Electrical Properties Of Schottky Diodes Based On Poly(O-Toluidine) Deposited By Spincoating

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Abstract- The poly(o-toluidine) (POT) were synthesized by chemically oxidization. Their thin films were fabricated by spincoating on indium-tin-oxide (ITO) coated glass substrate. A Schottky diode with configuration ITO/POT/Al devices is fabricated. The Current-Voltage characteristics of the devices were non-linear indicating rectification behavior. The observed current-voltage characteristics can be satisfactorily fitted using the modified Shockley equation. The diode parameters were calculated from I-V characteristics and discussed. On the other hand, the Capacitance-Frequency and Capacitance-Voltage characteristics are presented and discussed.

Keywords: Schottky diode, electrical properties, spin-coating, substituted polyaniline.

I. Introduction

Organic-based devices (Field Effect Transistors, Schottky diodes, light emitting diodes, gas sensors, flat-panel displays …etc) [1] have been extensively studied in the last decades. This interest stems from a combination of ease of fabrication and doping of the polymer, low cost, novel and tunable properties as well the valuable electrical parameters of the polymer that can be determined from these devices.

The properties of these devices are strongly influenced by the preparation conditions of the polymer films, their stability and the interface between the polymer and metal.

Polyaniline (PANI) has received greater attention as an organic p-type semi-conducting polymer due to its good environmental stability and moderate conductivity [2-3]. Among the PANI derivatives, poly (o-toluidine) is reported to be better soluble in common organic solvents such as chloroform than other derivatives. Thin films of this polymer can therefore be prepared by spin coating or dip coating. However, only a few studies were performed on diodes based on thin films prepared by this technique.

This prompted us to further to develop Metal/POT contacts where the POT is prepared by chemical oxidization. Compared to electro-polymerization, this technique offers the possibility to have an important polymerization degree of polymer. In order to show the advantage of the spincoating technique and the chemical oxidization, the electrical properties of ITO/POT/Al Schottky diodes are presented, discussed and compared with those of our diodes based on POT prepared by electro-polymerization [4-6] and others polymers.

II. Experimental

Poly(o-toluidine) was synthesized from of o-toluidine ($(CH_3)C_6H_4NH_2$) monomer by the procedure described in detail by Y. Cao et al [7] . The obtained polymer is filtered and washed using distilled water and HCl solution (1M) respectively. The resulting emeraldine base form of POT is subsequently dried under vacuum. The POT thin films were deposited by spincoating. Indeed, the emeraldine base form of the polymer was dissolved in chloroform at concentration of 1 % (wt). After stirring, the solution is filtered with a 0.45µm micropore filter. A few drops of the solution were then deposited on ITO-coated glass substrates which are subsequently spun at a spinning speed of 1800 rpm for 20s.

Schottky-barrier type devices were fabricated using the POT films which provided the back contact. The front (top) contact consisted of 2mm diameter circular aluminum dots. This contact was deposited by vacuum

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thermal evaporation of 99.99% purity Aluminum shots for two minutes and a base pressure of $1.5x10^{-5}$ mbar. The electrical measurements {Capacitance-Voltage (C-V), Capacitance-Frequency (C-F), Current-Voltage (I-V) characteristics} were performed on the ITO/POT/Al devices at room temperature. The measurements were carried out using a Keithley 3330LCZ impedance meter, a Keithly 410 programmable pico-amperemeter and a 610C programmable micro-voltmeter. All the instruments are controlled by a computer via a GPIB card.

III. Results and discussion.

III-1. (I-V) characteristics.

Figure 1 shows a typical I-V characteristic of an ITO/POT/Al device. The asymmetric nature of the I-V curve clearly indicates a Schottky barrier type behavior and suggests that Al forms rectifying contacts with POT. This is confirmed by the difference between the work function of PANI family (φ = 4.1 to 4.28eV) and Aluminum (φ_{Al}=3.7 to 4eV) [8]. The rectification ratio of these devices is about 10 at ± 0.9 V. This value is higher than that obtained for poly(o-methoxyaniline) (1.62) and POT electro- polymerized on ITO [4, 9] .

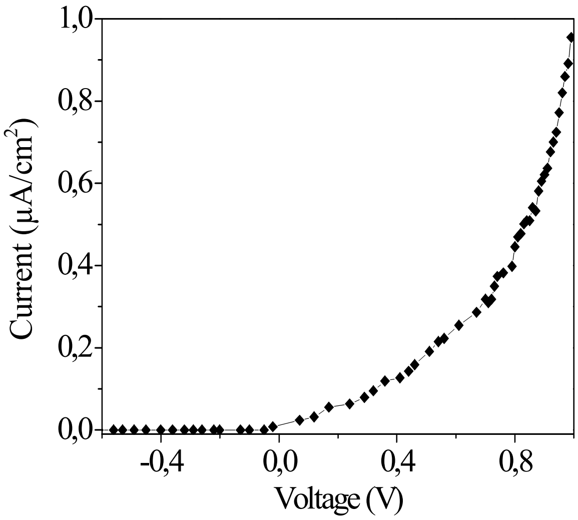

Fig. 1: I-V characteristics of ITO/POT/Al diode

Saxena et al. has proposed that the non-linear I-V characteristics of the polymer/metal junction could be due to the Space –Charge Limited current (SCLC), Poole-Frenkel emission or thermionic emission [1]. The non-linear LnJ vs. LnV and Ln(J/V) vs. $V^{1/2}$ curves eliminate the possibility of SCLC process and Poole- Frenkel emission. These results suggest that the thermoionic emission theory can be applied to calculate junction parameters.

For the thermionic emission [2], the I-V relationship is expressed by:

$$I = I_0 \exp\left(\frac{qV}{\eta kT}\right) \qquad (1)$$

I_0 is the saturation current, q is the elementary charge (e), V is the applied voltage, k is the Boltzmann constant, (η) is the diode ideality factor and T is the absolute temperature.
The saturation current density is given by:

$$I_0 = SA^*T^2 \exp\left(-\frac{q\Phi_B}{kT}\right) \qquad (2)$$

Where S is the surface area of the diode, A* is the Richardson constant (120 A cm^{-2} K^{-2} for free carriers) and Φ_B is the barrier height.

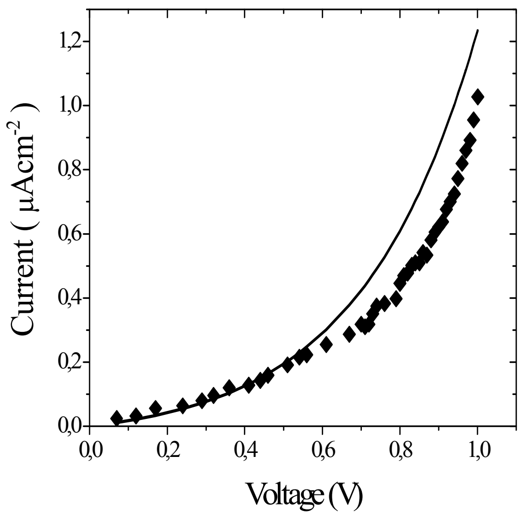

Fig. 2: Fit (line) of Experimental (o) I-V plot of the ITO/POT/Al junction using eq.1.

However, as revealed by fitting the thermoionic emission law (eq.1) to experimental data, this model (Fig.2) doesn't account for the measured I-V characteristics over the explored voltage range.

A better model taking into count the series resistance (R_s) of the structure was used. This model describes by the following modified Shockley equation:

$$I = I_0\left[\exp\left(\frac{q(V-R_sI)}{\eta kT}\right)-1\right] \qquad (3)$$

As shown in figure 3, this model accounts well for the experimental data over the explored voltage range in the forward bias region.

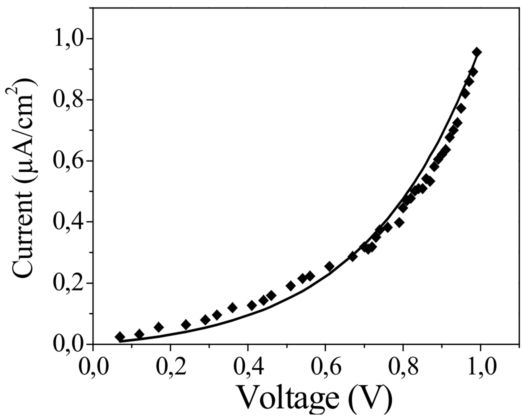

Fig. 3: Fit (line) of Experimental (o) I-V plot of the ITO/POT/Al junction using eq.3.

The fit (eq.3) yielded the following junction parameters: η = 10.8, saturation current density I_0=3.07x10^{-8} (A/cm^2), Φ_B = 0.85 eV and R_s =9.5 kΩ.

In both cases, the value of the ideality factor of ITO/POT/Al Schottky devices is high and of the same order as that of the polypyrrole and POT / metal Schottky diodes [4-5, 10]. The large value of ideality factor may be either due to accelerated recombination of electrons and holes in depletion region or by the presence of an interfacial layer as well as the reactive nature of Al contact [11].

The presence of other conduction mechanisms such as electrode limited and bulk limited currents in various voltage ranges are no excluded as in the obtained on poly(3-methylthiophene) based diodes [12-13].

III-2. (C-F) and (C-V) characteristics:

Figure 4 displays the frequency dependence of the zero-bias capacitance in the frequency range 40 to 12 KHz.

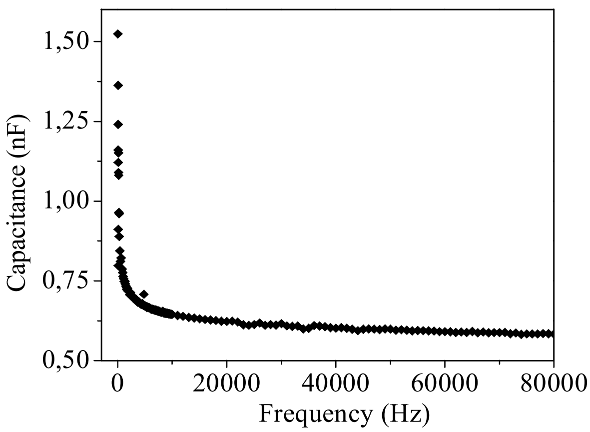

Fig. 4: C-F characteristics of ITO/POT/Al diode

The capacitance decreased when the frequency is increased. This dispersion in capacitance can be explained on the basis of a distribution of localized states in the band gaps of the amorphous polymer [2].

At high frequency (1KHz), the deep states can not follow the barrier modulation and capacitance must be replaced by the dielectric capacitance of the poly(o-toluidine). The influence of the barrier inhomogeneities and the series resistance of the diode are not ruled out as in the case of poly(3-methylthiophene)-based diodes [13].

Figure 5 shows the voltage dependence of the capacitance at 1 kHz for applied voltages between -0.5 V and +0.5 V.

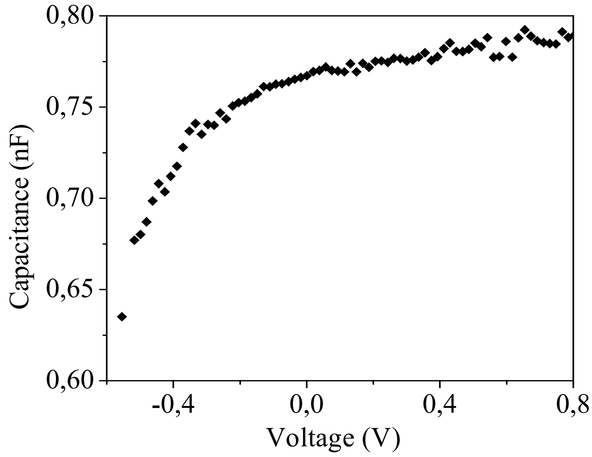

Fig. 5: C-V characteristics of ITO/POT/Al diode

As expected, the capacitance increased slightly when the voltage is scanned from the reverse to forward bias region. A similar behavior was observed in P3MT and POT/metal Schottky diodes [14]. This behavior further confirms the rectifying nature of the POT/Al contact.

IV. Conclusion

In summary, we have fabricated the Schottky diode using thin films based on chemically synthesized poly(o-toluidine), Aluminum as schottky contact and ITO coated glass as ohmic contact. The thermoionic emission theory has been satisfactorily applied. Various junction parameters as saturation current, ideality factor and barrier height have been calculated using the modified Shockley equation taking account of the series resistance.

V. References

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