Research Article

Synthesis and Characterization of In$_2$S$_3$ Nanorods in Sucrose Ester Water-in-Oil Microemulsion

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We report the synthesis of In$_2$S$_3$ nanorods in a nonionic sugar-based water-in-oil (w/o) microemulsion system using food grade sucrose ester as biosurfactant. In$_2$S$_3$ was formed by mixing indium (III) chloride and thioacetamide in the water core of the microemulsion system. The as-prepared yellowish In$_2$S$_3$ was characterized by X-ray diffractometry (XRD), UV-visible absorption spectroscopy (UV-Vis), transmission electron microscopy (TEM), and Fourier transform infrared spectroscopy (FTIR). Formation of spherical or rod-like In$_2$S$_3$ nanomaterials was dependent on reaction time. Rod-like In$_2$S$_3$, arranged in bundles, was formed only after 2 days of reaction time. Upon longer aging time, a mixture of rod-like and spherical In$_2$S$_3$ was formed. A plausible formation mechanism of the In$_2$S$_3$ nanorods in the sucrose ester microemulsion was postulated. The diameter of the In$_2$S$_3$ nanorods was found to be very small, which is 8.97 $\pm$ 2.36 nm with aspect ratio of 20 : 1 (length : diameter).

1. Introduction

Due to the toxicity of transition metals like Cd and Pb, alternative metals have been studied for the production of metal sulfides like ZnS, SnS$_2$, and In$_2$S$_3$ [1, 2]. In$_2$S$_3$ is an interesting semiconductor with band gap energy of ~2.0 eV for bulk material [3, 4]. In$_2$S$_3$ is a metal sulfide group III–VI with potential application in optoelectronic, solar cells, and photoelectric [5, 6]. Many different types of techniques have been introduced for the synthesis of In$_2$S$_3$ in thin film or powder form with various morphologies [7, 8].

Conventionally, In$_2$S$_3$ was synthesized through direct reaction between indium and sulfur in a quartz chamber under high temperature [9], thermal treatment by In$_2$O$_3$ in the presence of H$_2$S gas at high temperature, thermal degradation of butylindium at the temperature of 300°C [10], or self-propagation with metathesis reaction between InCl$_3$ and Li$_2$S at the temperature of 500°C [11]. There are a lot of reports on the solution synthesis method, which includes precipitation in aqueous solution that yields amorphous or low crystalline indium sulfide from reaction between InCl$_3$ and H$_2$S, (NH$_4$)$_2$S [5], or NaHS [12], In$_2$S$_3$ formation in sodium polysulfide solution using laser ablation technique; In$_2$S$_3$ nanoparticles precipitation method by adding Na$_2$S into the InCl$_3$ solution in the presence of polymeric stabilizing agent [13], injection of H$_2$S into the In(ClO$_4$)$_3$ solution [14], and precipitation of In$_2$S$_3$ nanoparticles in microemulsion system. However, few works reported on the formation of 1-D In$_2$S$_3$ nanomaterials [15], thus, synthesis of 1-D In$_2$S$_3$ remains a great challenge.

W/o microemulsion systems have been employed for some time now as media for the preparation of nanoparticles. More popular surfactants including cetyltrimethylammonium bromide (CTAB) [16], sodium dodecylsulfate (SDS) [17], polyoxyethylene (10) tertocetylphenyl ether (Triton-X) [18], sodium bis(2-ethylhexyl)sulphosuccinate (AOT) [19] and polyethylene glycol-dodecylether (Brij 30) [20] have been used for the synthesis of nanomaterials. Our group had reported on the synthesis of spherical-shaped metal sulfides [21], tungsten oxide [22], PbS nanorods [23], and brushite nanofibers [24] using sucrose ester-based microemulsion.

In this paper, we utilized sucrose ester S1670 as the nonionic food grade surfactant to form w/o microemulsion (water/heptan-1-ol/sucrose ester) as a soft template for the synthesis of In$_2$S$_3$ nanorods. Sucrose ester is a green and biodegradable biosurfactant with raw material that comes