Some of the physical properties for ZnO thin films prepard by pulse laser deposition technique for UV-NIR detection application

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Abstract

ZnO/Si heterojunction has been constructed on (001) oriented silicon substrate using a (7 ns, 1 J) Q-swiched Nd:YAG laser λ = 1.06 µm for the ablation of ZnO target in the presence of oxygen gas as a back ground atmosphere, in order to prepare ZnO TCO's films. Electrical and structural properties of these film has been investicated reaching to the optimum oxygen pressure at which the device has been prepared. ZnO films, formed at 300mtorr oxygen ambient, showed an electrical resistivity of 0.0221 Ω.cm, without using post-deposition heat treatment. The electrical properties of the prepared device has been carried out and later the detectors parameter has been measured.

Key word : TCO thin film, heterojuncton device, PLD deposition, electrical properties

الخلاصة

تم تصنيع مفرق هجين نوع ZnO/Si باعتماد ماده السليكون كقاعده للترسيب باستخدام ليزر النديميوم ياك النبضي Nd:YAG بطول موجي1.06□m وبضابط عامل نوعيه Q –swiched بطاقة 1J بعرض نبضة 7nsعلى هدف من اوكسيد الزنك بوجود غاز الاوكسجين في الجو المحيط لغرض تحضير اغشية اوكسيد الزنك . وقد تم دراسة الخصائص الكهربائية والتركيبيه لهذا الغشاء الرقيق لكي نصل ضغط الاوكسجين المثالي لتصنيع النبيطة الكهروبصريه . وقد اظهرت النتائج ان غشاء اوكسيد الزنك المحضر بضغط 300mbar يمتلك مقاومية الكهربائية مقدارها cm □□ 0.0221 بدون استخدام المعالجة الحرارية بعد الترسيب . وقد تم دراسة الخصائص الكهربائية لهذه النبيطة وتحديد معلمات الكواشف .

Introduction

Transparent **C**onducting **O**xide (**TCO**) film is an electrically conductive material that is highly transparent in the range of visible wavelengths as well as electrically conductive [Schropp.1987, Ismail.2005, Wang.2003, Millon.2000]. The importance of this material can be traced back to the 20th century when the first films were recorded with their unique properties [Daived.2000, Ryu.1988]. This material has found extensive applications in optoelectronic devices such as solar cells, Liquid Crystal Display (LCD), heat mirrors and many others different applications depending on the type of material [Raid.2007, Raid.2007, Simon.2005, Ohta.2002, Dengyuan.2001]. The aim of many manufacturers, beyond the fabrication of TCO films, is to achieve stable properties for large area coating processes with low film resistance and high transmittance within the visible region of the electromagnetic spectrum. The simultaneous occurrence of high optical transparency in the visible region and high electrical conductivity is not possible in intrinsic stoichiometric materials, but partial transparency and possibly good conductivity may be obtained in thin films of a variety of metals. The only way to obtain good transparent conductors is to create electron degeneracy in a wide band gap ($\geq$3eV) oxide by controllably introducing non - stoichiometry and/or appropriate dopants [Haupt.2001, Joshua.2003]. The properties of ZnO thin films are currently of great commercial and scientific interest. ZnO primarily crystallizes in the wurtzite structure, which exhibits strong piezoelectric characteristics. For this reason *c*axis- oriented thin ZnO films are of interest for the production of surface and bulk acoustic- wave devices[Singh.2001, Salem.2006] beside that, The wide band gap of this material makes it an excellent visible light transparent and UV absorbing material. This, together with its low toxic effect, makes it an ideal material to use in sunscreen as a UV blocking element.

Depending on the deposition conditions (substrate temperature and oxygen pressure), the ZnO films can be divided into three groups, the first group belongs to a mixture of ZnO and metallic zinc; and these films are conductive and opaque, the second group of films has a composition close to stoichiometric bulk ZnO; they are non-conductive but transparent, while films of the third group is of high importance in optoelectronic applications since they are transparent and conductive films[Trefny.1981, Choi.2003, Dengyuan.2001]. The electrical conductivity of these films increases with increasing temperatures and reduced partial pressure of oxygen. This is explained by the dissociation of cadmium oxide and the formation of a solid solution of the metal in its oxide.

Experiment

Undoped ZnO thin films were deposited on cleaned quartz substrates at (100-300) mbar oxygen pressure. The target was ablated using Q- switched Nd:YAG laser with 7 ns (FWHM) and λ = 1.064 μm, which focused through 20 cm focal length of converging lens onto a high purity Zinc oxide target (99.999% provided from Fluka com.) at 45_ angle of incidence. The target rotated with frequency of 10 Hz. The pulse energy density of laser at the target surface was maintained at 89.17 J/cm^2. The films were produced using 40 laser shots and deposited at 423K substrate temperature The film thickness was measured optically and found to be about 200nm. The sheet resistance and conductivity type of these films were determined using four point probe (FPP 5000). After that (001) crystilline Si substrate has been uesd for device preparation. Elecrtical, photovoltaic properties was carried out.

Results and Discussion

The value of the resistivity (ρ) increases as a function of oxygen pressure is shown in figure (1) were minimum resistivity found at 350mbar these values of O_2 pressure were found to be the optimum.

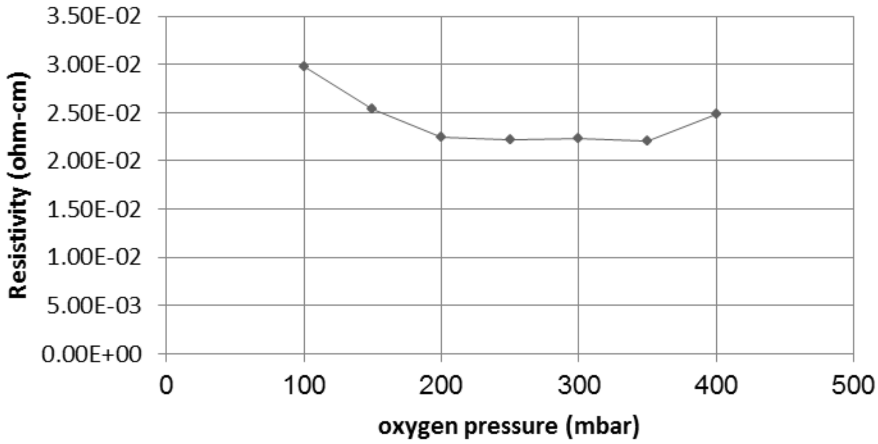


Figure (1) Resistivity *vs.* O_2 pressure for Zn samples

The optical properties of the prepared film was measured as shown in figure (2) Where the transmission of deposited films on quartz substrates was measured and recorded at the ultraviolet and visible regions for the films growth at optimum oxygen pressure and substrate temperatures.

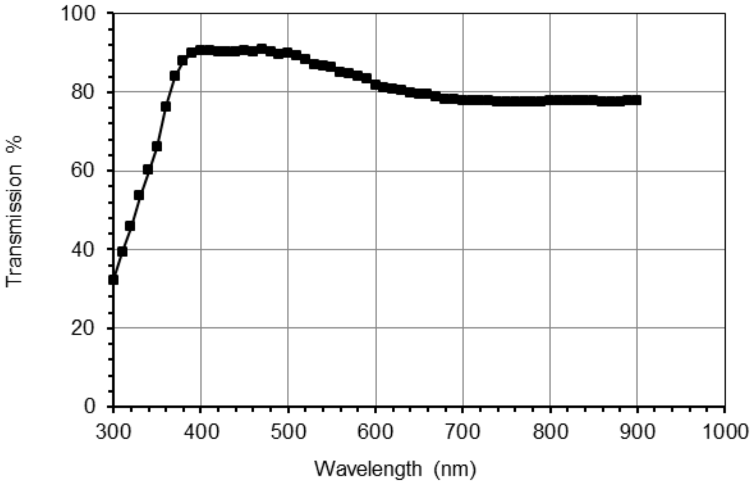


Figure (2) Optical transmission as a function of wavelength

It is found that the prepared films have a good transparency in the visible and in the NIR spectral range. The obtained transmission reached to about (~ 90 %) at short wavelength region and the peak transmission was in excess of 94%. It is known that the sharp decrease in transparency of Zinc oxide films in UV and slightly decrease IR regions is caused by fundamental light absorption and by free – carrier absorption respectively, this agrees with the result in similar work [Salem,2006].

The XRD pattern at the oxidation pressure of 300mbar are shown in figure (3), from this figure, we can recognize that the peaks appear at 2θ =31.7, 36.2, and 37.8 in the spectra of the ZnO films corresponding to the reflection from (100), (101), and (102) planes. The formation of the ZnO films was confirmed by the reflections from the given planes and the diffraction angle given above.

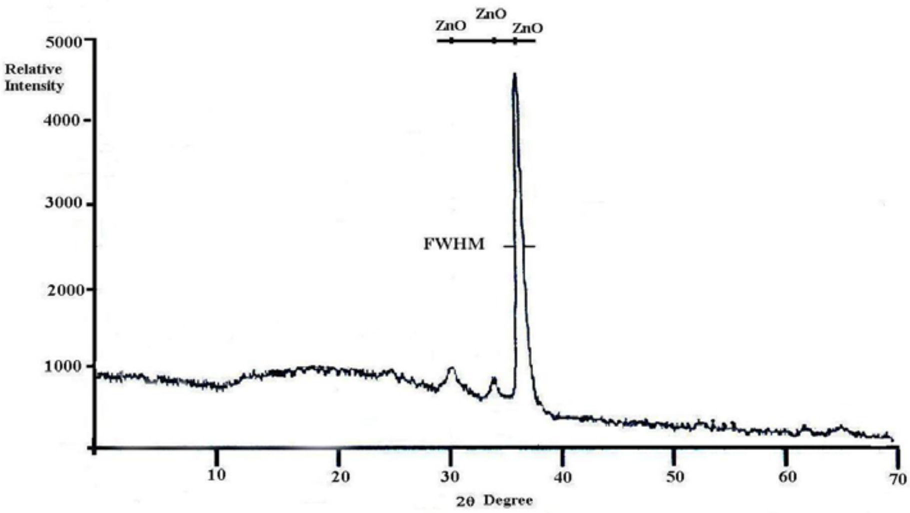


Figure (3) The XRD pattern of the prepared samples at O_2 pressure of 300 mbar and substrate temperature 423K.

The conductivity type of the prepared semiconducting films are introduced by measuring Seeback coefficient and figure (4)

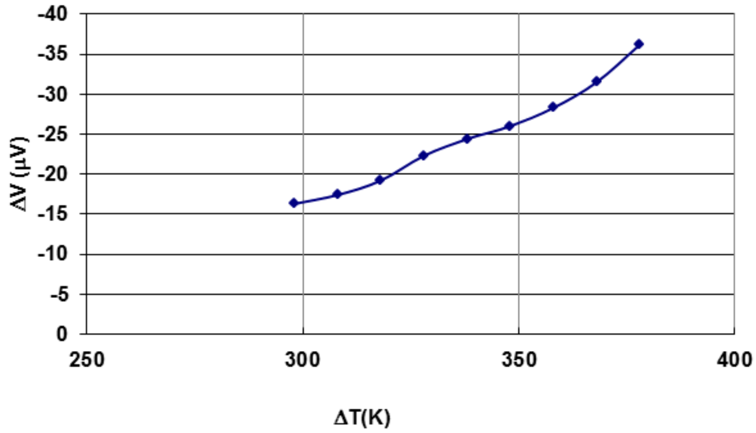


Figure (4) Voltage difference(thermoelectric power)as a function of heating temperature

gives the relation between voltage difference and the heating temperature for samples prepared at optimum O_2 pressure and substrate temperature. The results indicate that the studied materials are thought to be n-type semiconductor, this possibly due to the donor formation by O_2 vacancies and interstitial metal atoms, These results are agree with published literatures[Salem.2006, Trefny.1981]. Using p-type silicon substrate ZnO/Si heterojunction device was prepared, the results of the current-voltage (I-V) measurements in the dark for the prepared heterojunctions is shown in figures (5) .

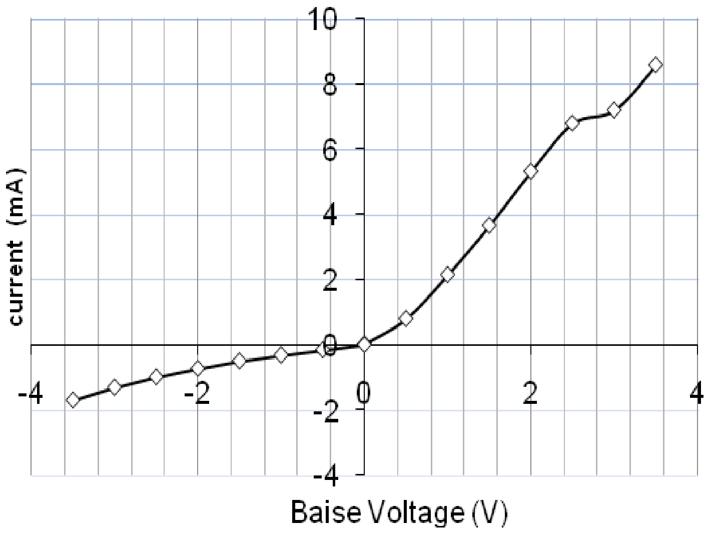
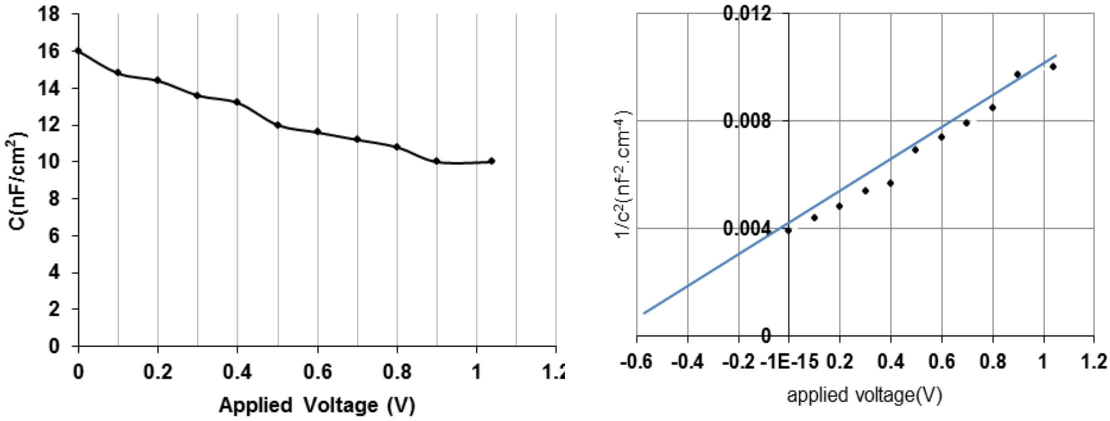


Figure (5) I-V characteristic in forward and reverse bias

These charecterstics are very important to describe the heterojunctin performance and all hetrojunction parameters depening on these charecteristics. In this curves, for the I-V characteristics under 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 generation of electron-hole pairs at low bias. In the second region, a significant increase can be recognized the reverse bias is increased. In this case, the current resulted from the diffusion of minority carriers through the junction. We can also note from this figure the rapid incremental in the reverse current at high reverse voltage, which is probably due to the leakage current arising from the surface layer. While the results in the forwored bias, a two regions are recognized; the first one represents recombination current while the second represents tunneling current. The ideality factor of (ZnO/Si) junction at optimum conditions of O_2 pressure and substrate temperature was estimated at the to be 1.3. These values refer to good rectification properties for the prepared junctions. C-V measurmnts is one of the most important measurements since it determines different parameters such as built-in potential, junction capacitance and junction type.



a b

Figure (6) C-V characteristics

Figures (6) give the C-V and $1/C^2$-V measurements for junctions at optimum substrate temperatures and O_2 pressures. Results show that the junction capacitance is inversely proportional to the bias voltage for all prepared samples. The reduction in the junction capacitance with increasing bias voltage resulted from the expansion of depletion layer with the built-in potential. The depletion layer capacitance refers to the increment in charge per unit area to the incremental change of the applied voltage. This property gives an indication of the behavior of the charge transition from the donor to the acceptor region, which was found to be “abrupt”, which is confirmed by the relation between $1/C^2$ and reverse bias being a straight line.

The spectral responsivity represents the ratio between the output generated current to the incident power and it is very important because it specifies the performance range of detector.

Figure (7) described the obtain rise time pulse from device, which find to be (868 μs),this reflected on the value of the response time achieved which found to be (394) μs.

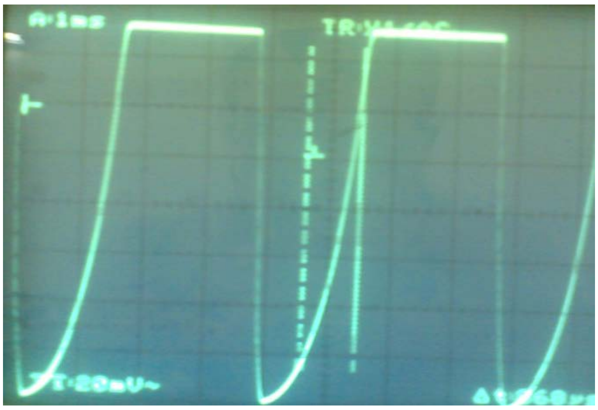


Figure (7) Device rise time

Conclusion

The prepared film by pulsed laser deposition technique exhibits n-type conductivity. The Electrical and photovoltaic characteristic of ZnO/Si heterojunction are strongly dependent on the preparation substrate temperature, while the C-V measurement reveled that both prepared device are abrupt. Detector rise time ensure the construction of high quality detectors.

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