Fabrication and Characterization of Gold Nanoparticles by Electrolysis Technique for Schottky Photodiode Applications

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Abstract. In this research gold nano-particles (AuNPs) was synthesized by electrolysis Technique. Au thin films were deposited on the silicon and the borosilicate glass at a Temperature (80 °C) by dropcasting method. Structural, optical and topographic properties of prepared Au NPs was estimated by UV-VIS spectrometer, TEM, AFM, and XRD diffraction. The open circuit Voltage (Voc=2.8 mV) and Short-circuit density (Isc=5mA). This resultant relive that the fill factor (FF) and conversation efficiency (η), were 32% and 9.3% respectively.

Keywords: Nano-particles, solar cell, thin film, gold nano-particles, TEM

1. Introduction: Schottky association execution and dependability are exceptionally impacted by the nature of the interface between the saved metal and the semiconductor surface. So as to comprehend the instrument of associating the Schottky obstruction diodes (SBDs), numerous endeavors have been made. By and large, SBD parameters are resolved at a wide scope of temperatures and doping focuses so as to comprehend the idea of the obstruction and the conduction system. Investigation of the present voltage attributes (I - V) of the Schottky hindrances dependent on the hypothesis of warm emanation proliferation (TED) uncovers an anomalous decline in the stature of the obstruction (BH) and the expansion of a perfect factor with lower temperature [1-4]. Also, the ideal factor was found to increase with increasing carrier concentration, while BH obtained from measurements of I-V decreases with increasing the level of steroids [1], and more recently the horizontal distribution of heterogeneity of BH [2-9]. In addition, it was postulated that the Gaussian BH distribution in the contact area describes homogeneity as another method [2,10]. In this study, the (I-V) and capacitance-voltage of Schottky gold were made in the temperature chamber.
2. Experimental work

In present job, glass substrates (2 x 2) cm² with a thickness of 0.1 cm were used. Glass substrates were cleaned using methanol and double-distilled water in the ultrasonic bath in order to get a clean surface. The gold nanoparticles were synthesized by an electrolysis cell as shown in Figure 1. The electric poles of this cell were made of molybdenum as the positive pole and gold as the negative pole. Water with hydrochloric acid in a ratio of about 8: 1 was used as an electrolyte fluid. The used voltage is 6V. The casting technique was applied to precipitate gold nano-particles on glass substrates. The annealing process is then used at 175 °C for 60 min on the samples. The film thickness is found about 200 ± 10 nm. Film thickness was measured using the Fizeau Interferometer technique. The crystal structure was studied in the following operating conditions: Cu-Kα source of radiation wavelength 1.5 = 1.5405 Å, voltage = 4 kV, current intensity = 20 mA, scanning speed = 5 cm / min by XRD 6100 Shimadzu. Optical transmittance measurements were recorded using the UV / Visible 1800 spectrophotometer. The transmittance energy band gap (T) was determined in wavelength (200 nm to 1000 nm). Shape and size were studied by AFM and XRD (AA 3000 Scanning Probe Microscope).

3. The Results

3.1. XRD measurement

Figure 2. shows XRD pattern to a thin film of gold . it can be observed that the film is a multi-faceted structure focused on the cube. Fig. 2 contains four peaks at the diffraction angle of 38.18, 44.26, 64.48 and 77.52 identical to the directions (111), (200), (220) and (311) respectively, Which were consistent with XRD (ASTM No. 00). -004-0784). It is convenient with literature [7].
it can be obtained the crystallite size from Scherrer’s equation [11]:

\[ G_S = \frac{0.9\lambda}{\beta \cos \theta} \]  

where \( \theta \) is the diffraction angle, \( \lambda \) is the X-ray wavelength and \( \beta \) is the FWHM. whereas equations 2 and 3 were utilized to calculate the dislocation density \( \delta \) and the micro strain \( \eta \) [12] which is listed in (Table 1):

\[ \delta = \frac{1}{G_S^2} \]  
\[ \eta = \frac{\beta \cos \theta}{4} \]  

3.2 Atomic force microscopy (AFM)

Figure 3 shows an AF-2-D image for the gold film deposited on glass. They are fully coated with nanostructures that are uniformly spread over glass. Table 2 appears the grain rate, roughness density and RMS of the gold thin film.
3.3. Transmission electron microscopy (TEM)

Figure 4 shows TEM image of gold nano-particles. The image show that the formation of nano-particles is Almost spherical and has a diameter of about 16 nm synthesized by electrolysis.

![Figure 4: TEM micrograph image of gold particles synthesized by electrolysis technique](image)

3.4. Optical properties

Figure (5) shows the relation between the absorption and the wavelengths of gold thin film. It can be observed that the decreasing absorption sharply till it reaches the minimum value at 300 nm , then increases slightly and then start to decrease again. The band gap of the Au thin film was estimated from the absorption spectra. Figure 5 show the absorption as a function of wavelength. It is obvious that the film gives good absorbance characteristics at the spectral range (200 nm – 300 nm). Figure (6) shows the reflectance of Au thin film as function of wavelength. It can be seen that the The highest reflectivity value can be obtained for the film at 272 nm and then the reflectivity begins to decrease and reaches the lowest value at 550 nm.

The energy gap of the gold was calculated by the equation [10]:

$$ ahu = C(hu - Eg)^m $$  \hspace{1cm} (4)

Where C is a constant , \( u \) is transition frequency,h is plank constant and \( a \) is the absorption coefficient ,

### Table 2: Grain size, roughness density and (RMS) for Au thin film

| Sample | Average grain (nm) | Roughness density (nm) | RMS (nm) |
|--------|--------------------|------------------------|----------|
| Au     | 75.46              | 1.69                   | 2        |

![Table 2](image)
Figure 7 illustrates the energy gap for the Au nano-particle thin film which it is chemically synthesized and deposited on a glass and the relation between \((\alpha h\nu)^2\) Vs. \((h\nu)\) gives the value of direct band gap. The extrapolation of the straight line to \((\alpha hv)^2=0\), gives the value of band gap is 4.67 electron volt.

![Absorption spectrum of Au nanoparticles](image1)

**Fig.5** Absorption spectrum of Au nanoparticles

![Reflectance as function of wavelength for Au nanoparticles thin film](image2)

**Fig.6** The reflectance as function of wavelength for Au nanoparticles thin film
3.5. Electric Properties

Au film has been examined as p-layer through the (pn) photodiode structure. For this reason, we chose the Au/Si film which was delivered gratis and was utilized in p-n intersections utilizing the Au/Si piece. (C-V) is one of the affirmed electrical estimations to figure the interior auxiliary voltage (Vbi), and showcases the centralization of the bearer and consumption region. Vbi was determined by plotting a connection between the transformed square limit (1/C^2) with the turnaround voltage scope of the predisposition (0-6) volts, and the (f=10 kHz) as in Fig.8: The connection between the applied voltage and the limit (Vbi) was 0.6 volts because of the decrease of the exhaustion region acquired because of the improvement of the precious stone structure of the film.

![Diagram](image)

**Figure 8. Characteristics 1/C2 as a function of the reverse bias voltage**

Fig. 9 shows the I-V properties in the front and back ways of the Au/c-Si/Al-hetero intersection. The front
current of the heterojunction is restricted to -1 volts. The current is alluded to as present reunification that happens just at low voltage and made when the electron is animated from the valence band to the conductive band. The second high-voltage zone alludes to the zone of dissemination or twisting, contingent upon the serological obstruction. In this district, the predisposition voltage can interface the electrons with adequate vitality to infiltrate the hindrance between each side of the intersection.

**Fig. 9: I-V characteristic of the Au/Si/Al**

Fig. 10 show that the current reflective properties of the instrument are calculated in the dark and that the optical current is less than $40 \times 10^{-6}$ W/cm$^2$ of tungsten light mass and the current inverse value of a given voltage of the solar cell Au / c-Si / Al under light is higher than the dark value. Photocell because of the production of electronic holes due to incident ray. This behavior produces useful information about electron hole pairs, which are effectively generated at the intersection by incidental photons [13].

**Fig. 10. Illuminated (I-V) characteristics of Au/Si/Al solar cell**

Also from Fig. 11. The open-circuit voltage ($V_{oc}$, $I = 0$, $R = \infty$) shows the ($I_{oc}=5$ mA) and ($V_{oc}=2.8$ mV), and the output power ($P_m = 2.5 \times 10^{-6}$ W). Then the fill factor (F.F) is that the maximum rate of output power ($V_m$ and $I_m$) respectively for the product $V_{oc}$ and $I_{oc}$. From these criteria, efficiency can be classified. The conversion efficiency ($\eta$) is defined as $100\% = (P_m / P_{in})$ and $F.F = (I_{m} V_m / I_{oc} V_{oc})$ 100% are 32% and 9.3% respectively.
4. Conclusions
The job shows how the gold film was prepared by electrolysis. Straightforward, easy and quick approach to introduce nanostructures. The film's conduct as appeared in figures demonstrate that the film has a decent visual progress with great crystallization. Likewise, this investigation reasoned that gold nanoparticles kept on c-Si delivers a Schottky photodiode with high proficiency that can be utilized; thus, to create the ideal electrical power.

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Fig. 11. I-V characteristics for solar cell with illumination, for Au/Si/Al
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