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SnO_2-N-Si Isotype Heterojunction Solar Cell with Efficiency of 7.1%

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Abstract

This paper presents the results of a study of the photovoltaic effect of SnO_2/n-Si solar cell formed by chemically sprayed SnO_2 on signal crystal silicon the main of using SnO_2 chemically sprayed thin films include low cost and the risibility of production in large scale, the photovoltaic characteristics included short circuit current (J_{sc}), open circuit voltage (V_{oc}), where the maximum (J_{sc}) and (V_{oc})obtained at AM1 were 14.3 (mA cm^{-2}) and 630($_m$V), respectively. The fill factor (FF) was (0.68). Photo-induced open carrier lifetime of these cells is about (29 µs).

Introduction

Heterojunction such as SnO_2, In_2O_3 indium tin oxide (In_2O_3.Sn) and cadmium tin oxide (Cd_2SnO_4) and $Cd_{1-x}Zn_xS$ deposited onto bulk semiconductors such as silicon, GaAs, germanium, CdTe etc. have attracted considerable attention over the past few years because of their possible photovoltaic applications[1-4]. These heterojunctions show considerable proms for use inexpensive simple high performance solar cell[1-5] and these devices have a number of advantage include [2,6].

(i) a lower junction-formation temperature,
(ii) higher spectral response of short wave lengths, and
(iii) many conducting oxides have the right indicates of refraction to act as antireflection coating.

The SnO_2 films are deposited by different methods most these films are deposited by either evaporation in vacuum or chemical spray [7,8]. E. Sader [7] was found that sprayed SnO_2 films adhere much than the thermally evaporated SnO_2 films, we report the preliminary results of the fabrication of SnO_2/n-Si heterojunction solar cells of high efficiency made chemical spray pyrolysis technique.

Experimental

Single-crystal silicon wafers of n-type with (111) orientation are used as substrates. They have a resistivity in the range of (0.2-0.45) Ω.cm and one face of the wafer is polished prior to deposition of SnO_2 these wafers were chemically etched in dilute hydrofluoric acid (Hf) to remove native oxides, then back contact metallization 300nm of (Al). Then we deposited the SnO_2 films by spraying an atomized $SnEl_4$ mixture onto a heated substrate maintained between 350-370°C. A typical spray mixture which gane a good results consists of a 0.8M solution of ($SnCl_4$) in athyalactiate. This solution is sprayed onto heated silicon substrate for about 60-80sec with produces a (Blue) SnO_2 films approximately 150nm thick.

After the deposition of SnO_2 the frontal metal-grid electrode is formed by sequentially evaporating 150 nm of (Al). The sensitive area was about 0.3 cm^3.

The photovoltaic measurement were done under illumination condition was achieved under simulated Am1 (92.5mW/cm^2) by halogen lamp type (Philips /120W), which connected to variance and calibrated by a silicon power meter.

We are used, (photo-induced open circuit voltage decay) technique [9] for measuring life time of junctions which is shown in Fig.(1). A stroboscope type (DAWE) is used to give a flash light. Open circuit voltage decay trace was monitored with a (HAMEG) type storage oscilloscope.

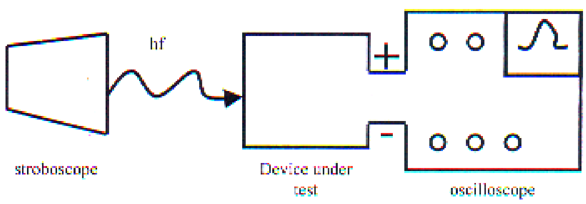

Fig. (1) Photo-induced open-circuit voltage decay measuring circuit.

Results and Discussion

The photovoltaic performance is shown in Fig.(2) in which the power can be extract from the cell form this curve we obtained the open circuit voltage (V_{oc}) is 630mV while shot circuit current density (J_{sc}) is 14.3mA/cm^2 and fill factor (FF=0.68). The high fill factor is probably due to high shunt resistance.

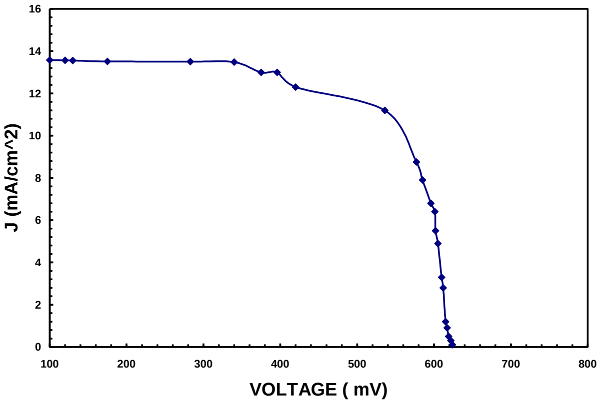

Fig. (2) J-V curve of solar cell under illumination at AM1.

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.(3) show the short circuit current density J_{sc}Vs. illuminating power 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 a exponentially behavior that explained to the saturate in carriers.

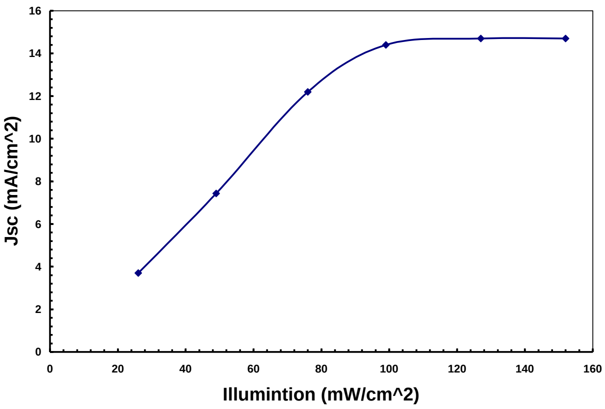

Fig. (4) demonstrates the variation of the output power (the power generated by the cell under simulated (AM1)) versus voltage across the load resistance, this figure reveals that sprayed SnO_2/n-Si heterojunction is a suitable device to produce a high efficient solar cell with conversion efficient of 7.1%.

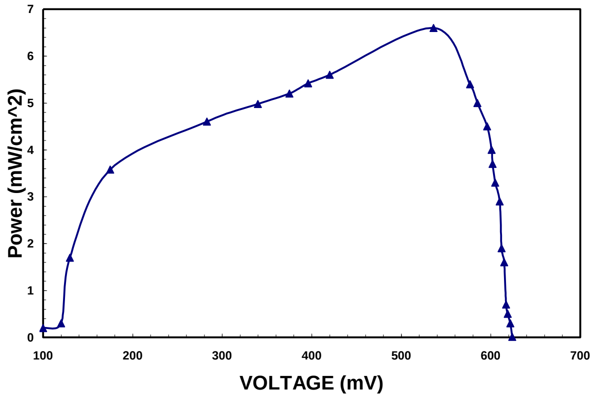

Fig. (4) Power vs. voltage of SnO2/n-Si solar cell.

Fig.(5a) shows open circuit voltage decay (life time of minority carrier) since these cells is horizontal junction devices.

Region II behavior is generally observed in silicon devices because, although, the strobe lamp intensity is often not sufficient to reach the high injection condition, its usually enough to excite the devices

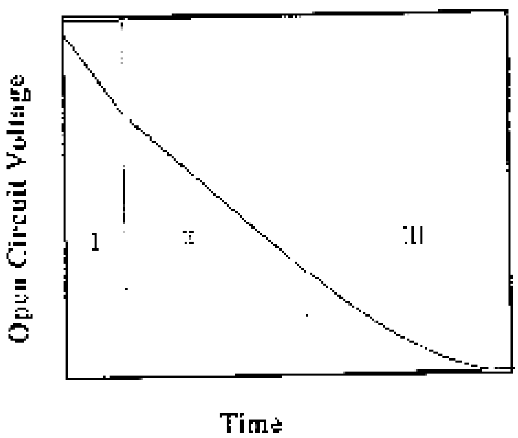

Fig. (5a) Theoretical open-circuit voltage decay curve.

to an injection level substantially higher than that at which discharge of the junction capacitance limits the V_{oc} decay rate, under these conditions the minority carrier, life time τ can be computed from the following expression [10]:

$$\tau = KT/q/dVoc/dt \quad \text{...(1)}$$

Where t is the decay time, k is Boltzmann's constant, T is the absolute temperature, q is the electron charge.

Fig.(5b) show a photograph of V_{oc} decay carve.

The lifetime was calculated from Eqn. (1) and it was around (29μs).

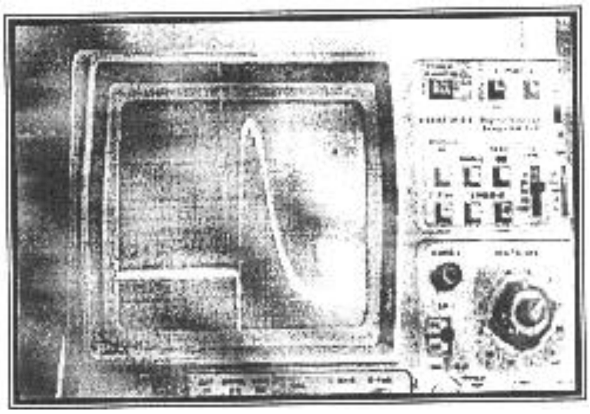

Fig. (5b) Photo-induced open circuit voltage decay photograph.

For single-crystal silicon SnO_2/n-Si cells, we have found that τ decreases as the resistivity increases as shown in Fig.(6). The decreases in τ as a function of resistivity can by explained as decreases of V_{oc} with increases resistivity this decreases of Voc because change in the reverse saturation current (Jo), as shown in our pervious paper [2].

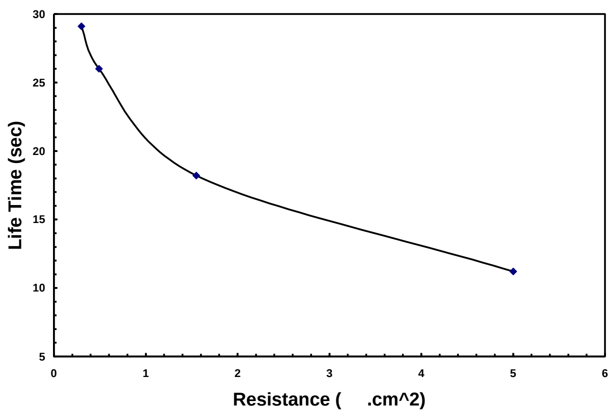

Fig. (6) Life time vr. Resistance of silicon.

Conclusions

SnO_2/n-Si isotope heterojunction solar cell formed on chemically sprayed SnO_2 films, results of these cell showed that this technique is an appropriate to fabricate highly efficient solar cells with a conversion efficiency about (7.1%) and fill factors about (0.68). This is because of the window effect taken place between these combinations, which reduces the role of the surface recombination effects.

The variation of J_{sc} with illumination intensity showed the exponantly behavior in Aml, lumintion that explained to the saturate in carriers, life time of minority carriers (τ) are decreases with increases of silicon resistivity.

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الخلاصة

فــي هــذا البحــث تمــت دراســة الخــواص الفولطائيــة (Photovoltaic) للخلية الشمسية SnO_2/n-Si والمحظرة بطريقة الرش الكيميائي الحراري لانتاج غشاء رقيق من مادة ثاني اوكسيد القصدير على قواعد سيليكونية احادية التبلور وتكمن اهمية هذه الخلية بأن طريقة الرش الكيميائي الحراري لها مزايا عديدة منها رخص التكلفة مقارنة مع الطرق الاخرى بالاضــافة الــى اطكانيــة تحضــير خلايــا شســمية بمساحات اكبر مما توفره الطرق الآخرى.

درست الخواص الفولطائية المتمثلة بتيار الدائرة القصيرة (J_{sc}) وفولتية الدائرة المفتوحة (V_{oc}) بالاضافة لعامل الملئ (FF) ووجد ان اعظم قيمة لكل من (J_{sc}) و (V_{oc}) لحالة AM1 هي ($14.3\ (mA\ cm^{-2})$) و $630\ (mV)$ على التوالي وان قيمة عامل الملئ هي (0.68) وقد قيست عمر الحاملات (lifetime) بطريقة اضمحلال فولتية الدائرة المفتوحة وهي طريقة بسيطة ودقيقة وكان عمر الحاملات هو ($29\ \mu s$).