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Synthesis and Characterization of Tin Oxide: A Review

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Abstract*: This review focuses on Tin oxide has been extensively investigated different synthesized method, Tin oxide nano materials with different morphologies and spatial assemblies have been fabricated in the last few years in order to improve their performances. This review describes the recent developments of different synthesized method for potential applications. Tin oxide is a candidate for applications requiring high electrical conductivity and optical transparency, such as a gas sensor material, oxidation catalyst, and transparent conductor, photo anode in dye-sensitized solar cells (DSSCs), due to their higher optical transparency and wider electron mobility to compare other metal oxide semiconductors (MOS), the chemical and physical structures of tin oxide to make suitable material for these applications.

Keywords- Transparent Conducting oxides, Tin oxide, Gas sensor, Oxidation catalyst, Photo anode, dye-sensitized solar cells .

I. INTRODUCTION

Tin oxide is widely used transparent conductive oxide, because of good electrical conductivity and optical transparency and also it is a promising material to use different applications such as photovoltaic's, biosensors and flat-panels [1] Tin oxide has exceedingly attracted more than one oxidation state due to its dual valency and more prefers to possess the oxidation states of 2+ or 4+, which greatly promotes the variation in the composition of surface oxygen [2] The mineral form of Tin oxide is called 'cassiterite' (Figure 1) and is the color less solid raw material in nature [3] Tin Oxide (SnO_2) is a n-type semiconductor with wide energy band gap (3.7 eV). The SnO_2 has high optical transparency and low electrical resistance in the visible range of the electromagnetic spectrum. These properties make tin oxide suitable for many applications [4-5].

II. LITERATURE SURVEY

A. Structure and properties of SnO_2

Tin (VI) oxide or stannic oxide (not to be confused with stannous oxide with tin in the oxidation state of 2+ is an amphotheric colorless solid. This inorganic compound shows high optical transparency and high reflectivity in the infrared region and the material is characterized by its good chemical and thermal stability SnO_2 has been considered for many applications Among others, the material was evaluated as a catalyst, as a sensor, and as a raw material for transparent films, infra-red mirrors or optoelectronic devices Also, the strongly oxidizing properties make the oxide an ideal tool for the elimination of pollutants from water and many other sources [6-7].

The crystal structure type of SnO_2 is similar to the rutile phase structure of TiO_2 (dimensions of the unit cell: a = b = 0.47374 nm and c = 0.31864 nm, polar crystal with octahedral and space group no. 136 P42/mnm In one unit cell, the tin(IV) ion is surrounded by 6 oxygen ions and every oxygen is bordered by 3 tin(IV) ions, resulting in a coordination structure [8-10] as shown in Figure 1. The discovery of the photocatalytic properties of TiO_2 also led to a range of proposals for photocatalytic applications of related oxides. The high photosensitivity and thermo stability, as well as their low cost and toxicity made ZnO and SnO_2 valuable alternatives as photocatalysts [11-12]. The octahedral network is considered a prerequisite for high photocatalytic activity because it increases the mobility of e−–h+ pairs and consequently affects the probability of their reaching the reaction sites on the surface of the photo catalyst [13].Some of the physicochemical characteristics of SnO_2 are summarized in Table 1.

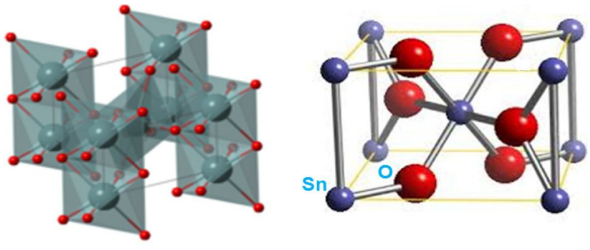

Figure 1 Tin Oxide

Table 1 Properties of SnO_2

Crystal structure	*Rutile structure*
Lattice constant	*a = 0.47374 nm and c = 0.31864 nm*
Molecular weight	*150.69 g/mol*
Density	*6.90 g/mol*
Melting point	*1500–1630 ◦C*
Boiling point	*1800–1900 ◦C*

Generally in semiconductors the lower energy band (conduction band, CB) is packed with electrons while the upper band (valence band, VB) is free of electrons. The energy difference between these bands, also called the energy band gap (Ebg), is responsible for the electronic properties of the material [14]. Together with the Fermi level (hypothetical energy level of electrons), the band gap is an important parameter for describing the potential of a material to act as semiconductor [15]. Generally less energy is required to excite electrons if the energy band gap between CB and VB decreases .The electronic properties of semiconductors is also, and to a much greater extent, determined by the presence of small amounts of impurities in the lattice structure of the metal oxide. These impurities either create an excess of free holes (p-type semiconductor) or free electrons (n-type semiconductor) [16]. The doping process changes the Fermi level by shifting the CB in the n-type or the VB in the p-type semi-conductor, and thus narrows the Ebg. As a consequence, less energy is required to generate excited electrons and photocatalytic activity can be observed upon irradiation of the catalyst with electromagnetic radiation in the visible range The electrical conductivity of SnO_2 can moreover be attributed to the presence of the inherent defects in the metal oxide [17-18]. Such defects contribute to a significant narrowing of the Ebg band, thus improving the properties of the material as a semiconductor. In this respect, additional oxygen anions trigger the oxidation of Sn2+ to Sn4+ in order to maintain the overall electrical neutrality [19-20].The large band gap energy of SnO_2 of 3.6 eV, which corresponds to photo activation in the UV range of the electromagnetic spectrum, makes this material, as well as ZnO and SnO_2 , ideal photocatalysts for the degradation of a variety of organic pollutants Modification of the metal oxides reduces the band gap energy and electro-magnetic radiation with lower energy can be utilized for the activation of the catalyst. The band gaps of silicon and a variety of metal oxides are shown in Table 2 In summary, SnO_2 combines many positive properties, such as low electrical resistance, high electrical conductivity and high optical transparency in the visible region of the electromagnetic range and the material has found many useful applications [21-22].

Table 2 Band gap energy some semiconductors

Si	1.1
TiO2 (rutile)	3.0
SnO2	3.6
WO3	2.7
ZnS	3.7
ZnO	3.3
TiO2 (anatase)	3.2
SnO	~2.5–3.0
CdS	2.4
ZnO	3.2

B. Synthesis and characterization of SnO_2

The chemical vapour deposition method is proposed to prepare tin oxide using in atmospheric pressure. XRD studies indicate synthesized SnO_2 have a tetragonal structure and highly oriented along the (110) plane. Four-probe method and Hall voltage measurement experiments give useful information regarding the electrical properties of films. The films indicated conductivity in the range 108 to 169 W-1cm-1. [23] The synthesized Fluorine doped and pure SnO_2 was prepared by electro deposition method from aqueous solutions containing SnCl2, HCl and butyl rhodamine Blue dye was used as a structure directing complex agent to control the growth of SnO_2 during the experiment. The scanning electron microscopy (SEM) micrographs of the films prepared in the absence of rhodamine Blue revealed irregularly connected nanoparticles randomly stacked in large domain. On the other hand, it can be seen that many smaller particles produce a larger porous particle with an average diameter of 50 nm for

the addition of 100 µM and 20 nm for 150 µM . The XRD data show that the film is SnO_2 with tetragonal rutile structure. The average grain size about 24 nm, which was determined using the Scherrer equation. The films were deposited on copper substrate by one step electro deposition without the pre treatment of electrolytes. An effect of deposition potential on the morphological properties was investigated using scanning electron microscopy [24-26] Pulsed laser deposition method as reported by Dolbec and Phillips et al [27-28]. The alumina and quartz substrates are use to synthesis SnO_2 with using of pure polycrystalline SnO_2 phase, SnO_2 films with a thickness between1000-2000 Å were successfully deposited on glass substrate. They point out that the films grown using Sn target exhibit a relatively high transmittance of 80% in the visible region. Fan and Reid report was discussed XRD patterns of pulsed laser deposited SnO_2 films at different stages of post deposition annealing and it is conclude at intermediate temperatures was influenced that the formation of the litharge of SnO and orthorhombic phase of SnO_2 are clearly visible. The effects of oxygen partial pressure percentage in the range of 1% to 10% on the magnetron sputtered tin oxide films have been studied by Leng et al [29]. The results indicate that introduce of oxygen would suppress the deposition process and the growth of films. They found when oxygen pressure was increase, resistivity of the film also reduces with its indicated in electrical measurement. In pure argon atmosphere SnO_2 films with resistivity was found 232 Wcm.Stedile et al [30] report was found magnetron sputtered SnO_2 films were submitted to thermal annealing and exposed to butane gas, its highly disordered. The SnO_2 films are modified under thermal processing and gas exposure, changing the oxygen vacancy concentration as could be observed in their experiment. They conclude that these behaviors should affect the steady state response of tin oxide sensors. Electrical measurements have been investigated on sputtered SnO_2 films at various anneal temperatures. The variation of the Hall mobility and conductivity with the annealing temperature could be attributed to increase in the grain size and to reduce in the oxygen vacancies of the SnO_2 thin films after heat treatment process. Czapla et al [31-32] prepared SnO_2 films using reactive sputtering technique. The obtained results reflect that the excess tin atoms locate in interstitial positions of the tetrahedral crystal. The influence of substrate temperature on the properties of SnO_2 films deposited by ultrasonic spray pyrolysis method was reported by Achour et al [33]. The average crystallite sizes and band gap energies were increased from 6.52 to 29.8 nm, and 4.03-4.133 eV, respectively with increasing substrate temperature from 400 to 500 °C. The warming applications SnO2high transmittance in the infrared region like 800 nm, as use to make good material. Jahnavi et al [34] was reported about thermal evaporation of Tin oxide thin films . They observe that band gap energy increases with an increasing annealing temperature for SnO_2 films. UV-visible transmission spectra of these films indicated that high transmittance of 99% in the visible region. From Shadia [35] report Thermally evaporated SnO_2 films has 100-600 nm of thickness were successfully deposited onto glass substrate and XRD pattern reveals that these films are amorphous. It was observed from the SEM micrograph study that the surface of the film is smooth, uniform and well covered with the material. EDAX indicated that these films are deficient in oxygen and SnO_2 films were prepared by chemical bath deposition method at 55 °C using tin chloride pentahydrate in aqueous medium. High quality SnO_2 films with transmittance more than 80% in the visible region are observed [36]. Annealed films are orthorhombic, highly stoichiometric, strongly adhesive and transparent with band gap about 4.4 eV. Chemical bath deposited tin oxide films were prepared on glass substrate with stannous chloride and urea as the precursor and buffer in aqueous medium. The peaks respond to the (110), (101) and (211) planes of rutile structure could be observed in XRD pattern. The influence of stannous chloride concentration and weight ratio of urea/water on the properties of The increasing of SnCl2 concentration and the reducing weight ratio of urea/water is observed to improve the crystalline of the SnO_2 films. Chemical bath deposited SnO_2 films have been prepared onto soda lime glass substrate in the presence of tin chloride and methanol solution as reported by Yusuf et al [37]. The Scherer formula was used to calculate the grain size. It is interesting to note that the average grain size was observed to be 29.6 nm, which increased to 30.04 nm after annealing in air at 400 °C. In the transmission spectra, optical transmittance was about 80 % in the visible range. chemical bath deposition method [38-40].The chemical bath contains tin chloride, hydrogen peroxide, deionized water, triethanolamine and ethylene diaminetetraacetic acid solution. Deposition was carried out about pH 7 and at 110 °C. The average crystalline size was about 18 nm. SEM studies reveal that the grains are well defined, spherical and of almost similar size (16 nm). Finally, the Fourier transform infrared spectroscopy (FTIR) spectrum displays the strong presence of SnO_2 .

III CONCLUSIONS

In this review, we have covered synthesis and characterization of Tin oxide (SnO_2) has been successfully prepared by using various deposition methods. The morphology, structure, composition and optical properties have been investigated by using different tools during the experiment. The obtained results reflect that the various deposition conditions have great influence on the properties of SnO_2 thin films.

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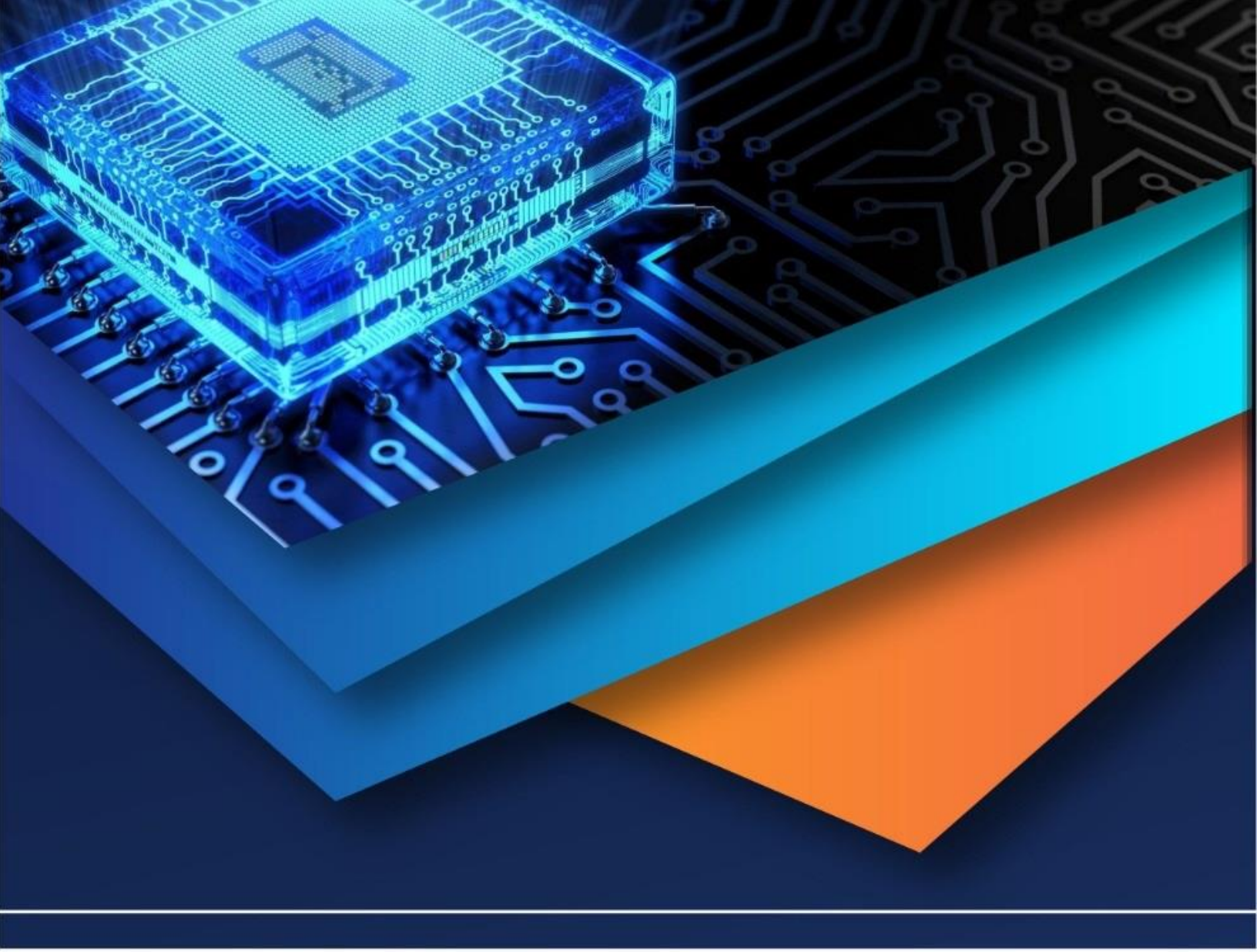

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