Proc. of the Intl. Conf. on Nanotechnology for Better Living, 2016
Editors K. K. Kar, A. Shah and R. Sharma
Vol. 3, No. 1, p. 32
doi:10.3850/978-981-09-7519-7nbl16-rps-32

Enhanced band gap of erbium doped In_2O_3 thin film prepared by spin-on technique

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Rare-earth element Erbium (Er) doped conducting oxides like $In_2O_3$and TiO_2 has been studied extensively for the application of up-conversion process in semiconductor lasers. The In_2O_3 is an important transparent metal oxide semiconductor material compared to TiO_2 and ZnO due to its high electrical conductivity. The trapped state emission due to Er lies in infrared region, reported widely for TiO_2 material. Very small studies have been done on the synthesis of Er doped In_2O_3 material. Hong Koo Kim et al reported the 1.54 μm emission from Er^{3+} ions from the sputtered synthesized Er doped In_2O_3 film [1]. But there is no report on the shifting of In_2O_3 band gap towards the higher energy after doping Er into the In_2O_3. The In_2O_3 is a good material for ultraviolate (UV) detector fabrication. Again it is still a big issue to detect the deep UV light using semiconductor material with high sensitivity. UV enhanced Si CCD ends its sensitive detection process around 400 nm. Keeping into mind this matter we have started to dope the Er into In_2O_3 film to enhance its main band gap by a simple and low cost chemical process.

The In_2O_3 nano dimension thin film (TF) was prepared on the glass substrate using spin coating (spin NXG-P1, apexicindia) technique. 0.5 g Indium(III)Chloride ($InCl_3$) anhydrous powder (5N purity, Sigma Aldrich) was dissolved into the 30 ml acetyl acetone (99.5% purity) by stirring it at 60^0C for 30 min. to make the solution for spin coating. The as deposited undoped In_2O_3 TF was prepared using 1000 rpm substrate rotation for 1 min. and then open air annealed at 400^0C for 10 min. into the muffle furnace. This sample is further used for the second time deposition by spin coating technique and the above process was repeated for four times to get the desired thickness of the film. Finally the sample was annealed at 400^0C for 30 min. To prepare Er doped In_2O_3 solution 0.1007 g Er_2O_3 (99.9% purity, Sigma Aldrich) nanopowder was added into the previously prepared $InCl_3$ and acetyl acetone solution. 10 ml HCl was then added into the solution and stirred at 60 °C for 30 min. to get a homogeneous solution. The Er doped In_2O_3 TF was synthesized by spin coating technique with substrate rotation speed of 6000 rpm for 5 min. The process was repeated for four times and finally the as prepared sample was open air annealed at 400^0C for 30 min.

The optical transmission of the film was measured by using UV-Vis Spectrophotometer (Hitachi,U-3010), shown in Figure 1(a). The In_2O_3 TF shows average 75% transmission all over the region from 200-280 nm and 350-500 nm. A deep valley has been observed at around 318 nm. The Er doped In_2O_3 TF sample shows higher transmission as compared to that of the undoped In_2O_3 sample. Average 90% transmission was observed rather than a deep at around 310 nm. Figure 1(b) shows the absorption spectrum of the undoped In_2O_3 and Er doped In_2O_3 TF samples. Maximum 80% and 35% absorption has been observed for undoped and Er doped In_2O_3 TF at around 318 nm and 310 nm respectively. Figure 1(c) shows the $(\alpha h\nu)^2$ versus (hν) plot for both the samples,where α is the absorption coefficient and hν is the photon energyThe optical band gap ~ 3.61 eV and ~ 3.89 eV of the undoped In_2O_3 and Er doped In_2O_3 TF as obtained from the extrapolation of the linear part of the curves to the hνaxis. The band gap of Er_2O_3 is ~ 7.6 eV reported by Strukov et al [2]. In our case the enhancement in band gap of the Er doped In_2O_3 material may be due to the formation of $Er_xIn_{1-x}O_3$ alloy TF. So Er doped In_2O_3 TF may be used for the fabrication of deep UV detector.

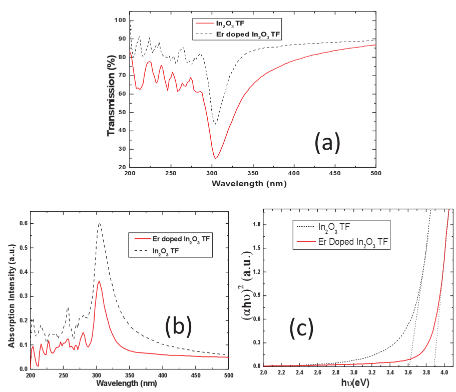

Figure 1: (a) Transmission (b) Absorption spectrum (c) $(\alpha h\nu)^2$ versus (hν) plot of both samples

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