Enhanced oscillator strengths and optical parameters of doped ZnS bulk and nanophosphors

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ABSTRACT

We synthesized, characterized, and investigated the oscillator-strength (OS), dipole-moment (DM) and integrated cross-section values (ICSVs) of singly (Mn) and doubly (Mn and Co or Ni) doped samples of ZnS bulk and nanophosphors. Although ZnS doped nanophosphors were extensively studied during recent years, most of the reports described available are related to lifetime and photoluminescence of these phosphors [1, 2]. However, there are limited numbers of reports which describe the OSVs, DMVs and ICSVs of ZnS doped bulk and nanophosphors. The theoretical models that were used previously to measure the OSVs of ZnS bulk/nanophosphors are cumbersome and they require tedious calculations which were found to be more complicated when one considers the multiple dopants for calculations of OSVs. Not only are these models labor intensive but they are also limited in the accuracy. To overcome all these difficulties encountered in the literature, we report a relatively simple model in present investigations to analyze these parameters from radiative transition probabilities, index of refraction and radiative wavelengths.

Keywords: Radiative transition probabilities, oscillator-strength, ZnS doped nanophosphors

Fig 1 shows the details of morphological characterization of the bulk and nano-samples under investigations. The phase identification was carried out using standard JCPDS database [3, 4]. The diffraction peaks are broadened in case of XRD patterns of nanophosphor samples. Further in our measurements, the crystallite size was calculated using well known Debye-Scherrer formula [1], and found to be ~2.5nm which is a case of strong quantum confinement. The confirmation of the particle size was also quite obvious from the TEM studies as indicated by Fig 1(d).

The oscillator-strength values (OSVs) are found to enhance by 3 orders of magnitude as shown in Fig 2 when Co or Ni dopant is incorporated in ZnS:Mn bulk phosphors which strongly suggest that quencher dopant triggered the energy transfer process in host ZnS material [5-7]. These quencher dopants were earlier considered to kill the luminescence from host material but we used these dopants in ZnS:Mn to create additional pathway for the relaxation of the carrier and to initiate the energy transfer mechanism. In case OSVs of nano samples, 6 orders of magnitude enhancement have been observed on introducing quencher dopants in ZnS:Mn nanophosphors which indicates that our nanosamples are related to strong confinement case and quencher dopant played a significant role in the variation of OSVs. Moreover, the analysis of OSVs showed that excitonic/defect level emission from ZnS host is due to weak electric dipole transition (WEDT) while in case of ZnS:Mn nanophosphors magnetic dipole transition (MDT) played significant role. Based on present investigations we clearly obtained the origin of excitonic and impurity related emission from doped ZnS bulk and nanophosphor samples which were almost vague in previous studies of other researchers. Synthesis and analysis methods used in the present investigations can be employed to prepare nanoparticles of various technologically important semiconductor systems for their applications in futuristic white LEDs, lasers, sensors and optoelectronic applications.

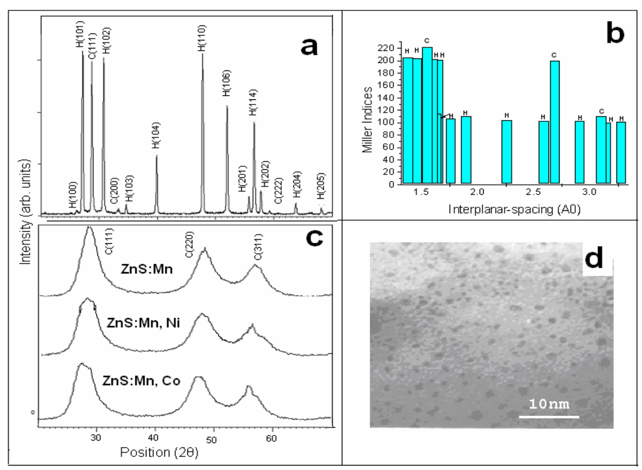
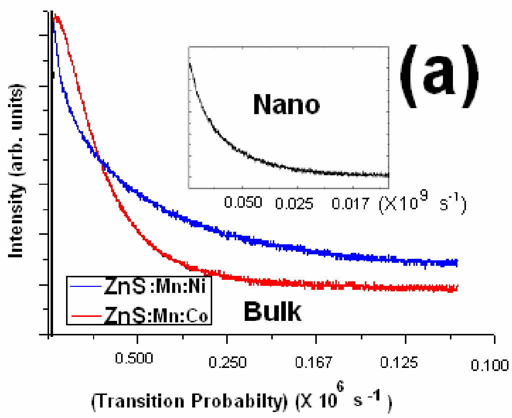


Fig. 1 (a) XRD spectra for ZnS bulk phosphors, (b) miller indices vs inter-planar spacing for ZnS bulk phosphors where C stands for cubic phase and H stands for hexagonal phase of synthesized bulk phosphors, (c) comparison of XRD pattern of ZnS:Mn, ZnS:Mn, Ni and ZnS:Mn, Co nanophosphor samples, (d) TEM image of ZnS nanoparticles.



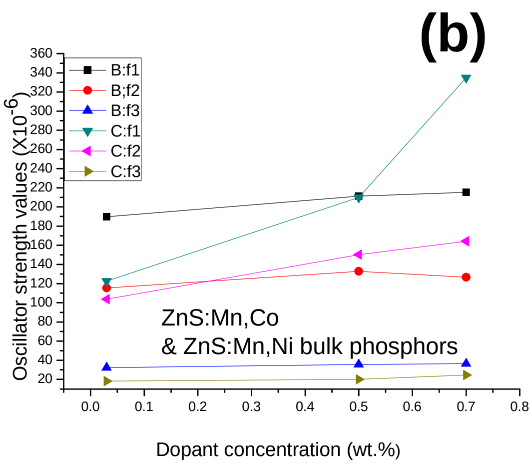


Fig. 2 (a) Multi-exponential luminescence decay curves (mainframe) of ZnS:Mn, Ni and ZnS:Mn, Co bulk phosphors while inset shows the luminescence decay curve of ZnS doped nanophosphor sample, (b) variation of oscillator strength values vs dopant concentration for ZnS:Mn, Ni and ZnS:Mn, Co bulk phosphors (mainframe) while inset is for ZnS:Mn bulk phosphors.

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