PROSIDING

SEMINAR KEBANGSAAN

SAINS, TEKNOLOGI & SAINS SOSIAL

27 ~ 28 MEI 2002
HOTEL VISTANA, KUANTAN, PAHANG

Anjuran :

Universiti Teknologi MARA
Cawangan Pahang

Dengan Kerjasama

Kerajaan
Negeri Pahang Darul Makmur

JILID 2

PREPARATION AND CHARACTERIZATION OF SURFACE MAGNETO-OPTIC KERR EFFECT (SMOKE) IN STRONTIUM FERRITE ($SrFe_{12}O_{19}$) VIA SOL-GEL ROUTE

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ABSTRACT

Surface Magneto-Optic Kerr Effect (SMOKE) measurements performed on polycrystalline $SrFe_{12}O_{19}$ ferrites was obtained using an applied field of ≈ 0.4 Tesla and at a temperature of 300 K temperature. In this project, strontium hexaferrites were prepared by the chemical sol-gel route to get fine, pure and homogeneous of powders. Ferum Nitrate Hexahidrate, $Fe(NO_3)_3.6H_2O$ and Strontium Nitrate, $Sr(NO_2)_3$ were dissolved in citric acid solution by using a magnetic stirrer. The solution was slowly evaporated until a gel was formed after 2 weeks. This gel was dried at 110 °C in an oven for 2 days. The powders were analyzed by using X-ray Diffraction at various temperatures (800 °C, 900 °C and 1000 °C) to confirm the formation of the strontium ferrite phase. These powders were then presintered at 800 °C for 3 hours. After that, the powders were sieved and were mixed with PVA liquid as a binding agent before being moulded into pellet shape. The samples were sintered at 950 °C and 1000 °C for 3 hours in air. From the results, it was found that the formation of $SrFe_{12}O_{19}$ phase occurs at 1000 °C. In conclusion, the both $SrFe_{12}O_{19}$ (sintered at 950 °C and 1000 °C) showed Kerr rotation, ψ_{Kerr}, about 1.1° and 1.5°, respectively.

Key words: Sol-Gel, Kerr Effect and Hexaferrites

INTRODUCTION

Strontium ferrite ($SrFe_{12}O_{19}$) and Yttrium Iron Garnet ($Y_3Fe_5O_{12}$) with Bi^{2+} as an additive has received special attention because of their application in many devices like isolators, magneto-optic switches, magnetic field sensors, M-O display, printers and bubble memory etc.[1]. The Kerr effect as applied to ferromagnetic materials involves the change in polarization of light reflected from a magnetized medium. Based on this, the Solid-State Laboratory of the Department of Physics in UPM had embarked a project studying magneto-optical effects, the Kerr Effect. High density and uniform as well as fine-grained microstructure are desirable in order to minimize the magnetic-energy loss at high frequencies. However, the hexaferrites are often prepared by high-temperature solid-state reaction technique. Alternatively, several novel techniques, such as the co-precipitation, pyrolysis and sol-gel techniques, have been used to obtain the desired properties by many researchers. By adopting these techniques, rather than the conventional processing technique, a large surface area can be achieved. However, the principle advantage, which has driven all solution, based approaches, is the fact that by mixing all the components in their solutions, atomic molecular homogeneity is achieved immediately [1]. Additionally, the sintering temperature required to yield the ferrite phase may be lower than those required for the conventional oxide-mixing route. Sol-gel processing has attracted much interest both for the processing of special powders and for forming thin coatings [2] and cast or extruded shaped samples. This process involves the separation of sol, which is a dispersion of solid-particles, the dispersed phase, in a liquid. In the dispersed medium, at least one dimension of the particles of the dispersed phase is between 1 nm and 1μm [3]. Based on the advantages mentioned, we attempted preparing $SrFe_{12}O_{19}$ samples by using the sol-gel technique.

EXPERIMENTAL PROCEDURE

Stoichiometric mixtures of $Fe(NO_3)_3.6H_2O$ and $Sr(NO_2)_3$ were dissolved in an aqueous solution of citric acid. The nitrates were dissolved by stirring them at the speed of 300 rpm in the acid for 2 weeks. The thick and clear reddish-brown gel was obtained. The gel was then dried in an oven at 110 °C for 24 hours. The dried powder was then divided into portions, which were then calcined for 3 hours at different temperatures to tract the reaction pathway. X-Ray Diffraction measurements were performed to identify the strontium ferrite phase. The green powder was then crushed for 4 hours. Granulation took place after zinc stearate as a lubricant and polyvinyl alcohol as a binder was added to the powder. The green powder was then moulded to a pellet shaped and pressed at 60kN by a hydraulic pressing machine. Sintering was then done for 3 hours in air at 950 °C and 1000 °C. X-

Ray measurements were carried out in Siemen D5000 machine using Cuα radiation, with λ = 1.54056 Å. The scanning speed of the counter is 2θ per min. The crystallite of the samples were calculated from the XRD line broadening of the maximum peak using the classical Scherrer relation,

$$D_{hkl} = \frac{K\lambda}{h_{1/2}\cos\theta} \qquad [1]$$

where D_{hkl} is the average particle diameter , K is the shape factor (0.94), λ is the wave length of the X-rays (1.54056), and $h_{1/2}$ is the half maximum line width in radian.

Magneto-optic Measurements (Photon Counting)

1. The light detector is the most sensitive light measurement instrument available, being a bi-alkali photodiode of good quantum efficiency.
2. The detector detects the light level by counting photons, one by one.

The equipment was set-up according to Figure 1.

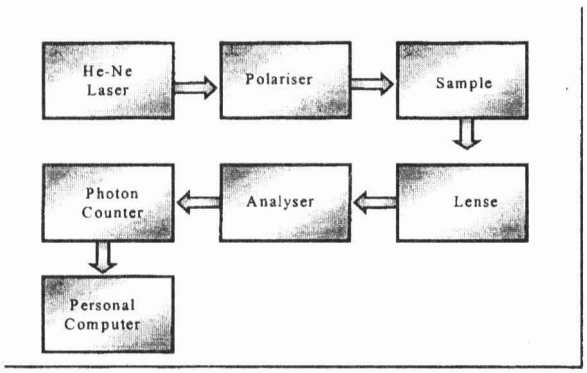

Figure 1 : Flow Chart of the Magneto-Optics Experimental Set-Up

Linearly polarised light was produced by passing the incident light wave through a polariser (Figure 2). The polariser was oriented so that its polarisation axis makes an angle θ (θ was fixed) with the y- axis. The next step was to pass the polarised light on to the sample and observe the reflected light. Upon leaving the sample, the wave passed through a second linear polariser, called an analyser (to differentiate the second polariser from the first). The total angle between the analyser and the polariser was set to be 90°. The analyser transmited one component of the elliptically polarised light. The Kerr effect was only observed after a magnetiser was used to magnetise the sample (Figure 3). The effect was detected (when there is a difference of reading before and when the sample was being magnetized) by the photon counter and dδ could be observed; the counter was connected to a computer. A bi-alkali photodiode was used instead of the multi-alkali as it has good quantum efficiency over the range from 300nm to 650nm. In this experiment, we used a He-Ne laser of 632.9 nm with a 1mW power.

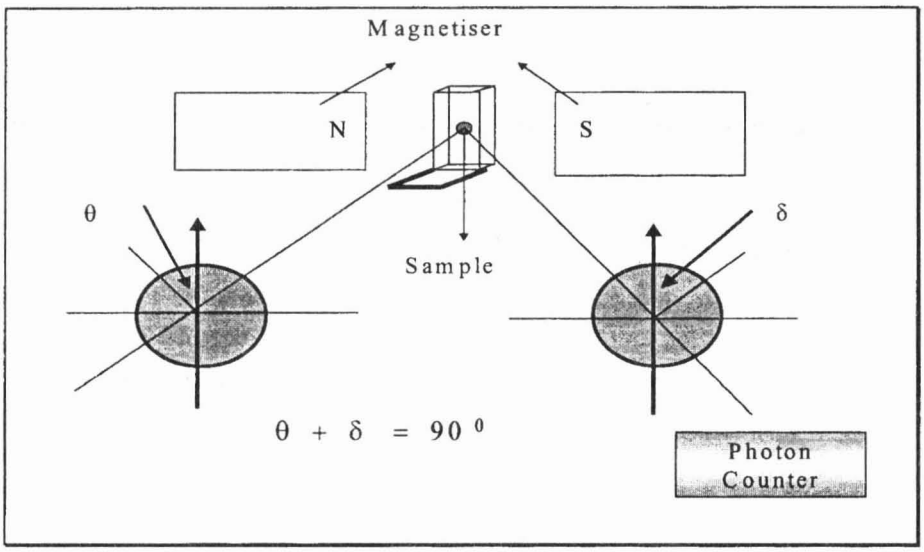

Figure 2: Schematic Diagram Before Magnetising the Sample

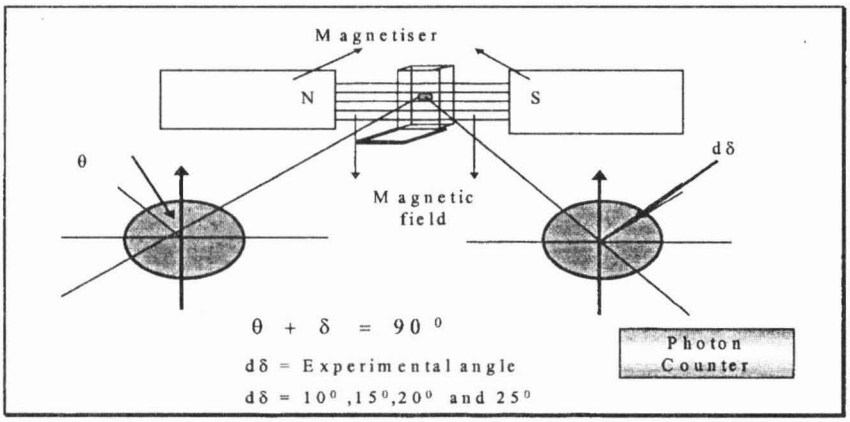

Figure 3 : Schematic Diagram After Magnetising the Sample (Energy Absorbed With Kerr Rotation)

NOTE: dδ is the angle that controls the amount of light that comes in through the photon counter. The Kerr angle (ψ_{Kerr}) is the angle difference between two minimum light intensities i.e. without and with the external field, H. Since the photon counter is too sensitive, we are unable to obtain the angle difference between two maximum light intensities.

RESULTS AND DISCUSSION

Figure 4 shows the XRD patterns of the $SrFe_{12}O_{19}$ particles after calcining for 3 hours in air. When the calcining temperature was at 800 °C, no significant diffraction lines were observed, indicating the amorphous state of the samples. Clear diffraction lines began to appear for powders calcined at 900 °C and followed by powders, which corresponded, to the progression of crystal growth of the entire particles. Sharp and clear diffraction lines could be observed for powders calcined at 1000 °C for the duration of 3 hours. All the particle size of the powders, which was calculated from Equation 1 is in the range of nano size (50 – 70 nm).

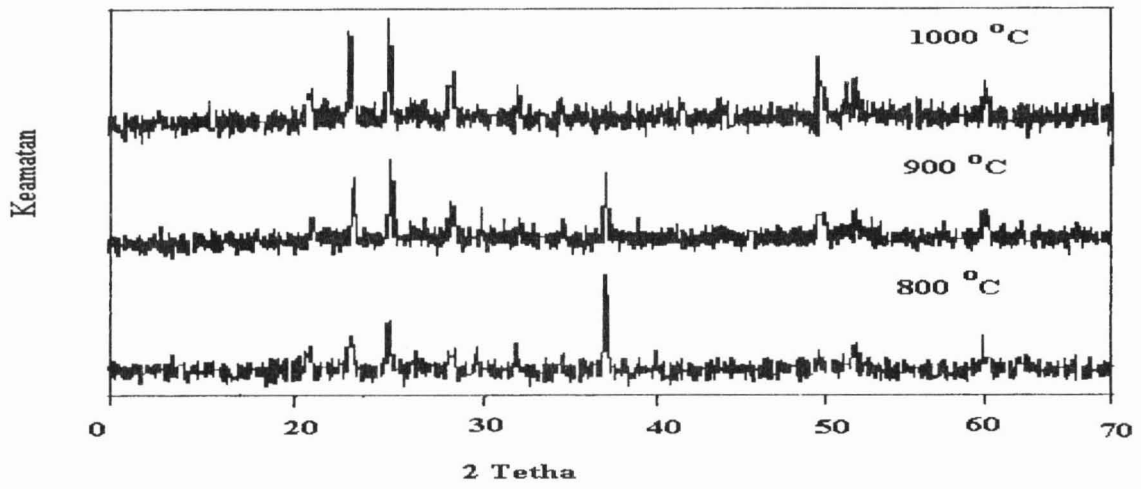

Figure 4 : X-Ray diffraction profile for $SrFe_{512}O_{19}$ powders prepared by thesol-gel technique at different temperatures (800 °C, 900 °C and 1000 °C)

Observation of Energy Absorption for sample $SrFe_{12}O_{19}$

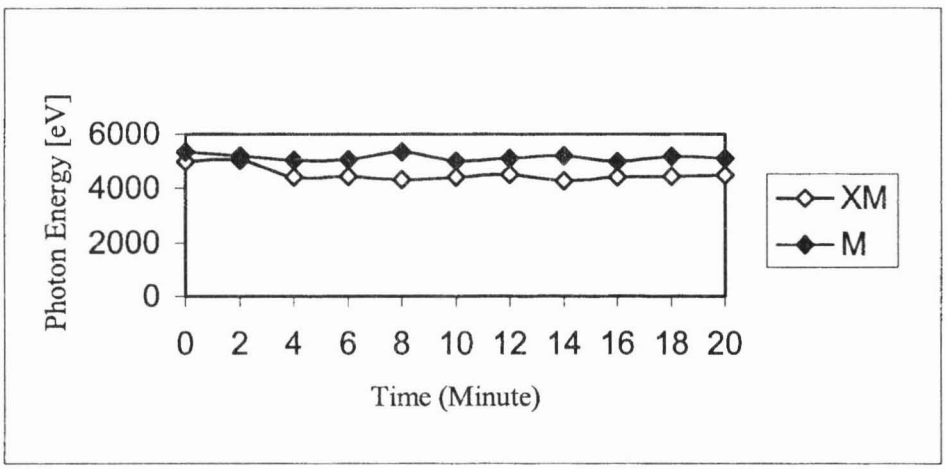

Figure 5: Photon Energy Against Time when dδ is 15 Degree for Sample $SrFe_{12}O_{19}$ (XM indicates without H field and M indicates with H field)

Figure 5 and 6 show the energy reflected when dδ are 15 deg and 20 deg, respectively. Summarising the result, it could be observed that there is a trend of increasing reflection of energy with the increased dδ. This shows that when dδ was large or, more energy can be detected by the photon counter, indicating that there was a response of magnetic moments towards the magnetic field coupled with the polarised light. However, it should also be noted that above this angle (dδ =20deg.) the photon counter was unable to detect or measure the energy as it was being shut down.

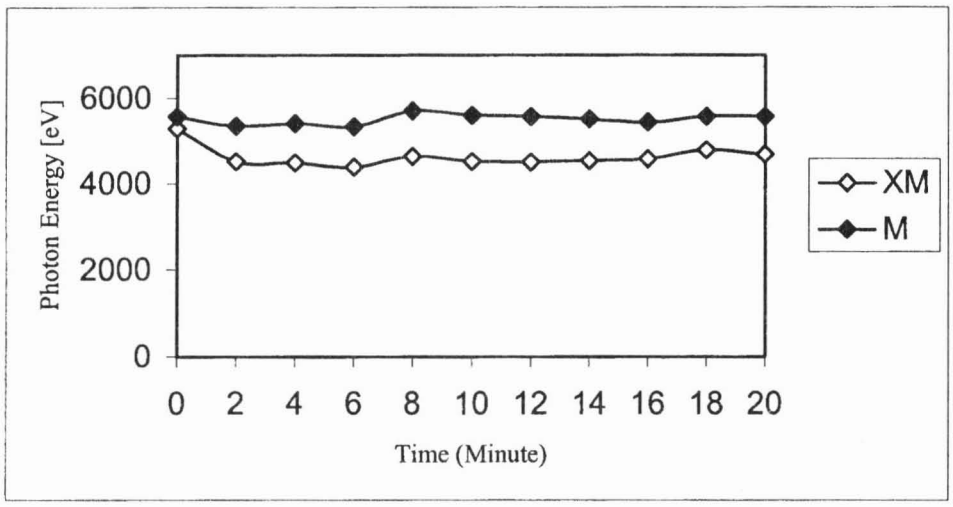

Figure 6: Photon Energy Against Time when dδ is 20 Degree for Sample $SrFe_{12}O_{19}$(XM indicates without H field and M indicates with H field)

The following part discusses the Kerr angle (ψ_{Kerr}). From Table 1, it could be observed that ψ_{Kerr} for sample $SrFe_{12}O_{19}$ sintered at 950 °C is 1.1 deg and 1.5 deg. For sample $SrFe_{12}O_{19}$ which was sintered at 1000 °C. Sample $SrFe_{12}O_{19}$ sintered at 1000 °C gives better Kerr rotation compared to that sintered at 950 °C. This is attributed to the better formation of $SrFe_{12}O_{19}$ phase, and thus giving a better microstructure.

Table 1: The ψ_{Kerr} for samples $SrFe_{12}O_{19}$ sintered at 950 °C and 1000 °C

Sample	Kerr Rotation Angle (ψ_{Kerr}) deg
$SrFe_{12}O_{19}$ sintered at 950 °C	1.1
$SrFe_{12}O_{19}$ sintered at 1000 °C	1.5

CONCLUSION

It is concluded that Kerr rotation occurred better for the $SrFe_{12}O_{19}$ sample sintered at 1000 °C due to the formation of better strontium ferrite phase (Figure 4). Secondly, increased optical energy reflection occurred if the samples were subjected to an external field H. This is actually the measure of an energy reflected when ferromagnetic order exists, relative to the situation when no random magnetic order exists.

ACKNOWLEDGEMENT

The authors thank the Ministry of Science, Technology and the Environmental, Malaysia for the fund provided under IRPA grant no. 03-02-04-012 .

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