REFRACTIVE INDEX OF TUNGSTEN OXIDE NANOSTRUCTURED THIN FILMS GROWN AT ROOM TEMPERATURE BY CHEMICAL BATH DEPOSITION METHOD FOR OPTICAL GAS SENSING

Nwifior Kelechi

Department of physics, Ebonyi State College of Education, Ikwo, Ebonyi State, Niger
Nwifiokele@gmail.com, 08068396009

ABSTRACT

Refractive index is a dimensionless number that gives the indication of the light bending ability of the medium. It determines how much the path of light is bent or refracted when entering a material. It also determines the amount of light that is reflected when reaching the interface, as well as the critical angle for total internal reflection and their intensity. It can be seen as the factor by which the speed and the wavelength of the radiation are reduced with respect to their vacuum values. Tungsten Oxide (WO_3) Nanostructured thin films were successfully developed on glass substrates using chemical bath deposition method at a temperature of 300K. The sources of W^+ is $Na_2WO_4.2H_2O$. EDTA was used as a complexing agent. WO_3 nanostructured thin film was prepared at the deposition periods of 24 and 29 hours. The optical characterization was done using Prolab-U756S UV-Vis Spectrophotometer measurements in the wavelength range from 200−1100nm, i.e. within the ultraviolet, visible and NIR regions of electromagnetic spectrum. My interest in this paper is on the effects of the concentrations of the precursor on the refractive indices of the thin films. Since the refractive indices of the film samples with tungsten oxide nanostructured concentrations of 0.1− 0.4M are 2.12, 2.30, 2.04 and 2.64 (which are above unity) respectively. The steadiness and stability of the refractive indices across the visible and infrared regions qualify these films good candidates for optical gas sensors.

Keywords: Refractive indices, tungsten oxide, concentration, thin film.

1.INTRODUCTION

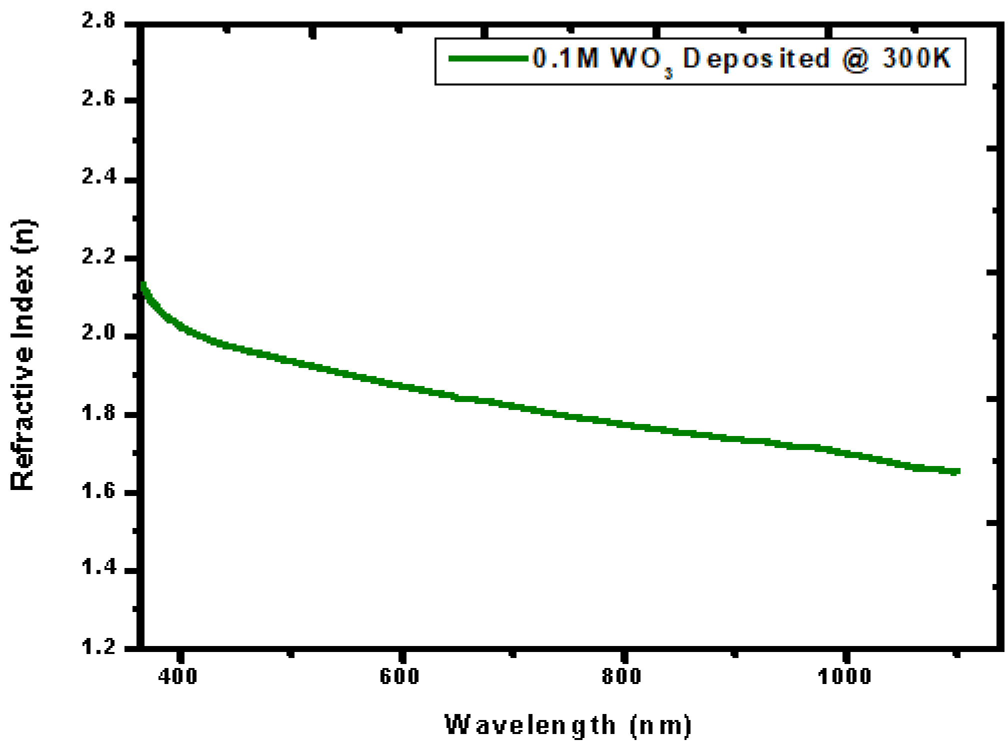
Nanoscience is the study of the fundamental principles of molecules and structures with nanoscale size in the range between 1nm to 100nm. Nanotechnology is the application of nanoscience in technological devices and also the manipulation of materials in nanoscale. Currently, nanotechnology was used to design one of the technological devices called a gas sensor. The increase in exhaust emissions of gases from industries has put a large demand on the sensitive and selective detection of hazardous gases for environmental pollution monitoring, process, control and safety for human health (Duncan, 2011., Lopez-Lorente & Valcarcel, Lopez-Lorente, 2016 & Valcarcel, et al., 2016). The nanostructured thin films are composed of thin layers of nanostructured particles such as nanorodes, nanowires, nanotube etc. The nanounits working together can show special properties that differ from that ones the individual objects have. The study and use of these nanoscale films came in focus in the years passed on different fields of sciences such as chemistry, engineering, physics, medicine. Nanostructured metal oxides, polymers and porphyrins are outstanding materials for application as sensors having ultrahigh sensitivity, switching like response and highselectivity (Ishihara, et al., 2014., Sanghavi, et al., 2015., Arafat, et al., 2012., Lee, et al., 2009 & Biju, 2014). Gas sensors based on metal oxides are very useful for detecting trace amount of pollutants in air at ppm and ppb levels. Tungsten trioxide thin films have captured the interest of research societies due to its remarkable signatures in optoelectronics and other sectors of technology. Tungsten (VI) oxide is known as tungsten trioxide is a chemical compound of oxygen and the transition metal tungsten. The compound is also called tungstic anhydride, reflecting its relation to tungstic acid H_2WO_4. It is a light yellow crystalline solid (Christian, et al., 2011). WO_3 is an n-type semiconductor having wide and indirect band gap in the range of 2.5–3.5 eV (Patel, et al., 2009., Johansson, et al., 2013., Keshri, et al., 2011., Usta, et al., 2012 & Joraid & Alamri, 2007). Besides gas sensing, tungsten trioxide films have excellent electrochromic, photoluminescent, smart windows and memresitive applications (Subrahmanyam & Karuppasamy, 2007., Feng, et al., 2006 & He, et al., 2013).

2. MATERIALS AND METHOD

Tungsten oxide nanostructured thin films were deposited using chemical bath deposition method.

Before the deposition, the glass substrates were degreased in acetone for 24 hours, washed with detergent, rinsed with de-ionized water and dried in air. The purpose of degreasing the surfaces is to provide nucleation centers for proper adhesive of the films, thereby yielding uniformity grown films. The films were grown at concentrations of 0.1M−0.4M at room temperature for 24 and 29 hours respectively. The reaction bath contains the solution of the mixture of $Na_2WO_4.2H20$, EDTA, HCL, and hydrogen perioxide which is the source WO_3. The complexing agent used in this work is EDTA which slows down the reaction in order to eliminate spontaneous precipitation. The substrates were dipped into the reaction baths vertically with help of the perforated synthetic foam. The substrates were allowed to remain in the bath for 24 hours after the films were removed from the reaction bath. The films were washed in de-ionized water and dried in air. After the deposition, the films were characterized for optical transmittance using Prolab-U756S UV-Vis Spectrophotometer. Refractive indices were determined using mathematical calculation in this paper.

3. RESULT AND DISCUSSION



Figures 1 to 4: show the plots of refractive index against wavelength of WO3 nanostructured thin film of 0.1M–0.4M grown at 300K.

Figure 1: Plots Refractive Index Against Wavelength of 0.1M at 300K

Figure 1, shows that plot of refractive index against wavelength of 0.1m layer. It indicates that refractive index increased to 2.12 and decrease sharply at the wavelength range of 380nm to

400nm and then remain steadily exhibiting minimum in the across the visible and infrared regions.

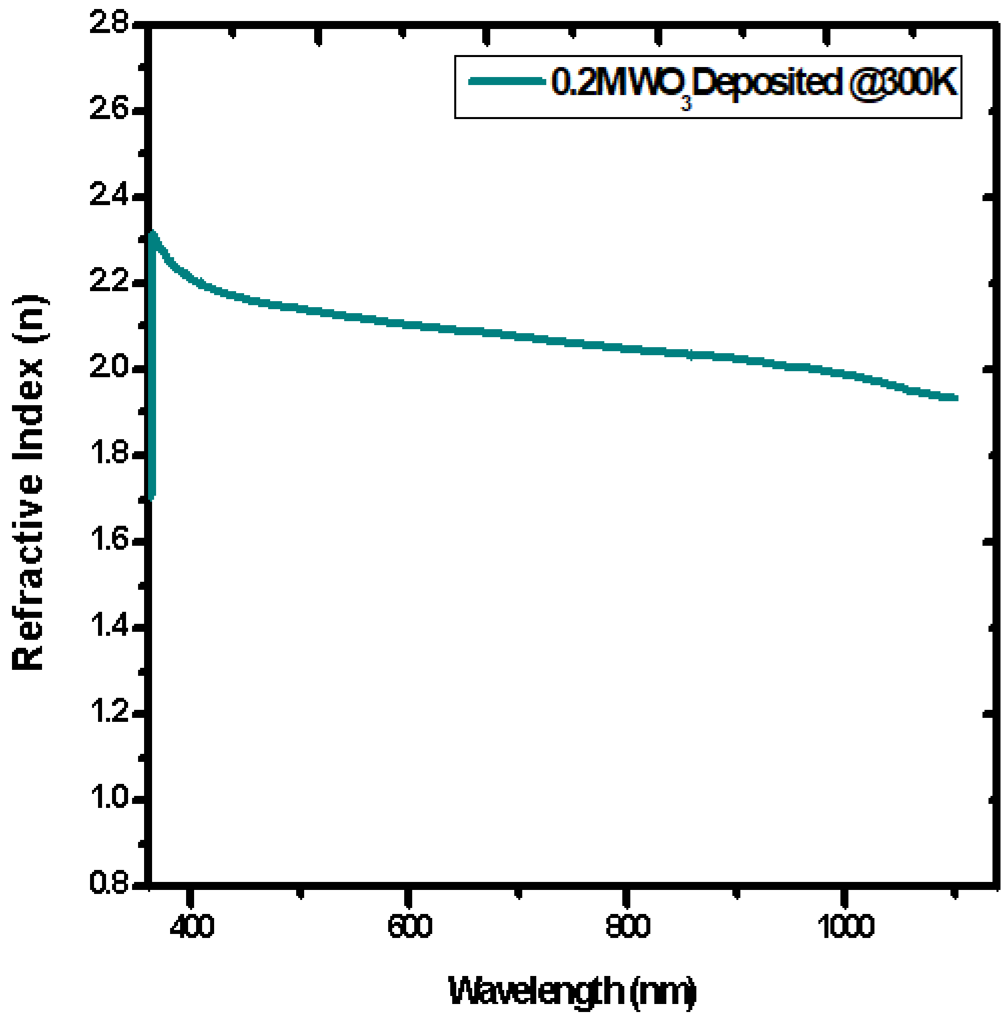
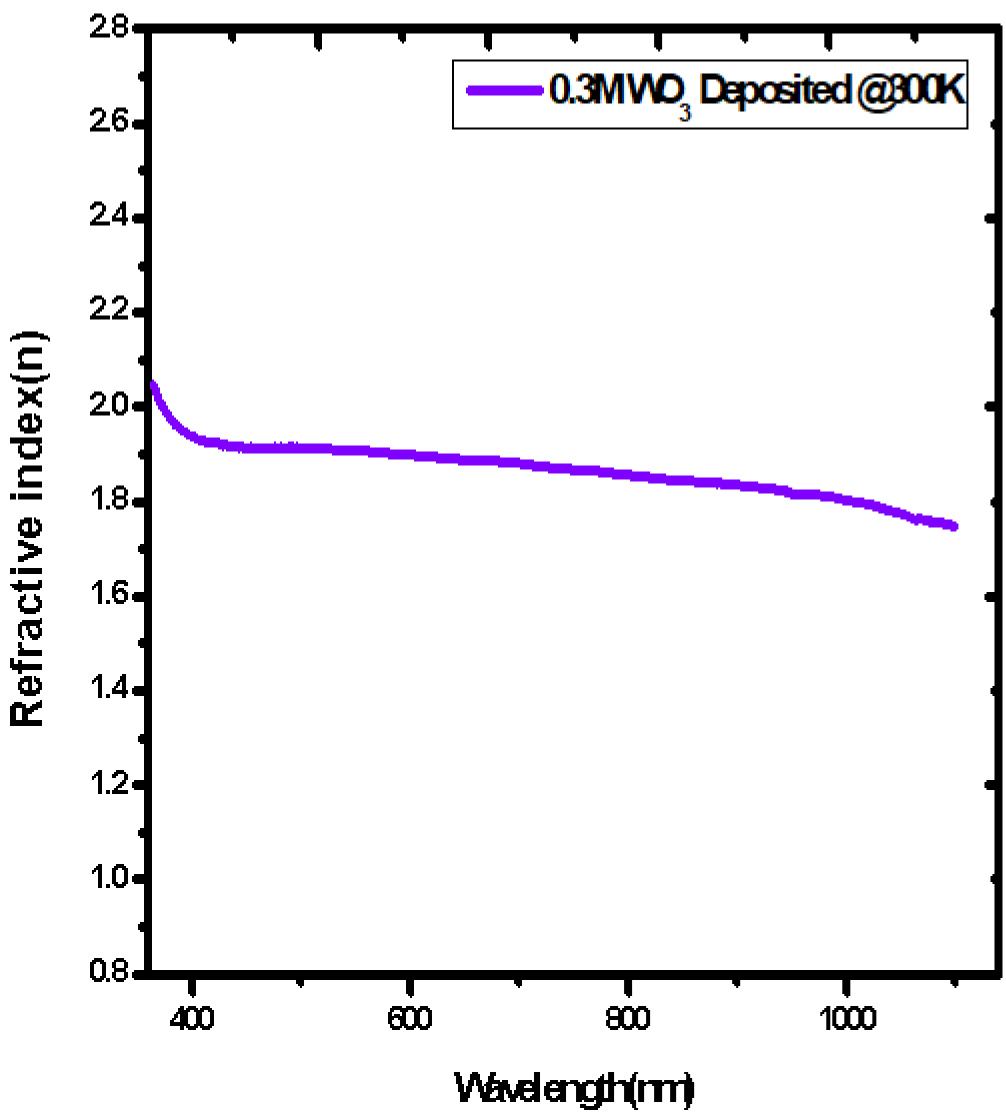


Figure 2: Plots of Refractive Index Against Wavelength of 0.2M at 300K

Figure 2, show the plots of refractive index against wavelength of 0.2M layer. It was observed that it increased from 1.7 to 2.3 and decreases sharply at the wavelength range of 380nm to 400nm exhibiting similar trend in the visible and infrared regions

Figure 3: Plots of Refractive Index Against Wavelength of 0.3M at 300K

Figure 3, shows the plot of refractive index against wavelength of 0.3M layer. It was observed that the refractive index increased to 2.04 and decrease sharply at the wavelength range of 380nm to 400nm and then remain steady across the visible and infrared regions



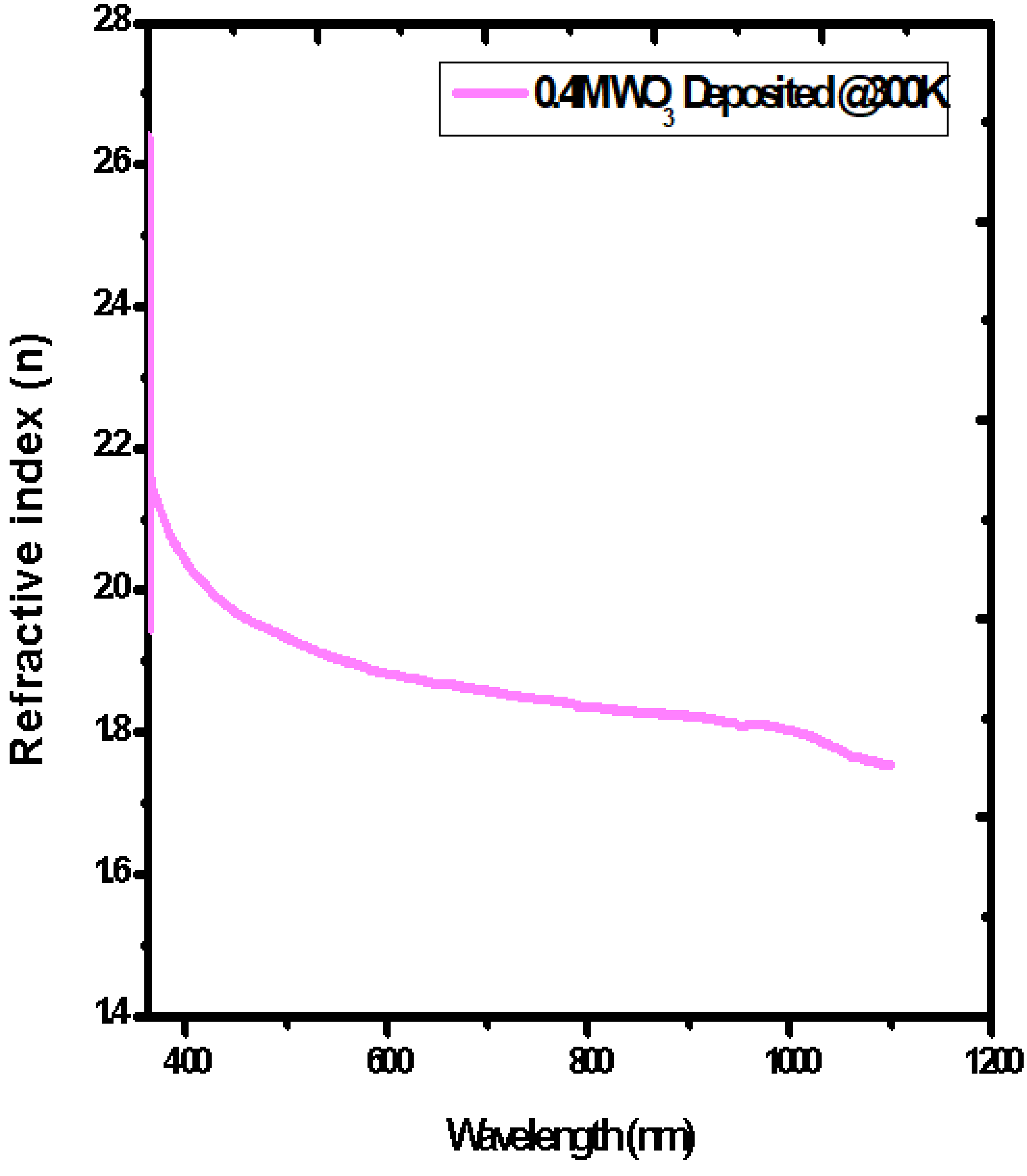


Figure 4: Plots of Refractive Index Against Wavelength of 0.4M at 300K

Figure 4, shows the plot of refractive index against wavelength of 0.4 layer. From the graph, it was observed that the refractive index increased 1.94 to 2.64 and sharply drops to 2.14 at the wavelength range of 380nm to 400nm and then linearly remain steady exhibiting minimum in the visible and infrared regions

4. CONCLUSION

Tungsten oxide (WO3) nanostructured thin film was deposited on the glass substrates using chemical bath deposition method at room temperature. The films were characterized for optical transmittance using Prolab-U756S UV-Vis Spectrophotometer. The refractive index properties were determined using mathematical calculations. The origin software was used to plot the graphs. The results obtained showed that the material fabricated is a perfect candidate for optical gas sensor. Based on the exhibited properties of the films, it can be concluded that the films are also promising material for various applications such as gas sensors and optoelectronic device applications

5. RECOMMENDATION

I recommend that further researchers should investigate and confirm the results through mathematical modeling.

REFERENCE

1. Arafat, M.M., Dinan, B., Akbar, S.A. & A. S. M. A. Haseeb, A.S.M.A. (2012). Sensors 12, 7207.

2. Biju, V. (2014).Chem. Soc. Rev. 43, 744.

3. Christian, J., Singh Gaur, R.P., Wolfe T. & Trasorras, J.R.L. (2011). Tungsten Chemicals and their Applications. Brochure by International Tungsten Industry Association.

4. Duncan, T.V. (2011). Applications of nanotechnology in food packaging and food safety: Barrier materials, antimicrobials and sensors. *Journal of Colloid and interface Science* 363, 1-24.

5. Feng, M., Pan, A.L., Zhang, H.R., Li, Z.A., Liu, F., Liu, H.W., Shi, D.X., B. S. Zou, B.S. & Gao, H.J. (2006). Appl. Phys. Letters 86, 141901

6.He, X., Yin, Y., Guo, J., Yuan, H., Peng, Y., Zhou, Y., Zhao, D., Hai, K.,W. Zhou, W. & D. Tang, D. (2013). Nanoscale Research Lett. 50, 1.

7. Ishihara, S., Labuta, J., Rossom, W.V., Ishikawa, D., Minami, K., P.Hillab, J. & Ariga, K. (2014). Phys. Chem. Chem. Phys. 16, 9713.

. 8. Johansson, M.B., Baldissera, G., Valyukh, I., Persson, C., Arwin, H., G. A. Niklasson, G.A. & Osterlund, L. (2013). J. Phys. Condens. Matter 25, 1.

. 9. Joraid A.A. & S. N. Alamri, S.N. (2007). Physica B 391, 199.

10. Keshri, S., Kumar, A. & D. Kabhiraj, D. (2011). J. Nano-Electron. Phys. 3, 260.

11. Lee, J.H. (2009). Sensors and Actuators B 140, 319.

12. Lopez-Lorente, A.I. & Valcarcel, M. (2016). The third way in analytical nanoscience and nanotechnology: Involvement of nanotools and nanoanalytes in the same analytical process. Trends in Analytical Chemistry 75, 1-9.

. 13. Patel, K.J., Panchal, C.J., Kheraj, V.A. & M. S. Desai, M.S. (2009). Mater.

Chem. Phys. 114, 475.

14. Sanghavi, B.J., Wolfbeis, O.S., Hirsch,T. &N. S. Swami, N.S. (2015). Microchim Acta 182, 1.

.15. Shi, X., B. S. Zou, B.S. & H. J. Gao, H.J. (2006). Appl. Phys. Letters 86, 141901.

16. Subrahmanyam A. & Karuppasamy, A. (2007). Sol. Energy Mater. Sol.Cells 91, 266.

. 17. Usta, M., Kahraman, S., Bayansal, F. & H. A. Çetinkara, H.A. (2012). Superlattices Microstruct. 52, 326.

18. Zhang, W., Hu, M., Liu, X., Wei, Y., Li, N. & Qin, Y. (2016). Synthesis of the cactus-like silicon nanowires/tungsten oxide nanowires composite for room-temperature NO2 gas sensor. *Journal of Alloy and Compounds* 679, 391-399