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Contents

Growth and Characterization of Indium doped Zinc Oxide Solar Cell

Yee Yee Oo[1], Aye Aye Swe[2] and Than Than Win[3]

Abstract

Indium doped Zinc oxide thin film was prepared on SiO_2/Si substrate structure by spin-coating technique. The micro-structural properties were studied by Scanning Electron Microscopy (SEM). An Indium Tin Oxide (ITO) conductive layer was deposited on In:ZnO film in order to minimize the cell degradation. Current and voltage characteristics of ITO coated In: ZnO solar cells were observed when the incident light was prevented from exciting the solar cell. Current-Voltage characteristic of illuminated cell was also measured by means of monochromatic Na lamp. Some performance parameters for the cell could be determined from I_{sc}-V_{oc} curve and compared to those of illuminated cell without buffer layer.

Key words: Spain-coating, SEM, In: ZnO cell, I_{sc}-V_{oc}.

Introduction

A solar cell, or photovoltaic cell, is a semiconductor device consisting of a large- area P-N junction diode, which in the presence of sunlight is capable of generating usable electrical energy (Salinger, 2006) .

The semi conducting metal oxide ZnO is a wide band gap (3.37 eV) compound semiconductor that is suitable for sensor applications. The one-dimensional ZnO nano structures have been synthesized successfully by several groups. Such nano tubes, nano wires and nano ribbons have attracted extraordinary attention for their potential applications like nano-electronics and molecular electronics ZnO is mainly used in sensors, catalysis, solar cells and other electronic applications (Siddheswaran, 2006).

ZnO thin films can be prepared by a wide variety of techniques, including sputtering, reactive evaporation, chemical vapour deposition, pray pyrolysis, and the sol-gel process. In particular, the sol-gel method has advantages over the other processes, because of its simplicity and low equipment cost (Kumar, 2006).

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Indium doped zinc oxide (ZnO:In) has emerged as one of the most promising window materials due to its large band gap (3.2 eV), high transparency and low resistivity managed by doping and heat treatment(Afify, 2005).

Substrate Preparation

The starting substrate used in this work was p-type Si wafer oriented in (100) plane. They were cut into relatively small segments (0.5 cm x 0.5 cm) to be used as base semiconductors. The cleaning sequences were

(i) The silicon wafers were washed ultrasonically in distilled water.

(ii) They were washed in boiling acetone, then in boiled propanol for 5 min to remove greasy films.

(iii) They were immersed in nitric acid HNO_3 for 3 min in order to remove ionic contamination.

(iv) The wafers were immersed in $HCl:HNO_3$ (3:1) for 3 min to remove metallic films.

(v) They were etched in buffered hydrofluoric acid (34.6 % NH_4F:6.8 % HF:58.6 % H_2O) for 2 min to remove oxide films.

(vi) The silicon wafers were cleaned in distilled water and over-dried at 100 °C.

(vii) It was purged and dried in N_2-atm of Glove-box.

Precursor Sol Preparation

0.2 M of Zinc acetate dehydrate was dissolved in a mixed sol of 80 % DIW and 20 % methyl alcohol. 2 % of $InCl_3$ dopant material was added into above mixture sol and 3 drops of acitic acid was also added to avoid precipitation. It was stirred by magnetic stirrer with 500 rpm for 1 h and homogeneous sol was formed. Next it was refluxed with water-bath at 80 °C for 1 h and secondary refluxing was performed with Oil-bath at 110 °C for 1 h. Thus In-doped ZnO sol-gel was obtained. The dynamic viscosity was calculated to be 48 cP.

SiO_2 buffer layer (insulating layer) Formation

SiO_2 buffer layer was formed on highly-polished Si-wafer by heating at 450 °C for 15 min.

Growth Mechanism

The precursor sol was deposited onto naked p-Si (100) and SiO_2/p-Si (100) substrates by spin-coating technique. The resulting layers were sintered at 400 °C for 1 h in O_2 – ambient and cooled at room temperature. The block diagram of preparative steps for both films were shown in Fig 1. Fig 2. (a and b) showed front and counter metallization formed on In:ZnO thin films and back of Si substrates. Fig 3. (a and b) gave the two solar cell multilayer configurations. In-conductive layers were deposited onto two ITO-coated layers by evaporation method. Ag-greases were also formed on ITO (0.4 cm x 0.4 cm) of back side of the Si-wafer. When the front and back potions of the cells were soldered with Cu-wire, top and bottom electrodes were appeared.

SEM Investigation

Scanning Electron Microscopy (SEM) studies was carried out to examine the surface morphology and microstructural properties of fabricated films. The observed SEM images were shown in Fig 4. (a and b).From the figure, it was clear that two SEM pictures consisted of well-defined and crack-free grains. Moreover, they were flat and circular features. It was well-known that In:ZnO film provided a good deposition on substrate.

I-V Characteristics in Dark Condition

Fig 5. showed the current and voltage characteristics of (ITO/ In: ZnO) - Si and (ITO/ In: ZnO)- SiO_2 - Si cells in dark condition. In the forward bias region, the current was exponentially increased with an increase in bias voltage and gave the diode characteristics. This figure revealed the rectification effect too. From ln I - V linear relation, zero- bias barrier height ($\O_{bo}$) and ideality factor (η) were calculated and described in Table.1.

Table 1. Diode parametres for fabricated cells

Fabricated cells	$Ø_{bo}$ (eV)	η
(ITO/In: ZnO)-Si	0.58	2.39
(ITO/In:ZnO)SiO_2-Si	0.57	2.33

Solar cell Evaluation

I-V characteristics were also measured under illumination and shown in Fig 6. The fourth quadrant of the circle indicated the solar behaviour. V_{oc}-I_{sc} relation was formal by rotating curvent axis with 180°. Fig 7. (a and b) indicated the V_{oc}- I_{sc} relations of both (ITO / In:ZnO)- Si and (ITO / In:ZnO)-SiO_2- Si cells.

From the detail analysis of the V_{oc}- I_{sc} curves, some performance parameters of fabricated cells were identified and listed in Table.2.

Conclusion

Growth of In-doped ZnO film and its cell performance parameters have been successfully implemented. To overcome the cell degradation problem, a layer of ITO was deposited on In:ZnO surfaces. It was confirmed that ITO layer almost prevent diffusion of oxygen to Si water which caused the increase of SiO_2 buffer layer. Thus conversion efficiencies of both fabricated cells were not much difference.

Table 2. Solar cell parameters for both fabricated cells

Solar cell parameters	(ITO/ In:ZnO)-Si	(ITO/In: ZnO)SiO_2-Si
max power generation (P_m) (μW)	4.85	5.50
Short circuit current (I_{sc})(μA)	15.40	17.80
open circuit voltage (V_{oc})(V)	1.02	0.79
conversion efficiency (η_{con}) (%)	4.41	5.00
fill-factor (F_f)	0.39	0.39
quantum yield (Y)	7.82×10^2	9.05×10^2

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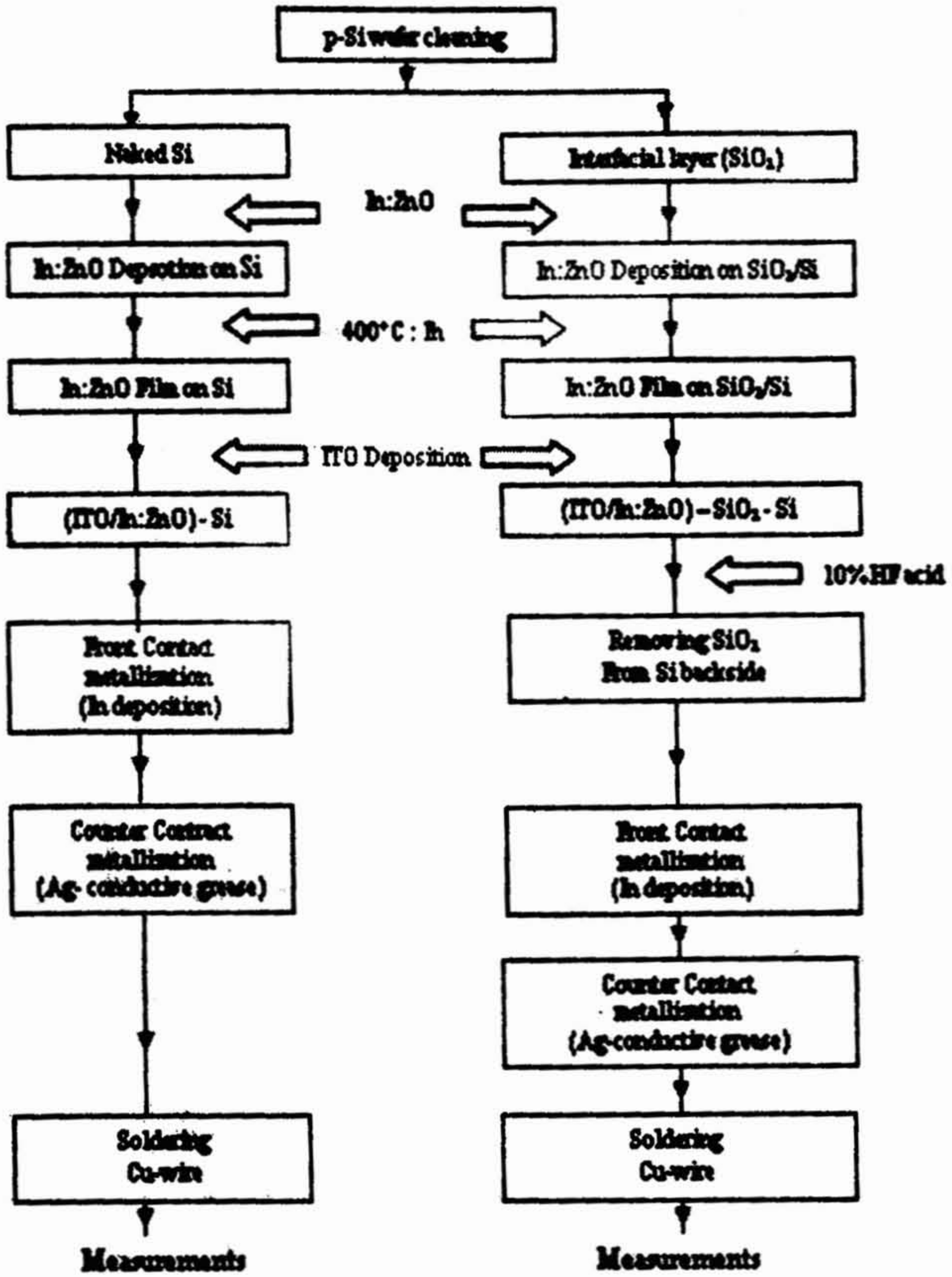

Figure 1. General Processing for both solar cell structurers [(ITI/In:ZnO)-Si and [(ITI/In:ZnO)-SiO_2-Si]

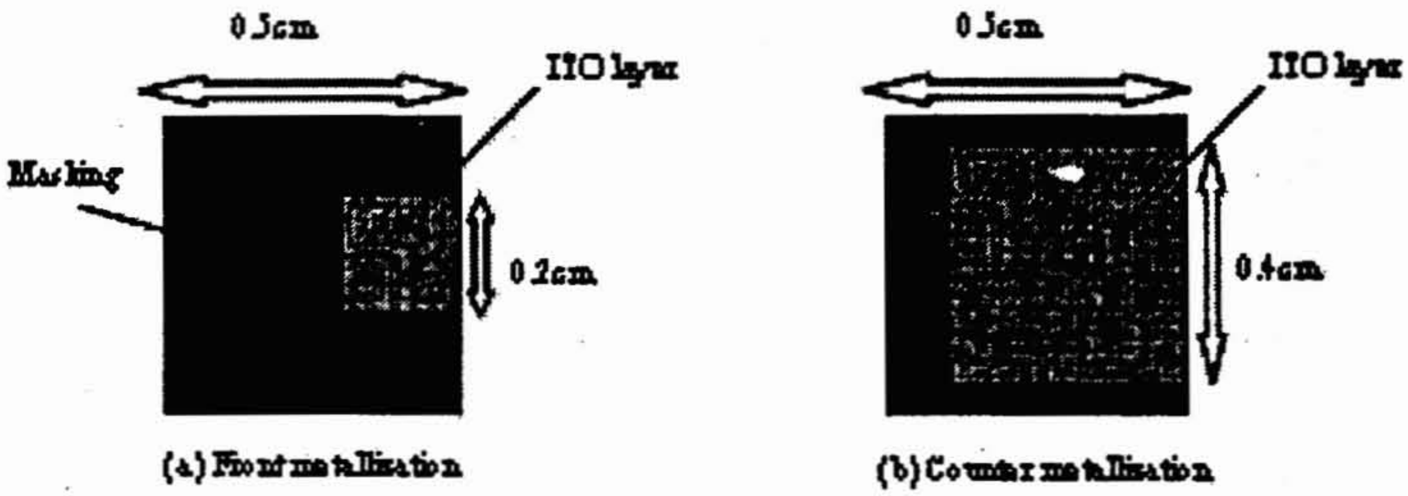

Figure 2. (a and b) Front and counter metallization formed on In:ZnO thin films and back of Si substrates

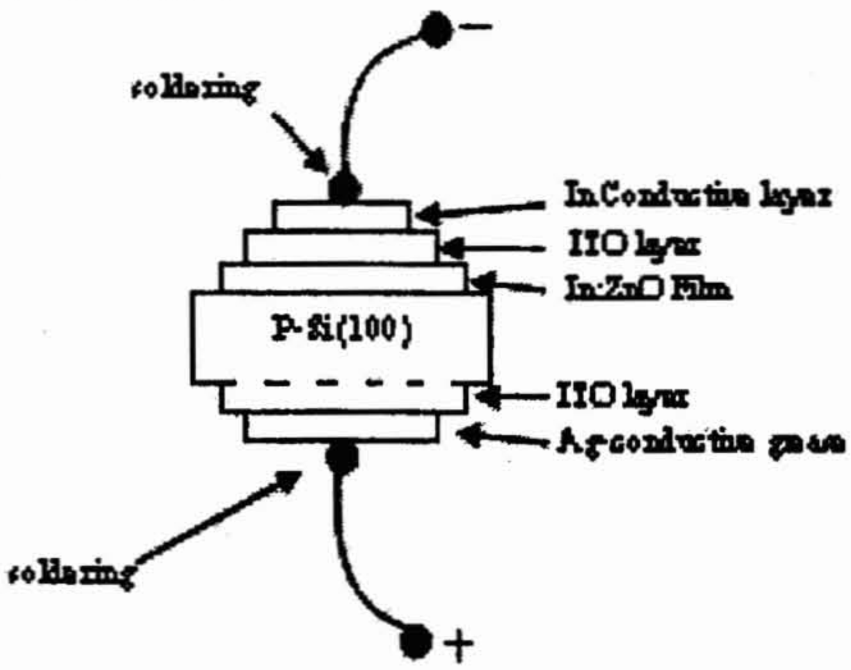

Figure 3. (a) Illustration of (ITO/In:ZnO)-Si

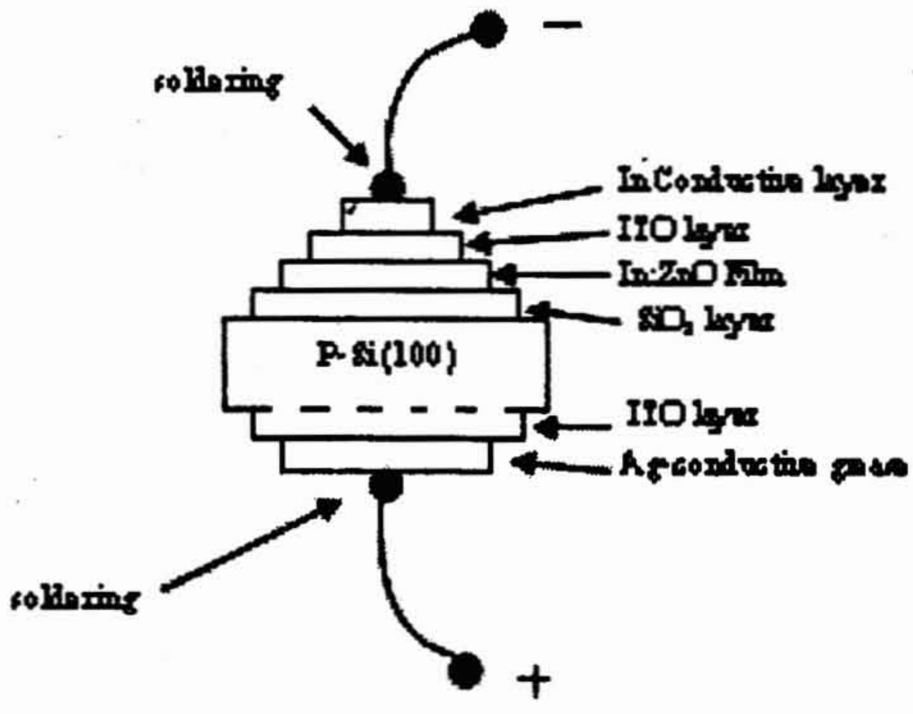

Figure 3 (b) Illustration of (ITO/In:ZnO)-SiO_1-Si

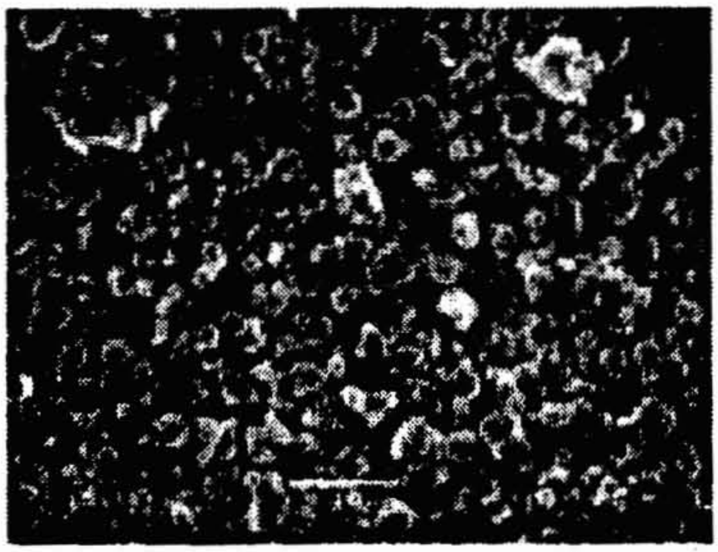

Figure 4.(a) SEM Image of (In:ZnO)-Si Film

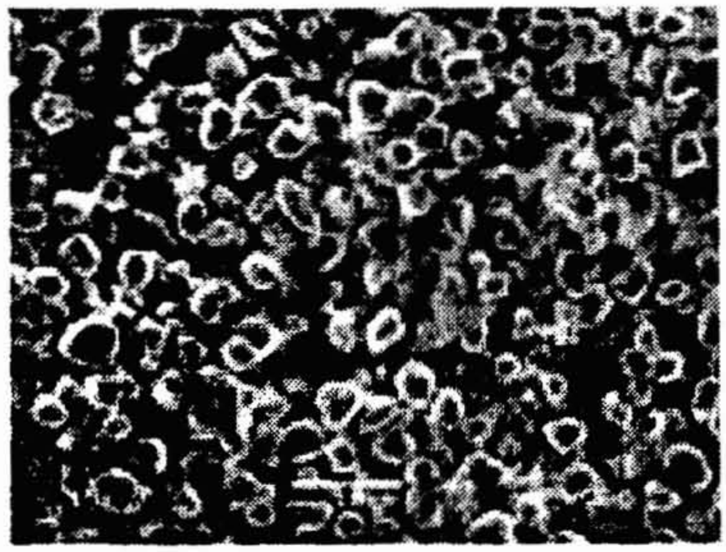

Figure 4.(b) SEM Image of (InZnO)-SiO_2-Si Film

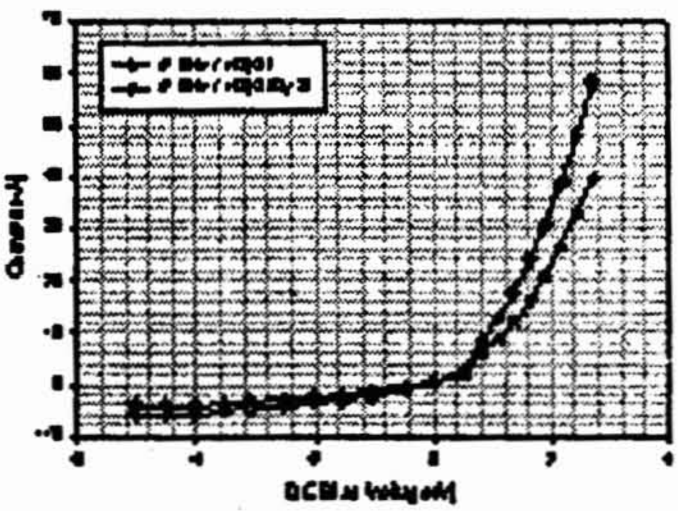

Figure 5. I-V Characteristics in dark condition for both ITO coated cells

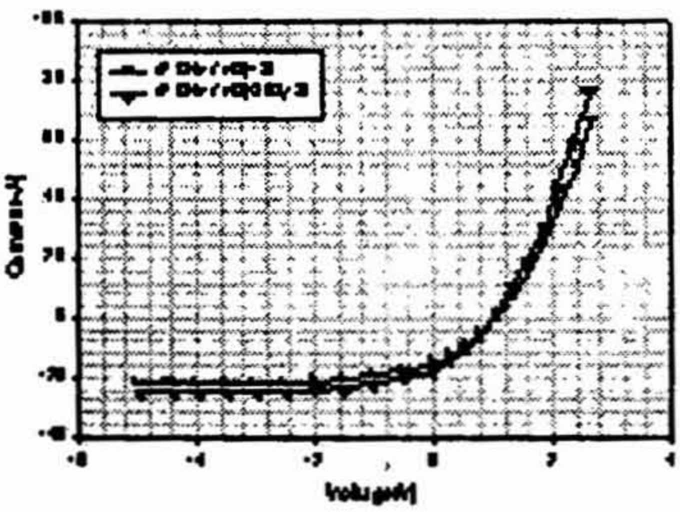

Figure 6. I-V Characteristics under illumination for both ITO coated cells

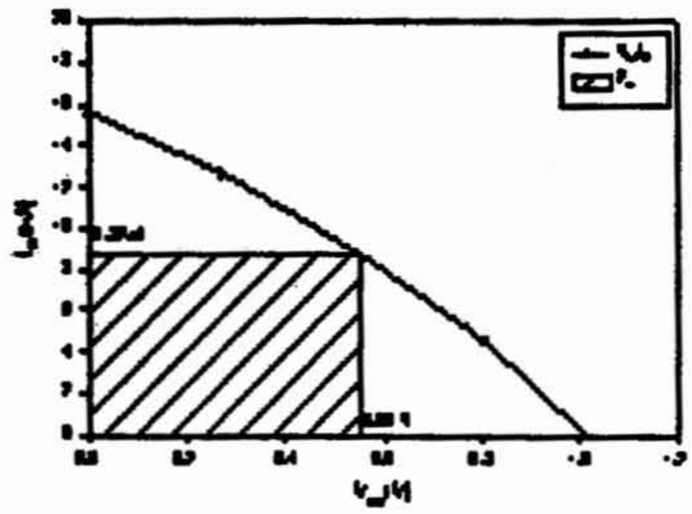

Figure 7.(a) V_{oc}-I_{sc} Characteristics of (ITO/InZnO)-Si cell

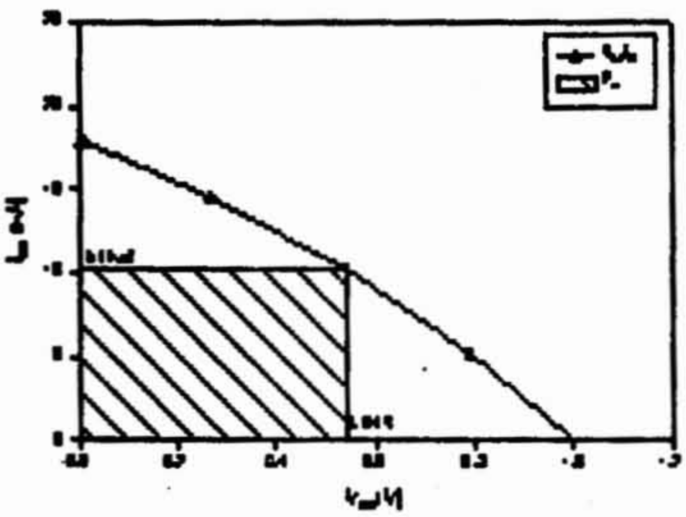

Figure 7.(b) V_{oc}-I_{sc} Characteristics of (ITO/In:ZnO)-SiO_2-Si cell

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