

## **Chitosan doping by Nicotine as the active layer in the Solar Cell**

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### **Abstract**

Chitosan is a natural polymer that is very common in many applications. In addition, Nicotine is a natural dye. To prepared Chitosan Nicotine (CN) layer we mix (1: 1) ratios from the Chitosan doping with Nicotine dye. After that, it is used as an active layer in solar cells. The morphology of the surface for the prepared layer is studied by scanning electron microscopy technique (SEM). From this study, We found that the surface of Chitosan could be more regular when it dopant with Nicotine than being a lone. The optical properties of samples were studied from UV-Visible spectra at wavelengths 300-900 nm. The analysis of optical measurements data showed that the absorbance increased after mixing the Chitosan with Nicotine. The parameters of solar cell were calculated within the voltage range (1-12Volt) and noted that the Short Circuit Current ( $J_{SC} = 1.6 \times 10^{-3}$ ) mA/cm<sup>2</sup>, Open Circuit Voltage ( $V_{OC} = 7 \times 10^{-2}$ ) V, Fill Factor (FF=0.51), Series Resistance ( $R_S = 60$ )  $\Omega$  and Shunt Resistance ( $R_{sh} = 250$ )  $\Omega$ . were noted

**Key word:** Solar Cell, Chitosan, Nicotine, DSC, SEM.

### **1. Introduction**

In order to solve the energy crisis and pollution in the environment, since we have an energy source that is inexhaustible and non-polluting environment, effective and cheap provides energy, which is called the green energy (the sun) [5]. A solar cell is a semiconductor device that converts the sunlight falling onto it directly to DC Current. There are three types of solar cells: Inorganic solar cells, inorganic solar cells consist of non-organic semiconductors, such as crystalline silicon solar cells, non-crystalline material, or precipitated materials such as Gallium Arsenide (Ga AS), which are more common and have good efficiency. Recently, there has been a turnaround in the manufacture of solar cells made of organic materials. These cells are characterized by being lightweight because most of their components are carbon, hydrogen and oxygen. They are found too easy to manufacture. They are flexible and can be sprayed on walls or printed on paper or cloth. The solid solidity that cannot be formed or deployed on large parts, the small absorption factor, the small power gap, the suitability of the highest occupied molecular orbit is (HOMO) denoted by a name with the lowest unoccupied molecular orbit is (LUMO) and the environmental stability that makes it distinctive. The third type of cell is the integration of organic matter with other inorganic called hybrid solar cells and have one of the other with a number of characteristics. In principle, the working methods of solar cells are similar[2, 7].

And the second classification according to the number of layers used[5]. Several researcher used Chitosan and NH<sub>4</sub> from fabrication of a solar cell[3]. Used Chitosan polymer, to provide inherent energy barrier and dyes as sensitizer, and used Chitosan and (ZnO, ZnS), Also, to reduce the recombination of electrons, enhanced ionic conductivity and the stability of the redox this electrolyte because Chitosan is a biodegradable and nontoxic polymer and it exhibits piezoelectricity[4,8] . When comparing the use of nanoparticles in the fabrication of a solar cell, the efficiency is higher because of the small size of the particles and the lack of viscosity which leads to the movement of particles that are more than the standard chitosan [9].

## **2. Experimental Materials**

Chitosan is extracted from shrimp shells [5] and dye Nicotine was separated from tobacco leaves[10]. Poly (3, 4Ethylene Dioxy Thiophene): Poly (Styrene Sulfonate) (PEDOT: PSS) provided by Sigma Aldrich company. Different solvents were used in the extraction and preparation process , such as Hydrochloric acid, Sodium hydroxide, Potassium hydroxide; ethyl alcohol and acetic acid purchased from Sigma Aldrich Company.

### **Preparation of Solar cell device by using Chitosan Nicotine(CN) as active layer**

The procedure of extracting the Chitosan and Nicotine has been discussed in our published paper[1]. The Solution of Chitosan: Nicotine (CN) was synthesized by mixing equal weight ratios (1:1) from the (Chitosan: Nicotine) which is known as n-type and used as an active layer in organic photovoltaic cells. The solution was stirred overnight without heating , then filtered using a micro-syringe. ITO coated glass slides is cleaned in acetone and distilled water by using Ultrasonic Bath. The PEDOT: PSS solution was spin coated onto ITO slides at a speed of (2000)rpm for (20) sec, then that annealing the sample for (10) min, which is known as P-type semiconductor polymer and was used as a buffer layer. The solution of CN (active layer) was spin coated on the PEDOT: PSS layer at a speed of (1000) rpm for (30) sec. A thin layer aluminum was finally deposited on the active layer for the sample under the vacuum of ( $2 \times 10^{-5}$ )Torr using thermal vacuum evaporation. through a shadow mask to form the cathode. The device structure for solar cell (ITO/PEDOT: PSS/CN/Al). The UV-Visible spectra (Shimadzu UV-Vis 1,800 spectrophotometer) at wavelengths (300-900) nm was used to record the spectra of active layer Chitosan: Nicotine (CN). The surface morphology and effect mixing on the prepared polymer were characterized by scanning electron microscopy (SEM) and differential scanning calorimetric (DSC). The Current –Voltage characteristic was measured using a Keithley 2400 digital source meter and a solar simulator with xenon DC at light source of 1000W/cm<sup>2</sup>.

## **3. Result and Discussion**

### **SEM Measurement**

Figure (1). Shows the surface morphology and size particle of the sample by using SEM. We found in this Figure (1a) the size of the nanoparticles of pure chitosan, which ranges from (41- 100) nm, while in Figure (1b) It is noted that the size of chitosan after mixing it with Nicotine, decreased to between (29-70) nm. In Figure (1c), It is noted that the surface of the pure chitosan was random. After that, It becomes more regular when doping chitosan with the Nicotine dye, as shown in Figure (1 d).

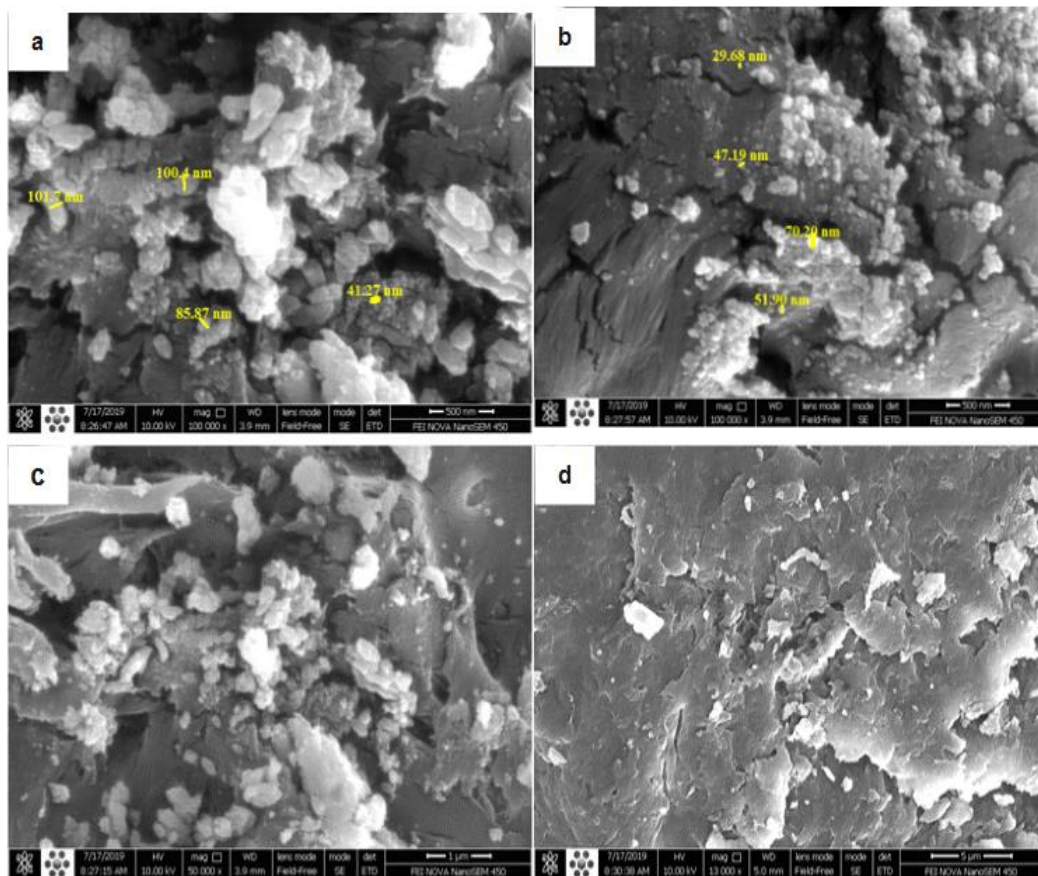


Fig. 1: SEM Chitosan and Nicotine dye (a) size of the nanoparticles of pure chitosan, (b) size of the nanoparticles of chitosan with Nicotine, (C) surface of pure Chitosan, (d) surface of chitosan with Nicotine.

### DSC Measurement

Differential scanning calorimetric (DSC) is a thermal analysis technique that measures the heat energy flow to or from a sample as a function of time or temperature at heating isothermal conditions under controlled thermal program. We measured DSC for the prepared material to know that utility and principle of the DSC comes from the fact that any changes in chemical structure or into the physical states of the materials involved or needed to the absorption or release of heat energy. During the heating of a sample from room temperature to 200, Its decomposition temperature peaks with positive and negative heat energy may be recorded. Each peak corresponds to a heat effect associated with a specific process, such as crystallization, melting point and the temperature at which a process occurs. The physical nature of the prepared sample falls within the range temperatures (0-200) °C. Figure (2,a) Shows the result of DSC from pure chitosan this result starters at (29.22°C ),the peak at (69.42°C),while the peak at(32.11°C) from Nicotine Figure (2,b) ,but the peak at (88.12°C ) from Chitosan doping with Nicotine showing figure(2,c). From this measure we proved that the interaction of the material with each other was successful and the reaction type was endothermic[1].

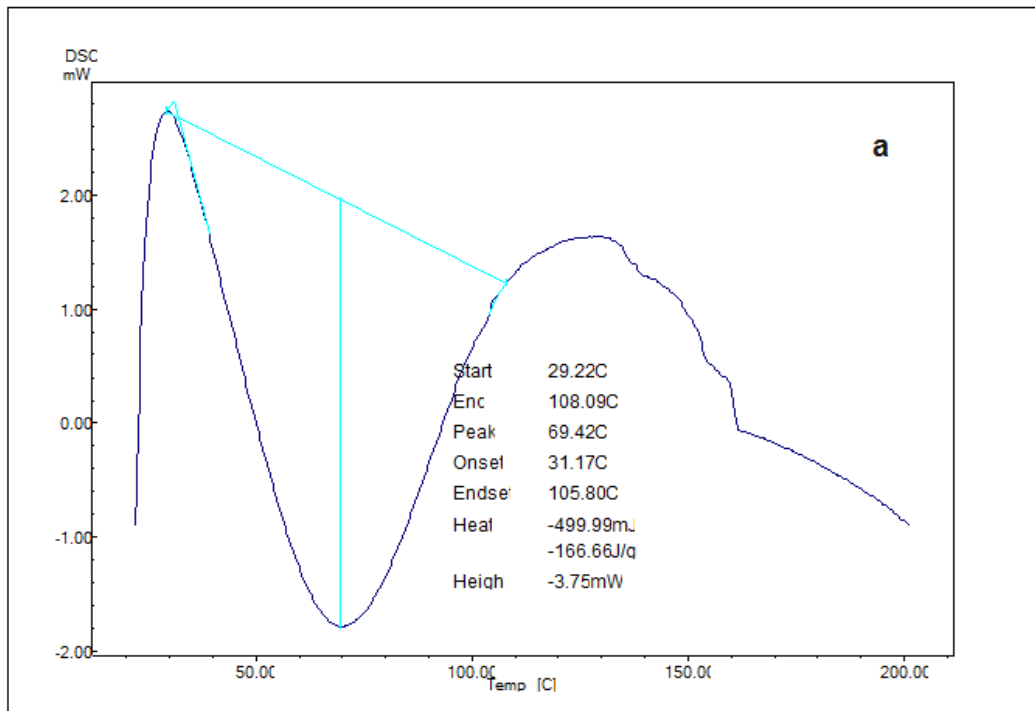


Fig. 2: (a) DSC of pure Chitosan, (b) pure Nicotine, (c) Chitosan with Nicotine

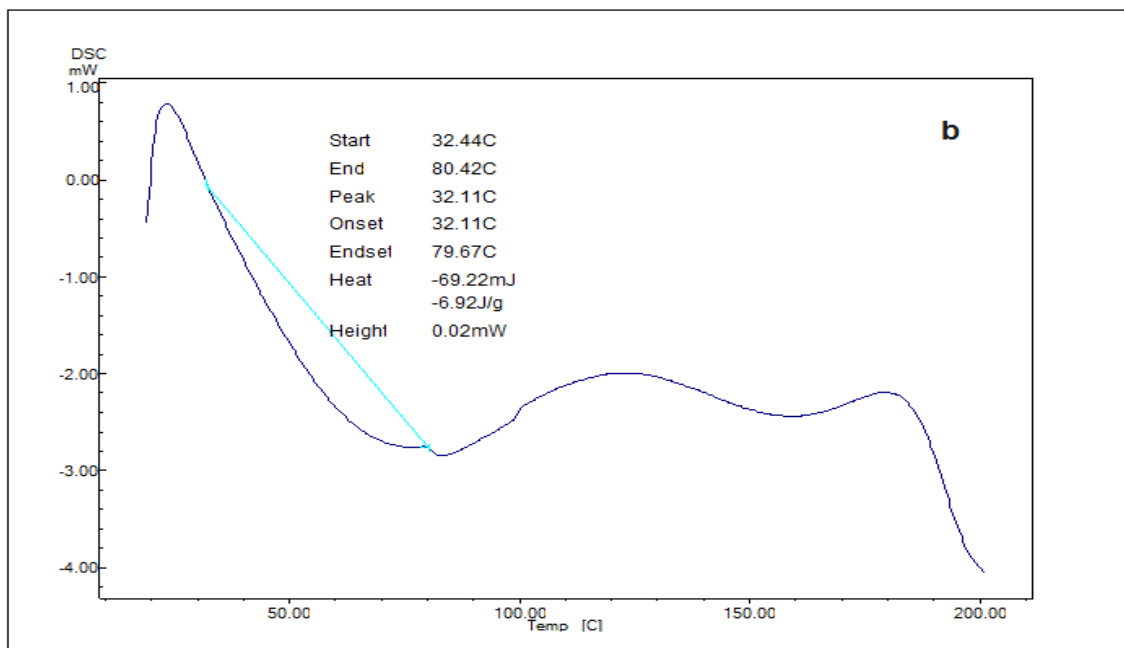
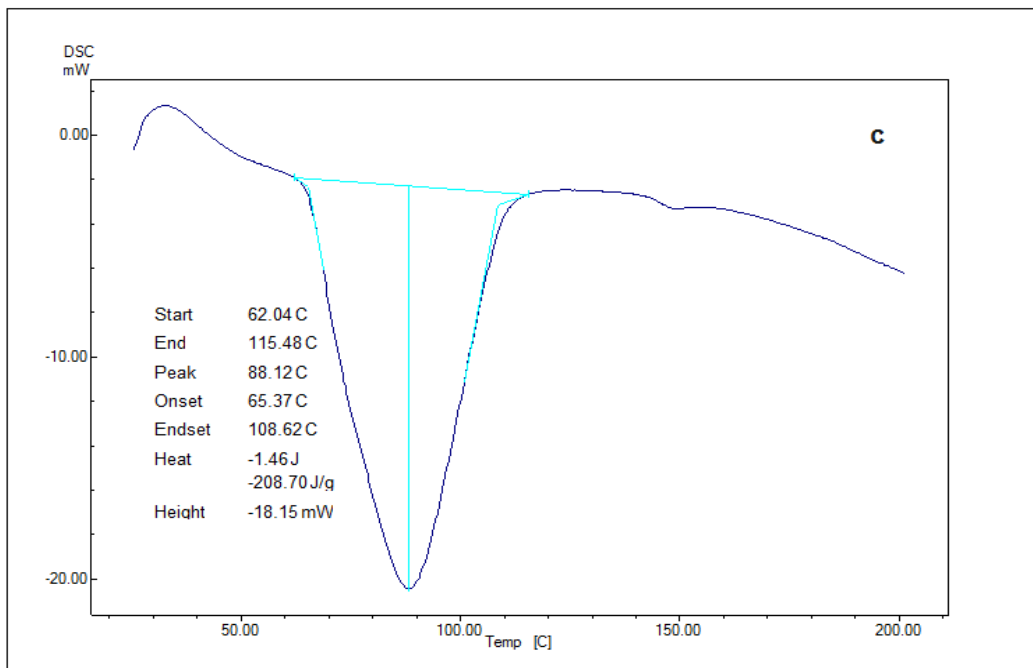


Fig. 2: (b), DSC of pure Nicotine



Fig(2): (c) Chitosan with Nicotine

### Optical Characterization

Optical characterization of samples gives information about other physical properties such as band gap energy and band structure. Figure (3). shows the absorption spectra of the blended active layer Chitosan: Nicotine (CN). The measure spectra falls in the range starting at (~700 nm) down to (~300 nm). From this figure we noted that the absorbance pure Nicotine dye and Chitosan was very low when compared with the blend Chitosan: Nicotine CN layer in the same wavelength 350 nm. We observed that it absorbs light at the same wavelengths of CN and was good for formation of solar cell as well as absorbed in the visible area.

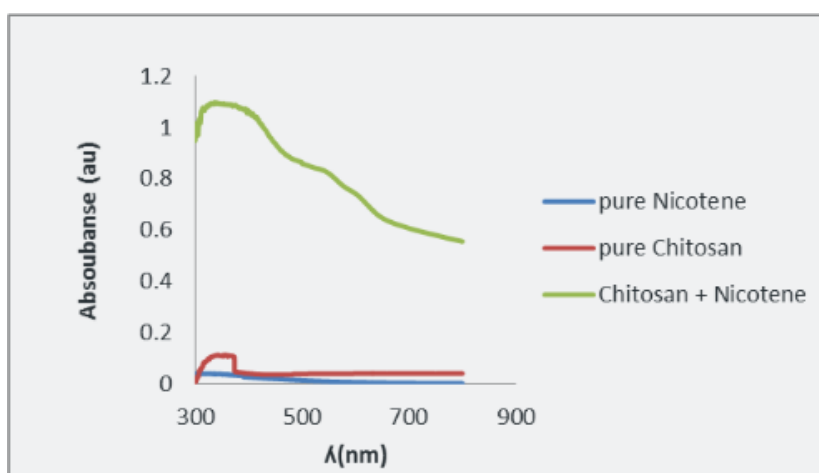


Fig. 3: The absorption spectra of Chitosan Nicotine ( CN)

To use the prepared blend CN in different photovoltaic applications , such as solar cells, transistors, etc., it is necessary to know the optical energy gap for these materials. The optical energy gap was set by drawing a straight line that extends from the edge of the absorption to the intersection of the photon energy axis ( $h\nu$ ). The energy gap of the Chitosan: Nicotine (CN) layer (HOMO)  $E_g$  was(2.2eV) as shown in Figure.4.

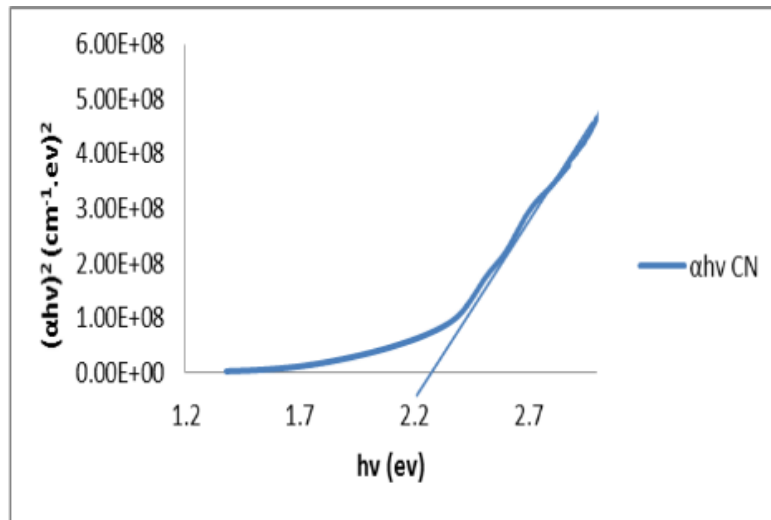


Fig. 4: Plot of  $(\alpha h\nu)^2$  as function  $(h\nu)$  for Chitosan nicotine (CN) layer.

**Electrical properties**

The Current- Voltage characteristic of the active layer was shown in Figure. 5. The electrical measurements were calculated within the voltage range (1-12) Volt. We noted from the curve that the current value was stable with the increase in the voltage, until it reached the voltage to the (8Volt). After that, the current value starts to with the increase with increase voltage.

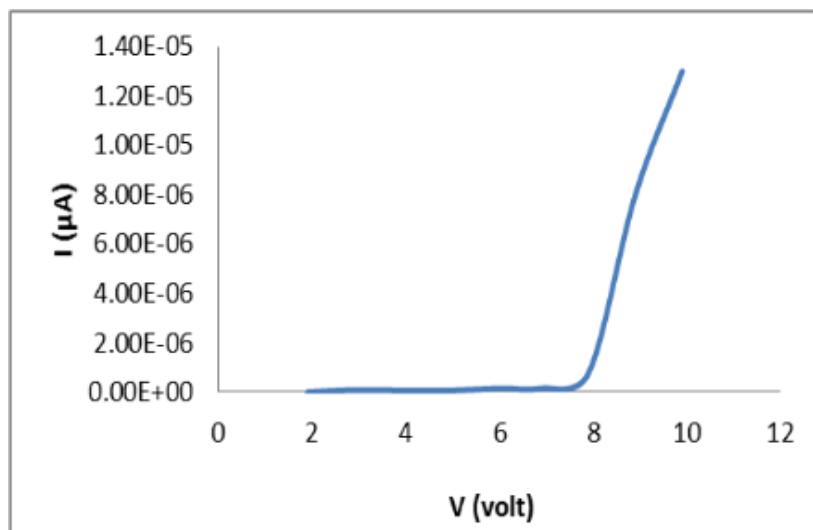


Fig. 5 :( I-V) characteristic for the active layer

**4. Parameter of Solar Cell**

The open circuit voltage ( $V_{oc}$ ), short circuit current density ( $J_{sc}$ ), and fill factor of the device were studied using J-V measurement. Figure (6) shows the J-V for the solar cell with structure (ITO/PEDOT: PSS/CN/Al). The  $V_{oc}$  for the organic solar cell is determined by the deference between the lowest unoccupied molecular orbital LUMO of the acceptor molecules and the highest occupied molecular orbital HOMO of the donor[3]. The solar cell in the case of lighting where the light was  $1000W / m^2$  and about (10cm) from the source of light. The light absorbed by the active layer results in excitation generation which were then separated into electron- hole. The CN hetrojunction controlls the transfer of the charge carriers to the electrodes and block the recombination between them, leading to improve the photocurrent. The parameter of the solar cell device is shown in Table (1).

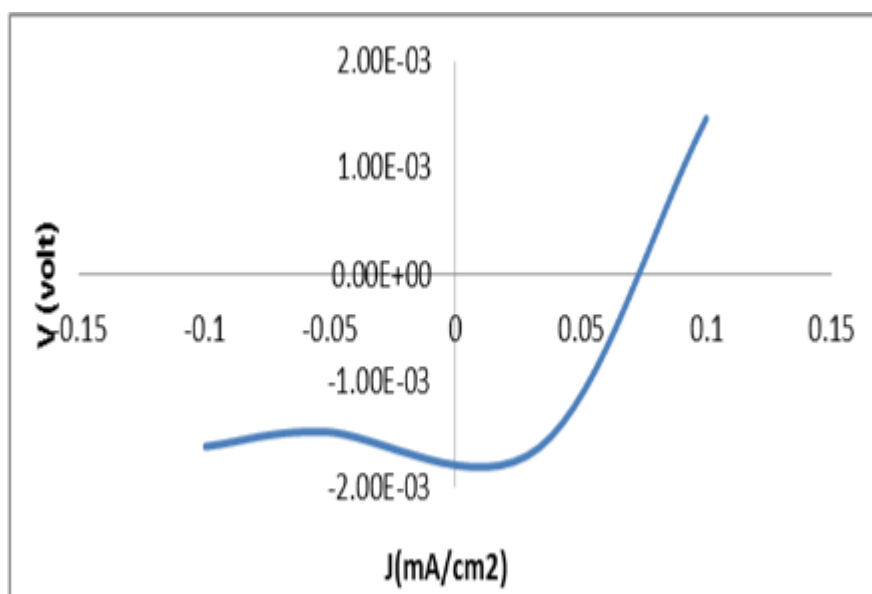


Fig. 6: The (J-V) curve for the solar cell device.

**Table 1:** Parameters for the Solar cell device.

$V_{oc}$ (volt)	$J_{sc}$ (mA/cm <sup>2</sup> )	FF	$R_{sh}$ ( $\Omega$ )	$R_s$ ( $\Omega$ )
$7 \times 10^{-2}$	$1.6 \times 10^{-3}$	0.51	250	60

**5. Conclusion**

Natural and available materials, low cost, rather good properties and not harming the environment to fabrication can be used as an active layer in the solar cell. From the results, the effect of adding Nicotine dye on the chitosan polymer is indicated, which is used to prepare the CN layer. The morphology surface studied by SEM indicated a combination of Nicotine dye-doped chitosan structure, making this blend useful in fabricating multifunctional materials for future technological applications such as solar cells. The effect of the dye addition on the polymer surface, if it is uniform and becomes nanoparticle size. In the DSC, we proved the reaction type is endothermic.

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## الكيتوسان بالنيكوتين كطبقة فعالة في الخلية الشمسية تشويب

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### المخلص

الكيتوسان هو بوليمر طبيعي شائع جداً في العديد من التطبيقات. بالإضافة إلى ذلك، يعتبر النيكوتين صبغة طبيعية. تم تشويب الكيتوسان مع النيكوتين بنسبة (1:1) لاستخدامها كطبقة فعالة في الخلايا الشمسية. تمت دراسة طبيعة السطح للطبقة المحضرة بواسطة تقنية المجهر الإلكتروني (SEM). من هذه الدراسة، وجدنا أن سطح الكيتوسان يمكن أن يكون أكثر انتظاماً عندما يكون مشبعاً بالنيكوتين أكثر من كونه وحيداً. تمت دراسة الخواص البصرية للعينات من الأطياف المرئية للأشعة فوق البنفسجية بأطوال موجية 300-900 نانومتر. أظهر تحليل بيانات القياسات الضوئية زيادة الامتصاص بعد خلط الكيتوسان مع النيكوتين. تم حساب معاملات الخلية الشمسية ضمن نطاق الجهد (1-12 فولت) ولاحظنا أن تيار الدائرة القصيرة ( $J_{sc} = 1.6 \times 10^{-3}$  مللي أمبير/سم<sup>2</sup>، فولتية الدائرة المفتوحة ( $V_{oc} = 7 \times 10^{-2}$  V)، عامل المليء ( $FF = 0.51$ )، ومقاومتا التوالي والتوازي ( $60, 250 \Omega$ ).

**الكلمات المفتاحية:** الخلايا الشمسية، الكيتوسان، النيكوتين، المجهر الإلكتروني، الماسح الحراري.