Strong coupling of defect levels in In$_2$S$_3$ nanoclusters due to plasmonic interactions

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1. Introduction
Surface plasmon incorporated in semiconductors lead to local field amplification which can cause enhancement in absorption and emission properties [1]. This phenomenon finds application in photonic devices [2]. In this work we report on the strong coupling of the defects levels of indium sulfide (In$_2$S$_3$) nanoparticles due to plasmonic interactions by Ag nanospheres.

2. Experimental details
In$_2$S$_3$ nanoparticles are synthesized by homogeneous precipitation method using equimolar solution of indium chloride (InCl$_3$) and thioacetamide (TAA) as precursors. The resultant mixture obtained by adding TAA to InCl$_3$ at room temperature is allowed to precipitate for 24 hours. The In$_2$S$_3$ nano powder is separated by centrifuging the solution at 4000 rpm and by washing it with ethanol to remove impurities. Ag nanospheres are synthesized by a simple chemical method [3] using AgNO$_3$ as precursor. AgNO$_3$ (2 gm) dissolved in 6 ml of ethylene glycol is added slowly to PVP (2 gm) dissolved in ethylene glycol (34 ml) which is heated in prior at 160 $^\circ$C. The pH of the PVP solution is maintained at 9 by adding Na$_2$CO$_3$. The colloidal solution Ag nanospheres thus obtained is added to In$_2$S$_3$ nanoparticles dispersed in water and sonicated for 30 minutes at room temperature. The mixture is deposited on micro glass slide by solvent evaporation method at 60$^\circ$C. The obtained films are characterized using FESEM, optical absorption spectroscopy and photoluminescence studies.

3. Results and discussion
Figure 1a and 1b shows the FESEM image of In$_2$S$_3$ particles and Ag nanospheres synthesized by simple chemical methods. The In$_2$S$_3$ nanoparticles agglomerate to form nanoclusters of size ~ 300 nm. The synthesised Ag nanospheres are of size ~ 100 nm.

Figure 2 Extinction spectrum of pure In$_2$S$_3$ and Ag: In$_2$S$_3$

The emission spectrum for excitation at 488 nm of the pure In$_2$S$_3$ nanocluster and Ag: In$_2$S$_3$ hybrid structure is shown in figure 3. The spectrum corresponding to pure In$_2$S$_3$ shows emission at ~ 650 nm (red region), which is reported of In$_2$S$_3$ as due to various defect levels in the material. Upon addition of Ag plasmonic structure the emission shifts to green region (559 nm). This indicates that in the presence of plasmonic structures there is strong coupling between the defect levels capable of emitting in the green region.

Figure 3 Photoluminescence of pure In$_2$S$_3$ and Ag: In$_2$S$_3$

4 Conclusions
In$_2$S$_3$ nanoparticles and Ag nanospheres synthesized by simple chemical methods are combined to form a hybrid nanostructure. Strong coupling of defect levels in In$_2$S$_3$ nanoclusters is observed when Ag plasmonic structures are incorporated. The blue shift of 10 nm is observed due to the strong coupling of excitons causing emission in green region.

Reference