**Experimental and Theoretical**

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**Synthesis and Characterization of Cu2CdSnS4 Quaternary Alloy Nanostructures**

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Cu2CdSnS4 (CCTS) quaternary alloy nanostructure is an important material of enhancing the sensors effectiveness. CCTS nanostructures have been synthesized using ultrasonic and deposited on SiO2/Si substrate using sol-gel method and under annealing temperature; 400 oC. Structural optical, topographical and morphological properties of CCTS were explored using Ultraviolet–visible spectroscopy, X-ray diffraction (XRD), atomic force microscopy (AFM) and scanning electron microscopy (SEM), respectively. Interdigitated electrodes (IDEs) have been manufactured via deposited silver on CCTS/SiO2/Si substrate via a physical vapor deposition and hard mask. Electrical properties of fabricated IDEs are further evaluated as a function of voltage and frequency. The proposed IDEs can be used in subsequent studies to develop a biological sensor capable of detecting the DNA for many types of diseases in order to facilitate the combating and eradicating. The resulted values are in agreement with others.

**Keywords:** Cu2CdSnS4; Nanostructures; Optical; Structural; Electrical.

**1. INTRODUCTION**

Due to high request of effective and accurate sensors, research is ongoing for new elements and methods to design and build biosensors that are based on capacitive electrodes. Common capacitive structures such as parallel plate and interdigitated electrodes (IDEs) are used widely in the literature, the first is distinguished by unpretentious design in terms of modeling [1], whereas, the second is more favored due to its effectiveness in acquiring stable and fixed temperature for the dielectric [2].

Four different electrodes models discussed thoroughly in the literature can be used as some capacitive sensors; interdigitated electrodes, spiral electrodes, meandered electrodes and serpentine electrodes. IDEs are considered for sensing; the signals have been detected by sensing materials. Analytical equations for the capacitance between electrodes fingers have been developed, which proposed a general model that can be used for any dimension and finger width as well as any number of layers with different

permittivity and thickness [3]. The geometry of interdigitated schottky-barrier has been enhanced thus, the quantum efficiency and response time are analyzed and the optimum spacing for interdigitated photodetector has been identified [4]. The process of IDEs manufacturing consists of different steps of exposure, photoresist coating and etching processes using special instruments [5-10]. Therefore, many attempts have been done for simplifying the fabrication process by introducing some new and different ones such as inkjet-printing [11-13], screen printing [14], micro fabrication [15] and stamp method [16]. IDEs have been explored extensively and used widely in many applications such as humidity sensing [17], gas sensing [18], bacteria sensing [19], pressure sensing [20], DNA sensing [21], pH sensing [22] and immunosensor [23].

**2. EXPERIMENTAL**

*2.1. Synthesis of CCTSsolution*

The solution was produced from copper (II) chloride dihydrate (CuCl2.2H2O) (0.6 M), tin (II) chloride dihydrate (SnCl2.2H2O) (0.8 M), cadmium (II) chloride dihydrate (CdCl2.2H2O) (0.8 M), thiourea (CH4N2S) (0.8 M), 2-methoxyethanol (C3H8O2) and monoethanolamine (C2H7NO) were all of analytical grade and purchased from Sigma-Aldrich. The stabilizer and solvent were 2- ethanolamine and methoxyethanol, respectively. The molar ratio of S, Sn, Cd and Cu in the solution was 4:1:1:2. The specified molar concentrations of the precursors were identified using the following equations;

$Molarity \left(M\right)=\frac{n}{V}$ (1)

$n=\frac{m(g)}{M\_{m}(g/mol)}$ (2)

where *n*is moles of solute, *V* is liters of solution, *m* is mass (g) and *M*m is molecular mass (g/mol). The precursors were mixed using a magnetic stirrer (WiseStir MSH 30D) at a speed of 1500 RPM for 3 hours, and temperature, 50 °C which results into a yellowish solution. The resulted solution has been placed inside the ultrasonic cleaner (DELTA DC200H) for 30 minutes at 50 °C to boost the physical and chemical properties of the solution.

**3. RESULTS AND DISCUSSION**

*3.1 Optical properties*

Reflection versus wavelength was conducted using UV-vis spectroscopy at the range, 200-1000 nm. In agreement with Tauc equation [35] for determining the optical band gap, that can be determined;

*(αhv)2= A(hv-Eg)* (3)

where *α* is absorption coefficient, *A* is constant, *Eg* is band gap, *v* is incident frequency and *h* is Planck’s constant. Tauc’s region is extrapolated to (αhv)2 = 0to obtain the energy gap as displayed in Fig. 1. The band gap is 1.35 eV, that is close to the available data in the literature [33,34] and an impetus to employ CCTS in photovoltaics and biosensors.



**Figure 1** (αhv)2 versus hv of CCTS quaternary alloy nanostructures deposited on SiO2/Si substrate.

The main observation is observed from Fig. 1, the reflection spectra is at ambient temperature. It is noticed that the reflection level is determined. The deduced band gap is in good agreement with the reported values [33,34]. The band gap is quite close to the optimum band gap, which indicates that CCTS quaternary alloy nanostructure is promising materials for photovoltaic applications.

In this study, the structure of CCTS belongs to the tetragonal crystal system and stannite structure that is in agreement with the standard (ICDD PDF2008, 00-029-0537). The lattice constants (a & c) with other parameters are determined from (112) peak as shown in Table 1.

**Table 1** The structural parameters of CCTS quaternary alloy nanostructures using XRD.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Crystallite size (D) (nm) | Lattice constants a and c (Å) | Strain (10-3) | Dislocation density (1014)  | N/area(1015) | Thickness(nm) |
| 26.8 | a=5.52 c=10.91a=5.48 c=10.84aa=5.46 c=10.48b | 0.086 | 19.17 | 6 | 54 |

 aRef. [30] Theo.; bRef. [38] Theo.

**4. CONCLUSIONS**

CCTS nanostructure has been prepared successfully and deposited on SiO2/Si via sol-gel method at 400 °C. UV-vis has demonstrated band gap, 1.35 eV. X-ray diffraction pattern has showed five peaks; (112) plane is attributed to the highest one whereas, particle size was 26.8 nm. Topography and morphology have indicated the nanostructures coherency and homogeneity as shown in AFM and SEM images, respectively. The roughness was 1.95 nm. Ag IDE was fabricated on CCTS/SiO2/Si via PVD and hard mask. The model of Herve and Vandamme is agreed well for CCTS quaternary alloy nanostructure. Also, the investigated bulk modulus exhibits the same chemical trends as those found elsewhere in the literature. As seen in electrical measurements, there is a proportional relationship between I and V which is interpreted as Schottky barrier. Otherside, impedance and capacitance measurements have showed inversely correlation with frequency, where they are slightly affected with voltage change. Furthermore, device conductivity increases as frequency increases. These results indicated that Ag IDEs deposited on CCTS/SiO2/Si using PVD and hard mask have showed good sensing capabilities and it can be used as biosensor for detecting different types of DNA in future studies.

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