Deposition	54
	4.4 Observation	55
	4.4.1 Elemental Analysis from EDS Data	56
	4.4.2 Surface Morphology from SEM Image	58

4.4.3 Summery of Elemental Analysis and Surface Morphology	59
5. Conclusion and Future work	61
5.1 Conclusion	61
5.2 Future Work	61
References	62-66

LIST OF TABLES

Table 1.1 Weight percentages of elements in earth's crust, applicable for PV	8
Table 3.1 Experimental Procedure for Alkaline Bath	40
Table 4.1 EDS Observation Table of Weight percentage	56
Table 4.2 Summery of Nickel Phosphorus from EDS data	58
Table 4.3 Surface morphology from SEM image	59
Table 4.4 Criteria for Quality of deposition	59
Table 4.5 Table for Quality of deposition	59

LIST OF FIGURES

Figure 1.1	Annual Production of Oil	2
Figure 1.2	Solar Radiation curve	3
Figure 1.3	Market share of solar cell types sold during 2006	5
Figure 1.4	Different losses of solar cell	7
Figure 2.1	Working of p-n junction solar cell	13
Figure 2.2	(a) Equivalent circuit of solar cell (b) I-V and P-V characteristics	14
Figure 2.3	Series resistance in a simple c-Si wafer based solar cell	16
Figure 2.4	(a) Magnified image of a screen used for printing the front contact of a Solar cell, (b) Front view of a completed screen printed multicrystalline Si- solar cell	18
Figure 2.5	The Screen-printing process: (1) the openings in the screen are filled With Paste; (2) the squeegee brings the screen in intimate contact with The Substrate and presses paste through the openings (3) while the screen is Lifted Up, paste is released from the screen and sticks to the substrate	19
Figure 2.6	SEM image of the Ag-Si interface of a thick-film finger on [100] Oriented Si and the re-grown Ag crystallites	20
Figure 2.7	Different possible current transport mechanisms from Si emitter to the Ag grid	20
Figure 2.8	Schematic diagram of the laser micro-sintering process	21
Figure 2.9	SEM image (cross-section view) of a silicon solar cell, with a laser micro-sintered silver contact and subsequently silver plated contact	22
Figure 2.10	Schematic of the light induced electroplating process	24
Figure 2.11	SEM images of the Ni/Cu contact system for high efficiency solar cells: (a) electroless plated Ni layer and (b) electroplated Cu on a Ni layer	25

Figure 2.12	SEM images of plated Ni films (a) before and (b) after annealing at 600°C for 30s	27
Figure 2.13	Diagrammatic representation of an electron-beam evaporation system	30
Figure 2.14	Printing head of the metal aerosol printing technique	32
Figure 2.15	(A) Setup for reducing photoelectric effect of Nickel bath [40] (B) Conventional Nickel bath	33
Figure 2.16	Experimental Setup for electroless deposition	34
Figure 3.1	Cutting and wrapping of the cell	36
Figure 3.2	Etching the ARC with 49% HF	37
Figure 3.3	lay out experimental setup for light condition	38
Figure 3.4	(A) Actual experimental setup for light condition (B) Distance between Sample and light source	38
Figure 3.5	Setup for Dark condition	39
Figure 4.1	SEM image of textured Si wafer (sample) without deposition	42
Figure 4.2	Energy dispersive spectroscopy of the textured Si substrate	42
Figure 4.3	SEM image of the nickel deposited sample for 3500±100 LUX Condition	43
Figure 4.4	EDS of the nickel deposited sample for 3500±100 LUX condition	44
Figure 4.5	SEM image of the nickel deposited sample for 2400±100 LUX Condition	44
Figure 4.6	EDS of the nickel deposited sample for 2400±100 LUX condition	45
Figure 4.7	SEM image of nickel deposited sample for 1800±100 lux luminous Intensity	45
Figure 4.8	EDS of nickel deposited sample for 1800±100 lux luminous intensity	46
Figure 4.9	SEM image of nickel deposited sample for ambient light condition	46
Figure 4.10	EDS of nickel deposited sample for ambient light condition	47
Figure 4.11	SEM image of nickel deposited sample under dark condition	47
Figure 4.12	EDS of nickel deposited samples under dark condition	48
Figure 4.13	SEM image of nickel deposited sample for 3500±100 lux luminous Intensity	48

Figure 4.14	EDS of nickel deposited samples under 3500±100 Condition	49
Figure 4.15	SEM image of the nickel deposited sample for 2400±100 LUX Condition	49
Figure 4.16	EDS of the nickel deposited sample for 2400±100 LUX condition	50
Figure 4.17	SEM image of nickel deposited sample for 1800±100 lux luminous Intensity	50
Figure 4.18	EDS of nickel deposited sample for 1800±100 lux luminous intensity	50
Figure 4.19	SEM image of nickel deposited sample for ambient light condition	51
Figure 4.20	EDX of nickel deposited sample for ambient light condition	51
Figure 4.21	SEM image of nickel deposited sample under dark condition	52
Figure 4.22	EDX of nickel deposited samples under dark condition	52
Figure 4.23	Mechanism; why deposition suppressed under light condition	53
Figure 4.24	Mechanism of deposition under dark condition	53
Figure 4.25	SEM image (Surface Morphology) deposition without using reducing Agent	54
Figure 4.26	SEM image (Cross-section) deposition without using reducing agent	54
Figure 4.27	SEM image; Initial Stage of Deposition for 30 second (A) Under 3500±200 LUX (B) Under Dark condition	55
Figure 4.28	Weight % of Ni Vs. light Intensity	57
Figure 4.29	Weight % of P Vs. light Intensity	57

NOMENCLATURE

A	Area
Ag	Silver
Al	Aluminum
AM	Air mass
Ar	Argon
ARC	Anti-reflective coating
Au	Gold
B	Boron
BSF	Back Surface Field
CIGS	Copper-indium-gallium-Selenite
Cl	Chlorine
$C_6H_7N_3O_7$	Triammonium Citrate
CO_2	Carbon dioxide
Cu	Copper
Cu_2SO_4	Copper Sulphate
c-Si	Crystalline Silicon
CZ	Czochralski Silicon
DI	Deionized Water
EBE	Electron Beam Evaporation
EDX	Energy Dispersive Spectroscopy
EN	Electroless Nickel Plating
ESCA	Electron Spectroscopy for Chemical Analysis
FF	Fill Factor
FZ	Float Zone
GaAs	Gallium Arsenide
GW	Giga Watt
GIXRD	Grazing Incidence Angle X-Ray Diffraction
HF	Hydrofluoric acid
H_2SO_4	Sulphuric Acid
H_2O_2	Hydrogen Peroxide

ICP-MS	Inductively Coupled Plasma Molecular Spectroscopy
ICDD	International Committee on Diffraction Data
InGaP	Indium Gallium Phosphide
LIP	Light Induced Plating
NH ₄ Cl	Ammonium Chloride
NH ₄ OH	Ammonium Hydroxide
NdYAG	Neodymium Yttrium Aluminum Garnet Laser
NaH ₂ PO ₂	Sodium Hypophosphite
NaOH	Sodium Hydroxide
NIST	National Institute of Standards and Technology
Ni	Nickel
NiCl ₂	Nickel Chloride
Ni ₃ P	Nickel Phosphide
NiSi	Nickel Silicide
Ni ₃ Si ₂	Nickel Silicide
Ni ₅ Si ₂	Nickel Silicide
OPEC	Organization of the Petroleum Exporting Countries
P	Phosphorus
Pd	Palladium
PdCl ₂	Palladium Chloride
PECVD	Plasma Enhanced Chemical Vapor Deposition
PESC	Passivated Emitter Solar Cell
PERL	Passivated Emitter Rear Locally Diffused Solar Cell
PV	Photovoltaic
PVD	Physical Vapor Deposition
R	Resistance
SCR	Space Charge Region
SEM	Scanning Electron Microscope
Si	Silicon
SiO ₂	Silicon Dioxide
S _x N _y	Silicon Nitride

SP	Screen Printing
SPV	Solar Photovoltaic
SRV	Surface Recombination Velocities
STC	Standard Test Conditions
Ti	Titanium
TLM	Transmission Line Model/Transfer Length Method
W	Tungsten
Xe	Xenon
XPS	X-Ray Photoelectron Spectroscopy
XRD	X-Ray Diffraction