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Preparation and Characterization of Copper Oxide CuO (II) nanoparticles Prepared by a Hydrothermal Method and for Solar Cells applications

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ABSTRACT

Metal oxide nanoparticles were synthesized by a hydrothermal method inside a self-designed stainless steel autoclave, sealed, and heated at different temperatures. X-ray diffraction (XRD) analysis revealed the single-phase structure of CuO nanoparticles with an average grain size of 52.64 nm at temperatures of 100 °C, respectively. The EDX analysis determined that the sample was of high purity and did not contain impurities. Visible and ultraviolet spectroscopy identified a broad absorption band for CuO nanoparticles at a wavelength of 570 nm. Using the Tauc diagram, the bandgap was calculated, as its value was equal to 1.7 eV. The photovoltaic performance values of a solar cell are sensitized to the natural red dye extracted from beetroot. The solar cell produced a conversion efficiency of 2.08. The synthesized CuO nanoparticles could be potential candidates for use in electronic devices.

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تحضير وتوصيف الجسيمات النانوية لأوكسيد النحاس CuO (II) المحضرة بعملية حرارية مائية وتطبيقها على الخلايا الشمسية

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الـــخُـــلاصـــة

تم تصنيع الجسيمات النانوية لأوكسيد المعادن بطريقة مائية حرارية داخل الأوتوكلاف المصمم ذاتيًا من الفولاذ المقاوم للصدأ ، ومحكم الإغلاق ، وتسخينه في درجة حرارة100 سيليزي. كشف تحليل حيود الأشعة السينية (XRD) عن بنية أحادية الطور لجسيمات النحاس النانوية بمتوسط حجم حبيبات يبلغ 52.64 نانومتر عند درجات حرارة 100 سيليزي، على التوالي. حدد تحليل EDX أن العينة كانت عالية النقاء ولا تحتوي على شوائب. حدد التحليل الطيفي المرئي والأشعة فوق البنفسجية نطاق امتصاص واسع للجسيمات النانوية CuO بطول موجة يبلغ 570 نانومتر. باستخدام مخطط Tauc ، تم حساب فجوة الحزمة ، حيث كانت قيمتها تساوي 1.7 الكترون فولت. قيم الأداء الكهروضوئية للخلية الشمسية حساسة للصبغة الحمراء الطبيعية المستخرجة من جذر الشمندر. أنتجت الخلية الشمسية كفاءة تحويل 2.08. يمكن أن تكون الجسيمات النانوية CuO المركبة مرشحة محتملة للاستخدام في الأجهزة الإلكترونية.

الكلمات المفتاحية:

الحرارية المائية
أوكسيد النحاس
الخصائص التركيبية
الخصائص الضوئية
الخلايا الشمسية

1. Introduction

Copper oxide is a substance that falls under the category of oxides. Copper oxide is categorized as a metal despite the unique properties of its molecules, yet it behaves more like a semi-metal. Due to their beneficial characteristics, such as their abundance, high optical absorption coefficient, low energy range, and lack of toxicity, copper oxide particles are of major interest as conductors at the nanoscale [1] . There are many methods and techniques that enable us to prepare CuO nanopowders. From the methods obtained is the hydrothermal method, hydrothermal synthesis can generate unstable nanomaterials at high temperatures .

High vapor pressure and little material loss can be used to create nanomaterials [2]. Both crystals and nanoparticles are produced, and they are of superior quality. The primary benefit of this approach is that it may be combined with other techniques like microwaves and electrochemistry. optical, hot, and chemical mechanics.

There is a significant drive to acquire benefits such as improved reaction kinetics and expanded capacity to generate novel materials. This has resulted in a heightened level of pressure to achieve these advantages. Furthermore, these techniques exhibit a greater degree of environmental sustainability. [3] . In addition to magnetic storage, solar energy conversion, microelectronics, and catalysts, transition metal oxides are a significant subgroup of semiconductors [4]

2. Experimental

Copper oxide nanoparticles were prepared by a hydrothermal process. By dissolving 0.1 M of copper sulfate pentahydrate ($CuSO_4.5H_2O$) in distilled water until a blue solution is obtained. After 25 minutes of stirring and sequential distillation, we add a 0.2 M NaOH solution, bringing the pH of the mixture to 9. After transferring the resultant solution to stainless steel (an autoclave), hydrothermal synthesis was carried out for 24 hours at a temperature of roughly 100 °C. The resultant dark precipitate was filtered and cleaned by washing it multiple times in ethanol and deionized water. The finished product was dried for one hour at 50°C [5.[

3. Results and Discussions

3.1 XRD Analysis

It is a technique used to determine some structural properties such as crystalline structure and crystalline size. Through this technique, crystalline size D can be calculated according to the Debye Scherer equation [6]:

$$D = K\lambda/\beta \cos\theta \ldots\ldots\ldots\ldots..(1)$$

Where K: shape factor and represents a constant amount that depends on the shape of the nanoparticles the amount of about 0.9 λ: The wavelength of x-rays is 0.154056 nm.

FWHM: full width half maximum (β),θ: Bragg diffraction angle. The distance between crystalline layers is calculated by Bragg's law.

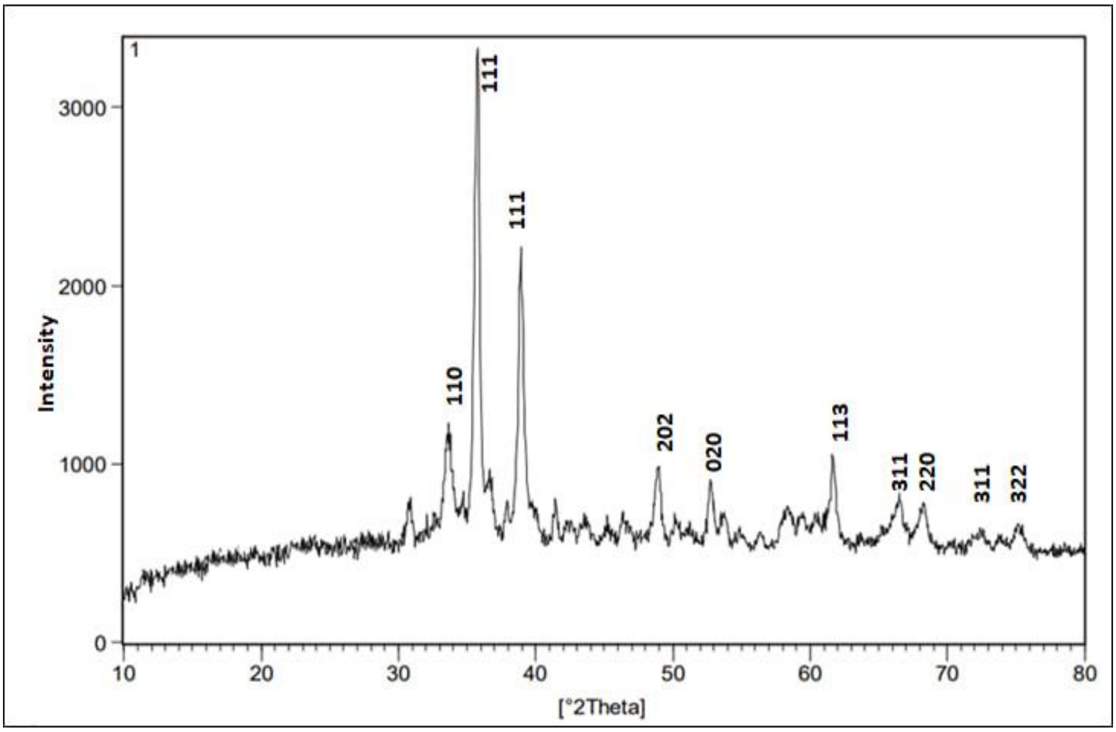

Figure (1): XRD pattern of CuO nanoparticle.

3.2. UV-Visible spectroscopy

A useful method for measuring the optical characteristics of identically sized objects is UV spectroscopy **[9]**. CuO particle optical spectra were measured using a UV-Vis streak photometer, and at room temperature, absorption spectra were obtained. Where this sample shows, in Figure (2), a strong absorption at a wavelength between (550nm-584nm).

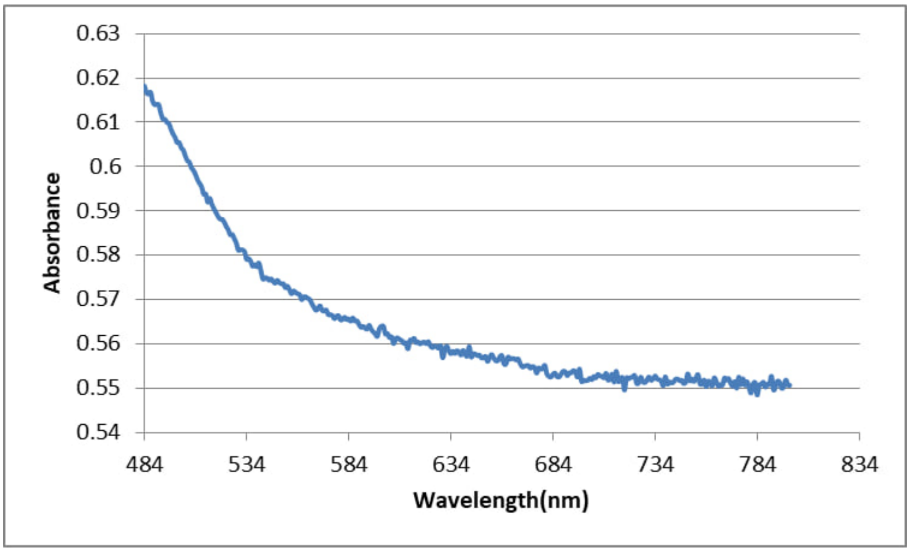

Figure (2): Ultraviolet-visible absorption spectrum of CuO nanoparticle.

The energy gap E_g of the prepared materials was calculated using the wavelength according to the Tauc equation **[10]:**

$$\alpha h\nu = A(h\nu - E_g)^{1/2} \qquad (2)$$

Where α is the absorption coefficient, hν is the accident photon energy, A is a constant independent of the photon energy and E_g the energy band gap for direct allowed transition. Where E_g stands for the optical band gap equal to be (1.7 eV) as shown in Figure (3) .

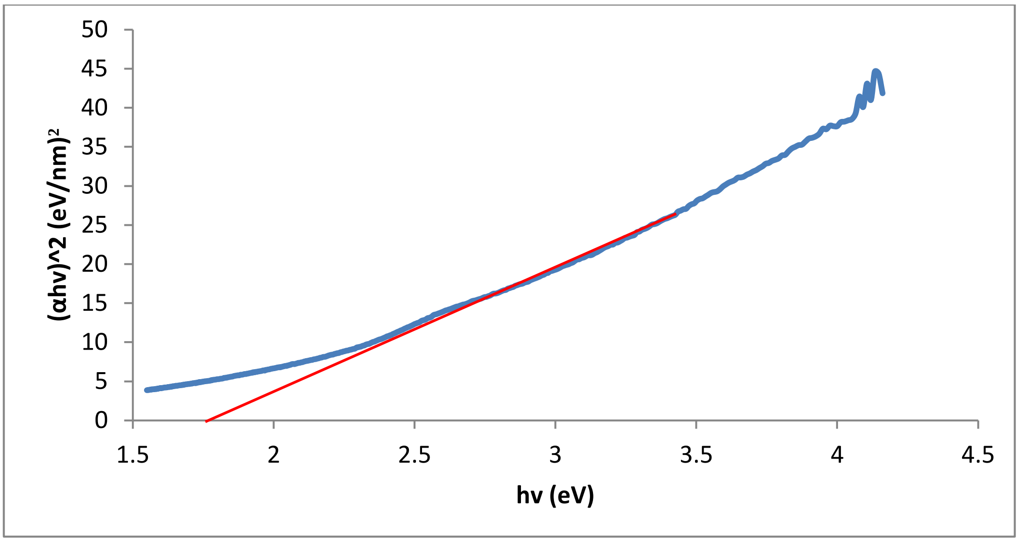

Figure (3): Tauc plot of CuO Nanosheet.

3.4. Field Emission Scanning Electron Microscopy (FE-SEM)

Figure 4) shows that the nanoparticles were prepared in the nanometer range. The copper oxide nanosheets appear irregular. The size ranges from (28.93-29.78)nm. and the shape is identical to that reported in the literature [11] SEM images indicated that some of the nanoparticles were well separated from each other, while most of them were present in agglomerated form. This agglomeration is due to the electrostatic effects in addition to the effect of the aqueous suspension, which reveals the agglomeration behavior of the nanoparticles. This is consistent with a behavior similar to the agglomeration of nanoparticles in previous studies [12].

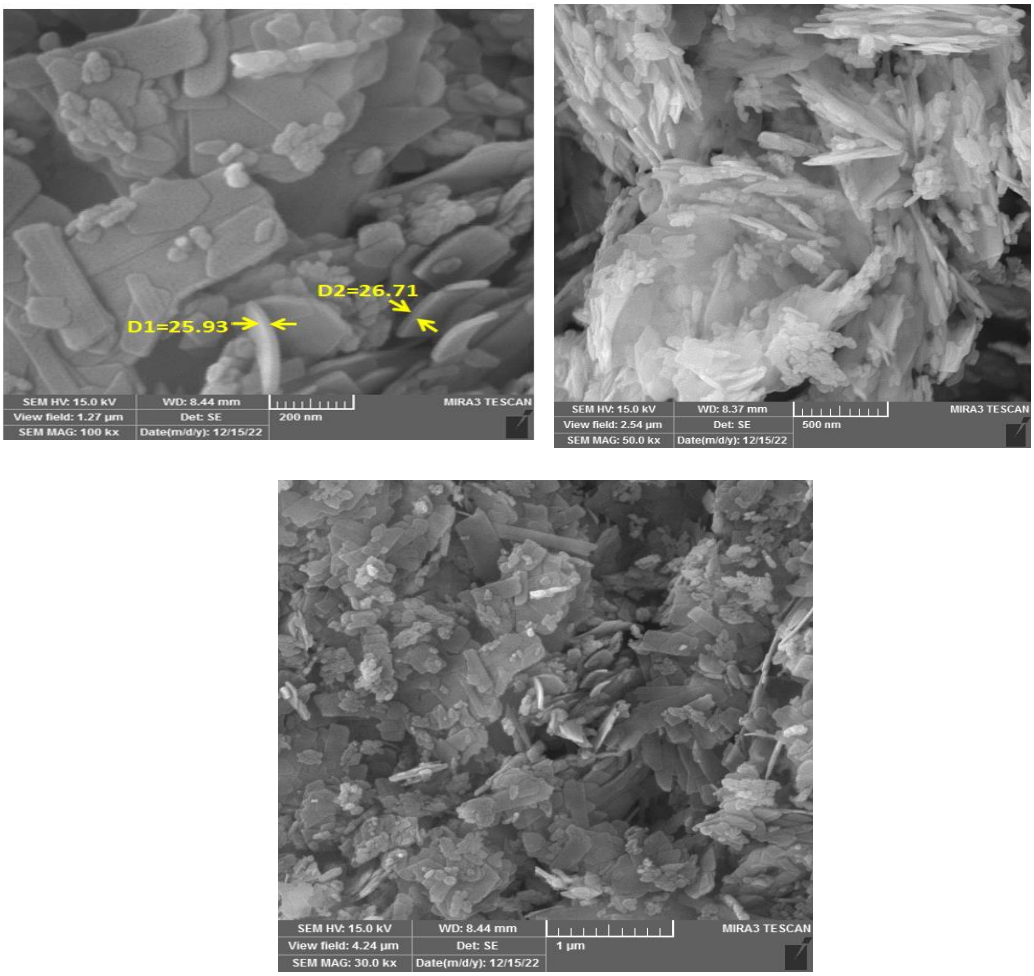

Figure (4): FESEM images of CuO nanoparticles.

Figure (5) shows a transmission electron microscope (TEM) image of copper oxide nanosheets. With a width ranging from (50- 100) nm as mentioned in the literature [13].

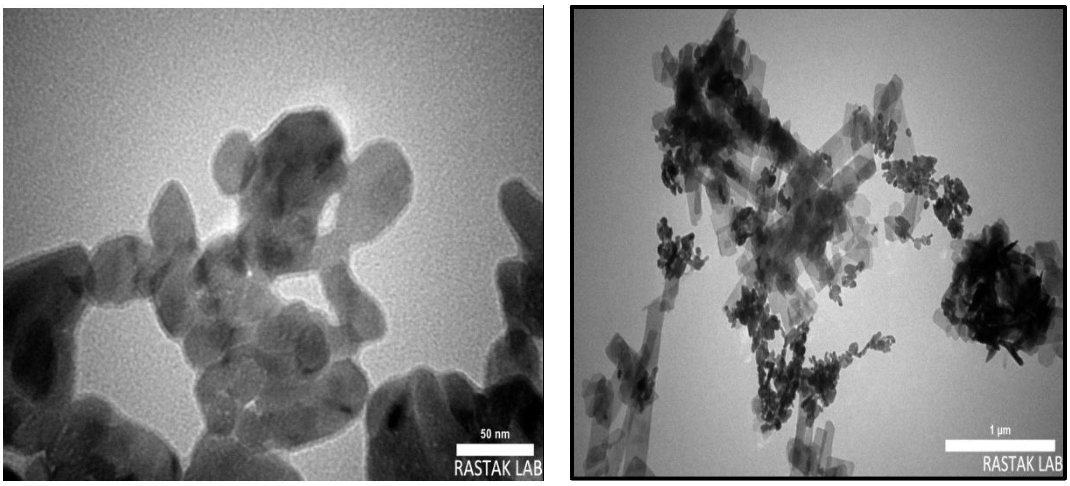

Figure (5): TEM Pictures for CuO nanosheets.

3.5. Energy-dispersive X-ray Spectroscopy (EDX)

The CuO nanosheet was equipped with energy-dispersive X-ray spectroscopy (EDX), and its purity and stoichiometry were assessed using this technique (see Figure 6) shows the results, which show that the samples were highly pure because there were only specific signals for Copper and Oxide in the histogram.

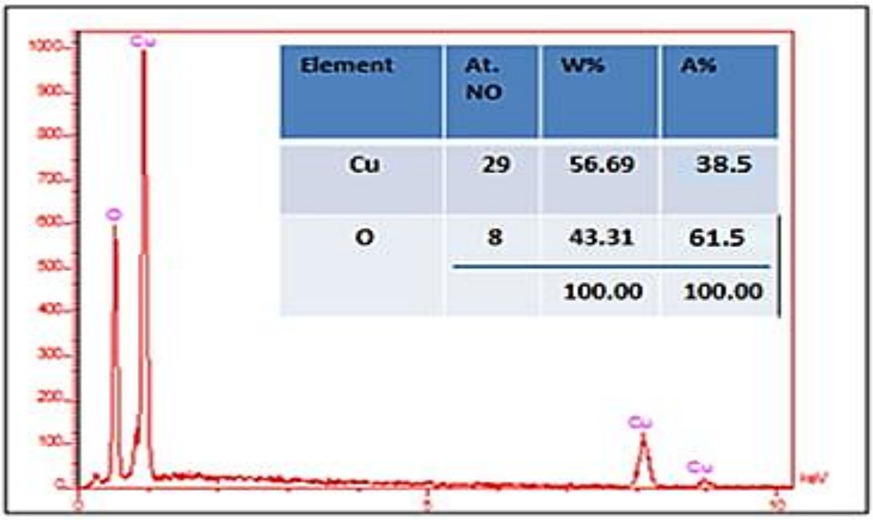

Figure (6): EDX diagram for CuO nanoSheet.

3.6. Study of the Prepared Composites Efficiency as Anodes for the Dye-Sensitized Solar Cell

The scale of the current-voltage curve (I-V) is one of the most important measurements for evaluating the efficiency of the solar cell. In order to be able to compare the performance of solar cells, the curve (I/V) was measured under the lighting of a lamp ((HID Xenon 100 w). The solar cells prepared using Copper Oxide nanosheet as photoanodes showed a good conversion efficiency after using a natural dye, which is beetroot plant dye. And, the energy conversion efficiency (ŋ) that is calculated according to the following equation **[14]:**

$$\eta = \frac{FF * V_{oc} * I_{sc}}{P_{in}} \times 100\% \qquad (3)$$

Where the photovoltaic properties of the prepared solar cells are shown as in the following table:

Table (1): Photovoltaic properties of prepared solar cells.

ɥ	FF	Isc*Voc	Isc	Voc	Pm	Im	Vm
2.076444	0.956167	48.86175	9.039505	5.405357	46.71998	9.039396	5.168485

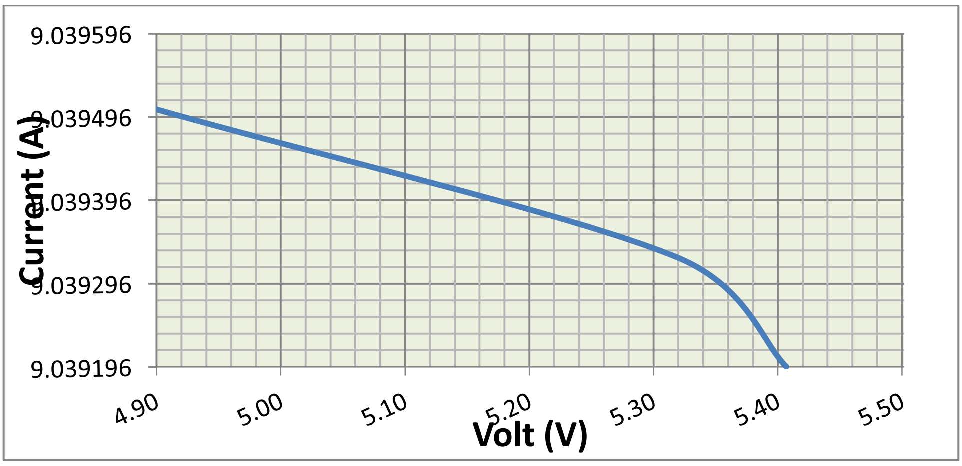

Figure (7): Curve (I/V) of solar cells banned from nano-Copper Oxide with natural dye (beetroot).

4. Conclusions

In conclusion, a simple hydrothermal method was used to synthesize CuO nanosheet with controllable shapes. No organic solvents were used throughout the process. In our study, A Copper Oxide nanosheet was successfully synthesized using a hydrothermal method. The structural phase was confirmed by XRD analysis, and the particle size was (52.64 nm). A wide 1.74 eV band gap was obtained, while the greatest absorption was located in the wavelength region 570nm . A current-voltage curve was studied to find out the efficiency of the solar cell, and the efficiency was (2.08).

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