Synthesis SnO$_2$:Bi$_2$O$_3$ Nanostructure Device for Bio Sensor

Ayah Mohammed Hassan*, Salma Mahdi Shaaban*, Asmaa Hadi Mohammed**
* Department of Physics, College of Science, Baghdad University , **Department of Physics, College of Science, Mustansyriah University
*aviamh.irag@gmail.com, **aviamohammed@yahoo.com

Abstract:
SnO$_2$:Bi$_2$O$_3$ colloidal NPs were synthesized by pulsed laser ablation of Sn:Bi target (50%:50%) in double distilled water (DDW) at room temperature. High purity Sn:Bi target (purity of 99.99%) was fixed at bottom of open a plastic cell containing 2 ml DDW and DDW+ PVP which represent the liquid media. Ablation is carried out with laser operating at 1.064 nm wavelengths at flounce set in the range of 40.5J/cm$^2$ and (60 laser pulses). The diffraction peaks in the XRD pattern broadened due to the particles in the sample are too small. The primary particle size calculated by Sherrer formula is about 150 nm. The spherical nanoparticles morphologies were carried out by scan electron microscope (SEM) analysis, exhibits spherical with average size distribution found to be 20 nm.

Keywords: SnO$_2$, Bi$_2$O$_3$, Piezo- sensor, Laser ablation.

Introduction
Transparent conducting oxides (TCOs) are electrical conductive materials with a comparably low absorption of light such as ZnO, In$_2$O$_3$, SnO$_2$, ITO, and Bi$_2$O$_3$. They are usually prepared with thin film technologies and used in opto-electrical devices such as solar cells, displays, opto-electrical interfaces and circuitries. Glass fibers are nearly lossless conductors of light, but electrical insulators; silicon and compound semiconductors are wavelength dependent optical resistors (generating mobile electrons), but dopant dependent electrical conductors. Transparent conducting oxides are highly flexible intermediate states with both these characteristics. Their conductivity can be tuned from insulating via semiconducting to conducting as well as their transparency adjusted. As they can be produced as n-type and p-type conductive, they open a wide range of power saving opto-electrical circuitries and technological applications [1-5].

Transparent Conducting Oxides (TCOs). Transparent conducting oxides are degenerately doped semiconductor oxides that are transparent to visible light. These simultaneous properties enable numerous applications, such as flat-panel displays, photovoltaic devices, and light emitting diodes (LED) [6-7].

Method Section
Q-switched Nd/YAG laser system type HUAFEI providing pulses of 1064 nm and 532 nm(frequency doubled) wavelength with maximum energy per pulse of 1000 mJ, pulse width of 10 ns, repetition rate of 5 Hz and effective beam diameter of 5 mm, was used for laser ablation. The laser is applied with a lens with 110 mm focal length is used to achieve high laser flounce. SnO$_2$:Bi$_2$O$_3$ colloidal NPs were synthesized by pulsed laser ablation of Sn: Bi target (50%:50%) in double distilled water (DDW) at room temperature. High purity Sn:Bi target (purity of
99.99% was fixed at bottom of open a plastic cell containing of 2 ml of DDW, DDW+PVP, DDW+methanol and methanol only which represent the liquid media. Ablation is carried out with laser operating at 1064 nm wavelengths. The laser beam was focused on the Sn:Bi target using convex lens of 11 cm focal length to produce sufficient laser flounce for the ablation.

The typical laser beam diameter on the target was varied in the range of 3 mm in diameter by changing the distance between the focusing lens and the Sn:Bi target. The position of metal plate was continuously translated mechanically using a controlled motor. The colloidal solution vibrated for 10 min by ultrasonic vibrator in order to get homogeneity for the product. The spot size of the laser beam on the surface of the metal plate of 0.6 mm in radius (r). The lasers flounce (F) where:

\[ F = \frac{\text{Pulse energy}}{A} \quad \text{and} \quad A = 2\pi r^2 \]

**Results and Discussions**

From the elemental analysis of thin films which prepared from the target that composited from Tin oxide SnO2 and Bismuth oxide Bi2O3 for different liquid solution (i.e. DDW+PVP, DDW, DDW+methanol, and methanol) as shown in the figures below. Many peaks were observed corresponding to tin (Sn), bismuth (Bi) and oxygen (O) come from featuring material composition of SnO2 and Bi2O3.

**Figure (1):** EDX analysis for SnO2:Bi2O3 composite under DDW+PVP  
**Figure (2):** EDX analysis for SnO2:Bi2O3 composite under DDW
To clarify the crystalline structure, an XRD pattern of the as-prepared SnO$_2$:Bi$_2$O$_3$ thin film. The diffraction peaks at around are assigned to No diffraction peaks due to metallic Sn, Bi or other tin oxides an bismuth oxides were discerned. The diffraction peaks in the XRD pattern broadened due to the particles in the sample are too small. The primary particle size calculated and found to be about 20 nm.

Table (1) shows the structural parameters for SnO$_2$:Bi$_2$O$_3$ thin film which contain Bragg angle (2θ), full width at half maximum (FWHM), experimental inter-planar spacing d (calculated using Bragg low), crystalline size of SnO$_2$:Bi$_2$O$_3$ thin films (D) (calculated using Sheerer formula).
Table (1) Structural parameters: Inter-planar spacing, crystalline size of SnO$_2$:Bi$_2$O$_3$ thin films.

| 2θ (Deg.) | FWHM (Deg.) | d Exp.(Å) | D (nm) | hkl |
|-----------|-------------|-----------|--------|-----|
| 26.301    | 0.313       | 3.3884    | 25.8nm | 110 |
| 33.912    | 0.252       | 2.6434    | 33.6nm | 022 |
| 37.102    | 0.233       | 2.4231    | 33.7nm | 020 |
| 41.522    | 0.351       | 2.1748    | 23.6nm | 131 |
| 47.542    | 0.221       | 1.9125    | 38.4nm | 140 |
| 49.989    | 0.331       | 1.8245    | 27.5nm | 113 |
| 60.912    | 0.253       | 1.5209    | 36.4nm | 310 |

The photoluminescence properties of SnO$_2$:Bi$_2$O$_3$ thin films grown by laser ablation deposition technique were investigated with fixed substrate temperatures (50) °C with different numbers of pulses and voltages. X-ray diffraction showed that the crystallinity of the grown thin films increased with increasing the numbers of pulses, voltages and the type of solution. In this figure shows narrow peaks were observed from the photoluminescence measurements at (578nm, 573nm, 567nm and 56nm). The intensity and shape of the peaks changed with increasing the numbers of pulses and voltages. The intensity of the peaks increased to the highest value at (850) volt and 550 pulse in DDW+PVP liquid solution and were observed that in blue spectrum, red spectrum for (750) volt with 450 pulse in DDW solution, green spectrum for (750) volt with 350 pulse in DDW+methanol solution, black spectrum for (700) volt with 250 pulse in methanol solution. This study found that the peaks is due to the concentrations of oxygen vacancies in SnO$_2$ and Bi$_2$O$_3$ and to structural defects come from Some impurities formed with thin films.

![Photoluminescence spectra of the SnO$_2$:Bi$_2$O$_3$ thin films grown at different numbers of pulses and voltages in DDW+PVP liquid solution.](image)

Where, photoluminescence spectrum is the result of emission, which produced by the recombination of photo excited carriers, and lower photoluminescence peak intensity means slower recombination. All the composited samples exhibit lower emission peaks than that of pure samples.
Piezoelectric properties and sensitivity measurements

The resonance frequency can be determined by measuring the output voltage as a function of frequency as shown in figures (7)(8)(9)(10)(11)(12) and (13), these figures show that the good sensing for samples prepared was observed. The results show that the increasing in laser pulses caused to shifting the values of the resonance frequency to higher ranges, this means the change in the preparation condition led to a change in the sensitive of the film and it may due to change in the application of the films that every resonance frequency and amplitude have a limit application.

Figure (7): Output voltage as a function of frequency for transparent conductive oxides (SnO$_2$:Bi$_2$O$_3$ thin film) prepared under DDW solution and deposited on ITO substrate.

Figure (8): Output voltage as a function of frequency for transparent conductive oxides (SnO$_2$:Bi$_2$O$_3$ thin film) prepared under DDW solution and deposited on ITO substrate.
Figure (9): Output voltage as a function of frequency for transparent conductive oxides (SnO$_2$:Bi$_2$O$_3$ thin film) prepared under DDW+Methanol solution and deposited on ITO substrate.

Figure (10): Output voltage as a function of frequency for transparent conductive oxides (SnO$_2$:Bi$_2$O$_3$ thin film) prepared under DDW solution and deposited on silicon substrate.
Figure (11): Output voltage as a function of frequency for transparent conductive oxides (SnO$_2$:Bi$_2$O$_3$ thin film) prepared under DDW+Methanol solution and deposited on silicon substrate.

Figure (12): Output voltage as a function of frequency for transparent conductive oxides (SnO$_2$:Bi$_2$O$_3$ thin film) prepared under DDW solution and deposited on porous silicon substrate.
Figure (13) shows the output voltage as a function of frequency for transparent conductive oxides (SnO$_2$:Bi$_2$O$_3$ thin film) prepared under DDW+Methanol solution and deposited on porous silicon substrate.

In figures (14), (15), (16), (17) (18)(19)and(20) shown that the small shifting vanish with increasing the source frequency, but the variation in pulses and substrate type has no effect.

Where, the effect of substrate type on resonance frequency can be seen in figures (21)and (22) respectively, and its clearly the values of the resonance frequency increased by increasing pulses this means that the optimum sensitive obtained in and for substrate temperature 50 °C and the decreasing means that the samples reach the saturation state, while the increasing in the laser pulses caused to shifted in the values of resonance frequency to higher, and that means the sensitivity of the films increased and this may be due to the enhanced in the structure of the films.

Figure (14): Shows the intensity of sensitivity that appears as a wave on a screen of portable electrical device, DDW solution, ITO substrate, sensing for glucose.
Figure (15): Shows the intensity of sensitivity that appears as a wave on a screen of portable electrical device, DDW + Methanol solution, ITO substrate, sensing for glucose.

Figure (16): Shows the intensity of sensitivity that appears as a wave on a screen of portable electrical device, DDW + Methanol solution, ITO substrate, sensing for salt.
Figure (17): Shows the intensity of sensitivity that appears as a wave on a screen of portable electrical device, DDW solution, silicon substrate, sensing for glucose.

Figure (18): Shows the intensity of sensitivity that appears as a wave on a screen of portable electrical device, DDW+Methanol solution, silicon substrate, sensing for glucose.
Figure (19): Shows the intensity of sensitivity that appears as a wave on a screen of portable electrical device, DDW + Methanol solution, silicon substrate, sensing for salt.

Figure (20): Shows the intensity of sensitivity that appears as a wave on a screen of portable electrical device, DDW solution, porous silicon substrate, sensing for glucose.
Conclusions

Thin films were prepared by laser ablation technique from the transparent conductive oxide (SnO₂:Bi₂O₃) as a target for different liquid solution (i.e DDW+PVP, DDW, DDW+methanol, and methanol) and there with explanation the characterization of the prepared thin films. Also explanation the result of sensitivity measurements of the transparent conductive oxide (SnO₂, Bi₂O₃) thin films after deposition on the silicon, porous silicon and ITO substrates, to the glucose and salt concentrations.

References

[1] Evan T. Salem, " Tin Oxide Nanoparticles Prepared Using Liquid Phase Laser Ablation for Optoelectronic Application", Nanoscience and Nanotechnology 2012, 2(3): 86-89 DOI: 10.5923/j.nn.20120203.08.
[2] Luhua Jiang, Gongquan Sun, Zhenhua Zhou, Shiguo Sun, Qi Wang, Shiyou Yan, Huanqiao Li, Juan Tian, Junsong Guo, Bing Zhou, and Qin Xin, " Size-Controllable Synthesis of Monodispersed SnO₂ Nanoparticles and Application in Electrocatalysts", J. Phys. Chem. B 2005, 109, 8774-8778.
[3] A. J. Salazar-Pérez, M. A. Camacho-López, R. A. Morales-Luckie, V. Sánchez-Mendieta, F. Ureña-Núñez, J. Arenas-Alatorre, "Structural evolution of Bi₂O₃ prepared by thermal oxidation of bismuth nano-particles", *Superficies y Vacío* 18(3), 4-8, septiembre de 2005 ©Sociedad Mexicana de Ciencia y Tecnología de Superficies y Materiales.

[4] Arun Prakash Periasamy, Singying Yang, Shen-Ming Chen, "Preparation and characterization of bismuth oxide nanoparticles-multiwalled carbon nanotube composite for the development of horseradish peroxidase based H₂O₂ biosensor", *Talanta* 87 (2011) 15–23.

[5] R.K. Swarnkar, S.C. Singh and R. Gopal, "OPTICAL CHARACTERIZATIONS OF COPPER OXIDE NANOMATERIAL", ICOP 2009-International Conference on Optics and Photonics CSIO, Chandigarh, India, 30 Oct.-1 Nov. 2009.

[6] M. H. Shahrokh Abadi, M. N. Hamidon, Abdul Halim Shaari, Norhafizah Abdullah, Norhisam Misron and Rahman Wagiran, "Characterization of Mixed xWO₃(1-x)Y₂O₃ Nanoparticle Thick Film for Gas Sensing Application", *Sensors* 2010, 10, 5074-5089; doi:10.3390/s100505074.

[7] Abdulrahman Khalaf Ali, "Preparation of Ag and Au Nanoparticles by Pulsed Laser Ablation in Liquids", phd thesis, 2010, Iraq.