Chapter 2

REVIEW OF LITERATURE
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Hundreds of products containing nanomaterials are in use by society. Some of these are in batteries, paints, coatings, antimicrobial textiles (Mcarthur, J.V. et al., 2012) and nanorobotics (Patel, G.M. et al., 2010) etc. Nano advancement is seen in many sectors including public health, employment and occupational safety and health, information society, industry, innovation, environment, energy, transport, security and space. Semiconductor nanoparticles gain more significance in research and technology because of their exciting optical properties which are important for nano electronics (Stier, O. et al., 1999), biological (Hosino, A. et al., 2004) and catalytical applications (Li, W. et al., 2002). Among the most studied transparent conducting oxides are tin oxide, zinc oxide and indium tin oxide.

SnO$_2$ is a widely used semiconductor oxide in most of the applications such as gas sensors and transparent conducting electrodes, transistors etc. Tin oxide (SnO$_2$) nanomaterials can be synthesized by using different methods such as sol gel method (Kundu, V.S. et al., 2013), co-precipitation method (Lanje, A.S. et al., 2006), spray pyrolysis method (Chacko, S. et al., 2006), hydrothermal method (Patil, G.E. et al., 2012), microwave synthesis method (Jouhannaud, J. et al., 2008), surfactant mediated method (Wang, Y. et al., 2002), mechanochemical processing (Cuckrov, S. et al., 2001) and dip coating method (Hammad, T.M. and N.K. Hejazy, 2011).

Tin oxide (SnO$_2$) nanomaterials with size range of 19 to 100 nm were successfully synthesized using wet chemical process by Sikhwivhilu, L.M. et al. (2011). Li, F. et al. (2001) developed a new one step solid state reaction synthesis method of tin oxide nanomaterials. Jiang, L. et al. (2005) prepared size controllable tin oxide nanomaterials by heating ethylene glycol solutions containing SnCl$_2$ at atmospheric pressure. Gnanam, S. and V. Rajendran (2010) synthesized tin oxide nanomaterials by the reaction of SnCl$_4$.5H$_2$O in methanol, ethanol and water via sol-gel method. A systematic study has been conducted by Adnan, R. et al. (2010) on the preparation and applications of SnO$_2$ nanomaterials. Their sol-gel technique turned out a method for the controlled synthesis of SnO$_2$ nanomaterials controlled by reactant concentration, reactant feed rate and reaction temperature. Resulting nanoparticles were found to act as good catalyst for the hydrogenation of styrene using ethanol. Krishnakumar, T. et al. (2008) successfully synthesized tin oxide nanoparticles by chemical digestion method preferred to humidity sensing property towards the moisture. Gu, F. et al. (2004) synthesized nanocrystalline SnO$_2$ particles by sol-gel method and
systematically investigated the oxygen-vacancies-related photoluminescence of pure, cerium and manganese doped SnO$_2$ nanomaterials.

Senthilkumar, V. et al. (2010) also synthesized fluorine doped tin oxide (FTO) nanomaterials by sol–gel technique. Cadmium doped tin oxide nanocrystalline powders of about 2.5–4.5 nm in size have been synthesized by using different solvents via sol–gel method by Gnanam, S. et al. (2010). Co-doped SnO thin films were prepared by the spray pyrolysis method using SnCl$_4$.5H$_2$O and Co(NO$_3$)$_2$ as a precursor and a dopant, respectively by Pirmoradi, H. et al. (2011). Similarly, tin oxide-intercalated polyaniline nanocomposite was also prepared using tin chloride (SnCl$_4$.5H$_2$O) as precursor during polymerization of aniline. Kondawar, S.B. et al. (2012) prepared polyaniline-tin oxide (PANI/SnO$_2$) nanocomposite by an in-situ polymerization of aniline in the presence of as synthesized SnO$_2$ nanoparticles. Pure and Indium doped SnO$_2$ nanocrystalline thin films have been fabricated by Singh, S. et al. (2012) using sol-gel technique to study the effect of In-doping on structural, optical and magnetic properties. Zhang, J. and L. Gao (2004) successfully synthesized antimony-doped tin oxide (ATO) nanomaterials for the first time by the co-precipitation method from the starting materials granulated tin and Sb$_2$O$_3$. Antimony doped tin oxide ATO thin films were also prepared using dip coating method by Hammad, T.M. and N.K. Hejazy (2011). Bajpai, N. et al. (2012) prepared tin oxide (IV) nanophosphor doped with europium by sol-gel technique using SnCl$_4$ as precursor. Nickel-doped tin oxide nanoparticles were synthesized by a simple co-precipitation method and the structural, morphological and optical properties of these nanoparticles were investigated. Aliahmad, M. and M. Debbashi (2013) synthesized Ni-doped SnO$_2$ nanocrystalline powders by the co-precipitation method from SnCl$_2$.2H$_2$O and NiCl$_2$.6H$_2$O.

In recent years, heterogeneous photocatalysis (Schuyten, S. et al., 2008) using transition metal oxides have received increasing attention for environmental applications such as air purification, water disinfection, hazardous remediation and water purification. Studies have proved that such semiconductors can degrade most kinds of persistent organic pollutants such as detergents, dyes, pesticides and volatile organic compounds under UV-light irradiation. So attempts are being made to improve the photocatalytic activity of semiconductors for the degradation of organic compounds in water and air.
Han, Y. et al. (2011) reported the synthesis of porous SnO$_2$ nanowire bundles and photocatalytic effect in the degradation of rhodamine B (RhB) and electrochemical properties as a Li-ion battery anode. Firooz, A.A. et al. (2011) reported the preparation and photocatalytic activity of ZnO/SnO$_2$ and SnO$_2$ nanoparticles synthesized by hydrothermal method. He showed that the use of ZnO/SnO$_2$ as photocatalyst have better photocatalytic activity for degradation of congo red than SnO$_2$ or TiO$_2$ alone. Dodd, A. et al. (2006) found that the SnO$_2$ doped ZnO powder show significantly higher photocatalytic activity than either single phase SnO$_2$ or ZnO powders. A biomolecule assisted hydrothermal route has been reported for generating SnO$_2$ with diameters <10 nm which present excellent photocatalytic degradation of rhodamine B (Wu, S. et al., 2009).

Nanomaterials with distinctive physical and chemical properties including small size and high surface area-to-volume ratio allow an increased ability to interact with pathogen membranes and cell walls (Blecher, K. et al., 2011). Hence, several nanomaterials have shown antimicrobial activity against many bacteria such as *E. coli*, *P. aeruginosa*, *B. subtilis* and *S. aureus* etc. through multiple mechanisms including the interruption of transmembrane electron transfer, disruption of the cell envelope, oxidization of cell components or production of (ROS) reactive oxygen species (Li, Q. et al., 2008 and Kong, H. and J. Jang, 2008). Sawai, J. (2003) evaluated a number of ceramic powders and found that metal oxides like MgO, CaO and ZnO show strong bacterial growth inhibiting activity. Nanoparticles formulations prepared from copper, cobalt, titanium oxide and silicon oxide had an inflammatory and toxic side effect on cells (Ochekpe, N.A. et al., 2009). Antibacterial activity of SnO$_2$ nanoparticles have been less reported. Ayeshamariam, A. et al. (2013) observed effective antibacterial and antifungal activities for SnO$_2$ nanoparticles, particularly for *Streptococcus pyogenes* microorganisms and antifungal microorganisms of *Aspergillus niger*, *Mucor indicus* microorganism than bulk SnO$_2$. 