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Metal oxide nanoparticles suspension for optoelectronic devices fabrication

Evan T. Salem*,[1], Makram A. Fakhry[2], Hala Hassen[1]

[1]*University of Technology, Applied Science Department, Laser Science Branch, Baghdad, Iraq.*
[2]*University of Technology, Laser and Optoelectronic Department, Baghdad, Iraq.*

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Abstract

In the present work, simple and single step method has been used to prepare metal oxide Nanoparticles suspension, this done by laser ablation of pure metal in liquid. While direct spraying of the prepared colloidal suspension on silicon substrate leading to the formation of heterojunction device. The x-ray diffraction results insure the formation of monocrystallines ZnO nanoparticles with a wirtize structure. The atomic force microscopic result also show a direct depended of the particle size on laser parameter such as laser fluency number of laser pulse and laser wavelength.

Key words: ZnO Nanoparticles, LP-PLA, AFM, Device fabrication.
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1. Introduction

Nanostructured ZnO materials have received broad attention due to their distinguished performance in electronic, optics and photonics, since with reduction in size, novel electrical, mechanical, chemical and optical properties are introduced, which are largely believed to be result of surface and quantum quanfinement effects [1]. In bulk semiconductors, such as ZnO the electron and hole orbit each other at a distance that depends on the semiconductor's dielectric constant. When semiconductor particles are synthesized with dimensions smaller than the natural exciton radius (called the Bohr radius) quantum-size effects occur.

ZnO nanoparticles do not only have the merits of ZnO semiconductor such as a large exciton binding energy of 60 mev and excellent stability, but also have some novel characteristics because of the particularity of nanostructure, it is well known that small particles have the large surface-to-volume ratio and surface defect [2], thus Zinc oxide nanoparticles are used in a variety of applications such as UV absorption, antibacterial treatment, catalyst, photo catalyst and others [3].

Among different preparation methods for producing Nanoparticles, laser ablation technique has been successfully developed and laser ablation in liquid has been recognizance as an important technique for the fabrication of Nanoparticles. This method are typical examples of top-down approach in fabrication of Nanoparticles [4] Pulsed laser

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*) For correspondence, E-mail: evan_tarq@yahoo.com

ablation in liquid media (PLAL) is a promising technique for the controlled fabrication of Nanomaterials via rapid reactive quenching of ablated species at the interface between the plasma and liquid. PLAL is a versatile technique. For preparing various kinds of Nanoparticles (NPs) such as noble metals, alloys, oxides and semiconductors [5]. Application of such nanoparticles colloidal in optoelectronic device was not yet extensively studied.

In this work effect of laser fluency number of laser pulse and laser wavelength on the structural and surface morphology was present, optimum condition for nanoparticles fabrication was depended for optoelectronic device fabrication.

2. Experimental Work

High purity (1×1 cm) (99.99) Zn plate from (Fluke) was used as a target, so it fixed at the bottom of an open plastic cell containing (3 ml DIW). And ablated using pulsed Nd-YAG laser system type (HUAFEI) at different laser fluence (48, 71 and 142) J/cm^2 focusing 20 cm converging lens as show in Fig. 1. The position of metal plate was continuously translated mechanically using a controlled motor so that each laser pulse falls on the fresh surface and ablates the target surface homogeneously also to avoid a deep ablation traces or crusts. The colloidal solution vibrated for 10 min by ultrasonic vibrator in order to get homogeneity for the product, and then dropped on the glass substrate, dried in an oven at 60 °C temperature in order to convert ZnO nanoparticles colloidal to nanoparticles thin films as shown in Fig. 2, this method was depended in other work [6]

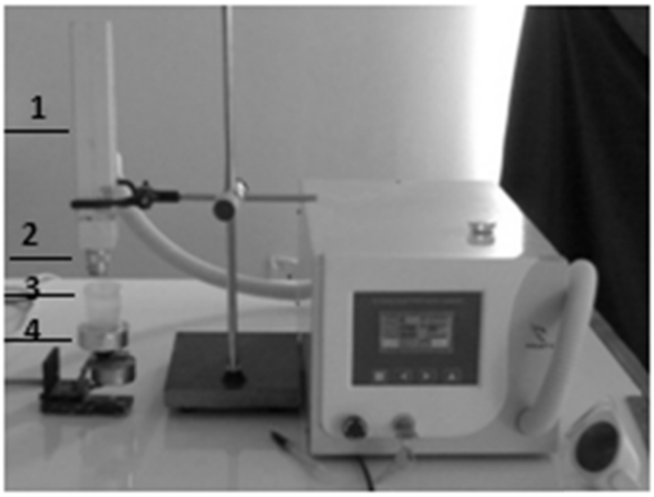


Fig. 1: Experimental setup for nanoparticles synthesis, by laser ablation technique, 1) Laser head, 2) Converging lens, 3) Container cell, 4) Rotating motors.

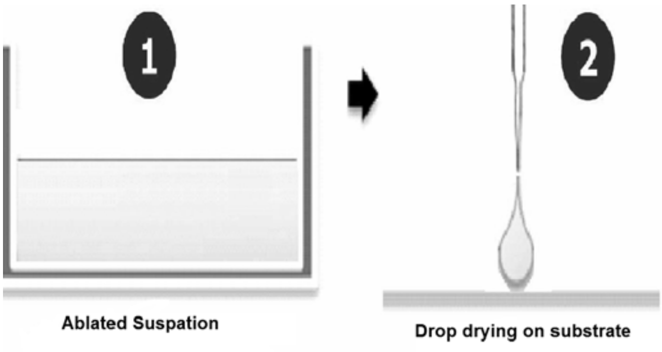
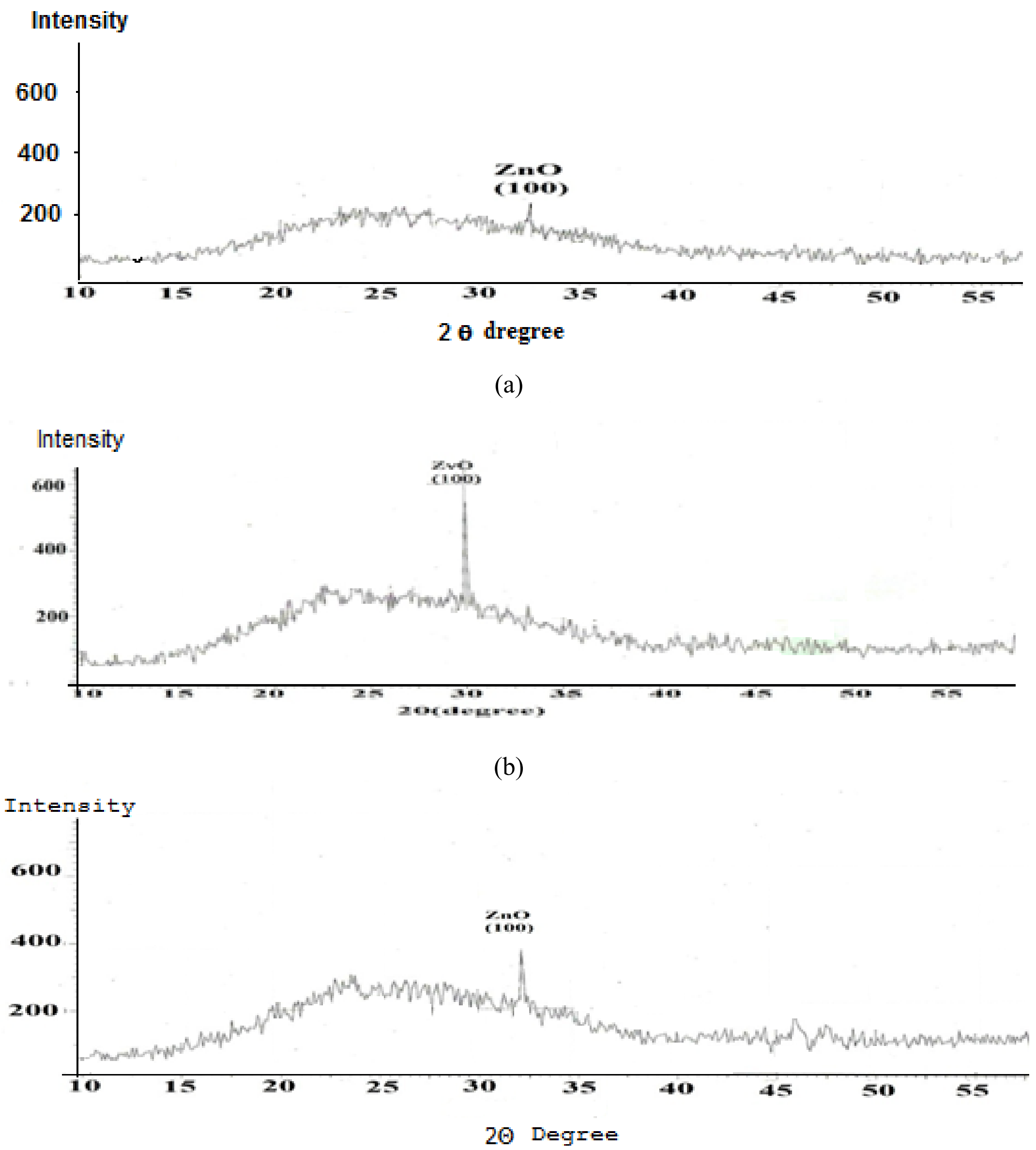


Fig. 2: The drop drying method.

In order to explain the structural properties, the nature and the crystal growth of the dried films at different preparation conditions, X-ray diffraction measurement has been done according to the ASTM (American Society of Testing Materials) cards, using Philips PW 1050 X-ray diffract meter of 1.54 Å from Cu-kα. The particle size distributions of the nanoparticles prepared under various conditions were analyzed using atomic force microscope (AFM). The surface morphological studies of the ZnO nanoparticles were conducted by tapping mode atomic force microscopy (AFM) from (AA3000). For device fabrication Simply by Direct spraying of the ZnO NPs colloidal using a glass nozzle connected with an air compressor on Si wafer surface heated to 150 °C to obtain an uniform distributed Nanoparticles thin film, and hence heterojunction ZnO/ p-Si was obtained. For heterojunction devise characterization A Kiethley-616 electrometer was used to measure the flow current in a solar cell manufactured from the produced structure in dark condition as voltage been applied from a Farnell power supply of range (0.2-3) V in forward biasing and reverse biasing.

3. Result and Discussion

The XRD patterns of the ZnO NPs formed by laser ablation of a Zn plate in DIW at room temperature at laser flunce (48, 71 and 142) J/cm^2 are shown in Fig. 3a, b and c. At laser fluence of (43 J/cm^2) a very week diffraction peak apear at (100) diffraction plane, with increase laser power density, due to increase the amount of the ablated material, we could recognize the peak lacated at 2θ = 32.37 with lattice constant of (2.76^o). By increasing the laser flunce up to (71 J/cm^2) Fig. (b) a specific sharp peak apear due to the diffraction from the same plane which located at 2θ=30.015^o with coresponding latice constant (2.97^o). With farther increas in the laser fluncy Fig. (c) the diffraction peaks still sharp and specific.



(a)

(b)

(c)

Fig. 3: X-ray diffiraction result for ZnO NPs prepared using 1.06 μm wavelength at different laser flency (a-43, b-71, c-142) J/cm^2.

The surface morphology of ZnO Nanoparticles colloidal prepared by LP-PLA at laser flunce was obtain using Atomic force microscopic images. Multi- drop of the colloidal suspension was drying on glass substrate at 60 C^o. Fig. 4a, b, and c show the particle size distribution and nanoparticles topography of drying colloids prepared at different laser fluency (43, 71 and 142 J/cm^2) the surface morphology and hens particles size distribution could be recognize. It's clearly obvious the increase in the particles size with increasing the laser fleuence, this attributed to the effect of laser power on the states of the plasma during the laser ablation process in liquid. This is related to the overall process of the oxide nanostructure formation by LP-PLA mechanism. Briefly comprise three different but almost coinstantaneous process [7] the first one is the instantaneous initiation, short-lived persistence and rapid annihilation of the local plasma with HTHP (high temperature and high pressure). The second is the nucleation and growth of the species during and after the annihilating period. The last one is the aqueous oxidation and quenching of the formed clusters. It can be seen that the state of plasma play a basic and decisive role in such instantaneous formation mode. As to the morphology controlling by laser fluency in present work, it can attributed to the effect of laser fluency on the state of plasma, especially the life time and intensity of plasma. In case of low laser fluence (Fig. 4a) the plasma plume is weak and has a relatively low temperature and pressure in addition to space distribution of laser power and environmental disturbance in homogenous density distribution in plasma plume become more obvious.

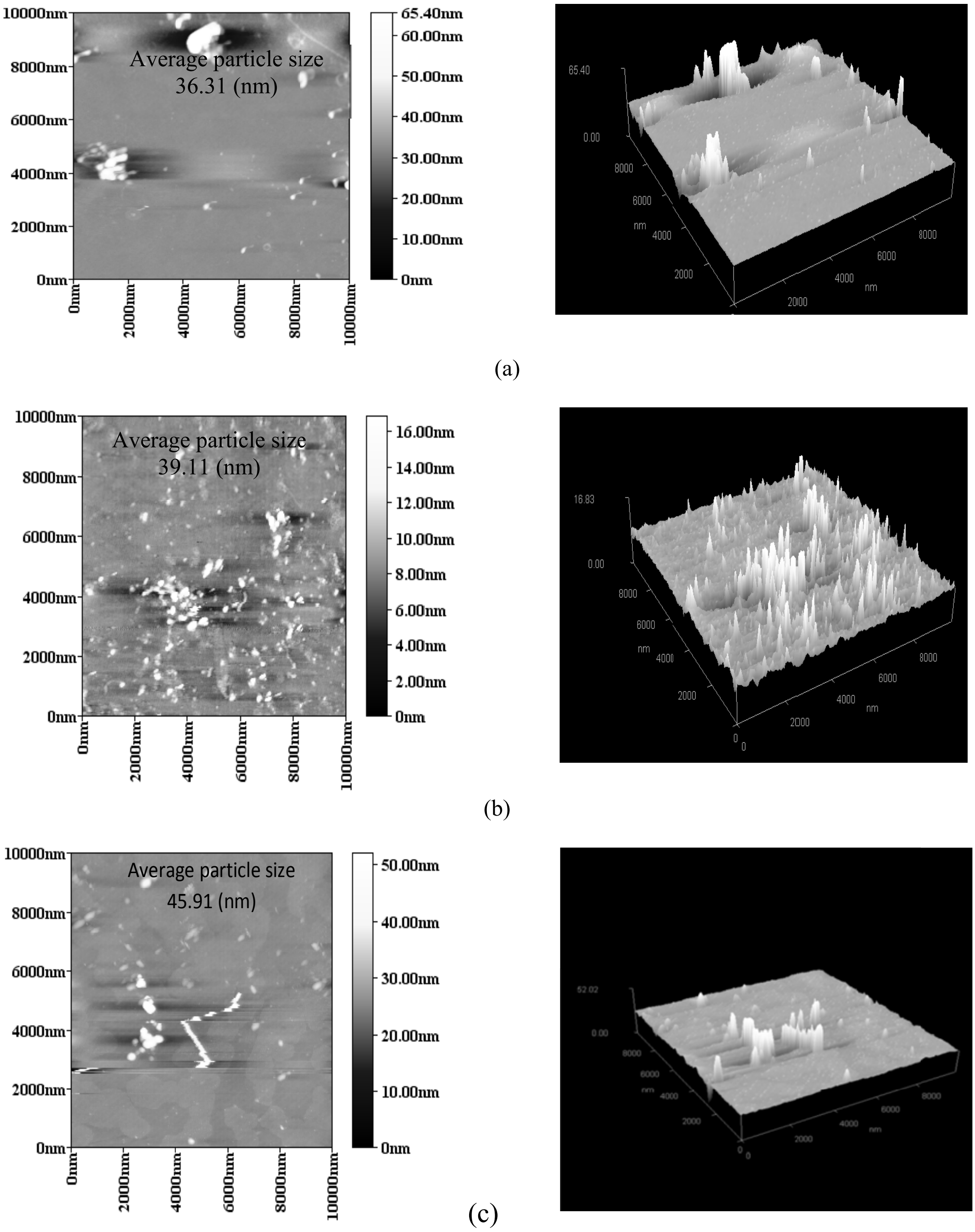


Fig. 4: Surface morphology of ZnO NPs prepared at 1.06 μm laser wavelength and different laser fluency (a-43, b-71, c-142) J/cm^2 and 20 pulse.

In such liquid environment within homogeneously distributed species the plasma is strongly affected by liquid media and laser fluence, so the pre formed ZnO cluster incline to self-assemble into different shape Nanoparticles from flack like structure, helical structure to spherical nanoparticles and this result is in consistence with other work [8,4]. Fig. 5 show the surface morphology of direct spraying ZnO nanoparticle colloidal on glass substrate at (60 C^o) resulted in highly uniform ZnO Nanoparticles thin film. In this case 1.06 μm laser wavelength with (71) J/cm^2 laser fluency was used to the preparation of ZnO colloidal suspension with an average grain size of about (34.06) nm which are very close to the value of the grain size of sample prepared at same laser fluency and its drop drying on glass substrate Fig. 4a. Surface roughness of spraying thin film is about (0.214 nm) which reflect a high quality thin film. Such result open a new gate toward introduced such colloidal in to optoelectronic application, e.g fabrication of thin films solar cell detectors, and others. to describe the heterojunctin performance.

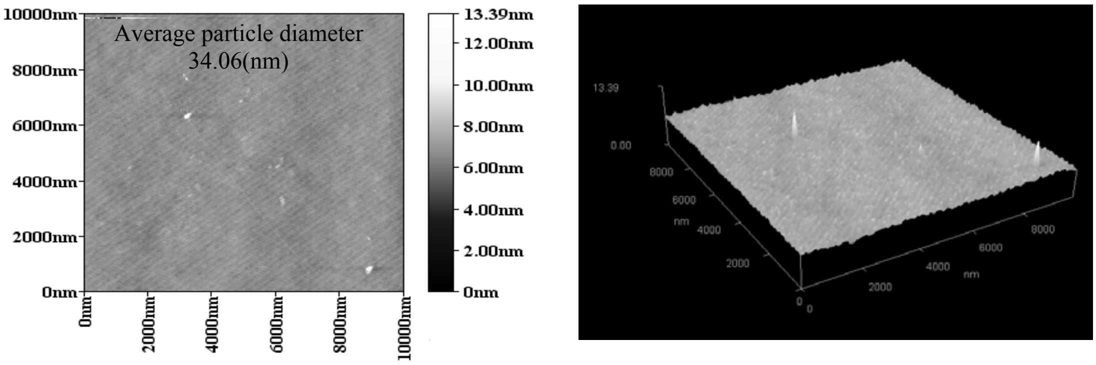


Fig. 5: Surface morphology of ZnO NPs thin film prepared by direct spraying using 1.06 μm laser, (28) J/cm^2, and (20) laser pulses.

Fig. 6 decribes the results of the current-voltage (I-V) measurements in the dark for the prepared heterojunctions. Where current-voltage characteristics of the ZnO/p-Si heterojunctions in theforward and reverse bias is shown. In forward biase, Two regions are recognized; the first one represents recombination current while the second represents the tunneling current. In the reverse bias, It is clear that the curve contains two regions; the first is the generation region where the reverse current is slightly increased with the applied voltage and this leads to generate electron-hole pairs at low bias

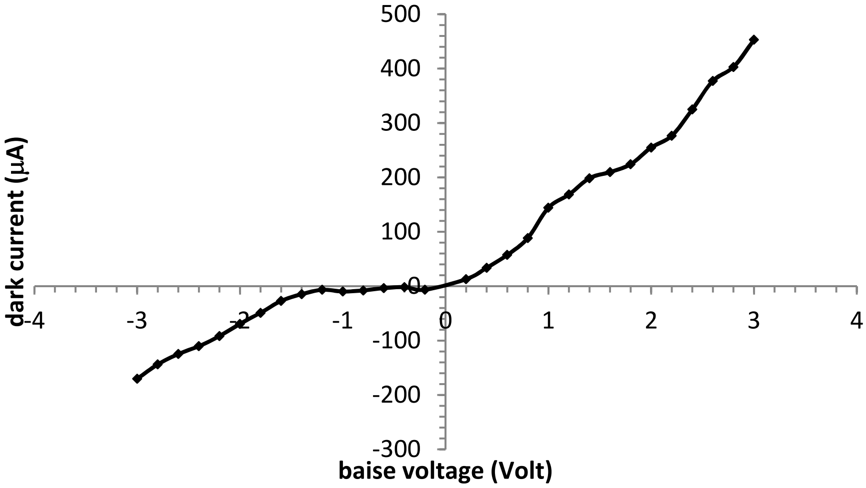


Fig. 6: I-V charecteristics for ZnO\P-Si heterojunction device.

In the second region, a significant increase can be recognized the reverse bias is increased. In this case, the current is resulted from the diffusion of minority carriers through the junction. We can also note from this figure the rapid increment in the reverse current at high reverse voltage, which is probably due to the leakage current arising from the surface layer. The photocurrent is a very important in photodetector and heterojunctin performance.

The current-voltage (I-V) measurements in the illumination for ZnO/p-Si heterojunction is shown in Fig. 7. This figure shows the behavior of the current as a function of the applied reverse bias voltage with different illumination powers, operating the detector under external revers bias causes the deplation region to be extended. So, a large photon number of incident beam transmited through the ZnO layar and absorbed mainly in the deplation region, creating electron-hole pair's generation that generated photocur. As the result, the internal electric fields in the depletion region cause separation of the electron and the holes, this electric field is much higher when the device in the reverse bias. So, when the incident power density increased the absorbed photo number becomes greater and large number of electron-hole pair is generated, also it shows that the current reashes a saturation value at higher bias voltage because the electric field is strong enough to separate any generated pair for certain incident power.

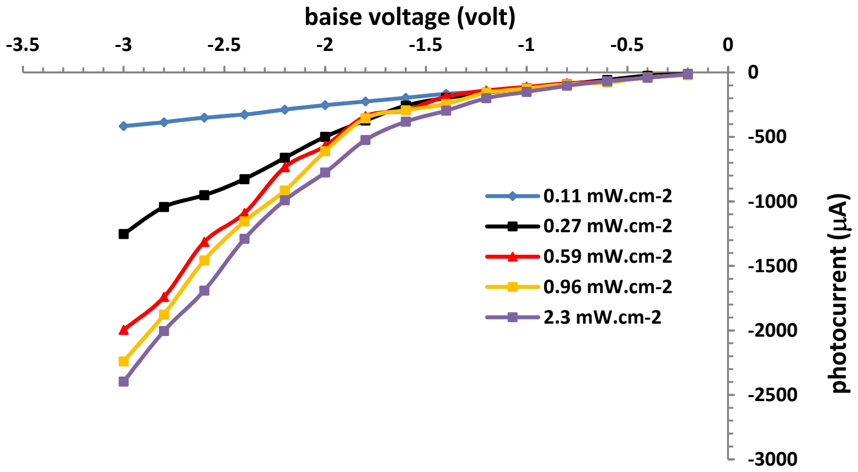


Fig. 7: Dark I-V charecteristics under reverse bias for ZnO\Si heterojunction device.

4. Conclusion

Photovoltaic optoelectronic device was sucssfuly fabricated usin ZnO Nanoparticles suspension. The result show a direct dependent of the prepared Nanoparticles on the laser parameters. XRD analysis show that the monocrytaline structure of condence ZnO nanoparticles increase with laser flunce. Morphology of dryed suspension shows that the particles size increases with increasing the laser fluency, Electrical preoerties of the prepared devise show good rectification and photorespose.

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