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Study of some optical properties of cupric oxide

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Abstract

In this work Oxidation method was used to prepare nanostructure of cupric oxide (CuO) film. The aim of this work is to calculate the results obtained via experiments conducted on samples of CuO, UV-Visible spectrophotometer was used at normal incident of light in the wavelength range of 200–1100nm . The UV–vis spectrum of the material shows significant amount of blue-shift in the band gap energy(Eg) and is found to be 2.458 eV due to the quantum confinement effect exerted by the nanocrystals.

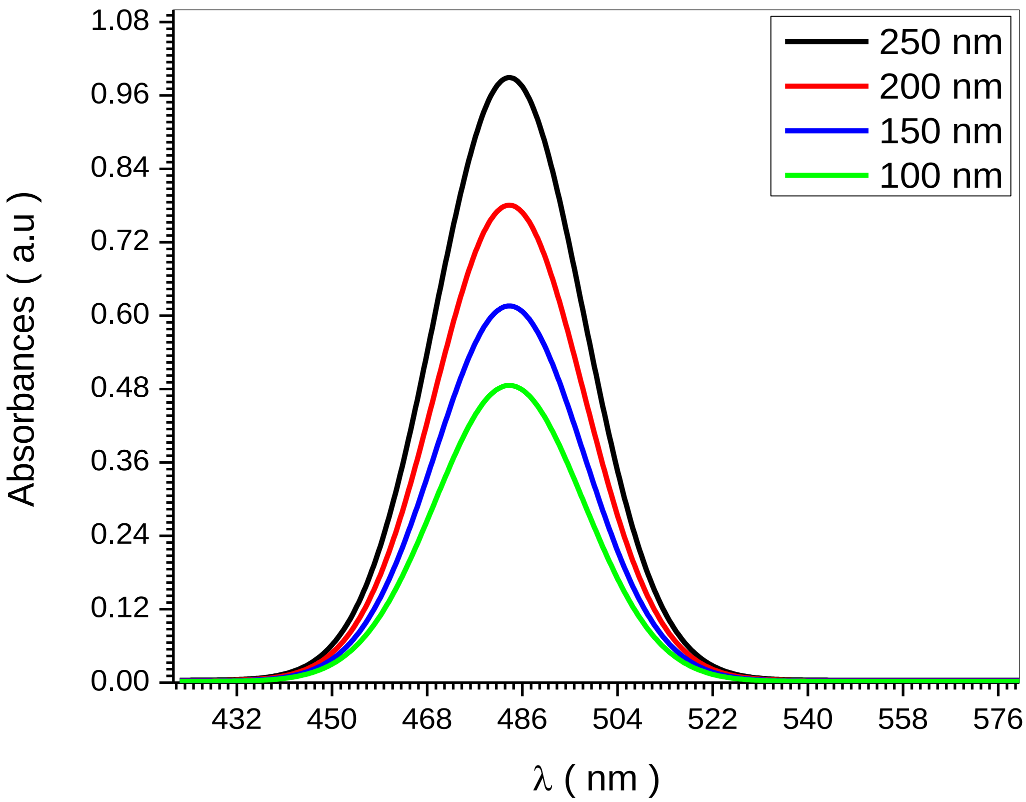
Keywords: cupric oxide (CuO), Oxidation method, Thin films, optical properties, quantum confinement.

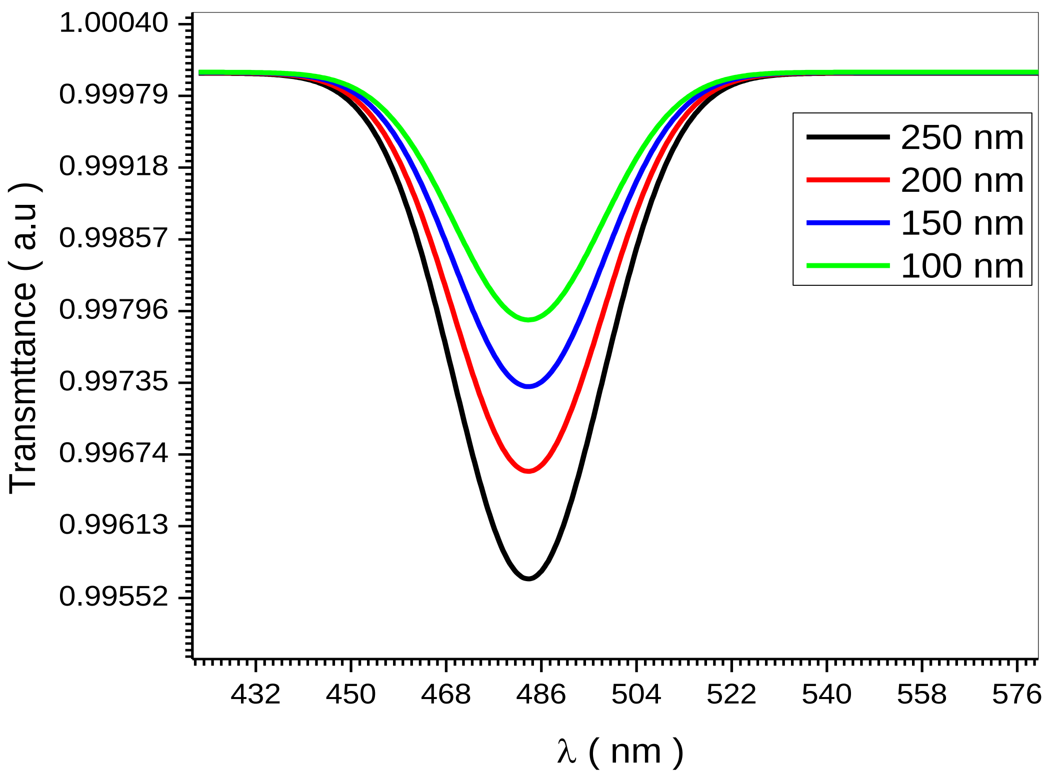
1.Introduction:

Research interest in nanomaterials has increased exponentially thanks to their unique chemical and physical features, different of those of their bulk materials, including but not limited to diffusivity, electrical resistivity, electrical conductivity, strength and hardness, chemical reactivity and diverse and versatile biological activity [1,2][3]. Nanocrystalline semiconductor particles have drawn considerable interest in recent years due to their interactive properties such as large surface-to-volume ratio and distinctive electronic and optical properties as compared to bulk materials [4]. Nanomaterials are different from bulk materials and isolated molecules because of their unique optical, electronic and chemical properties [5, 6]. They manifest extremely fascinating and useful properties, which can be exploited for a variety of structural and non-structural applications [7]. Metal oxide nanoparticles belong to a family of nanomaterials that have been manufactured on a large scale for both industrial and household applications, and they hold promise for future applications [8, 9]. Copper Oxide is an extensively studied group II-VI semiconductor with optical properties that permits stable emission at room temperature having immense application in sensors, field emission and photonic devices [10].Nanoparticles of CuO can be used as gas sensors, optical switch, and magnetic storage media owing to its photoconductive and photochemical properties [11]. Furthermore it is a promising semiconductor for solar cell fabrication due to its suitable optical properties[12,13].

Copper oxide, a semiconductor transition metal oxide with a band gap of 1.2 eV, has attracted greater attention since it is used for photoconductive and photothermal applications [14]. An improved understanding of nanoparticles and biological cell interactions leads to the development of new sensing, diagnostic, and treatment capabilities, such as improved targeted drug delivery [15], gene therapy, magnetic resonance imaging (MRI) contrast agents [16], and biological warfare agent detection [17]. Nano-sized copper oxide possesses good potential for photo-catalytic [18,19], and sensing applications [2,21]. Also, their usage in bio-related fields including fouling control and nano-toxicology [22,23] are being explored. Nanoparticles may or may not exhibit size-related properties that differ significantly from those observed in fine particles or bulk materials [24, 25].

In the past few years, the different morphologies of copper oxide nanoparticles like nanorods [26], nanoleaves [27], nanowires [28, 29], nanoribbons [30], nanobelts [31], dumbbell-like [32], urchinlike [33], flower-like [34] and plate-like [35] nanoarchitectures are developed for numerous practical applications. In this direction, vapour and liquid phase techniques are the two broad methods for preparing size and shape selective nanoparticles. Liquid phase techniques [36 - 37,38,39] were most widely used due to ease in operation and being a promising one to obtain different size and shape. However, each technique has its own merits and demerits in terms of purity of particles, equipment cost and synthesis time [40,41,42].


250 nm
200 nm
150 nm
100 nm
Absorbances (a.u)
λ (nm)
1.08
0.96
0.84
0.72
0.60
0.48
0.36
0.24
0.12
0.00
432
450
468
486
504
522
540
558
576


1.00040
0.99979
0.99918
0.99857
0.99796
0.99735
0.99674
0.99613
0.99552
Transmtance (a.u)
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200 nm
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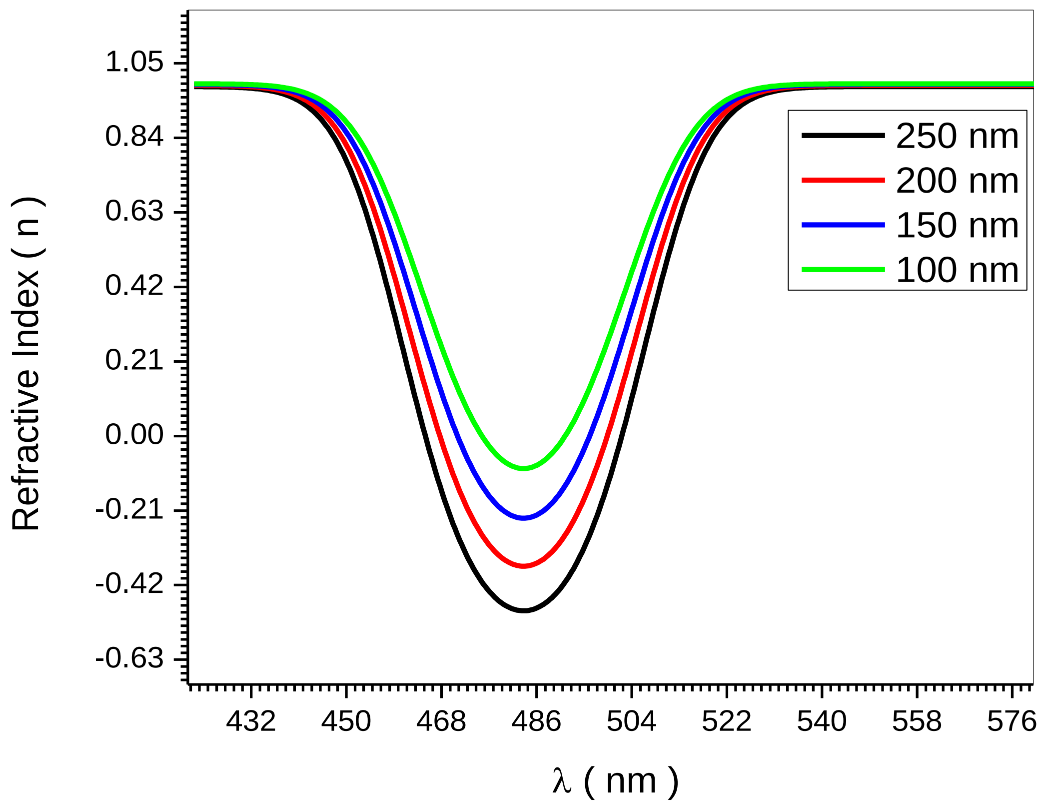
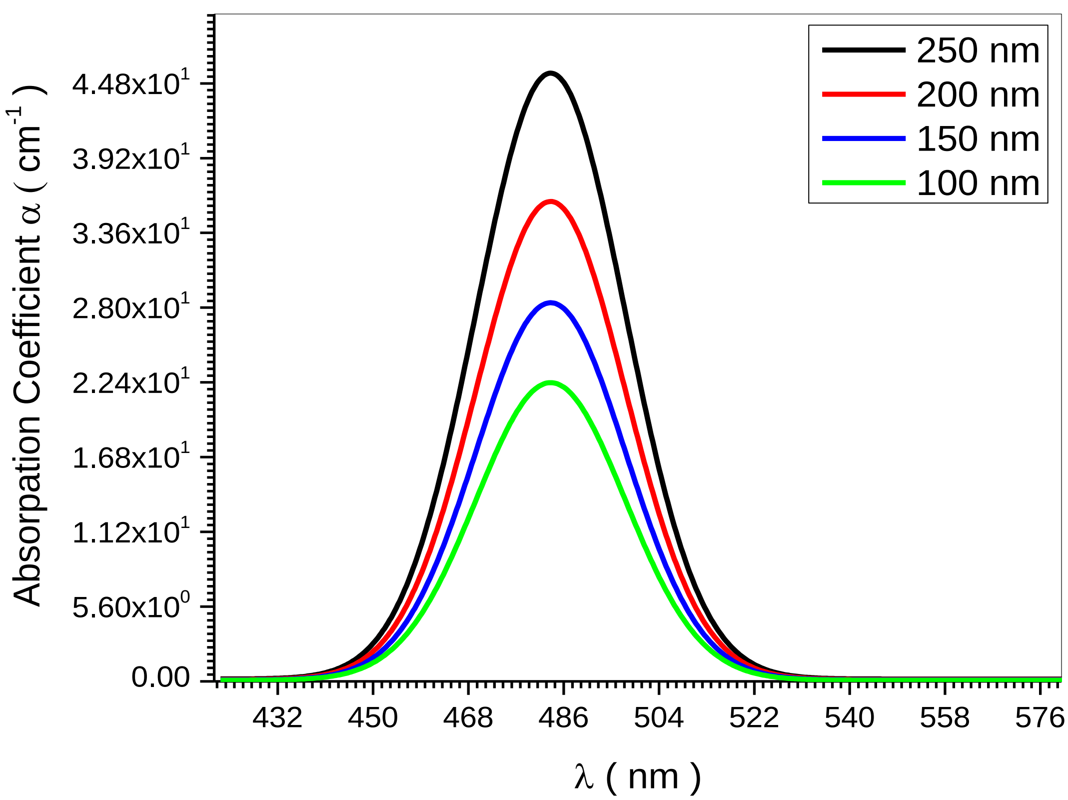
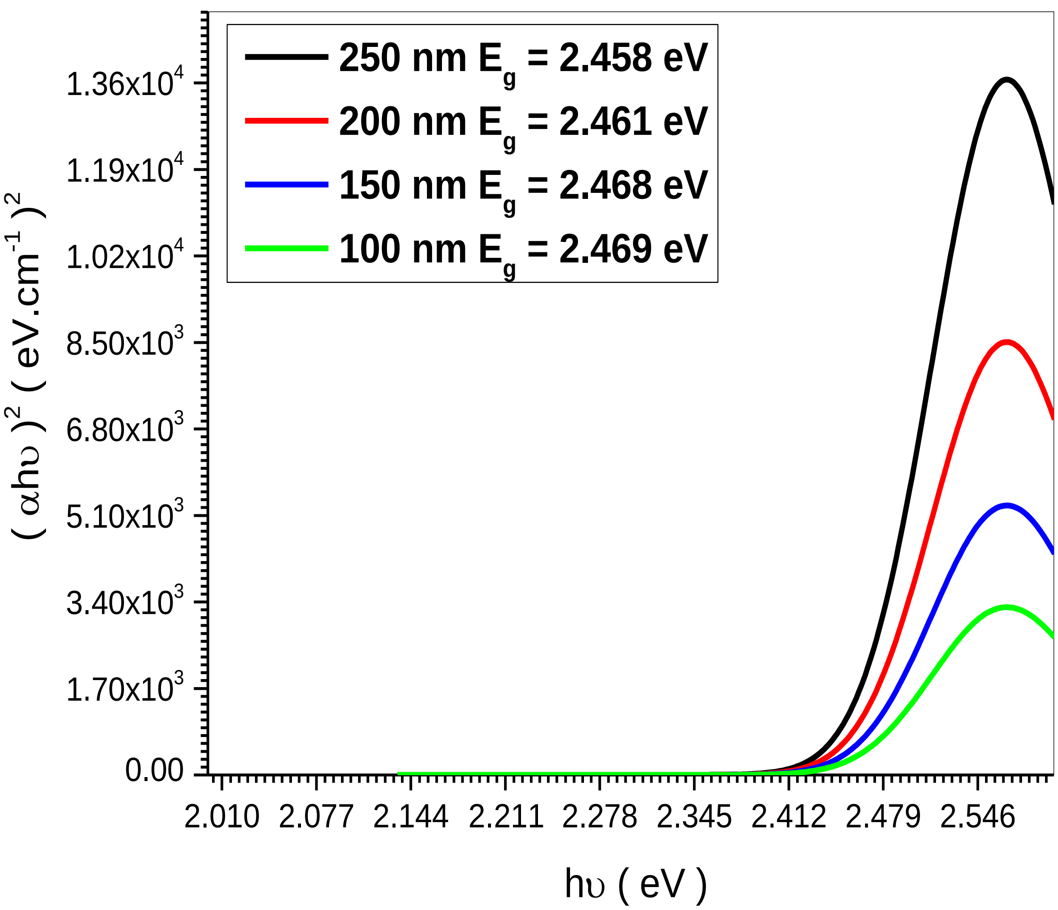
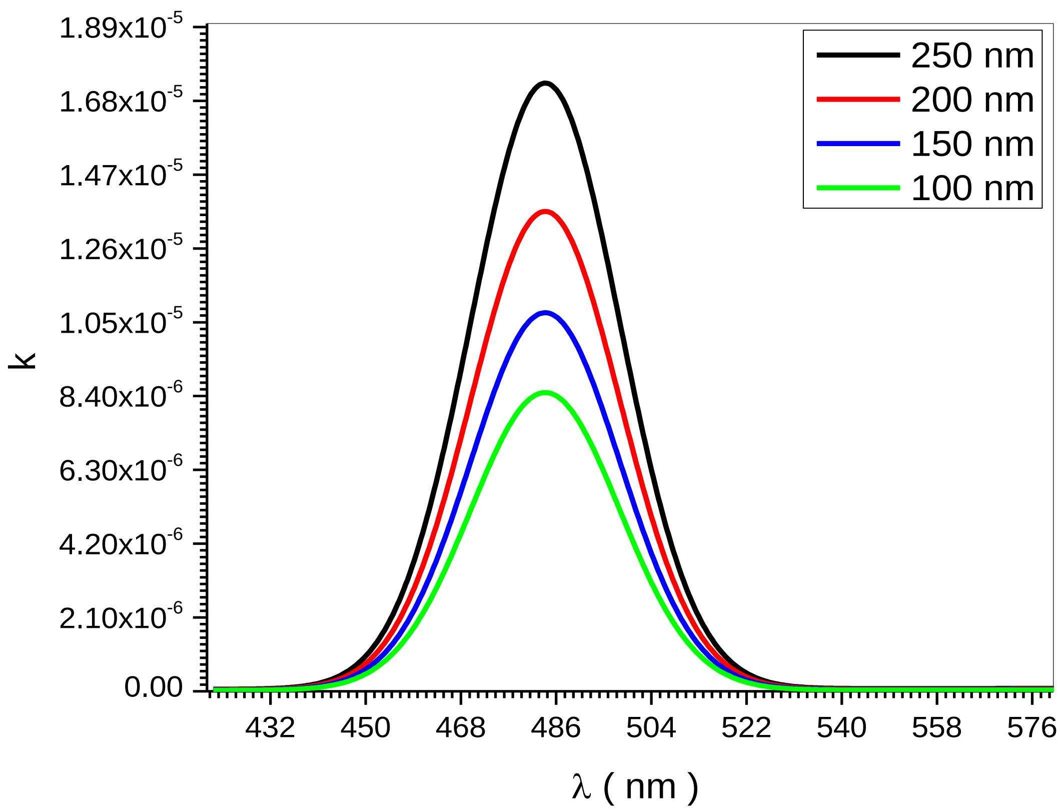

Refractive Index (n)
1.05
0.84
0.63
0.42
0.21
0.00
-0.21
-0.42
-0.63
432
450
468
486
504
522
540
558
576
λ (nm)
250 nm
200 nm
150 nm
100 nm


250 nm
200 nm
150 nm
100 nm
Absorpation Coefficient α (cm-1)
4.48x10^1
3.92x10^1
3.36x10^1
2.80x10^1
2.24x10^1
1.68x10^1
1.12x10^1
5.60x10^0
0.00
432
450
468
486
504
522
540
558
576
λ (nm)


250 nm E_g = 2.458 eV
200 nm E_g = 2.461 eV
150 nm E_g = 2.468 eV
100 nm E_g = 2.469 eV
$(\alpha h\upsilon)^2$ (eV.cm^{-1})^2
1.36x10^4
1.19x10^4
1.02x10^4
8.50x10^3
6.80x10^3
5.10x10^3
3.40x10^3
1.70x10^3
0.00
2.010
2.077
2.144
2.211
2.278
2.345
2.412
2.479
2.546
$h\upsilon$ (eV)


1.89x10^{-5}
1.68x10^{-5}
1.47x10^{-5}
1.26x10^{-5}
1.05x10^{-5}
8.40x10^{-6}
6.30x10^{-6}
4.20x10^{-6}
2.10x10^{-6}
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432
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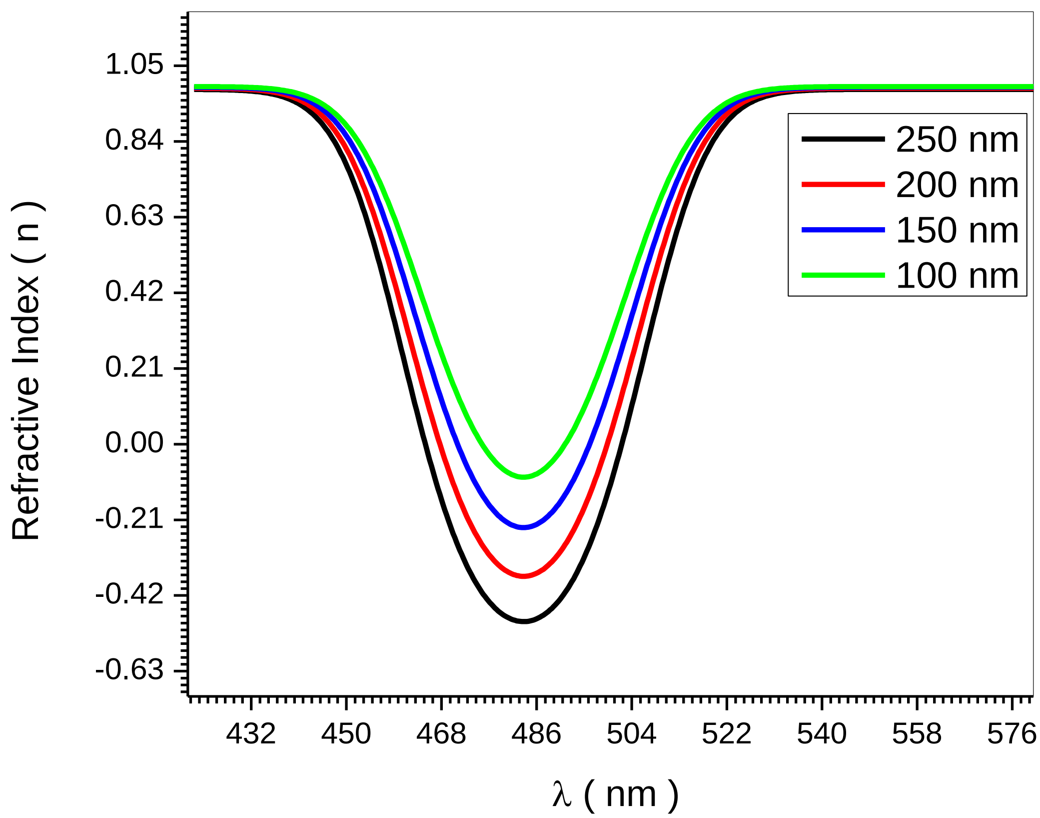
504
522
540
558
576
λ (nm)
250 nm
200 nm
150 nm
100 nm


Refractive Index (n)
λ (nm)
250 nm
200 nm
150 nm
100 nm
1.05
0.84
0.63
0.42
0.21
0.00
-0.21
-0.42
-0.63
432
450
468
486
504
522
540
558
576

Result and Discussion

Determination of the optical properties of CuO

The optical absorption (A), transmittance (T) and reflectance(R) spectra in the (420–580) nm wavelength range for CuO thin film are depicted in Fig. (1) the maximum absorption observed at wavelength (465-502 nm) region then it decreases to CuO at wavelength >484 nm. The absorption edge of the film occurs at wavelength (484 nm) corresponding to photon energy (2.56 eV).

The optical transmittance and reflectance of the films as a function wavelength are shown in Fig.(2) and fig (3) , the transmittance spectra increase in the wavelength e (483.7 nm) and the curves reach's saturation above 523 nm and the average transmittance of the films is 99.79 % . Fig (3) show the reflectance spectra and it has a maximum value at region (441-527.5 nm) and it decreases in the wavelength region (452-518 nm).

Determination of optical constant:

The energy band gap of these materials is determined using the absorption spectra. According to the Taucc relation, the absorption coefficient α for direct band gap material is given by Sharma [43]

$$\alpha h\nu = B(h\nu - E_g)^n \qquad (1)$$

Where the (E_g) energy gap, (B) constant is different for different transitions, (hυ) is energy of photon and (n) is an index which assumes the values 1/2, 3/2, 2 and 3 depending on the nature of the electronic transition responsible for the reflection. The absorption coefficient, is given by

$$\alpha = \frac{2.303*A}{d} \qquad (2)$$

Where (d) is the thickness of the sample and (A) is the absorbance. Fig. (4) shows the plot of (α) with wavelength (λ), which obtained that the value of $\alpha > 4.48\ cm^{-1}$ for all films in the visible region , this means that the transition must corresponding to a direct electronic transition [44] , and the properties of this state are important since they are responsible for electrical conduction. Also, fig (4) shows that the value of (α) decrease in absorbance coefficient when decrease thickness of the thin films. To understand the nature of energy band gap transition in this material, a graph of hυ vs $(\alpha h\upsilon)^2$ is drawn for the case of sample as shown in Fig (5). The plot in the figure is a straight line, the slope of which gives n = 2. This confirms that the transition is a forbidden direct transition in these materials. When graph is plotted between hυ and $(\alpha h\upsilon)^2$, a straight line is obtained. The extrapolating of the straight part of the curve to meet the(x) axis, the intersection point gives the energy gap of the sample as it is shown in the Fig (5) the value of (Eg) obtained was (2.458) eV , which is approach the value of (2.469) eV .

The refraction index of the CuO thin film is given by the following relation [45]

$$n = [\left(\frac{1+R}{1-R}\right)^2 - (1-k^2)]^{\frac{1}{2}} + \frac{1+R}{1-R} \qquad (3)$$

Where (k) is the extinction coefficient $k = \frac{\alpha\lambda}{4\pi}$ which is shown in the Fig.(6) and it is noticed that the refractive index has a maximum value of 1.00652786 at wavelength 548.8 nm as shown in the Fig. (7), which is due to interactions takes place between photons and electrons. The refractive index changes with the variation of the wavelength of the incident light beam due to these interactions, i.e.

the optical loss caused by absorption and scattering, which decreases the amplitudes of the transmission intensity oscillations at shorter wavelengths.

Conclusion

Copper Oxide is an extensively studied group II-VI semiconductor with optical properties, in this paper Oxidation method was used to prepare nanostructure of cupric oxide (CuO) film. Thin film of Copper metal were deposited on substrate (quartz) in a thermal vacuum evaporator. The thickness of the film was measured to about 20 μm. The thermal oxidation of this evaporated film was done in a horizontally heated quartz furnace at temperature (400°C) **,** through this studies. Optical properties of CuO nanoparticles were analyzed clarified through UV absorption. The direct band gap of CuO nanoparticles was found to be) the value of (Eg) obtained was (2.458) eV , which is approach the value of (2.469) eV .and this value was large. Moreover, the absorption coefficient, optical conductivity, refractive index along with extinction coefficient and energy gap were calculated through UV absorption**,** The CuO nanoparticles could be used as an extensive semiconductor, optical devices, solar cell applications, and so on.

References

[1] Sahooli, M.; Sabbaghi, S.; Saboori, R. Synthesis and characterization of mono sized CuO nanoparticles.
Mater. Lett. 2012, 81, 169–172. [CrossRef]

[2] Khashan, K.S.; Sulaiman, G.M.; Abdulameer, F.A. Synthesis and Antibacterial Activity of CuO Nanoparticles
Suspension Induced by Laser Ablation in Liquid. Arab. J. Sci. Eng. 2016, 41, 301–310.

[3] Methods of Synthesis, Properties and Biomedical Applications of CuO Nanoparticles, Madalina Elena Grigore etal, Academic Editor: Jean Jacques Vanden Eynde Received: 17 August 2016; Accepted: 22 November 2016; Published: 30 November 2016.

[4] (Huang et al. 2010; Son et al. 2009; Xu

[5] Study of structural and optical properties of cupric oxide Nanoparticles ,N. R. Dhineshbabu1 et al, Appl Nanosci (2016) 6:933–939 DOI 10.1007/s13204-015-0499-2

[6] Sahooli, M.; Sabbaghi, S.; Saboori, R. Synthesis and characterization of mono sized CuO nanoparticles.
Mater. Lett. 2012, 81, 169–172.

[7] Khashan, K.S.; Sulaiman, G.M.; Abdulameer, F.A. Synthesis and Antibacterial Activity of CuO Nanoparticles

Suspension Induced by Laser Ablation in Liquid. Arab. J. Sci. Eng. 2016, 41, 301–310.

[8]Ahamed, M.; Siddiqui, M.A.; Akhtar, M.J.; Ahmad, I.; Pant, A.B.; Alhadlaq, H.A. Genotoxic potential of copper oxide nanoparticles in human lung epithelial cells. Biochem. Biophys. Res. Commun. 2010, 396, 578–583.

[9]Mortimer, M.; Kasemets, K.; Kahru, A. Toxicity of ZnO and CuO nanoparticles to ciliated protozoa
Tetrahymena thermophila. Toxicology 2010, 269, 182–189.

[10] Katwal, R.; Kaur, H.; Sharma, G.; Naushad, M.; Pathania, D. Electrochemical synthesized copper oxide nanoparticles for enhanced photocatalytic and antimicrobial activity. J. Ind. Eng. Chem. 2015, 31, 173–184.

[11] Nations, S.; Long, M.; Wages, M.; Maul, J.D.; Theodorakis, C.W.; Cobb, G.P. Subchronic and chronic developmental effects of copper oxide (CuO) nanoparticles on Xenopus laevis. Chemosphere 2015, 135, 166–174.

[12]Perreault, F.; Melegari, S.P.; Da Costa, C.H.; Rossetto, A.L.d.O.F.; Popovic, R.; Matias, W.G. Genotoxic effects of copper oxide nanoparticles in Neuro 2A cell cultures. Sci. Total Environ. 2012, 441, 117–124.

[13] G. Varughese1, et al, CHARACTERISATION AND OPTICAL STUDIES OF COPPER OXIDE NANOSTRUCTURES DOPED WITH LANTHANUM IONS, DOI: 10.2478/adms-2014-0021

[14] Javier, V; J. Phys. Chem. Lett.2013, 4, 653. DOI:10.1021/jz302100r

[15] Dipranjan, L.; Arindam, P.; Sourav, C.; Sandip, K. D.; Somenath, R.; Panchanan, P.; Parimal, K; RSC Adv.2015, 5, 68169.
DOI: 10.1039/c5ra08110f

[16] Perlman, O.; Iris, S. W.; Haim, A; Phys. Med. Biol.2015, 60, 5767.
DOI:10.1088/0031-9155/60/15/5767

[17] Ayekpam, B.; Dinesh, S. M.; Narayan, C. T.; Damayanti, D. M.; Rajen, S. N.; Meitram, N. L; Chin. Chem. Lett.2014, 25, 1615.
DOI: 10.1016/j.cclet.2014.07.014

[18]Zaman, S.; Zainelabdin, A.; Amin, G.; Nur, O.; Willander, M; J. Phys. Chem. Solids, 2012, 73, 1320. DOI:10.1016/j.jpcs.2012.07.005

[19] Juan, W.; Wei-De, Z; Electrochim. Acta,2011, 56, 7510.
DOI:10.1016/j.electacta.2011.06.102

[20] Ren, G.; Hu, D.; Cheng, E. W. C; Int. J. Antimicrob. Agents, 2009, 33, 587.
DOI: 10.1016/j.ijantimicag.2008.12.004

[21] Henrich; Victor; Cox, P. A; The Surface Science of Metal Oxides, Cambridge University Press, 2000. ISBN: 0521566878

[22] Zhipeng, C.; Jiming, X.; Hui, Z.; Xiaozhong, C.; Juan, S; Mater. Lett.2011, 65, 2047. DOI:10.1016/j.matlet.2011.04.021

[23] Wang, L.; Gong, H.; Wang, C.; Wang, D.; Tang, K.; Qian, Y; Nanoscale, 2012, 4, 6850. DOI:10.1039/c2nr31898a

[24] Manoj, D.; Ranjith Kumar, D.; Santhanalakshmi, J; Appl. Nanosci.2012, 2, 223. DOI:10.1007/s13204-012-0093-9

[25]Anita Sagadevan, E.; Joon Kang, D; Nanoscale Res. Lett.2012, 7, 70. DOI:10.1186/1556-276X-7-70

[26] Hong, X.; Wang, G.; Zhu, W.; Shen, X.; Wang, Y; J. Phys. Chem. C, 2009, 113, 14172. DOI:10.1021/jp9039786

[27] Qing, Y.; Hongwen, H.; Ru, C.; Peng, W.; Hangsheng, Y.; Mingxia, G.; Xinsheng, P.; Zhizhen, Y; Nanoscale, 2012, 4, 2613. DOI:10.1039/c2nr30135k

[28] Reda, M. M.; Farid, A. H.; Ahmed, S; Ceram. Int.2014, 40, 2127. DOI: 10.1016/j.ceramint.2013.07.129

[29]Wang, H.; Shen, Q.; Xinping, L.; Fenglin, L; Langmuir, 2009, 25, 3152. DOI: 10.1021/la803276z

[30] Wang, Z.; Xiao, Y.; Xiaobiao, C.; Cheng, P.; Wang, B.; Gao, Y.; Xiaowei, L.; Yang, T.; Zhang, T.; Geyu, L; ACS Appl. Mater. Interfaces, 2014, 6, 3888. DOI: 10.1021/am404858z

[31] Zhou, B.; Wang, H.; Liu, Z.; Yang, Y.; Huang, X.; Lü, Z.; Sui, Y.; Wenhui, S; Mater. Chem. Phys.2011,126, 847. DOI: 10.1016/j.matchemphys.2010.12.030

[32] Ling, X.; Hai-Yan, X.; Wang, F.; Feng-Jun, Z.; Ze-Da, M.; Zhao, W.; Won-Chun, O; J. Korean Ceram. Soc.2012, 49, 151. DOI:10.4191/kcers.2012.49.2.151

[33]Topnania, N.; Kushwaha, S.; Athara, T; Int.J. Green Nanotechnology: Material Science and Engineering, 2010, 1, M67. DOI: 10.1080/19430840903430220

[33] Yanyan, X.; Dairong,.C.; Xiuling, J.; Keyan, X; J. Phys. Chem. C, 2007, 111, 16284. DOI: 10.1021/jp075358x

[34]Karthik, K.; Victor Jaya, N.; Kanagaraj, M.; Arumugam, S; Solid State Commun.2011, 151, 564. DOI: 10.1016/j.ssc.2011.01.008

[35] Bouazizi1, N.; Bargougui, R.; Oueslati, A.; Benslama, R; Adv. Mater. Lett.2015, 6, 158. DOI:10.5185/amlett.2015.5656

[36] Lijuan, W.; Qing, Z.; Guling, Z.; Yujie, L.; Baoshun, W.; Weiwei, Z.; Bo, L.; Wenzhong, W; Mater. Lett. 2012, 74, 217. DOI: 10.1016/j.matlet.2012.01.123

32. Chengfa, L.; Yin Hou, Y.; Naiying, F.; Yuan, F.; Yanmei, S.; Meng, Q; Solid State Commun.2010, 150, 585. DOI: 10.1016/j.ssc.2009.12.039

[37] Yunling, Z.; Yan, L.; Zhang, N.; Xiulin , L; Bull. Mater. Sci.2011, 34, 967. DOI: 10.1007/S12034-011-0223-0

[38] Zheng, Z.; Huang, B.; Wang, Z; Guo, M; Xiaoyan, Q.; Zhang, X.; Wang, P.; Dai, Y; J. Phys. Chem. C, 2009, 113, 14448. DOI: 10.1021/jp904198d

[39] Min, Y. L.; Wang, T.; Chen, Y. C;Appl. Surf. Sci.2010, 257, 132. DOI: 10.1016/j.apsusc.2010.06.049

[40] Li, Q. L.; Yong, W; J. Mater. Chem.2011, 21, 17916. DOI: 10.1039/C1JM12589C

[41] Dar, M. A.; Ahsanulhaq, Q.; Kim, Y. S.; Sohn, J. M.; Kim, W. B.; Shin, H. S; Appl. Surf. Sci.2009, 255, 6279.

[42] S.M. Sathiya , etal, Optical And Electrical Properties Of Copper Oxide Nanoparticles Prepared Through Microwave Assistance See discussions, stats, and author profilesforthispublicationat:https://www.researchgate.net/publication/318005722 Structural,

[43] S. Sirohi and T. P. Sharma Opt. Mater. 13, 267- 269,, (1999).

[44] B.Thangaraju and P.Kaliannan: Cryst.Res.Technol. (2000)Vol. 35, No.1, pp.(77-75).

[45] F. Yakuphanogle , A. Cukurovali and I. Yilmaz, Physica B 351 53 -58 (2004) .