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Antimony Doped Tin Oxide Aerogels for Applications in Energy Conversion and Energy Storage

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Tin (IV) oxide is an important n-type semiconductor with a large band gap (E_g = 3.6 eV at 300 K). As a promising functional semiconductor material, SnO_2 has stimulated considerable research interest for its potential application in various fields such as gas sensors [1], Li ion batteries [2], solar cells [3] and photocatalysis. SnO_2 powders are frequently modified with dopant elements such as In, Sb and F to give transparent-conductive oxides (TCOs) with high optical transmittance in the visible range, low electrical resistivity and good stability [4,5]. The stoichiometry, along with the nature, quantity and microstructural distribution of dopants plays an important role in determining the electrical and optical properties of SnO_2 [5,6]. In this study, antimony-doped tin oxide (ATO) in aerogel form were synthesized with different Sb content (5, 10 and 15%) by a sol-gel process. Because of the small difference in ionic radius and electronegativity between Sn^{4+} and Sb^{5+} (10.8% and 5.6% difference, respectively) the replacement of the Sn^{4+} ions by Sb^{5+} can be done easily [7].

The morphology and structure of the ATO aerogels were characterized using field-emission scanning electron microscopy (FESEM) and transmission electron microscopy (TEM). To produce TEM specimens, the ATO aerogels were dispersed in ethanol using a sonicator; a single drop of this suspension was placed on a 3mm copper TEM grid with a thin layer of amorphous carbon. When the grid had fully dried, the ATO aerogels were analyzed by SEM. X-ray energy dispersive spectroscopy (XEDS) confirmed that their chemical composition was unaltered. TEM analysis revealed that the dopant concentration had a profound effect on the physical properties of the particles. It was found that the increase in the Sb concentration corresponded to a decrease in particle size from 10-15nm for undoped SnO_2 to 3-10nm for 15% ATO. The increase in Sb content also caused a lattice contraction. This effect is presumably related to the lower ionic radius and higher oxidation state of Sb^{5+}. The introduction of the antimony dopant may also produce additional adsorption sites on the surface of SnO_2 particles, impeding particle growth and resulting in a significant increase of the specific surface area [8,9].

The importance and limitations of the characterization of this and similar materials will be discussed.

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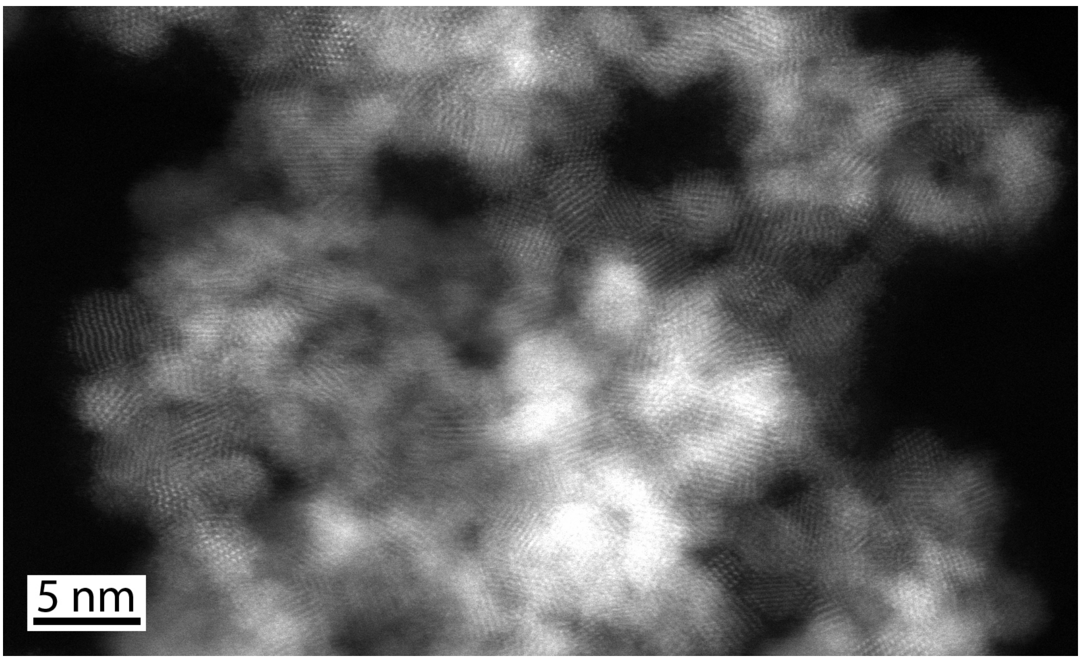
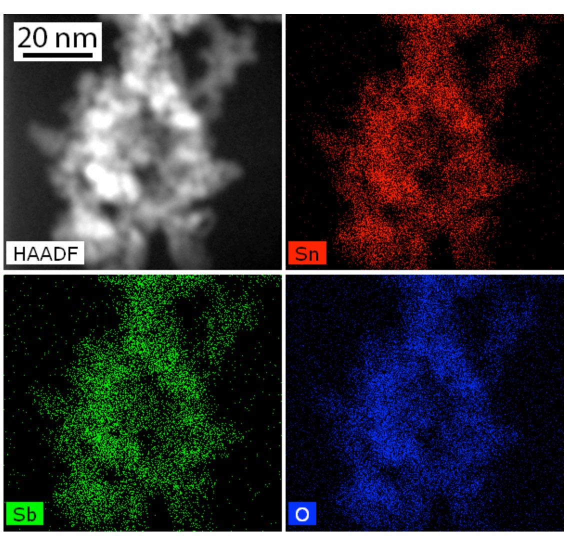


Figure 1. STEM image of 15% ATO showing the size of the particles and their crystallinity.



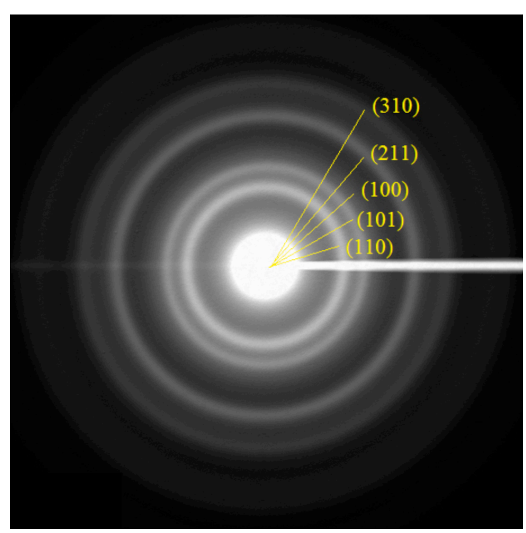


Figure 2. (Left) TEM Set of Titan Chemi-STEM images showing that the Sn, Sb and O are all co-located.

Figure 3. (Right) The selected-area diffraction pattern confirming that the oxides has the rutile (tetragonal) crystal structure, consistent with $d_{(110)}$ =3.41 Å, $d_{(101)}$=2.65 Å, d_{200}=2.33 Å, $d_{(211)}$=1.8 Å, $d_{(310)}$=1.45 Å.

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