

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قال تعالى:

نُورَهُ اللَّهُ مُتَوَكِّئًا عَلَىكَ وَاللَّهُ يَوْمَئِذٍ سَمِيعٌ عَلِيمٌ
شَجَرَةٍ مَبْرُورَةٍ زَيْتُونَةٍ غَلَّابَةٍ يُقَاتِدُ فِيهَا وَيُضِيءُ وَ لَوْ
لَمْ يَأْتِ لَسَوَّاهُ فَمَنْ يَشَاءُ وَيَضْرِبُ اللَّهُ الْأَمْثَالَ لِلنَّاسِ وَاللَّهُ بِكُلِّ
شَيْءٍ عَلِيمٌ

صدق الله العظيم

(سورة النور الآية (35))

Dedication

Dedicated to my mother whose I love dearly and owe everything.

To all my great teachers.

To all colleagues, friends, and everyone who helped.

Marwa

Acknowledgement

I would like to thank God for helping me and giving me life, health and time to accomplish this work .thanks to Sudan University of Science and Technology - Institute of Laser for giving me the opportunity to present this work .

I extend my gratitude to my supervisor Dr. Ali A. AlrahmanSaeedMarouf who gave me much useful advice and support which has encouraged me throughout this whole process.

I would like to thank Mrs. Mohammed Baba for his helping me in the experimental part of this work and thanks to all teachers in Institute of laser(SUST) and its Dean Dr. Faiz Mohammed BudrElshafiaand to everyone who have helped me with his valuable advice and efforts.

Last but not least, I wish to thank my parents for being there, make me strong than I would be without you.

Abstract

Solar energy is rapidly becoming one of the most promising renewable energy sources available to us. This work aimed to modify the surface of mono crystalline silicon solar cell. Texturing of semiconductor surface can be utilized to capture as much of the incident light as possible to decrease reflection and increase absorption to enhanced device performance without altering the bulk properties. Laser Direct Writing technique was used to achieve the texturing results, that's based on the interaction between ultra short pulses of CO₂ laser (10.6 μ m) and silicon used for solar cells. An increase in short circuit current by 75.1% and efficiency by 50% was observed.

مستخلص

الطاقة الشمسية سرعان ما أصبحت واحدة من مصادر الطاقة المتجددة والواعدة المتاحة. يهدف هذا البحث إلى تعديل سطح الخلية الشمسية السيلكونية أحادية التبلور. استخدام تغيير النسيج لسطح شبة الموصل يؤدي إلى إلتقاط أكبر قدر ممكن من الضوء الساقط لتقليل الانعكاس وزيادة الامتصاص وذلك لتعزيز أداء الجهاز دون تغيير في خصائص المادة. استخدمت تقنية الحفر المباشر بالليزر لتحقيق النتائج والتي تعتمد على التفاعل بين نبضات قصيرة جدا من ليزر ثاني أكسيد الكربون النبضي بطول موجة (10.6 ميكرومتر) و السيليكون المستخدم في الخلايا الشمسية. أظهرت النتائج زيادة في تيار دائرة القصر بنسبة 75.1% وفي الكفاءة بنسبة 50% .

Table of contents

Article	Page No.
Alaayah	I
Dedication	II
Acknowledgement	III
Abstract	IV
Abstract (Arabic)	V
Table of Contents	VI
List of Figures	IX
List of Tables	XI
Chapter One	
Introduction	
1-1 Study Objectives	2
1-2 Literature Review	2
1-3 Thesis Outlines	5
Chapter Two	
Theoretical Background	
2-1 Solar Cells Technology	7
2-1-1 Solar cell construction & Theory	8
2-1-2 Optical properties of semiconductors	10
2-1-3 Photovoltaic Effect	11
2-1-4 Basic Parameters of Solar Cell	11
2-1-4-1 Overall Current (I)	11
2-1-4-2 Short-Circuit Current (I_{sc})	11
2-1-4-3 Open-Circuit Voltage (V_{oc})	12
2-1-4-4 I–V Characteristics	12
2-1-4-5 Fill Factor (FF)	13
2-1-4-6 Maximum Power (Pmax)	14
2-1-4-7 Solar Cell Efficiency (η_{ec})	15
2-2 Interaction between laser and matter	15
2-2-1 Relation between Reflectance, Transmission and Absorption	16

2-2-2Energy Absorption Mechanisms	18
2-2-3Material Response	18
2-2-3-1 Thermally Activated Processes	18
2-2-3-2 Surface Melting	19
2-2-3-3 Ablation	19
2-2-4 Interaction between Laser and Silicon	20
2-3 Laser surface Modification	21
2-3-1Surface Texturing for Enhanced Optical Properties	21
2-3-2 Laser Direct-Write Processing	27
2-3-3 Direct Beam, Scanning, and Interference Patterns	28
2-3-3-1 Direct Beam	29
2-3-3-2 Scanning	29
2-3-3-3 Interference Patterns	29
2-3-3-4 Pore Geometry, Size, and Frequency	30
2-3-4 LDW laser Source	30
2-3-4-1 Carbon Dioxide laser	30
2-4 Effect of Temperature	34
Chapter Three Experimental Part	
3-1 Experimental setup	35
3-2IV characteristic curve Investigation	38
3-3 Treatment with laser	39
Chapter Four Results and Discussion	
4-1 IV characteristic curve results	42
4-1-1 before Irradiation	42
4-1-2After Irradiation	43
4-2Irradiation with Co₂ laser (10.6μm)	44
4-3 Discussions	46
4-4 Conclusions	47
4-5 Future work	47
References	48

LIST OF FIGURES

Figure	Page No.
Chapter One Introduction	
Fig (1:1) Texture decreases front surface reflectance for all wavelengths	2
Chapter Two Theoretical Background	
Fig (2.1) A conventional crystalline silicon solar cell.	8
Fig (2.2) Solar cell Theory	9
Fig (2.3) I–V characteristics of a solar cell with and without illumination.	12
Fig (2.4) Characteristic and power curve for determining the fill factor	14
Fig(2.5) Reflection and transmission of light for a textured Si solar cell.	23
Fig (2.6) A square based pyramid which forms the surface of an appropriately textured crystalline silicon solar cell.	24
Fig (2.7) SEM photograph of a textured silicon surface.	25
Fig (2.8) Magnified image of patterned hemispherical depressions	26
Figure (2.9) Schematic illustration of a laser direct-write system.	28
Fig (2.10) The three independent modes of vibration of the CO ₂ molecules	32
Fig(2.11) The vibrational levels of nitrogen and CO ₂ molecules	33
Chapter Three Experimental Part	
Fig(3.1a) Experimental Setup for Solar cell (with & without surface texture) IV curve Measurements.	35
Fig(3.1b) setup arrangement to measure I-V characteristic of solar cell.	39
Fig (3.2) 125x125mm mono-crystalline solar cells	36
Fig (3.3) Plus line S 500W R7s 230V 1CT Lamb and his Flood light	37
Fig(3.4) 450-1 photometer	38
Fig (3.5) CNC table for CO ₂ engraving & cutting application.	40

Fig (3.6) Technique of deliver laser beam to working area by mirrors.	40
Chapter Four Results and Discussion	
Fig (4.1) plot of the I-V characteristics for cell before irradiation	43
Fig (4.2)plot of the I-V characteristics for cell after irradiation	44
Fig (4.3) textured area on the cell	45
Fig (4.4) Plot shows the changes in I-V characteristics for cell before and after texturing.	45

List of tables

Contents	Page No.
Chapter Three Experimental Part	
Table(3.1) Solar cells samples specifications	36
Table (3.2) Lamp commercial & electric's specifications	37
Table (3.3) Co ₂ laser commercial specifications	39
Chapter Four Results and Discussion	
Table (4.1) List of voltage /current density value before irradiation	42
Table (4.2) List of voltage /current value after irradiation	43
Table (4.3) electrical properties for cell before and after irradiation	46