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Synthesis and the Study of Optical Characteristics of Nano $SmFe_{1-x}Al_xO_3$ by the Double Sintering Ceramic Method

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Abstract: *The goal of this study was a synthesis of nanocrystals $SmFe_{1-x}Al_xO3$ (x=0. 0, 0.05, 0.1, 0.15) and an examination of their optical properties. $SmFe_{1-x}Al_xO_3$ were prepared by the double sintering ceramic technology. The product was characterized by X-ray diffraction (XRD) and Photoluminescence (PL). The XRD analysis confirmed the formation of single phase crystals of perovskite structure. Photoluminescence is used to analyze the optical properties of the materials. PL spectra show Uv emissions that slightly shifted with Al content. The PL intensity of multiferroic material enhanced with increasing Al content (x). The wide band gap that was determined from PL spectra of the investigated metal oxide recommends it to be used in optical applications.*

Keywords - *PL, Energy Gap, XRD*

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I. Introduction

About thirty years, nanotechnology began to develop and achieved many great improvements not only in research but also in many modern applications. New physical and chemical effects and properties appeared by using nano materials. These properties do not exist in bulk materials with the same chemical composition [1]. Materials widely used in light sources are optical materials and other functional materials, which are applied to various electronic devices such as detectors, voice recorder, video recorder. These materials, having ABO3 typed perovskite like structure (where A is a such as Sm, Y, La, Ln (rare earth metals), Bi and B is transition metal such as Mn, Fe, Co, Ni, Cr), are studied intensively due to their properties and difficult synthesis [2-4].

Modified ABO_3 compounds are materials where A or B or both A and B ions are partially replaced by other metal ions (such as Sm, Sr, Cd, Ln (rare earth metals), Mn, Fe, Ni, Al, etc.) [5-6]. This modification produces mixed valence state of metals and structural defects, which create more interesting effects such as thermal effects, thermomagnetic effects, and large magnetoresistance for material substrate. That has opened up new application of perovskite materials in a number of modern industrial areas such as electronics, information, petrochemical processing technologies.

In this study, nano $SmFe_{1-x}Al_xO_3$ typed perovskite materials (x = 0.0, 0.05, 0.1 and 0.15) were synthesized using double sintering ceramic method and studied their optical properties. Optical properties of SmFe1-xAlxO3 were studied by using Photoluminescence (PL) method and XRD.

Photoluminescence (PL) method can be defined as, the spontaneous emission of light from a material under optical excitation. A variety of material parameters can be characterized by using PL investigations. PL spectroscopy provides electrical characterization, and it is a selective and extremely sensitive probe of discrete electronic states. Identification of surface, interface, and impurity levels and to gauge alloy disorder and interface roughness could be considered as features of the emission spectrum. The quality of surfaces and interfaces can be determined from the intensity of the PL signal. Indeed, the PL technique requires very little sample manipulation. Because the sample is needed to excite optically, electrical contacts and junctions are unnecessary and high-resistivity materials pose no practical difficulty. In addition, time-resolved PL can be very fast, making it useful for characterizing the most rapid processes in a material. The main limitation of PL analysis is its dependence on radiative events. Ordinary PL analysis couldn't be used with a poor radiative efficiency materials, such as low-quality indirect bandgap semiconductors. Also, identification of impurity and defect states depends on their optical activity. PL is a simple method. The instrumentation that is required for PL analysis is (Optical source, Optical power meter, Detector). A PL setup is shown in Figure 1 [7]. The paper is organized as follows: in section II materials and fabrication method is explained in detail. In section III, Characterization technique is explained and show the XRD and PL intensity and the results which shows energy gap and how it is affected by Al concentration. In Section IV, the conclusion.

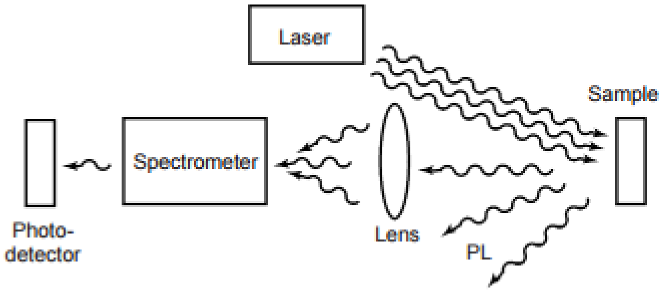

Fig. 1 Experimental setup for PL measurements

II. Materials and methods

Double sintering ceramic technology is a method that used to prepare the sample of $SmFe_{1-x}Al_xO_3$ with different concentration of Al start from 0 to 0.15 with step 0.05. The chemicals used in the research were analytically pure. Sm_2O_3, Al_2O_3, Fe_2O_3 were mixed together. The preparation consists of four steps:

1. Stoichiometries ratios were well mixed.
2. Grinding for four hours and a pre sintering in air at 900 ^oC with a heating rate of 4 ^oC /min.
3. Regrinding again for three hours and final sintering in air at 1150 ^oC for 2 h.
4. The samples were pressed into pellets using a uniaxial press of pressure 5x108 N/m2.

III. Characterization technique

3.1 XRD ANALYSIS

In this paper, the crystal structure and microstructure of $SmFe_{1-x}Al_xO_3$; $0 \leq x \leq 0.15$ are explored and shows the influence of Al^{+3} ions content (x) by using XRD. XRD helps us to investigate the structural variations of the unit cell of $SmFeO_3$ parent compound upon the substitution with Al^{+3} ions. Figure 2 illustrates the XRD pattern for the samples $SmFe_{1-x}Al_xO_3$; $0.0 \leq x \leq 0.15$. The analysis of the XRD pattern reveals the formation of the structure. The data was compared and indexed with reference ICDD card number 04-006-8304. The intensity of the diffraction lines depends slightly on the Al^{+3} content in the orthoferrite lattice. Al^{+3} content (x) was limited at the value of 0.15 due to the appearance of secondary phase which mean The material has another component indexed as Al_2O_3 with relatively small intensities [11].

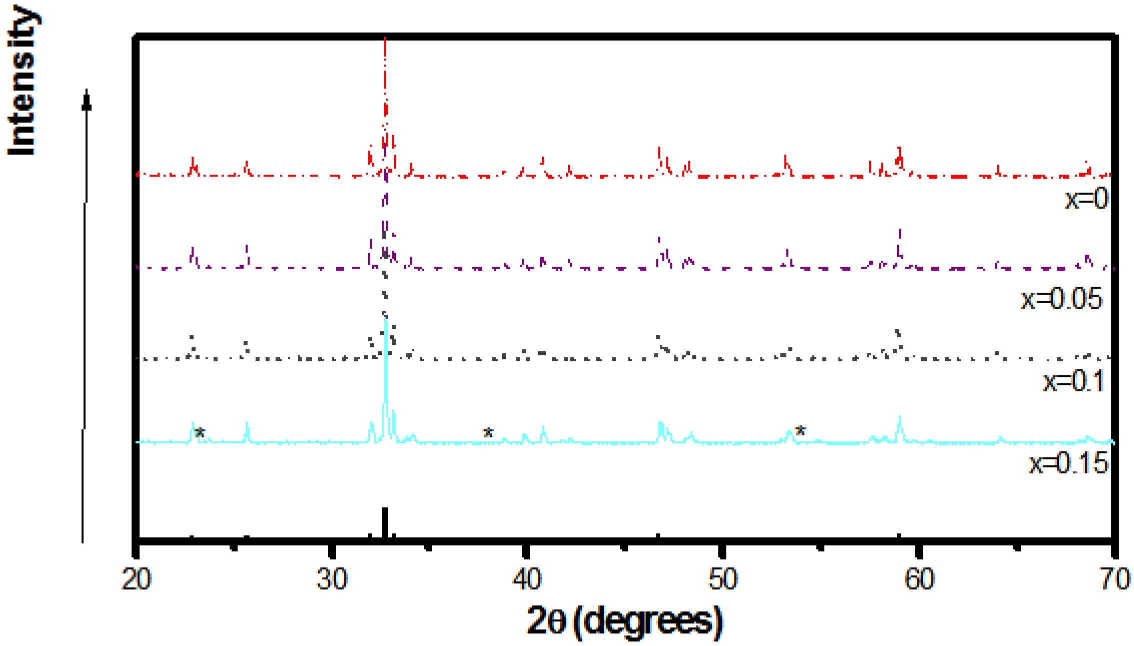

Fig. 2. X-ray diffraction patterns of the samples $SmFe_{(1-x)}Al_xO_3$; x= (0, 0.05, 0.1, 0.15) *Secondary phase

3.2. PHOTOLUMINESCENCE (PL) ANALYSIS

Room temperature photoluminescence (PL) is shown in Figure 3 under the UV excitation wavelength of 220 nm of Al doped SmFeO3 samples at different Al content (x) (0, 0.05, 0.1, 0.15). The emission spectra is found in the wavelength range from 240 to 800 nm. From Figure 3 the band gap energy Eg of the sample could be estimated from the UV emission. Where the UV emission broadband can be attributed to band to band transition. So the accurate value of the Eg can be determined which be around 4.5 ev. It was found that the energy gap value shifts towards lower values and tunable with the Al content (x).

The peaks corresponding to the blue emissions may be attributed to the oxygen vacancies. The observed slightly shift for the emission maximum gives further support to the band edge shift dependency on the particle size, which is in good agreement with XRD data. The obtained SmFe1-xAlxO3 nanomaterial showed a wide band gap, hence it could be used for optical components [8-10].

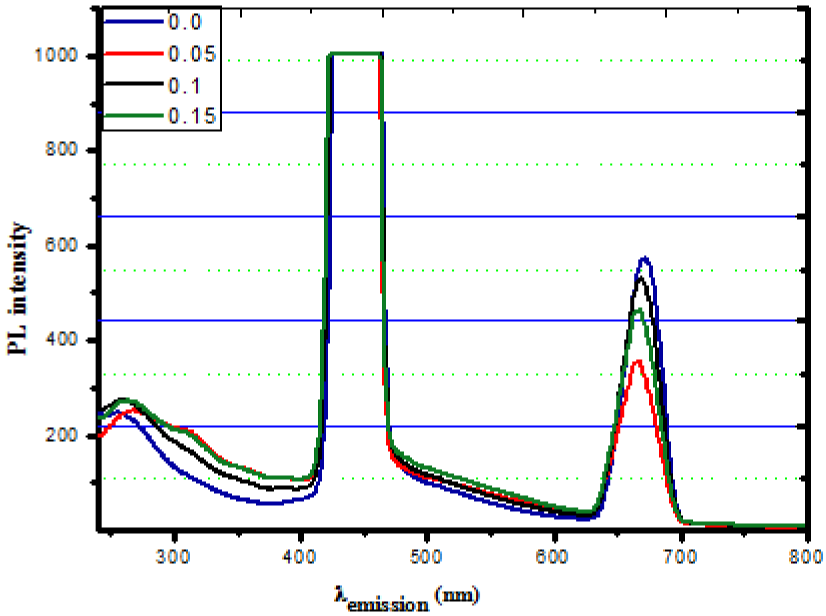

Figure 3. PL of SmFe1-xAlxO3 where x (0.0, 0.05, 0.1, and 0.15) under excitation of 220 nm.

IV. Conclusion

Material of SmFe1-xAlxO3 (x= 0.0, 0.05, 0.1, 0.15) with a particle size in range 100 nm was synthesized by double sintering ceramic technology. The XRD analysis proved the formation of a single phase crystals perovskite structure. PL spectra shows that the emission slightly moved with Al content. The band gap can be determined in accurate method by using PL investigation. The obtained SmFe1-xAlxO3 nanomaterial showed a wide band gap, hence it could be used for optical components.

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