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"Deposition of Colloidal Titanium Oxide Nanoparticles using Pulsed Nd: YAG Laser Ablation in Liquid to Increase the Efficiency of the Si Solar Cell"

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Abstract

This work reports the attempts to carry out pulsed laser ablation in liquid (PLAL) for synthesizing colloidal Titanium dioxide nanoparticles (NPs). TiO_2 NPs was synthesized by 7ns Nd:YAG laser ablation of high purity titanium target (99.99 %) immersed in water ,and deposited the film on silicon solar cell to increase the efficiency of the Si solar cell . The surface morphology of the deposits materials have been studied by using atomic force microscopes (AFM). Atomic Force Microscopy(AFM) analysis showed that the average grain size of TiO_2NPsinwater were 150 nm and rms roughness values are (2.27 nm) for TiO_2 thin film. The photovoltaic characteristics before and after deposited Titanium dioxide nanoparticles (NPs) included short circuit current (Jsc),open circuit voltage (V_{oc}), where the maximum (J_{sc}), (V_{oc})and fill factor (FF) obtained at AM1after deposited were 40.2 (mA cm^{-2}) , 630(mV) and(0.7) respectively. After deposited Titanium dioxide nanoparticles (NPs)increase the efficiency of the Si solar cell13.8 % instead of 10.3% conversion efficiency before the deposited.

Keywords: Laser ablation, Titanium dioxide nanoparticles inliquids,solar cell.

Introduction

TiO_2 has been investigated for many years. Titanium dioxide is a fascinating class of inorganicsolids in a wide range of common and high technique applications due to its wide application in the photocatalysis, optical materials, dye-sensitized solar cell, and lithium-ion batteries fields[1−4]. Crystalline TiO_2 exists in three forms: rutile, anatase and brookite, of which, rutile is the most thermodynamically stable phase[5].In recent years, pulsed laser ablation of metal targetin liquid media has attracted great interest because suchlaser ablation in liquid (LAL) can produce the extremeconditions and lead to the formation of the novelnanostructures [6−10]. When a pulsed laser beam withenough energy irradiates on a metal target in atransparent liquid, a local plasma with super-high temperature (about 6000 K) and high-pressure (about1 GPa) will instantly be produced on the solid-liquidinterface, and quench quickly after one pulse due toadiabatic expansion of the plasma and its interaction withsurrounding media. The whole process is finished inabout 1 μs. So, the laser ablation of metal targets inliquid media can form some special nanomaterialsthatare difficult to be obtained by the conventional methods[11−14].

In this work, we reported successful one-stepfabrication of rutile TiO_2 nanoparticles by LAL oftitanium plate in distilled deionized waterat room temperature.

In this work, we have performed laser ablation of Titanium target in water to synthesize Titanium oxide nanoparticles and deposited the film on silicon solar cell to increase the efficiency of the Si solar cell. The surface morphology of the deposits materials have been studied by using atomic force microscopes (AFM).

Experiment

Titanium oxide NPs were produced by laser ablation of high purity Titanium target immersed in water at room temperature. Fig.(1) displays the schematic diagram of experimental set-up of PLAL system. The Titanium target is placed in the bottom of glasses vessel filled with 2mlof liquid. The Titanium target was is irradiated with Q-switched Nd:YAG laser operated at wavelength of 1064nm ,7ns pulse duration, and repetition frequency of 1Hz.The laser energy was used to ablate Titanium target was 80mJ/pulse, the ablation time was 5min . The laser beam was focused on Titanium target using focusing lens of 50mm focal length. AblatedTi NPs were analyzed by atomic force microscopy (AFM) model (SPMAA 3000 Angstrom Advanced Inc. USA).

Result and Discussion

After laser ablation of Titanium target, the color of suspension is changed from colorless to white color as depicted in Fig.(2), indicating the production of Titanium oxide colloidal nanoparticles [11].

Fig.(3) demonstrate 3D atomic force microscopes AFM images of Titanium oxide NPs ablated in water with scanning area of 1μm×1μm. The average grain size reaches 81.04 nm in diameter and its height around 7nm. Andrms roughness values are (2.27 nm) for TiO_2 thin film. It can be noticed from AFM images that particles have different morphologies with nanoparticles sizes.

Fig.(4) shows the short circuit current density JscV as afunction ofilluminating powerbefore and after deposited Titanium oxide NPs ,at low levels of illuminating powers we noted that the J_{sc} have a linearity behavior with increasing power. But at high levels of illuminating power J_{sc} have aexponentially behavior that explained to the saturate in carriers, the maximum (J_{sc}) after deposited Titanium oxide NP swere 40.2 (mA cm^{-2}).

Fig.(5) shows the open circuit voltage V_{oc}V as a function of illuminating power before and after deposited Titanium oxide NPs ,we noted that the V_{oc} increase when illuminating power increase, the maximum (V_{oc}) after deposited Titanium oxide NPs were 630(mV).

The photovoltaic performance is shown in Fig.(6.a,b) in which the power can be extract from the cell before and after deposited Titanium oxide NPs form this curve we obtained the open circuit voltage (V_{oc}) is 630mV while shot circuit current density (Jsc) is 40.2 mA/$cm^2$and fill factor (FF=0.7). The high fill factor is probably due to high shunt resistance. The higher short circuit current density may be because the photons is due to carriers that are generated deep in the bulk of the silicon.

Fig.(7 a,b) demonstrates the variation of the output power (the power generated by the cell under simulated (AM1) versus voltage across the load resistance before and after deposited Titanium oxide NPs, After deposited Titanium dioxide nanoparticles (NPs) increase the efficiency of the Si solar cell 13.8 % instead of 10.3% conversion efficiency before the deposited.

Conclusion

Colloidal Titanium dioxide nanoparticles have been prepared successfully by pulsed laser ablation of Titanium target in water. Formation of Titanium dioxide nanoparticles was emphasizing by atomic force microscopy (AFM) confirmed that synthesized TiO_2 NPs have different grain size and morphology showed that the average grain size of TiO_2 NPs in water were 81.04 nm and rms roughness values are (2.27 nm). The photovoltaic characteristics after deposited Titanium dioxide nanoparticles (NPs) included short circuit current (Jsc),open circuit voltage (V_{oc}), where the maximum (J_{sc}) ,(V_{oc})and fill factor (FF) obtained at AM1were 40.2 (mA cm^{-2}), 630(mV) and (0.7)respectively and increase the efficiency of the Si solar cell 13.8 % instead of 10.3% conversion efficiency before the deposited.

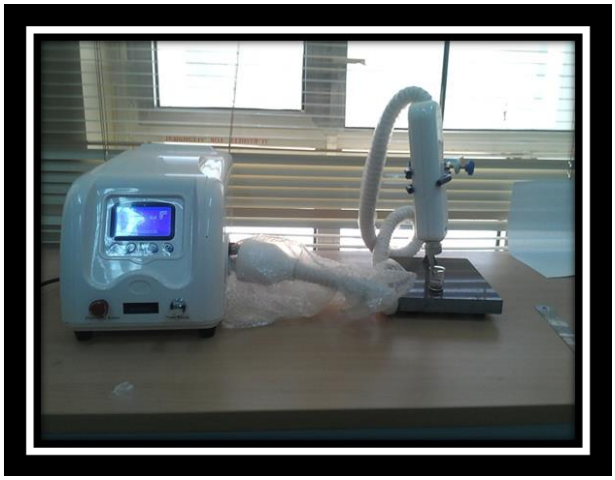

Fig.(l) Experimental setup.

Fig.(2) Freshlypreparedcolloidal Titanium dioxide NPs in water(white color).

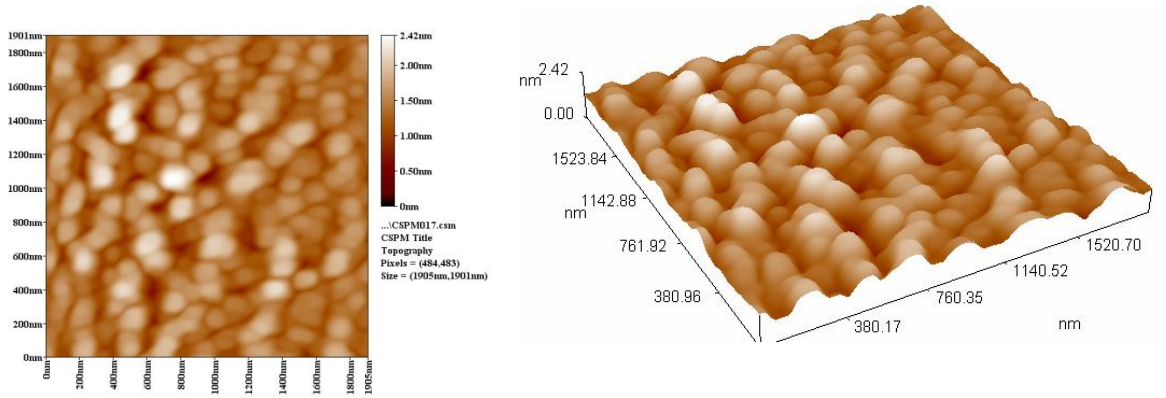

Fig.(3) AFM images of TiO_2 NPs ablated in water.

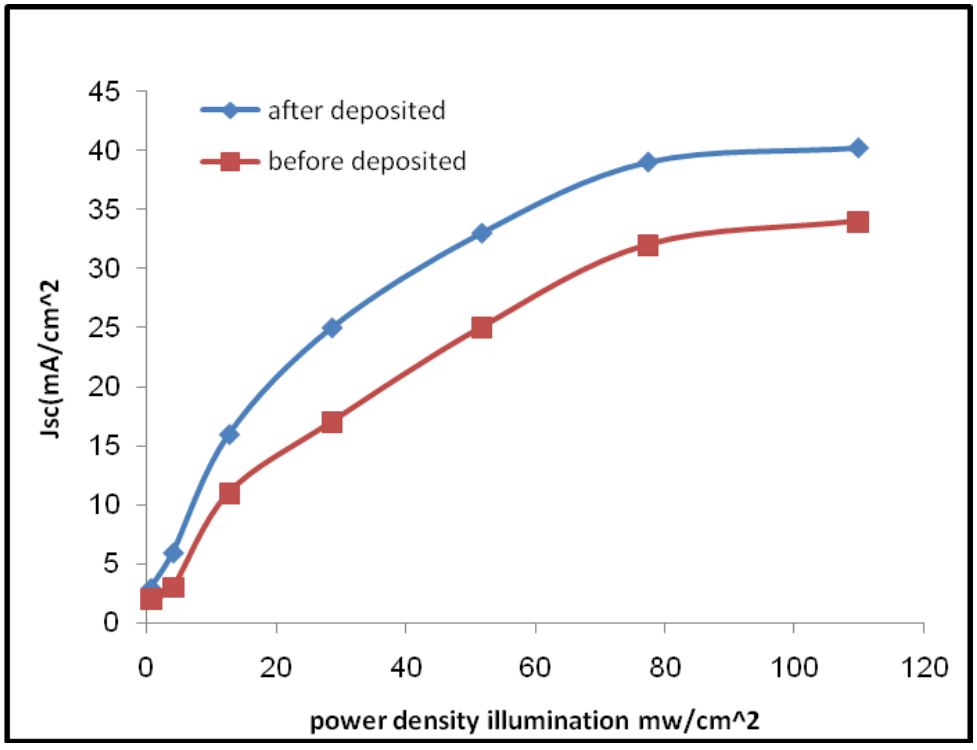

Fig.(4) Current density Jsc as a function of illumination plot after and before deposition.

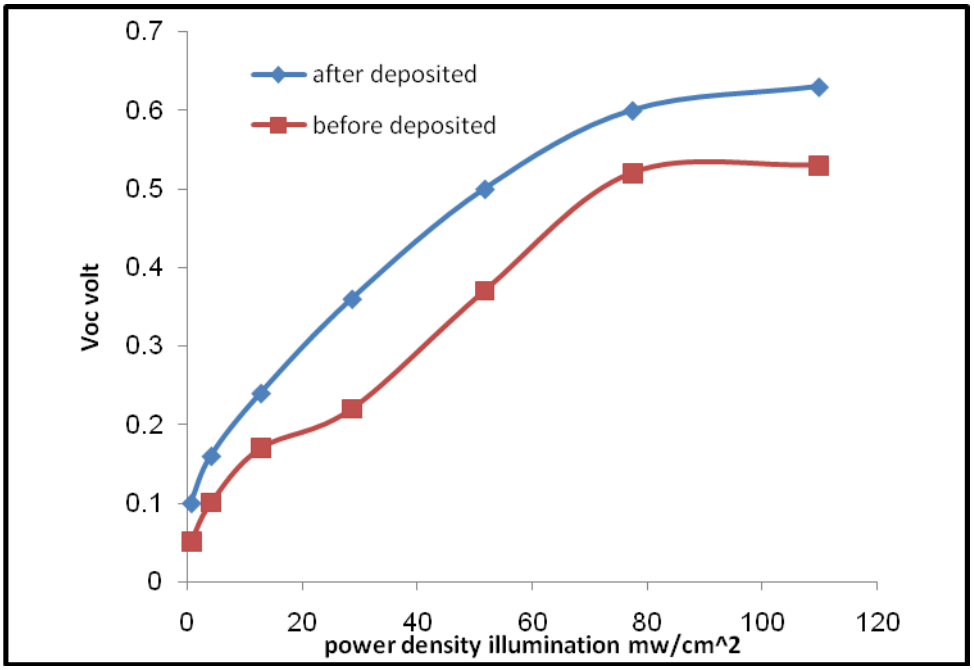

Fig. (5) Open circuit voltage V_{oc}as a function of illumination plot after and before deposition.

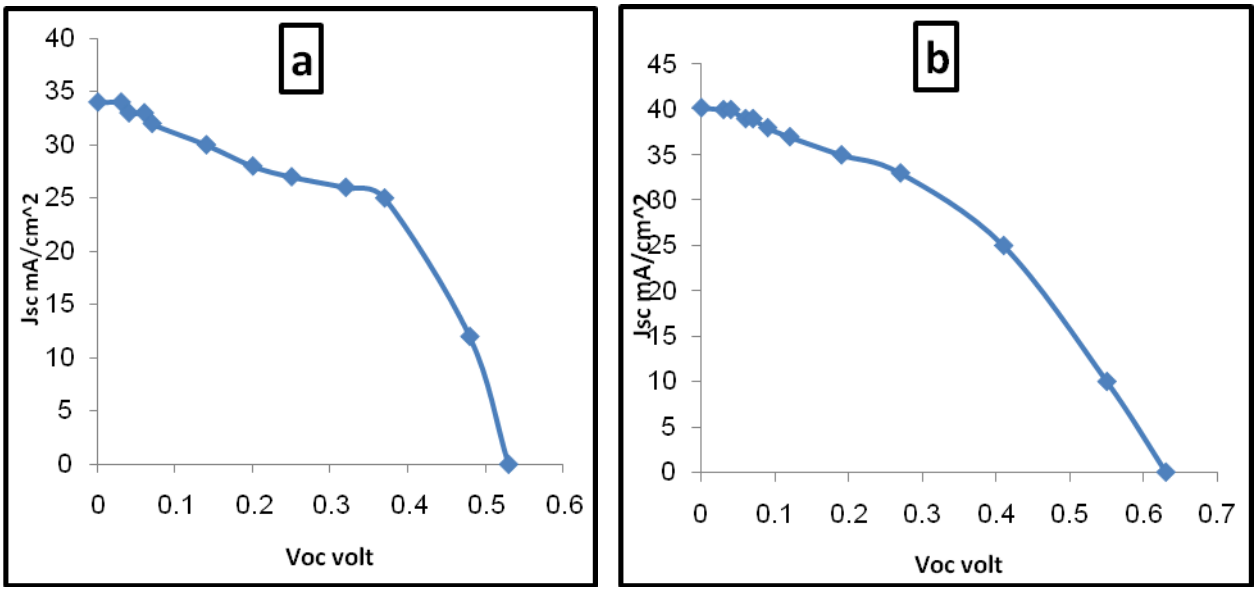

Fig.(6) The Photovoltaic Performance a) before deposited, b) after deposited Titaniumoxide NPs.

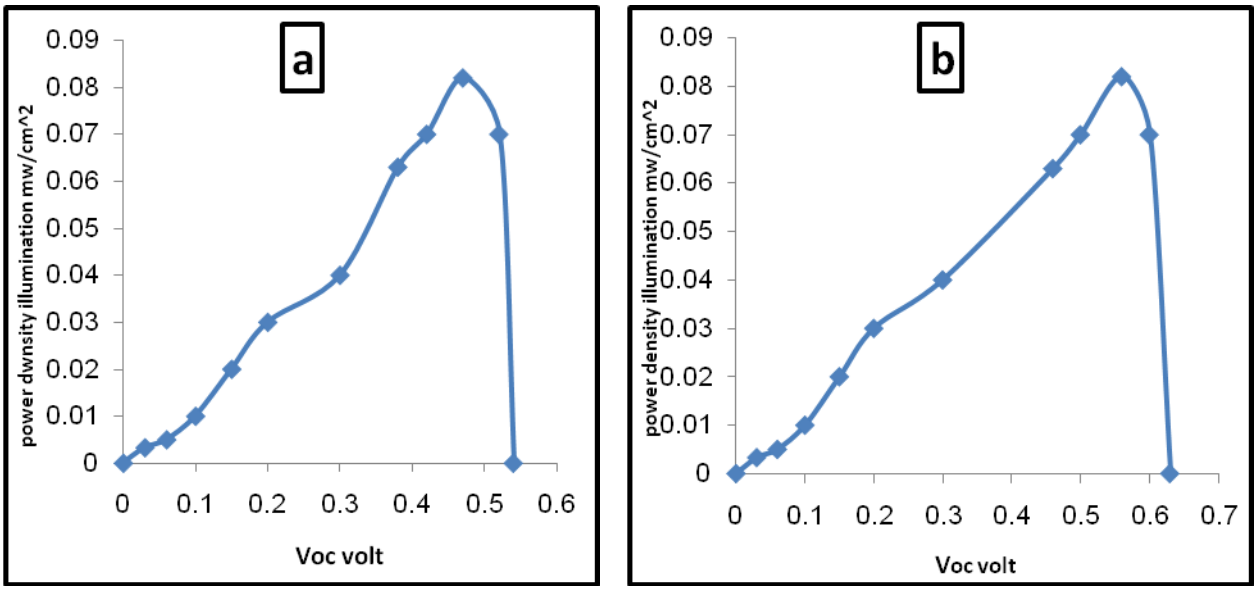

Fig.(7) The Output power a) before deposited, b) after deposited Titaniumoxide NPs.

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الخلاصة

يهدف هذا البحث الى تحضيرمحلول للجسيمات النانوية لاوكسيد التيتانيوم باستخدام طريقة الاستئصال بالليزر النبضي تم تحضير الجسيمات النانوية لاوكسيد التيتانيوم بزمن ٧ نانوثانية بواسطة الليزر نوع نيديميوم ياك لهدف من التيتانيوم عالي النقاوة (% 99.99) مغطس بالماء, ثم ترسيب غشاء اوكسيد التيتانيوم النانوي على سطح خلية شمسية سليكونية وذلك لزيادة كفاءتها. تم دراسة طبيعة السطح لجسيمات الاوكسيد النانوية باستخدام مجهر القوى الذرية حيث بينت تحاليل مجهر القوى الذرية(AFM) ان معدل الحجم الحبيبي لجسيمات الاوكسيد المستئصلة بالماء هي 150 نانو متر وبلغت قيمة خشونة السطح لغشاء اوكسيد التيتانيوم 2.27 نانو متر. درست الخواص الفولطائية للخلية قبل وبعد ترسيب جسيمات اوكسيدالتيتانيوم النانوية المتمثلة بتيار دائرة القصر ,(Jsc) وفولتية الدائرة المفتوحة ,(V_{oc}) بالاضافة لعامل الملئ (FF) لحالة AM1 حيث بلغت قيمتهم بعد الترسيب (40.2 ($mA\ cm^{-2}$),,630(mV) و 0.7 على التوالي. لقد ازدادت قيمة كفاءة الخلية الشمسية الى % 13.8 بدلا" من % 10.3 بعد ترسيب غشاء اوكسيد التيتانيوم النانوي.