Manganese doped ZnS nanophosphors as radiation dosimeter

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The ZnS:Mn nanophosphors were prepared by chemical precipitation method using Zinc Sulphate, Sodium Sulphate and Manganese Sulphate. The concentration of manganese sulphate used varied from 1 mole to 3 moles in order to obtain different doping concentration. The formations of the nanophosphors are characterized by high resolution scanning electron microscopy, FESEM, XRD and EDX. The nanophosphors consist of particles ranging in size from 85-150 nm. The radiation dosimeter is based on thermoluminescence (TL) process whereby parts of the radiation energy stored in the irradiated nanophosphors are released during heating. The TL intensity i.e. light output v. heating temperature or glow curve has a single peak at temperature of about 250°C using a heating rate of 5°C/s. The TL response increase linearly with increasing radiation dose. It is found that ZnS doped with 2 moles of Mn is most sensitive to radiation. However, the TL signal is fading at the rate of about 40% per day when stored in the dark at room temperature. As such more parameters such as the size of the nanoparticles need to be adjusted in order to obtain the most suitable radiation detector.

I. INTRODUCTION

A typical group II–IV compounds is promising materials for producing phosphors because of their wide band gap [1]. Nanocrystalline ZnS crystals are known to have different characteristics such as photoluminescence and thermoluminescence properties as compared with bulk materials [2]. Commonly used thermoluminescence dosimeter (TLD) materials such as LiF:Mg,Ti (TLD-100) is either suitable to measure low dose or high dose only. Most TLD materials suffer from severe sup linearity at high doses reducing the choice of TLD materials for high dose application such as megavolt therapy. So we are trying to look for materials which are highly sensitive so as to be able to measure low dose and also shows linear response to radiation dose from very low up to extremely high dose (Mrad region).

II. METHODOLOGY

Chemical precipitation to produce colloidal nanoparticles is used to prepare ZnS nanophosphors. Sample is prepared by adding $ZnSO_4$ to Na_2S which is continuously refluxed to get a colloidal form of ZnS. $MnSO_4$ is injected into the colloid to obtain ZnS:Mn nanophosphors. Samples with 1 M, 2 M and 3 M of $MnSO_4$ are prepared.

The physical properties of the nanophosphors are studied using field effect scanning electron microscope (FESEM), x-ray diffraction (XRD) and EDX. For thermoluminescence study, the samples are first annealed using a step heating of 500°C, 300°C and 100°C each at 30 minutes annealing time. About 30 mg of the sample is then irradiated to gamma ray from Co-60 to various doses before being glowed in TLD reader (Harshaw 3500).

III. RESULTS AND DISCUSSION

The morphology and chemical compositions of the sample are depicted in Fig. 1 and Fig. 2 respectively.

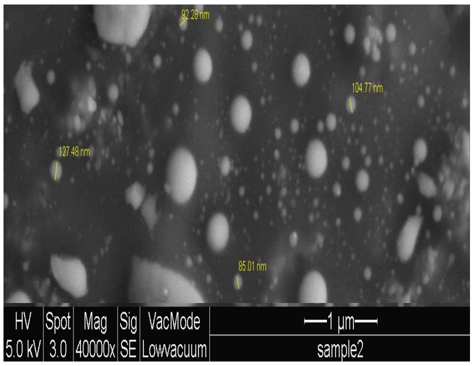

FIG. 1. Micrograph of ZnS:Mn nanophosphors.

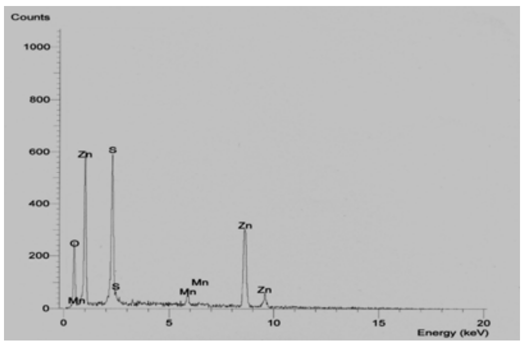

FIG. 2. Elemental composition of the nanophosphors.

As can be seen from Fig. 1, the nanophosphors obtained are mostly sphere with diameter of about 85-150 nm. The presence of manganese peak is clearly shown in Fig. 2. The typical TL glow curve (A plot of light intensity v. heating temperature) is shown in Fig. 3. An intense broad peak at temperature of ~250°C indicate the suitability of ZnS:Mn nanophosphors as TLD material. The glow curve shape is typical of semiconductor material [3]. The TL sensitivity is obtained by measuring light output against irradiated dose. The response is linear up to the dose of 100 Gy. It is found that the TL sensitivity increases with increasing Mn molarity as shown in Fig. 4. The most likely explanation is the increase in Mn resulted in the ZnS becoming more conductive. The thermal stability at room temperature in the dark of ~250°C peak is also studied. Fig. 5 shows the fading rate of the TL peaks for nanophosphors with different Mn concentrations.

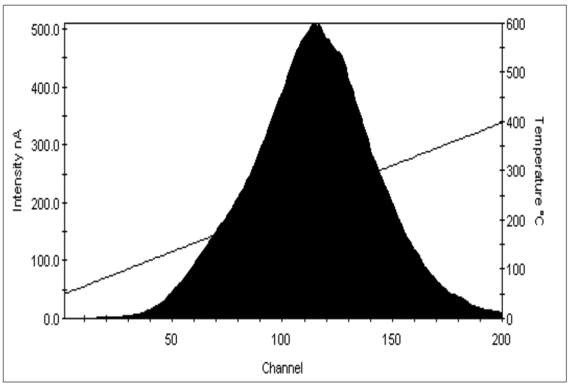

FIG. 3. Typical TL glow curve of ZnS:Mn nanophosphors.

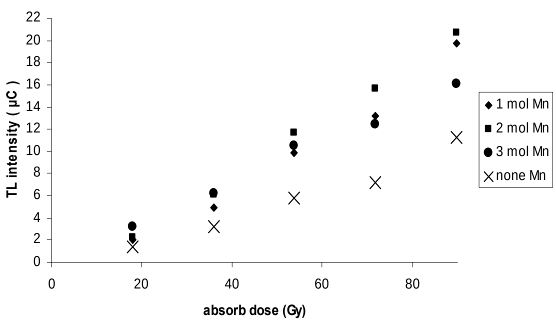

FIG. 4. TL sensitivity of nanophosphors with different Mn molarity.

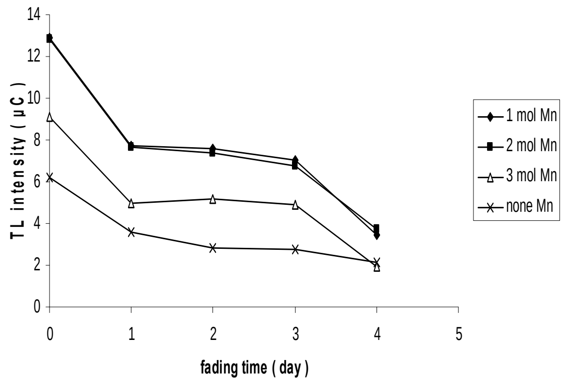

FIG. 5. Fading rate of ~250°C TL peak at room temperature of nanophosphors with different Mn concentration.

Clearly the initial fading rate is high whereby after only ~1 day, almost 40% of the signal is gone. After 4 days only ~30% of the signal is left. Clearly in order to be useful as radiation dosimeter the fading rate has to be reduced perhaps by annealing or adding different rare earth elements.

IV. CONCLUSION

The ZnS:Mn nanophosphors obtained by chemical precipitation shows a good TL sensitivity and a linear response up to the dose of 90 Gy. The increase in Mn concentration seems to increase the TL sensitivity. However the ~250°C is not stable and faded to about 60% of the original signal only after 1 day. In order for the nanophosphors to be used as TLD material, this drawback has to be overcome.

ACKNOWLEDGEMENT

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