Enhanced photoluminescence and Raman spectra in SnS-Sn nanohybrids structures with Sn nanosheets

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1. Introduction

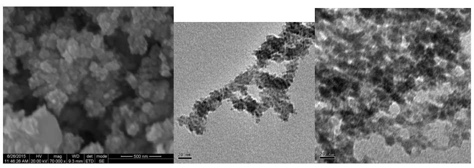
Tin is a highly researched plasmonic material, but only very few groups have reported on the visible light surface plasmon resonance (SPR) of Tin nanoparticles [1]. In this work, we synthesis Sn nanoparticles of different morphology (spheres and sheets) by chemical route and obtain SPR peak tunable in the ultraviolet- visible region of the electromagnetic spectrum. SnS nanoparticles were embedded in a mesh of Sn nanoparticles to obtain SnS-Sn nanohybrids. Metal nanoparticle - semiconductor quantum dots nanohybrids or superstructures are well studied both theoretically and experimentally. The usually probed structures are silver and gold in combination with different semiconductors like SnS, In_2S_3, GaAs, SnO, ZnO etc [2]. We report on synthesis of SnS nanoparticles, Sn nanoparticles, SnS-Sn nanocomposite and SnS-Sn nanohybrids (super structures) using chemical reduction method. The influence of morphology of Sn nanostructures on the surface plasmon resonance and its consequences on the optical properties of SnS semiconductor are investigated.

2. Experimental details

SnS nanocolloid is synthesized by dispersing 20 mg of SnS nanoparticles in 2 ml of PVP (1g in 100 ml of distilled water). For synthesis of SnS-Sn nanohybrids, 20 mg of $SnCl_2$ is injected into 2 ml of SnS nanocolloi10 mg of $NaBH_4$(dissolved in 8 ml of water and 20 ml of ethanol) is added to the mixture of SnS and $SnCl_2$ and sonicated for 15 minutes at room temperature. Sn nanoparticles thus grows in the PVP matrix and SnS nanoparticles are embedded in the mesh forming SnS-Sn nanohybrids. The resulting colloid is centrifuged at 4000 rpm and stored in powder form after drying thoroughly. The SnS-Sn nanohybrids are synthesized by varying the concentration of $NaBH_4$ as 10 mg, 20 mg, 30 mg and 40 mg.

3. Results and discussion

The SnS nanoparticles synthesised by homogenous precipitation method are brown in colour. The phase and crystallinity of SnS nanoparticles is determined from the X-Ray diffraction pattern. The peak orientation corresponds to [131], [211], [122] and [023] of the orthorhombic β-SnS. The particles have uniform size distribution and are nearly spherical in shape. The particles are of size ~ 20 nm and forms aggregates, but can be well dispersed in PVP and ethylene glycol (Figure 1a).



(a) (b) (c)

FIGURE 1. a) FESEM Image of SnS nanoparticles (b) SnS nanoparticles (c) HRTEM image of Sn hybrids

The Sn nanostructures synthesised with 20 mg $NaBH_4$ are spherical with size of ~ 15 nm (Figure 1b) and those synthesised with 40 mg of $NaBH_4$ form layered nanosheets and thus show SPR in the visible region of the electromangetic spectrum. The morphology of SnS-Sn nanohybrids is shown in Figure 1c. In nanocomposites, SnS and Sn nanoparticles are randomly distributed and not well coupled to each other whereas in nanohybrids, the SnS nanoparticles are embedded in a network of Sn nanoparticles. Thus the possibility of interaction between the SnS quantum dots and Sn nanoparticles are more probable in nanohybrids structures. On comparing the emission enhancement of SnS-Sn nanocomposites (10 times), the enhancement for SnS-Sn nanohybrids is much higher (10^2). Among the different morphology of Sn nanoparticles the nanohybrids made with Sn nanosheets has an enhancement of ~ 10^3. Apart from that, the Raman lines of SnS nanoparticles are also enhanced by an order of ~ 10^3 in the presence of Sn nanosheets.

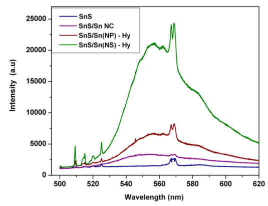


FIGURE 2. Photoluminescence spectra of SnS, SnS-Sn nanocomposites and SnS-Sn nanohybrids

Conclusion

SnS nanoparticles though is largely preferred due to the economic feasibility, abundance and eco-friendly, these structures are reported to have very low quantum efficiency and poor photoluminescence. In this work we report on the enhancement of emission and Raman intensity of SnS nanoparticles by coupling them with Sn nanoparticles of different morphology. The Sn nanoparticles exhibit surface plasmon resonance in the UV-Visible region and can be controlled by varying the morphology on the nanostructures. The optical abosorption spectrum of SnS nanoparticles coupled with Sn nanoparticles exhibit a blue shift ~ 500 meV indicating a strong interaction between the excitons and the plasmons of the nanohybrids.

Reference

1. M Patel, I Mukhopadhyay, A Ray, Optical materials, 35 (2013) 1693–1699
2. R. J. Parmar, V. R. Solanki, R. J. Pathak, and M. D. Parmar, AIP Conference Proceedings **1837 (2017)**, 040023