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Effect of LABS and Triton X-100 surfactants on the particle size of nanocrystalline ITO powder

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The nanocrystal indium tin oxide (ITO) particles were prepared by liquid-phase coprecipitation under given conditions with solution of indium chloride, tin chloride, and ammonia solution. The deionized water was used as solvent and the LABS and Triton X-100 surfactant were used as a dispersant in the reaction system. The sample powder was characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM) after heat treatments. Based on scanning electron micrograph, the influences of the two different ammonia and ethylendiamide participants and also, the two different dispersants the LABS and Triton X-100 on the distribution and size of nanoparticle were studied. The results showed that the ITO particles are finely crystallized body centered cubic structure. The particle size has distributed in 30-120 nm. Using the LABS surfactant, the particles size were decreased to 30 nm while using the Triton X-100 surfactant, the particles size were increased to 120 nm. Finally, the crystallinity of ITO nanoparticles was increased by using ethylendiamide precipitant, and some porosity appeared.

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1. Introduction

Indium tin oxide (ITO) is an advanced ceramic material with many electronic and optical applications such as anti-frost coatings, low emissivity windows, rear view automobile mirrors, heat reflecting oven windows, solar cells, liquid crystal displays and photo luminescent phosphor displays [1,2] because of its excellent electrical conductivity, good visible light transparency, and high infrared reflectivity [3,4]. Several chemical routes for the preparation of ITO nanoparticles have been previously reported such as coprecipitation of metal precursors followed by thermal treatment, hydrothermal and sol gel route [5-7] and also physical methods such as sputtering, chemical vapor deposition, reactive thermal deposition, electron beam evaporation, and spray pyrolysis to fabrication of ITO thin films [8-10]. In most of the cases, results have been reported for the preparation of ITO in the bulk form. With the development of nanometer material research, several kind of preparation route for nanosized ITO emerged. The current methods for nanometer indium tin oxide preparation mainly include solid-phase method, liquid-phase method, and gas phase method [11-13]. The liquid-phase approach, with the advantages of simple operation and controllable granularity, can realize the atomic scale level of mixing. The doping of components achieves easily, and the nanoscale powder material has high-surface activity. The liquid-phase routes include liquid phase precipitation, hydrothermal (high temperature hydrolysis), Sol-gel (colloidal chemistry), radiation chemical synthesis, and so forth [14,15].

In present work, we first fabricated the ITO nanoparticles by liquid-phase coprecipitation method under given conditions with solution of salts composition of $InCl_3{\cdot}4H_2O$ and $SnCl_4{\cdot}5H_2O$ and ammonia precipitant with deionized water. Then, the effect of LABS and Triton X-100 surfactants and also ethylendiamide and ammonia precipitants on the size and distribution of ITO nanoparticles have been investigated.

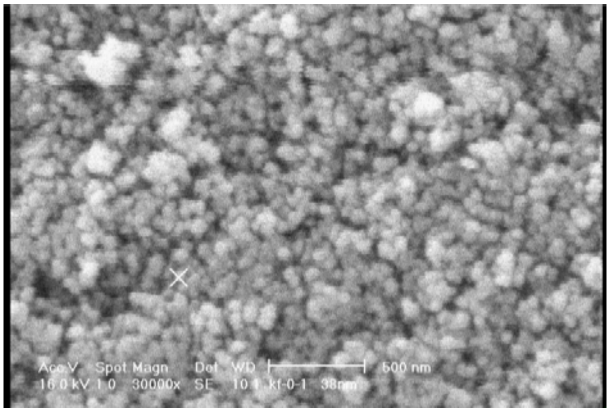
2. Experiment method

The synthesis process of ITO nanoparticle by liquid phase co-precipitation was carried out as follows. A certain quality of indium chloride ($InCl_3{\cdot}4H_2O$ 99%, Aldrich) and tin chloride ($SnCl_4{\cdot}5H_2O$ 99%, Aldrich) was dissolved in pure deionized water or ethanol, keeping the ratio of In_2O_3: SnO_2 = 9: 1. Certain concentrations (5.00%) of ammonia solutions were made by mixing certain amount of ammonia ($NH_3{\cdot}H_2O$, 25%) with pure water. The prepared $InCl_3$ solution (0.3mol/L) was transferred into fixed three-neck flask, keeping in 40 ^{o}C to 50 ^{o}C temperatures under electromagnetic agitation. The ammonia solution was added to the flask, controlling the stirring speed and testing the pH value till the required pH value and a certain amount of linear alkyl benzene sulfunate (LABS) or Triton X-100, was added as dispersant. The precipitate precursor of ITO was aged a certain time and washed with deionized water and absolute alcohol for three times, respectively. After washing, the precipitates were dried for one hour at 120 ^{o}C. The dried samples were calcinated for 1 hour at 600 ^{o}C to get the indium tin oxide nanopowder by thermal decomposing. The morphology and structure of the prepared nanoparticles were characterized by means of a scanning electron microscopy (SEM) and X-ray diffraction (XRD). The microstructure of the ITO samples were analysed by a

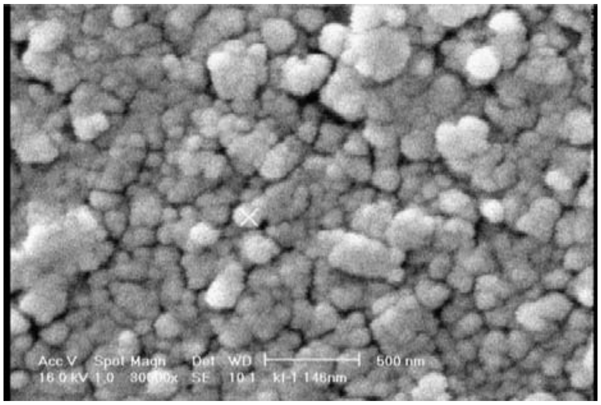
KYKY-Ammray2800 type scanning electronic Microscopy (SEM) with 200 kV acceleration voltage. To determine the nanoparticles' structure, the X-ray diffraction (XRD) measurement nanopowder were performed using a Seifert with Cu Kα radiation (wavelength = 1.54 A°).

3. Results and discussion

Fig. 1(*a)* and (*b)* show the SEM images of SnO_2 and ITO nanoparticles prepared by liquid phase coprecipitation method respectively. The particle size of tin oxide sample after 600 ^{o}C calcinations is 30 to 35 nm (Fig. 1*a*), while the particle size of ITO is 100 to120 nm with less uniformity in size (Fig. 1*b*). Because the pH value of coprecipitation solution compositions of tin and indium salts are different from the pH value for thin oxide,



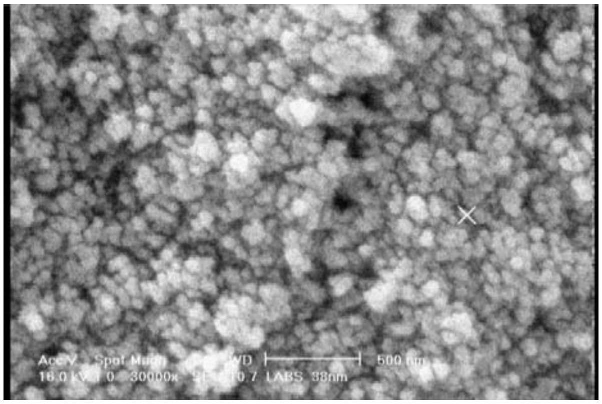
(a)



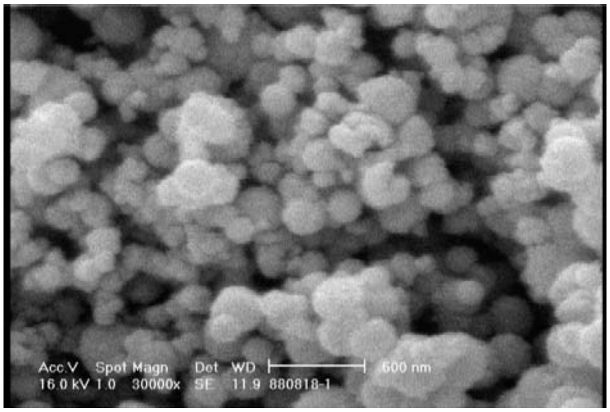
(b)

Fig. 1. The SEM images of (a) SnO_2 and (b) ITO nanoparticles.

SEM images of Fig. 2(*a)* and (*b)* show the effect of LABS and Triton X-100 surfactants on the particle size and distribution size of ITO nanoparticles. Comparing Fig. 2(*a)* with Fig. 2(*b)*, it can be seen that by adding the LABS surfactant to the solution ITO nanoparticles the size of ITO decrease to 30 nm (Fig. 2*a*). While adding the Triton X-100 surfactant to the solution of ITO nanoparticles the size particles of ITO increase and reach to 100 nm (Fig. 2*b*). It is cause that the LABS is a cationic surfactant while the Triton X-100 is an anionic surfactant.



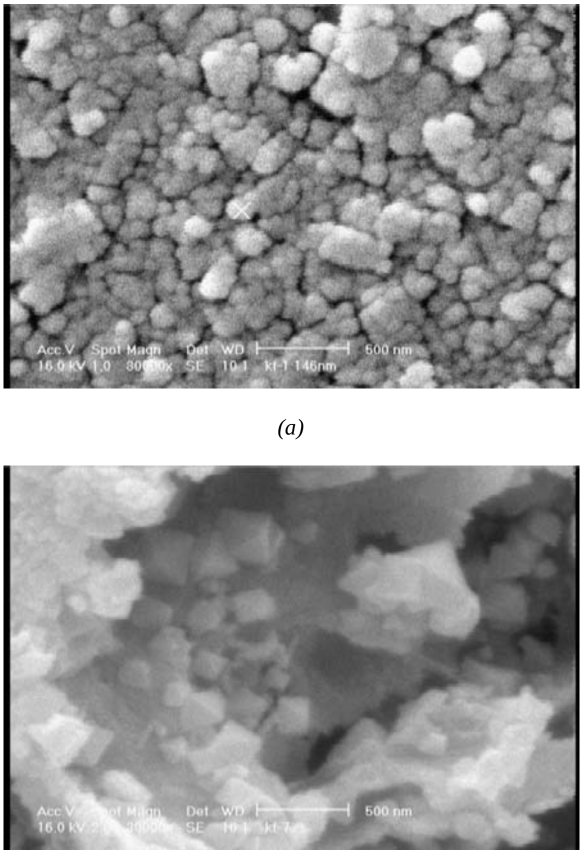
(a)



(b)

Fig. 2. SEM of ITO nanoparticles, (a) with LABS and (b) with Triton X-100 surfactants.

In Fig. 3(*a)* and (*b)* the effect of ammonia and ethylendiamide precipitants are studied. As we can see the ammonia participant make the ITO nanoparticles with uniformity (Fig. 3*a*) comparing to ethylendiamide precipitant which make the crystalline ITO particle with some porosity (Fig. 3*b*). Because the ethylendiamide precipitant has the high alkaline and complex agent and the ITO particles are formed faster and then more concentration of particles precipitates.



(a)

(b)

Fig. 3. SEM images of ITO (a) with ammonia and (b) with Ethylenediamide precipitant

Fig. 4 show the XRD pattern of SnO_2 and ITO nanoparticles were calcinated for 1 hour at 600 ^{o}C. The large wide of the picks for SnO_2 pattern indicate that this particles have the amorphous structure (Fig. 4*a*), while the ITO nanoparticles were crystallized after annealing and the strung and sharp picks indicate the body centered cubic structure (Fig. 4*b*).

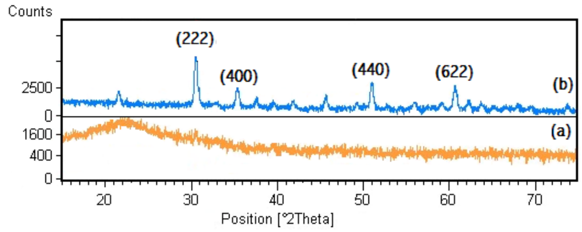


Fig. 4. X-ray diffraction pattern of (a) SnO_2 and (b) ITO nanoparticles after heat treatments at 600 ^{o}C for 1 hour.

4. Conclusions

The nanoscale indium tin oxide (ITO) particles were successfully synthesized by liquid phase co-precipitation method under given conditions with reactants of indium chloride, tin chloride, and ammonia solution. The deionized water was used as solvent, and the LABS or Triton X-100 surfactants used as a dispersant in the reaction system. The ITO particles were finely crystallized body centered cubic structure. The particles size was preferably distributed in 30 to 120 nm. The results show that LABS surfactant decrease the size of ITO and increase the uniformity of particles, while using the Triton X-100 increase the particle size. Also using Ethylendiamide precipitant the particle size and crystallinity of ITO nanoparticles increased.

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