Quantum size effect as evidenced by small-angle X-ray scattering of In_2O_3 nanoparticles

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Abstract. Indium oxide nanoparticles were synthesized by a surfactant-free room-temperature soft chemistry route. The medium particle size of the thermally treated gel was evaluated by X-ray diffraction experiments, nitrogen adsorption measurements, transmission electron microscopy observations and small-angle X-ray scattering using synchrotron radiation. The main results show the single-crystalline nature of the prepared nanoparticles with 8 nm in diameter. The photoluminescence emission spectrum at room-temperature shows a broad peak with onset at, approximately, 315 nm as a result of quantum size effect produced by a small population of nanoparticles with average size of about 2.8 nm as revealed by small-angle X-ray scattering.

Keywords: SAXS, indium oxide, quantum size effect.
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INTRODUCTION

Indium oxide, a wide band gap (about 3.6 eV) transparent conductor, is of great interest for many device applications due to its unusual combination of high transparency in the visible region and high electrical conductivity.

In this work, In_2O_3 nanoparticles were synthesized by a surfactant-free room-temperature soft chemistry route. Structural and microstructural properties were evaluated by several techniques.

EXPERIMENTAL

Nanosized indium oxide was synthesized by homogeneous precipitation at room-temperature. The colloidal dispersion was dried and thermally treated at 400°C for 2 h. The specific surface area was determined from nitrogen adsorption measurements. The average value of the crystallite size was estimated from X-ray diffraction patterns. The morphology of powder particles was observed by transmission electron microscopy. Photoluminescence emission spectra were recorded at room-temperature. Small-angle X-ray scattering measurements were carried out at

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the Brazilian Synchrotron Light Laboratory. Experimental data were fitted using the GNOM software [2].

RESULTS AND DISCUSSION

The particle size diameter calculated from specific surface area assuming a spherical shape for the particles resulted in 7.8 nm. This value is in close agreement with the crystallite size (about 8 nm) estimated for the most intense (222) reflection of the cubic bixbyite-type structure of In_2O_3.

Transmission electron microscopy observations show that indium oxide nanoparticles are spherical in shape with a narrow distribution of size. The primary particle size estimated is 8 nm in diameter.

The room-temperature photoluminescence spectrum of indium oxide nanoparticles shows a broad emission peak with onset at ~ 315 nm, which is blue-shifted compared to that of commercial In_2O_3.
Small-angle X-ray scattering results were fitted assuming a polydisperse system of spherical particles [3]. Figure 1 shows the resulting distribution curve.

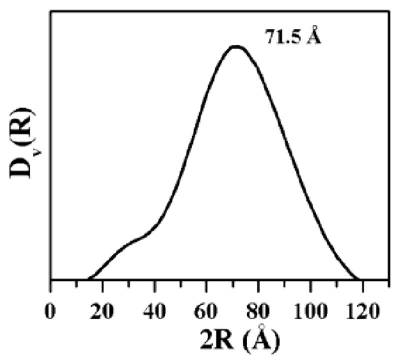

Figure 1 – Volumetric size distribution curve calculated from fitted experimental SAXS data.

The size distribution curve consists of two populations of particle sizes. The smallest one is centered at ~ 2.8 nm giving a direct evidence of a quantum size effect in In_2O_3 nanoparticles, which in turn, is responsible for the photoluminescence emission at room-temperature.

CONCLUSIONS

A quantum size effect was verified by small-angle X-ray diffraction in In_2O_3 nanoparticles. This method proved to be suitable for a detailed study of very fine particulate materials.

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