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Photoluminescence Study of Tin Oxide-Zinc Oxide Nanocomposites

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ABSTRACT- Undoped and Cu^{2+} doped $(SnO_2)_{1-x}(ZnO)_x$ nanocomposites were synthesized using a simple microwave assisted solvothermal method with ethylene glycol as solvent. The as-prepared samples were calcinated at 500 ^{0}C for 1hr. The optical studies were carried out using Photoluminescence measurements. A small shift in the peak position was observed for doped samples when compared to undoped samples. The shifting was due to the incorporation of dopant into the host matrix and also coupled with the variation of band gap energies of the nanocomposites. The results obtained were reported and discussed herewith.

Key words: Nanocomposite, Photoluminescence, Solvothermal, Tin oxide, Zinc oxide.

1. INTRODUCTION

In the past three decades, nanostructured materials are considered as an exciting research area. Nanotechnology is an interdisciplinary area where the theories in Physics, Chemistry, Biology and Engineering are used to manipulate and design new devices. Nanomaterials are used as safer and efficient product in agriculture, industry, medicine, transport and communication [1]. SnO_2 and ZnO nanoparticles are used as sensors [2, 3, 4], solar cells [5, 6], catalyst [7, 8], antibacterial agent [9], in lithium ion batteries [10, 11] and so on. Luminescence is a phenomenon in which a material when excited with an external source like electrons, photons, etc will emit light in the visible range, UV or IR. The process in which a substance absorbs photons and get excited to a higher energy state and then return to lower energy state with the emission of another photon is termed as photoluminescence. SnO_2-ZnO nanocomposites can be synthesized via sol-gel method [12-14], hydrothermal [15], co-precipitation method [16, 17], atomic layer deposition technique [18] and spray pyrolysis [19, 20]. The properties of the nanoparticles can be modified by the inclusion of suitable dopants into the parent matrix.

In the present work the phototoluminescence studies were carried out for $(SnO_2)_{1-x}(ZnO)_x$ nanocomposites (with x values 0.0, 0.2, 0.4, 0.5, 0.6, 0.8 and 1.0). Different excitation wavelengths ranging from 272 nm to 335 nm were used to record the emission spectra. The results obtained were reported and discussed. This article is organized as follows: Section I gives the introduction about photoluminescence studies. Section II explains the experimentation and characterization of tin oxide- zinc oxide nanocomposites. The results and discussions of the related work are discussed in section III and in the last section IV the conclusions of the research work are given.

II. EXPERIMENTATION AND CHARACTERIZATION

Undoped and Cu^{2+} doped $(SnO_2)_{1-x}(ZnO)_x$ nanocomposites (with x values 0.0, 0.2, 0.4, 0.5, 0.6, 0.8 and 1.0) were synthesized using a simple microwave assisted solvothermal method. The experimental procedure for the synthesis of undoped and Cu^{2+} doped $(SnO_2)_{1-x}(ZnO)_x$ nanocomposites (with x values 0.0, 0.2, 0.4, 0.5, 0.6, 0.8 and 1.0) was explained in detail in our earlier work [21,22]. The as prepared samples were calcinated at 500 ^{0}C for1hr. The photoluminescence measurements of calcinated samples were carried out at room temperature.

III. RESULTS AND DISCUSSION

The photoluminescence spectra of undoped and Cu^{2+} doped $(SnO_2)_{1-x}(ZnO)_x$ nanocomposites are shown in Figures 1- 14. Undoped SnO_2 nanoparticles show two prominent peaks at 421 and 462 nm. The strong indigo peak at 421 nm was attributed to electron transition due to oxygen vacancies and defects in SnO_2 nanoparticles [23,24]. The strong blue emission peak at 462 nm was due to electron transition arbitrated by defect levels such as oxygen vacancies in the energy gap [25]. $(SnO_2)_{1-x}(ZnO)_x$ nanocomposites with x values (0.2, 0.4, 0.5, 0.6 and 0.8) show prominent peaks at

415 and 453 nm; 418 and 460 nm; 419 and 461 nm; 421 and 462 nm; 430 and 465 nm respectively. The strong violet peaks at 415, 418 and 419 nm and the strong indigo peaks at 421 and 430 nm are due to electron transitions arbitrated by defects levels in the band gap such as oxygen vacancies or tin interstitials [23, 24]. The strong blue emissions at 453, 460, 461, 462 and 465 nm are due to electron transitions arbitrated by defect levels such as oxygen vacancies in the energy gap [25].

ZnO nanoparticles show four prominent peaks at 464, 502, 660 and 684 nm. The weak blue emission peak at 464 nm was ascribed to the transition between the shallow donor levels of zinc vacancies and the shallow acceptor levels of oxygen vacancies [26]. Also the excitons on the surface of ZnO nanoparticles give rise to emission peak around 465 nm [27]. The weak green emission peak at 502 nm was due to the presence of singly ionized oxygen vacancies and the recombination of photogenerated hole with the singly-ionized charge state results in green emission [28, 29]. The radioactive recombination of a photogenerated hole with an electron occupying the oxygen vacancy causes luminescence emission peak [30]. The occurrence of red emission peaks around 660 and 684 nm are attributed to deep level emission. Oxygen interstitial defects in ZnO nanoparticles paved way for deep level emission [31]. The peaks at 660 and 684 nm are highly intense and the reason for high peak intensity at this region is mainly due to the increase in the number of oxygen vacancies [32]. Cu^{2+} doped $(SnO_2)_{1-x}(ZnO)_x$ nanocomposites show shift in the peak position when compared to undoped $(SnO_2)_{1-x}(ZnO)_x$ nanocomposites. The shifting was due to the incorporation of dopant into the host matrix and also coupled with the variation of band gap energies of the nanocomposites [33].

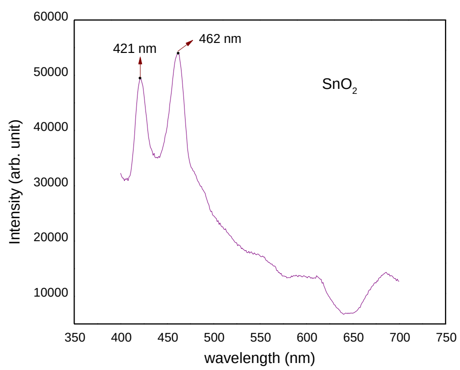

Figure 1: PL spectrum of SnO_2 nanoparticles

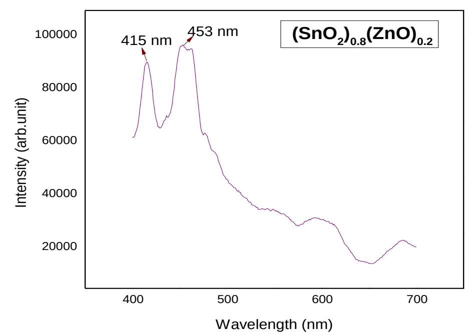

Figure 2: PL spectrum of $(SnO_2)_{0.8}(ZnO)_{0.2}$ nanocomposite

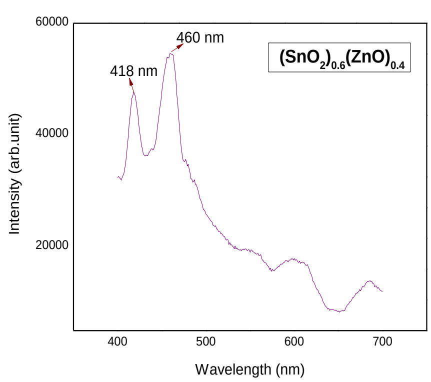

Figure 3: PL spectrum of $(SnO_2)_{0.6}(ZnO)_{0.4}$ nanocomposite

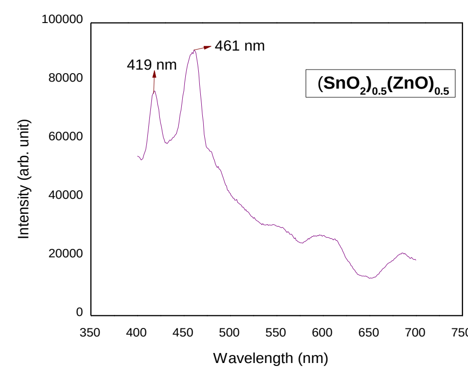

Figure 4: PL spectrum of $(SnO_2)_{0.5}(ZnO)_{0.5}$ nanocomposite

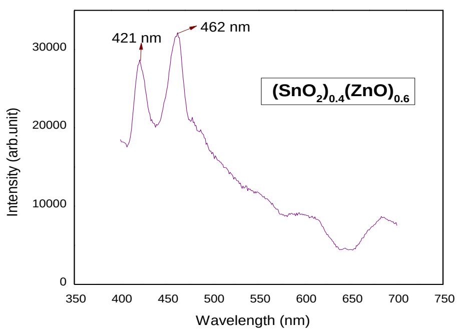

Figure 5: PL spectrum of $(SnO_2)_{0.4}(ZnO)_{0.6}$ nanocomposite

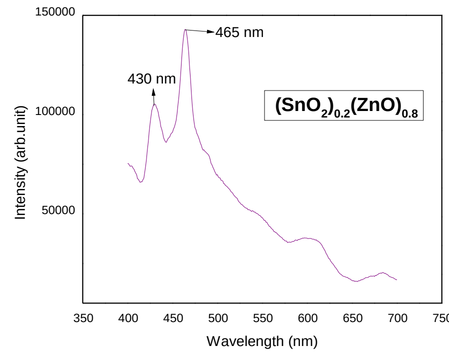

Figure 5: PL spectrum of $(SnO_2)_{0.2}(ZnO)_{0.8}$ nanocomposite

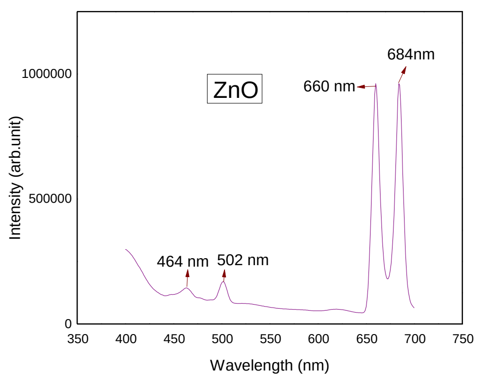

Figure 7: PL spectrum of ZnO nanoparticles

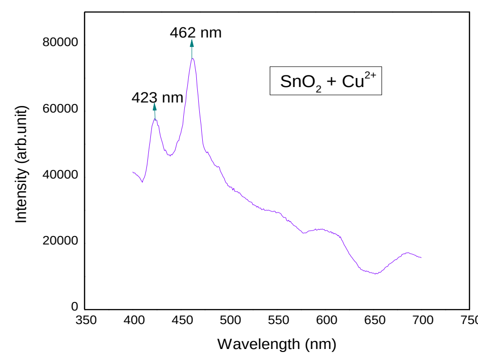

Figure 8: PL spectrum of $SnO_2 + Cu^{2+}$ nanoparticles

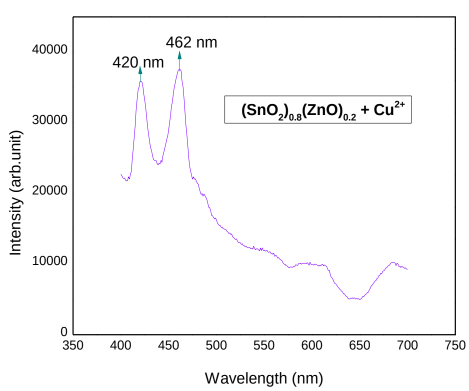

Figure 9: PL spectrum of $(SnO_2)_{0.8}(ZnO)_{0.2}$+ Cu^{2+}nanocomposite

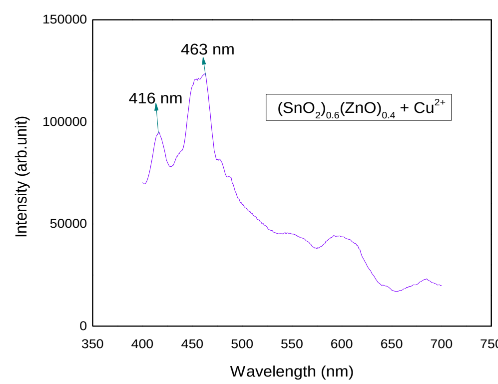

Figure 10: PL spectrum of $(SnO_2)_{0.6}(ZnO)_{0.4}$+ Cu^{2+}nanocomposite

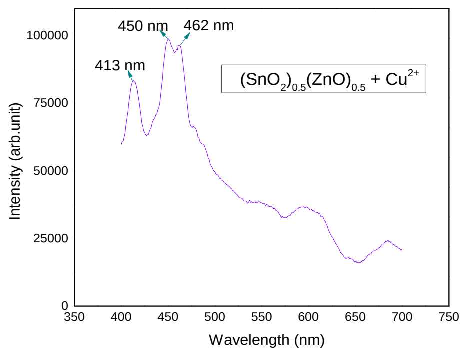

Figure 11: PL spectrum of $(SnO_2)_{0.5}(ZnO)_{0.5}$+ Cu^{2+}nanocomposite

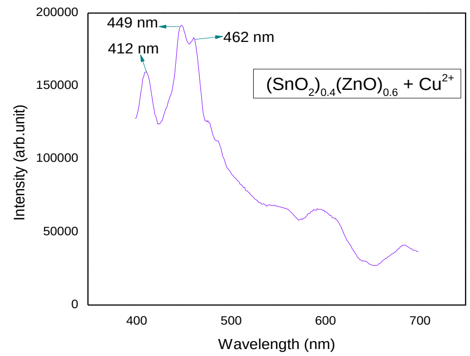

Figure 12: PL spectrum of $(SnO_2)_{0.4}(ZnO)_{0.6}$+ Cu^{2+}nanocomposite

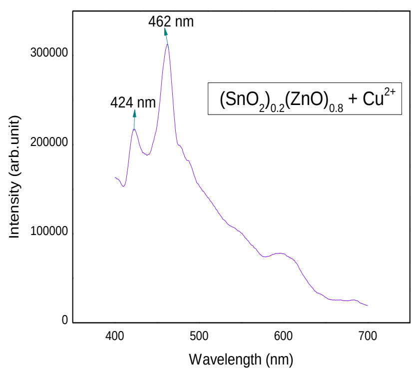

Figure 13: PL spectrum of $(SnO_2)_{0.2}(ZnO)_{0.8}$+ Cu^{2+}nanocomposite

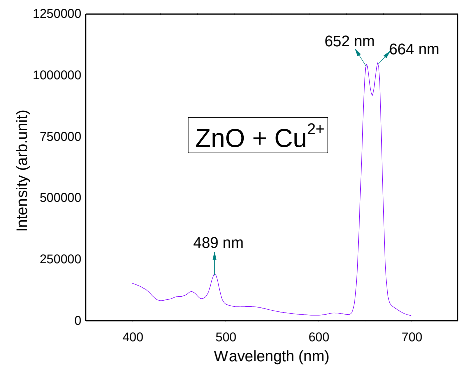

Figure 14: PL spectrum of ZnO+ Cu^{2+}nanoparticles

IV. CONCLUSION

The PL spectra of SnO_2 nanoparticles show two prominent peaks at 421 and 462 nm. $(SnO_2)_{1-x}$ $(ZnO)_x$ nanocomposites with x values (0.2, 0.4, 0.5, 0.6 and 0.8) show prominent peaks at 415 and 453 nm; 418 and 460 nm; 419 and 461nm; 421 and 462 nm; 430 and 465 nm respectively. While ZnO nanoparticles show four prominent peaks at 464, 502, 660 and 684 nm respectively. Shifting in the peak position of Cu^{2+} doped $(SnO_2)_{1-x}(ZnO)_x$ nanocomposites when compared to undoped $(SnO_2)_{1-x}(ZnO)_x$ nanocomposites was observed. The shifting was mainly due to the incorporation of dopant into the host matrix and also it was coupled with the variation of band gap energies.

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