

is confirmed from XRD study, hexagonal ZnO compounds match perfectly with the hexagonal structure possessing C46V (P63mc) space group [12] (JCPDS File no: 36-1451) [13]. The striking similarity of Bragg peaks with the standard pattern confirms ZnO compound synthesized at 400°C temperature for combustion methods are possessing desired phase purity and crystalline. A high intensity prominent peak at 37.2 degrees, which is the characteristic peak that belongs to (101) plane. The (100) plane and (002) planes lying beneath the prominent peak, which conclude the formation of hexagonal wurtzite phase in the synthesized powder. From the XRD data approximated crystallite size was measured using Scherer formula $L = 0.9\lambda/\beta\cos\theta$ [14]. The average particle size is 27nm with confirmed wurtzite hexagonal, the lattice constants 'a'= 3.221 and 'c'= 5.212 values are measured by using the the formula [15] $1/d^2 = [4/3][(h^2+hk+k^2)/a^2] + [l^2/c^2]$.

Where 'd' corresponds to the interplaner distance, 'a' and 'c' are the lattice parameter of the unit cell. Lattice parameter values are evidence for the formation of single crystal structure (wurtzite) of ZnO nanoparticles.

The particle size analysis of ZnO synthesized clearly evidences the presence of nano crystalline particles with 66nm particle size for 400°C temperature. It corresponds with the crystallite size calculated from the XRD pattern.

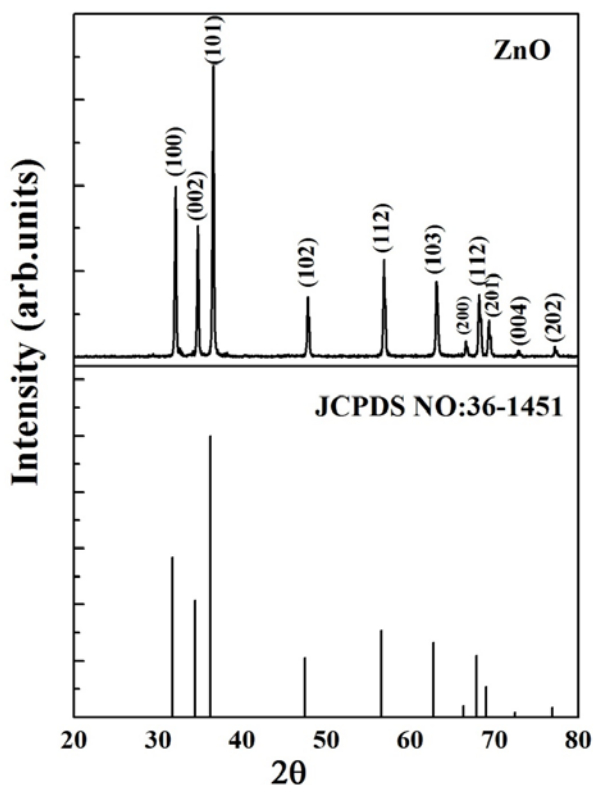


Figure 1: XRD Patterns of ZnO synthesized by CMC-assisted combustion method using 400°C temperatures.

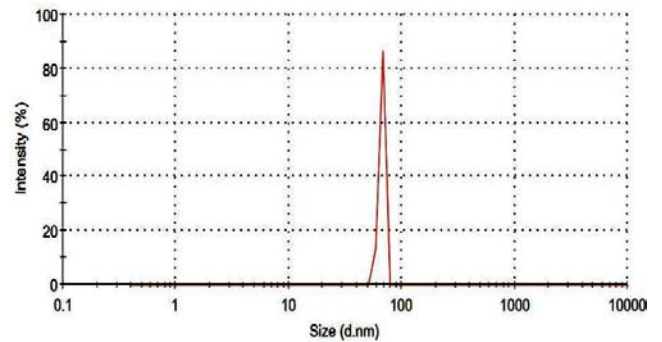


Figure 2: Particles size distributions of ZnO synthesized by CMC-assisted combustion method using 400°C temperature

3.2 Surface Morphology

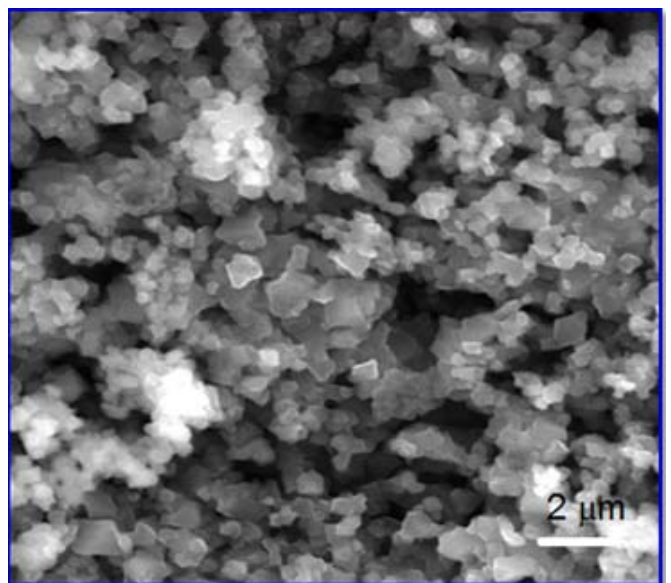


Figure 3: Surface Morphology of ZnO synthesized by CMC-assisted combustion method using 400°C temperatures

Figure 3 shows the presence of perfectly formed hexagonal particles with definite grain boundaries and preferred surface morphology is observed in ZnO synthesized at 400 °C, formation of reduced grain size is understood from the SEM images and slightly particles seems aggregate. The particles size was approximately 1-2 μm. The CMC assisted combustion process in controlling the growth and wider distribution of particles via. Multistep and controlled rate of heating (20C/min.) along with the process of intermittent grinding.

3.3 FTIR

Figure 4 shows the vibrational frequency of the functional groups of CMC assisted combustion synthesized ZnO were analyzed by recording FTIR spectrum in the range 4000-500 cm⁻¹. Characteristic vibrational peaks at $\nu = 556.7 \text{ cm}^{-1}$ corresponding to the stretching Zn-O bonds and $\nu = 3379$ absorbed peak indicate the presence of OH- residue. On the other hand Significant shift in FT-IR frequencies of Zn-O bonds observed with ZnO prepared at low 400°C indicates the presence of hexagonal structure instead of the preferred ZnO.

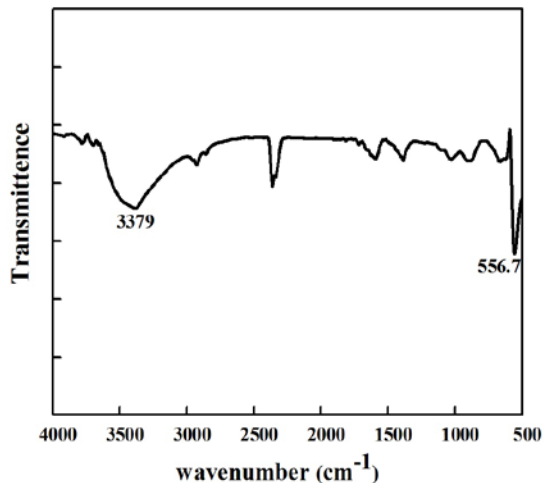


Figure 4: FTIR spectra of CMC-assisted combustion synthesized ZnO

3.4 Optical studies

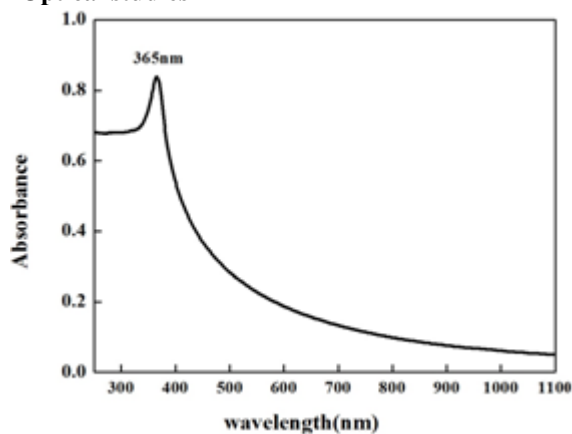


Figure 5: UV-vis absorption spectrum of CMC assisted Combustion synthesized ZnO.

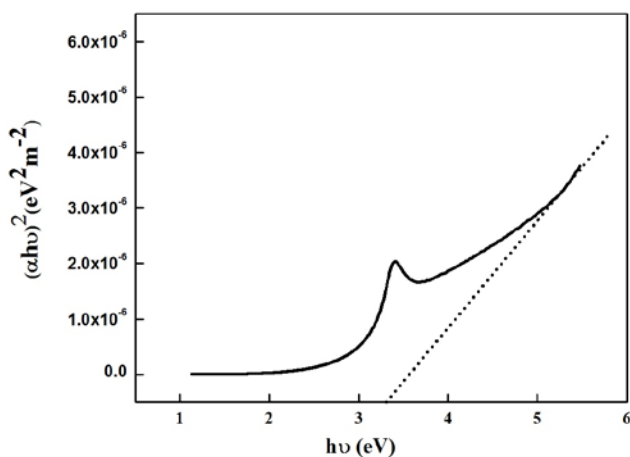


Figure 6: Optical band gap values of CMC-assisted combustion synthesized ZnO

Figure 5. Shows the absorption spectrum of CMC assisted combustion synthesized ZnO nanoparticles at low temperature. UV-visible spectrums were recorded in the range of 200nm and 1200nm. Strong exciton absorption at 365nm is observed in the absorption spectrum region. The direct band gap energy (E_g) for the ZnO nanoparticles is determined by fitting the reflection data to the direct

transition equation [16]

$$(\alpha hv)^2 = A (E_g - hv)$$

E_g is the optical band gap of the CMC assisted combustion synthesized ZnO, A is a constant, α is the optical absorption coefficient and $h\nu$ is the photon energy, the variations of $(\alpha hv)^2$ versus $h\nu$ in the fundamental adsorption region are plotted. The optical band gap is found to be 3.3eV which is confirmed from the figure 6. As a consequence of wide band gap, this ZnO can be a suitable material for the optoelectronic devices like LED and laser diodes(17).

4. Conclusion

By adopting a novel CMC-assisted combustion method, ZnO has been prepared at low temperature range 400°C. Interestingly, a phase temperature as low as 400°C is found to be sufficient to prepare phase pure and hexagonal ZnO, which is lower than the temperatures reported in the literature on the same topic. Presence of hexagonal particles with definite grain boundaries, possessing an average particle size of ~100nm is obtained at 400°C. The study demonstrates the feasibility of deploying a novel and low temperature, CMC-assisted combustion method to prepare phase pure and better performing ZnO besides evidencing the variation of powder properties such as phase purity, surface morphology, particle size and band gap as a function of temperature involved in the synthesis approach

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Reference

- [1] C. Lee, Y. Hui, W.F. Su, C.F. Lin, Electroluminescence from monolayer ZnO nanoparticles using dry coating technique , *Applied Physics Letters*, 92, **2008**, 261107.
- [2] I. D. Kim, J. M. Hong, B. H . Lee, D.Y .Kim, E .K . Jeon, D. K. Choi, D. J. Yang, Dye-sensitized solar cells using network structure of electrospun ZnO nanofiber mats, *Applied Physics Letters* 91, **2007**, 163109.
- [3] F.M . Li, G.W. Hsieh, S. Dalal, M.C. Newton, J.E. Stott, P.Hiralal, A.nNathan, P.A.Warburton, H.E. Unalan, P. Beecher, A.J. Flewitt, I. Robinson, G. Amaratunga, William I. Milne, Zinc Oxide Nanostructures and High electron mobility nanocomposite thin film transistors, *IEEE transacions electron devices*, 55, **2008**.
- [4] Anderson Janotti and Chris G Van de walle, Fundamentals of zinc oxide as a semiconductor, IOP publications, *Rep. Prog. Phys.* 72 (**2009**) 126501 (29pp).
- [5] L. Znaidi, T. Touam, D. Vrel, N. Souded, S. Ben Yahia, O. Brinza ,A. Fischer and A. Boudrioua, ZnO Thin Films Synthesized by Sol-Gel Process for Photonic Applications, *ACTA POLONICA A* Vol. 121 (**2012**).

- [6] Sunandan Baruah and Joydeep Dutta, Effect of seeded substrates on hydrothermally grown ZnO Nanorods, *J Sol-Gel Sci Technol* (2009) 50:456–464.
- [7] Gaston P. Barreto, Graciela Morales, and Ma. Luisa Lopez Quintanilla, Microwave Assisted Synthesis of ZnO Nanoparticles: Effect of Precursor Reagents, Temperature, Irradiation Time, and Additives on Nano-ZnO Morphology Development, *Journal of Materials Volume* (2013), Article ID 478681, 11 pages.
- [8] Singanahally T.Aruna, Alexander S. Mukasyan, Combustion synthesis and nanomaterials, *Current Opinion in Solid State and Materials Science* 12 (2008) 44–50.
- [9] Hooyoung Song, Jae-Hoon Kim and Eun Kyu Kim, Rapid Thermal Annealing of ZnO Thin films Grown by using Pulsed Laser Deposition, *Journal of Korean physical Society*, Vol 53, No.1, July 2008, pp. 258-261.
- [10] T. B. Ivetic, M. R. Dimitrievska, N. L. Fincur, Lj.R. Daanin, I. O. Guth, B. F.Abramovic, S. R. Lukic-petrovic, Effect of annealing temperature on structural and optical properties of Mg-doped ZnO nanoparticles and their photocatalytic efficiency in alprazolam degradation, *Ceramics International* 40 (2014) 1545-1552.
- [11] K. S. Sumana, B. M. Nagabhushana, C. Shivakumara, M. krishna, C. S. Chandrasekhara murthy, N. Raghavendra, Photoluminescence studies on ZnO Nanopowders Synthesized By solution Combustion Method, *International Journal of science Research* vol.01, Issue 02, September 2012, pp.83-86.
- [12] Nuengruethai Ekthammathat, Titipun Thongtem, Anukorn Phuruangrat and Somchai Thongtem, Photoluminescence of Hexagonal ZnO Nanorods Hydrothermally Grown on Zn Foils in KOH Solutions with Different Values of Basicity, *Journal of Nanomaterial Volume* (2013), Article ID208230.
- [13] Chang Chun Chen, Benhai Yu, Ping Liu, Jiang Feng Liu and Lin wang, Investigation of nano-sized ZnO particles fabricated by various Synthesis route, *Journal of Ceramic Processing Research* Vol.12, No.4, PP. 420-425 (2011).
- [14] S. Rasouli, Sh. Saket, One Step Rapid Synthesis of Nano-Crystalline ZnO by Microwave- Assisted Solution Combustion Method, *Prog. Color Colorants Coat.* 3(2010), 19-25.
- [15] Soosen Samuel M, Lekshmi Bose and George K C, optical properties of ZnO Nanoparticles, *ISSN: 0973-7464* Vol. XVI: No. 1 & 2 SB Academic Review 2009: 57-65.
- [16] Mohd Hafiz Mohd Zaid, Khamirul Amin Matori, Sidek Hj. Abdul Aziz, Azmi Zakaria and Mohd Sabri Mohd Ghazali, Effect of ZnO on the Physical Properties and Optical Band Gap of Soda Lime Silicate Glass, *Int J Mol Sci.* 2012; 13(6): 7550–7558.
- [17] Umit Ozgur, Member IEEE, Daniel Hofstetter, and Hadis Morkoc, ZnO Devices and Applications: A review of current status and future prospects, *Proceedings of the IEEE* 98, issue 7, 1255-1268, 2010.