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Optical, Structural, Morphological and Thermal Properties of Mixed Co_3O_4 - CuO - ZrO_2 Nanoparticles

S. Alwin David[1], C.Vedhi [2]

[1,2] PG and Research Department of Chemistry, V.O Chidambaram College, Tuticorin 628008, Tamilnadu, India

Abstract: - Mixed Co_3O_4 - CuO - ZrO_2 nanoparticles were synthesized via wet chemical method. Optical, structural, morphological and thermal properties of mixed Co_3O_4 - CuO - ZrO_2 nanoparticles were studied using UV- DRS, SEM, TEM, TG/DTG and DSC. UV-Vis diffuse reflectance spectrum indicated that the band gap of Co_3O_4 - CuO - ZrO_2 nanoparticles is about 2.37 - 2.52 eV. The synthesized Co_3O_4 - CuO - ZrO_2 nanoparticles have irregular morphology with size ranging from 10 - 40nm as evident from SEM and TEM micrographs. TG/DTG and DSC studies revealed good thermal stability of the Co_3O_4 - CuO - ZrO_2 nanoparticles. From the TG analysis, a total mass loss of only 28.86% was observed in the temperature range from RT to 1200°C.

Keywords: Co_3O_4 - CuO - ZrO_2, Morphology, Band gap, Thermal stability.

1. INTRODUCTION

Semiconductor nonmaterial is one of the richest classes of nonmaterial. A semiconductor is a material with electrical conductivity because of electron flow intermediate in extent between that of an insulator and a conductor. Semiconductor has governed a major role in succeeding research in nanoscience and nenotechnology, which consequences in novel classes of semiconductor nanomaterials. Metal oxide proved to be incredibly promising for a range of handy applications. The good chemical and thermal stability of these inorganic materials facilitate them to be broadly used. Metal oxides take part in a very important role in many areas of physics, chemistry and materials science [1 - 4]. Synthesis of metal oxide nanoparticles is cheaper than the synthesis of metal nanoparticles [5].

Due to the tunable and exceptional characteristics of these metal oxides such as optoelectronic, optical, electrical, magnetic, thermal, mechanical, photochemical, catalytic etc. made themselves admirable candidates for various high level scientific applications. For instance, secondary battery materials, fuel cells, chemical sensors, ceramics, solar cells, gas sensors and biosensor, alkaline and lithium ion batteries, piezoelectric, pyroelectric, ferroelectric, actuator, magnetic, super capacitors, lasers, optical devices, gate dielectric, waveguides, infrared(IR) and solar absorbers, High TC superconductivity, decoupling capacitors dielectrics in dynamics random access memories, magneto-resistance and so on [6 - 10]. Hence metal oxide nanostructure materials have been actively studied in a broader viewpoint by the researchers. Therefore it is necessary to look at its understanding in immense details interms of their synthesis, properties and applications.Here in this paper, we will study the synthesis, optical, structural, morphological and thermal properties of mixed Co_3O_4 - CuO - ZrO_2 nanoparticles.

2. EXPERIMENTAL DETAILS

2.1. Synthesis of Co_3O_4 - CuO - ZrO_2 NPs

About 25mL of 0.1M cobalt(II) chloride was added to the aqueous solution of 75mL of 1.0M sodium hydroxide solution and stirred well. To this mixture 25mL of 0.1M copper sulphate and 25mL of 0.1M zirconium(IV) oxychloride were added. The resulting mixture was stirred well and refluxed at 100 - 110°C for 3 hours. The product was filtered, washed with water and dried. Similar procedure was carried out to synthesize various concentrations of (0.2M - 0.5M) Co_3O_4 - CuO - ZrO_2 NPs [11].

2.2. Characterization

UV-Vis diffuse reflectance spectra were performed with JascoV-600 spectrophotometer. Philips-CM200 Transmission Electron Microscopy (TEM) was utilized to find the shape and particle size of the nanoparticles. The morphology of the nanoparticles was found by JEOL JSM 6390 Scanning Electron Microscopy (SEM). Thermogravimetric (TG), derivative thermogravimetric (DTG) analysis and Differential scanning calorimetry

(DSC) were carried out on a NETZSCH STA 449F3 thermal analyzer.

3. RESULTS AND DISCUSSION

3.1. Optical properties

The band gap (E_g) of the NPs can be determined using well-known Tauc relation.

$$(\alpha h\nu)^n = A\,(h\nu - E_g)$$

where α, h, ν and A are the absorption coefficient, Plank constant, light frequency and a constant, respectively. While n = 2 for direct inter band transition. The Eg value can be estimated by plotting $(\alpha h\nu)^2$ versus hν and extrapolating the linear part of curve to energy axis at α = 0.

The band gap energies obtained for the Co_3O_4 - CuO - ZrO_2 NPs are 2.52eV (0.1M), 2.43eV (0.2M), 2.39eV (0.3M), 2.38eV (0.4M), and 2.37eV (0.5M). This clearly shows that the synthesized Co_3O_4 - CuO - ZrO_2 NPs has potential as a photocatalyst and excitation of electrons from valence to the conduction band using visible radiation is achievable.

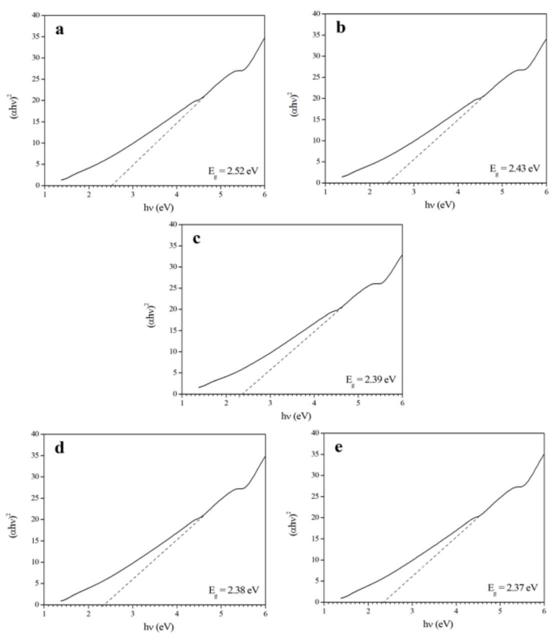

Figure 1. Plot of $(\alpha h\nu)^2$ versus (hν) of a) 0.1M Co_3O_4 - CuO - ZrO_2 NPs b) 0.2M Co_3O_4 - CuO - ZrO_2 NPs c) 0.3M Co_3O_4 - CuO - ZrO_2 NPs d) 0.4M Co_3O_4 - CuO - ZrO_2 NPs e) 0.5M Co_3O_4 - CuO - ZrO_2 NPs

3.2. Structural and morphological properties

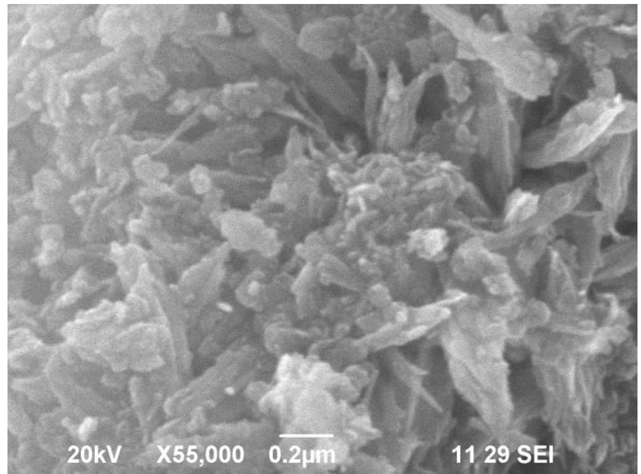

Figure 2. SEM image of Co_3O_4 - CuO - ZrO_2 NPs in 0.2μm scale

SEM micrographs of Co_3O_4 - CuO - ZrO_2 NPs is shown in figure 2. The synthesized Co_3O_4 - CuO - ZrO_2 NPs show granular flakes like morphology.

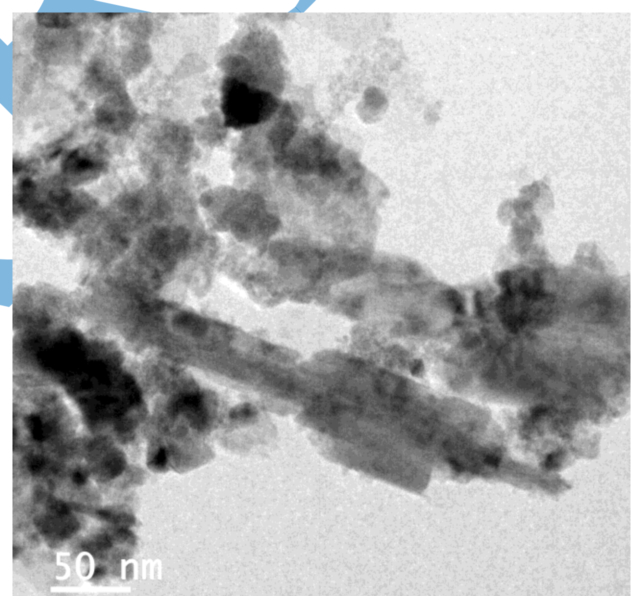

Figure 3. TEM image of Co_3O_4 - CuO - ZrO_2 NPs in 50 nm scale

TEM images of Co_3O_4 - CuO - ZrO_2 NPs are shown in figure 3. The Co_3O_4 - CuO - ZrO_2 NPs show irregular shaped with some rod shaped morphology with 10 – 40nm size.

3.3. Thermal properties

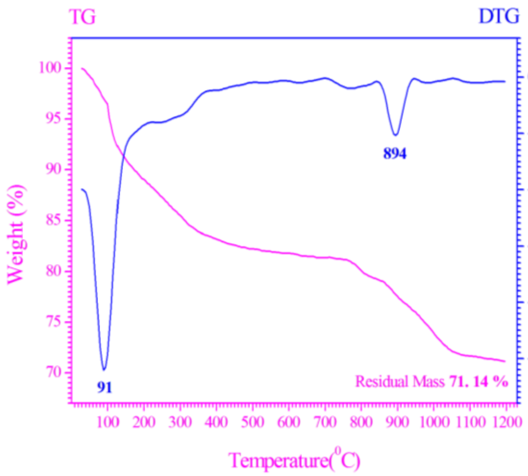

Figure 4. TG/DTG Curves of Co_3O_4 - CuO - ZrO_2 NPs

The TG/ DTG analysis curve of the as- synthesized Co_3O_4 - CuO - ZrO_2 NPs is shown in figure (4). Two apparent weight loss steps are observed in the TG curve, accompanied with two peaks at 91°C and 894°C on the DTG curve. This can be ascribed to the removal of water molecules and the degradation of mixed metal oxides, respectively. From the TG analysis, a total mass loss of 28.86% can be observed in the temperature range from room temperature up to 1200°C.

In the case of DSC curve (figure 5), the endothermic peak at 94°C is attributed to the removal of water molecules. When the heating temperature is raised, there are two more endothermic peaks at 801 and 1159°C, indicating the decomposition of mixed metal oxides [12].

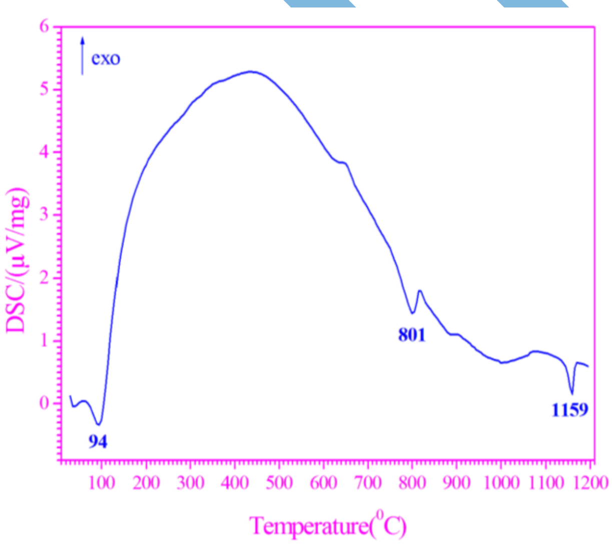

Figure 5. DSC Curve of Co_3O_4 - CuO - ZrO_2 NPs

4. CONCLUSIONS

Cobalt(II) chloride, copper sulphate, zirconium(IV) oxychloride and sodium hydroxide were used for the synthesis of mixed Co3O4 - CuO - ZrO2 nanoparticles. The band gap energy values for the Co3O4 - CuO - ZrO2 NPs are 2.37 -2.52eV, which was calculated by Tauc relation. This results indicated that the synthesized Co3O4 - CuO - ZrO2 NPs can be used as a photocatalyst in the presence of visible light irradiation. TG/DTG and DSC studies revealed good thermal stability of the Co3O4 - CuO - ZrO2 NPs.

5. REFERENCES

[1] Y. Wang, L. Zhou, X. Duan, H. Sun, E. Tin, W. Jin and S. Wang, "Photochemical degradation of phenol solutions on Co3O4 nanorods with sulfate radicals," Catalysis Today, vol. 258, pp. 576–584. 2015.

[2] S. A. David, V. Veeraputhiran and C. Vedhi, "Synthesis and characterization of Co3O4-ZnO-ZrO2 ternary nanoparticles," Journal of Nanoscience and Technolog, vol. 3(3), pp. 270–272, 2017.

[3] S. A. David and A. Mathavan, "Thermal, morphological and impedance behavior of Polydiphenylamine- Vanadium pentoxide nanocomposites," International Journal of Advance Research in Science and Engineering, vol. 6(1), pp. 262-274, 2017.

[4] S. A. David, V. Veeraputhiran and C. Vedhi, "Spectroscopic and Morphological Behavior of Co3O4-MnO2-ZrO2 Ternary Nanoparticles," Journal of Nanoscience and Technolog, vol. 3(4), pp.296–298, 2017.

[5] S. A. David, K. M. Ponvel, M. A. Fathima, S. Anita, J. Ashli and A. Athilakshmi, "Biosynthesis of silver nanoparticles by Momordica charantia leaf extract: Characterization and their antimicrobial activities," Journal of Natural Product and Plant Resources, vol. 4 (6), pp. 1-8, 2014.

[6] S. A. David and C. Vedhi, "Photocatalytic activity of Co3O4 - ZnO - ZrO2 ternary nanoparticles for the degradation of methylene blue dye," International Journal of Advance Research in Science and Engineering, vol. 6(11), pp. 1914 – 1923, 2017.

[7] S. A. David and C. Vedhi, "Synthesis of nano Co3O4 - MnO2 - ZrO2 mixed oxides for visible-light photocatalytic activity," International Journal of Advance Research in Science and Engineering, vol. 6(01), pp. 613-623, 2017.

[8] S. A. David and C. Vedhi, "Photocatalytic Activity of Co3O4 - CuO - ZrO2 Ternary Nanoparticles," International Journal of Science, Engineering and Management, vol.2 (12), pp. 105-108, 2017.

[9] S. A. David, S. I. Rajadurai and S. V.Kumar, “Biosynthesis of copper oxide nanoparticles using Momordica charantia leaf extract and their characterization,” International Journal of Advance Research in Science and Engineering, vol. 6(03), pp. 313-320, 2017.

[10] S. A. David and L. U. Revathi, “Green synthesis of Fe3O4 nano particles using Camellia angustifolia leaf extract and their enhanced visible-light photocatalytic activity,” International Journal of Advance Research in Science and Engineering, vol. 7(2), pp. 422-428, 2018.

[11] S. A. David and C. Vedhi, “Synthesis and Characterization of Co3O4 - CuO - ZrO2 Ternary Nanoparticles”, International Journal of Chem Tech Research, vol.10, pp. 905 – 912. 2017.

[12] M. Huang, Y. Zhang, F. Li, Z. Wang, H. Alamusi, Z. Wen and Q. Liu, Q, “Merging of Kirkendall Growth and Ostwald Ripening: CuO@MnO2 Core-shell Architectures for Asymmetric Supercapacitors,” Scientific reports, vol. 4, pp. 4518, 2014. Retrieved from https:/ /rbi. org. in/ scripts/ Publication VisionDocuments.aspx?Id=842

Sahney, S., Banwet, D.K., and Karunes, S. (2004). A SERVQUAL and QFD approach to total quality education: A student perspective. International Journal of Productivity and PerformanceManagement, 53(2), 143-166.

