Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

Synthesis, Characterization and Mechanoluminescence of Europium doped $BaAl_2O_4$ phosphor

S.J.Sajan[1], N.Gopakumar[1]*, P.S.Anjana[2] and S.J.Akhilesh[1]
[1]Post Graduate Department of Physics, Mahatma Gandhi College, Thiruvananthapuram, Kerala, India - 695004
[2]Department of Physics, All Saints College, Thiruvananthapuram, Kerala, India- 695007
***Corresponding Author: E-Mail: gopkumar.n@gmail.com**

ABSTRACT

The $BaAl_2O_4$:0.1%Eu sample was prepared via high temperature solid state reaction method. The phase formation of the powder sample was confirmed by taking X-ray diffraction analysis. The mechanoluminescence (ML) property of the sample by impact method was studied by using ML measuring apparatus. The variations in the ML peak intensity due to the impact velocity of a load falling from different heights and due to the variation of composition were investigated. The Photoluminescence studies of the samples were also conducted.

KEY WORDS: doped, Europium, ML.

1. INTRODUCTION

Mechanoluminescence (ML) is an interesting phenomenon, which is caused by mechanical stimuli such as grinding, cutting, collision, striking and friction. It is a defect related phenomenon, associated with trap involved process in which electrons (holes) dwell in the trap for some time and then recombine with the luminescence centre either by travelling in the conduction band or by electron (hole) tunneling (Rai, 2011). It is interesting to note that all solids do not exhibit ML. That means origin of ML in certain solids is related with the nature of materials (Chandra, 2013). Earlier studies reported about the intense ML emission of rare earth doped strontium aluminate phosphors. Hence a considerable amount of work had been conducted by researchers to exploit the ML property of rare earth doped strontium aluminates for stress sensing applications (Chandra, 2011; 2009; Jha, 2013). Akiyama (2002) measured the ML intensity of different phases of Eu, Dy codoped strontium aluminates and studied the influence of repeated application of stress, number of filled traps and the stiffness of host lattices on mechanoluminescence intensity (Akiyama, 2002). Recent studies reported that Eu doped strontium aluminates can be used for health monitoring of an aged bridge.

But only limited number of works were reported in the ML studies of barium based compounds (Khare, 2014; Wani, 2014). Rai (2011) have reported the ML study of gamma irradiated $BaAl_2O_4$: Eu prepared via combustion synthesis method. In the present paper we report the ML studies of europium (Eu) doped $BaAl_2O_4$ without any pre-irradiation prepared via high temperature solid state reaction method in air atmosphere.

2. EXPERIMENTAL

Stoichiometric weights of high purity (99.99%) $BaCO_3$, Al_2O_3, Eu_2O_3 were used as starting reagents. The stoichiometric weights of the reagents were taken using an electronic analytical balance (Schimadzu) and the mixture is thoroughly mixed for two hour by adding double distilled water as mixing medium using a pestle and agate mortar. The slurry was dried and then preheated at 105^0C for I hour and then calcined at 115^0C for 4 hours. The calcined powder was then grounded well for two hours.

The phase formation of the sample was investigated by X-ray diffraction analysis (XRD) [model D8 Advance Antonn Paar, TTK450 using Cu X-ray source (λ=1.5406Å)].

The ML measurements were taken via impact method using ML measuring apparatus. The samples were placed on a flat Lucite glass plate and a load of mass 100gm was dropped from a height on to the sample using a guiding cylinder. A photomultiplier tube (PMT 931Å) placed just below the Lucite glass plate detected the ML and the same was visualized as a peak in the screen of a digital storage oscilloscope which was connected to the PMT. The variation in peak intensity with respect to the impact velocity was also studied by dropping the mass from different heights. The deformed samples were irradiated using UV for 15 min, 30min, 1hr, 2hr etc and once again its ML intensity with impact velocity was taken. The PL studies of the samples were carried out using PL apparatus. (Horriba Fluorolog Spectro Flurometer)

3. RESULTS AND DISCUSSION

Fig.1 shows the XRD patterns of the $BaAl_2O_4$:0.1%Eu phosphor powder. The observed pattern matched well with standard data of the compound $BaAl_2O_4$. (ICDD No.00-017-0306). Fig 2 shows the ML response with change in impact velocities of the samples. An impact was made on the sample by dropping a load of 100gm is dropped from heights 5cm, 10cm, 15cm and 20cm. The impact velocity is calculated using $\sqrt{2gh}$, where g is acceleration due to gravity and h is the height from which the load is falling. The sample is seemed to be sensitive for small values of impact velocities and ML intensity shows an appreciable increase with increase in impact velocities. Fig 2 shows that a single peak was observed when sample $BaAl_2O_4$:Eu was deformed and the peak intensity shows a sudden rise when impact velocity increases from 100cm/s to 171cm/s. Several models were proposed by various researchers as the origin of ML in many crystals. This includes ML due to hole detrapping model (Choubey, 2012), local piezo electric field caused by impurities and defects, movement of charged dislocations, baro diffusion of defects in crystals (Chandra, 2012) etc. In our present study it is to be mentioned that the calcined phosphor powders without any pre-irradiation exhibits intense ML. Also the ML intensity decreases with successive number of impacts of load and the ML intensity cannot be fully recovered when the deformed sample is treated under UV exposure for different exposing times like 15 min, 30min, 1hr, 2hr. This rule out the applicability of hole detrapping model as the origin of ML in the samples. The results suggests that the origin of ML in the samples may due to piezo electrification or due to the movement of charged dislocations or the combination of the both (Chandra, 2012; Pateria, 2015).

Fig 3 shows the PL emission of $BaAl_2O_4$: 0.1%Eu peaking at 503 nm under 325 nm excitation. This has attributed to the energy transition between the ground state of $4f^7$ and the excited state of $4f^6 5d^1$ of Eu^{2+} ions.

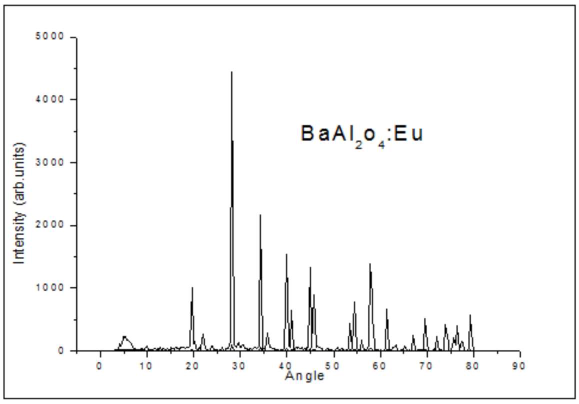

Fig.1.XRD of $BaAl_2O_4$: Eu powder sample prepared via high temperature solid state reaction method

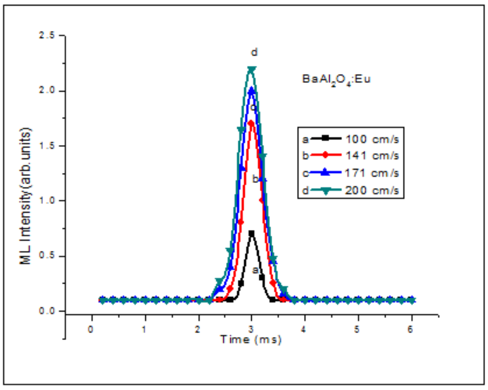

Fig.2.Variation of ML intensity of $BaAl_2O_4$:Eu sample with impact velocities

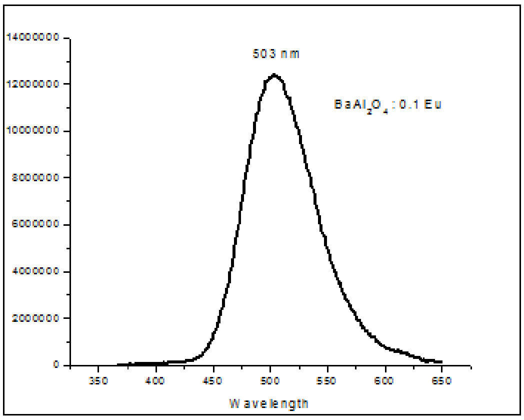

Fig.3.PL emission spectrum of of $BaAl_2O_4$:Eu

Fig 3 shows the PL emission of $BaAl_2O_4$: 0.1%Eu peaking at 503 nm under 325 nm excitation. This has attributed to the energy transition between the ground state of $4f^7$ and the excited state of $4f^6 5d^1$ of Eu^{2+} ions [1].

4. CONCLUSIONS

$BaAl_2O_4$:0.1%Eu phosphor was successfully synthesized by high temperature solid state reaction method in air atmosphere.$BaAl_2O_4$:Eu sample without any pre-irradiation exhibits ML. No regaining of ML was observed even after treating the deformed samples under UV exposure indicates the possibility of ML can be discussed using induced piezo electrification model and movement of dislocations. The ML property of the sample and enhancement in ML intensity with impact velocities were investigated. It was found that good ML intensity was obtained when the impact velocity is 200cm/s. The ML emission of $BaAl_2O_4$:0.1%Eu phosphor is so significant even for small change in impact velocities and hence it can be suggested for stress sensing applications. The PL studies of the sample was also conducted and the PL emission results shows that emission peak at 500 nm which is attributed to the energy transition between the ground state of $4f^7$ and the excited state of $4f^65d^1$ of Eu^{2+} ions.

5. ACKNOWLEDGEMENTS

The authors are thankful to the University Grants Commission (UGC), New Delhi for the financial support, Sophisticated Analytical Instruments Facility (SAIF), STIC, Cochin for providing XRD characterization and Department of Physics, Mahatma Gandhi University, Kottayam for providing PL characterization. The authors are thankful to the Department of Chemistry, Mahatma Gandhi College, Thiruvananthapuram for providing the facility for UV irradiation.

REFERENCES

Akiyama M, Chao-Nan Xu, Liu Y, Nonaka K, Watnabe T, Influence of Eu, Dy co-doped strontium aluminate composition on mechanoluminescence intensity**,** J. Lum., 97, 2002, 13-18.

Anil Kumar Choubey, Nameeta Brahme, Bisen D.P, Mechanoluminescence by Impulsive Deformation and Photoluminescence of $SrAl_2O_4$:Eu Phosphor Prepared by Combustion Synthesis**,** Phys. Procedia, 29, 2012, 104 – 108.

Chandra B.P, Baghel R.N, Luka A.K, Sanodiya T.R, Kuraria R.K, Kuraria S.R, Strong mechanoluminescence induced by elastic deformation of rare-earth-doped strontium aluminate phosphors**,** J. Lum., 129, 2009, 760-766.

Chandra B.P, Chandra V.K, Jha P, Rashmi Patel, Shende S.K, Thaker S, Baghel R.N, Fracto-mechanoluminescence and mechanics of fracture of solids**,** J. Lumin., 132, 2012, 2012-2022.

Chandra B.P, Sonwane V.D, Haldar B.K, Pandey S, Mechanoluminescence glow curves of rare-earth doped strontium aluminate phosphors, Opt. Mater., 33, 2011, 444-451.

Chandra V.K, Chandra B.P, Piyush Jha, Models for intrinsic and extrinsic elastico and plastico-mechanoluminescence of solids**,** J. Lum., 138, 2013, 267-280.

Chandra V.K, Chandra B.P, Suitable materials for elastico mechanoluminescence-based stress sensors**,** Opt. Mater., 34, 2011, 194-200.

Deepthi Pateria, Baghel R.N, Bisen D.P, Jha P, Chandra B.P, Mechanoluminescence of $(ZnS)_{1-x}$ $(MnTe)_x$ nanophosphors excited by impact of a load**,** J. Lumin., 166, 2015, 335-345.

Jha P, Chandra B.P, Lum J, Impulsive excitation of mechanoluminescence in $SrAl_2O_4$:Eu, Dy phosphors prepared by solid state reaction technique in reduction atmosphere**,** 143, 2013, 280-287.

Khare A, Nag Bhargavi B, Chauhan N, Brahme N, A high flattening C + L band broadband source based on single pump and the same erbium-doped fiber, Optik, 125, 2014, 4655-4658.

Rai R.K, Upadhyay A.K, Kher R.S, Dhoble S.J, Mehta M, $BaAl_2O_4$:Eu – Phosphor for mechanoluminescence dosimetry**,** Rad. Meas., 46, 2011, 1393-1396.

Wani J.A, Sahu A.K, Choudhary P.S, Nayar V, Dhoble S.J, Mechanoluminescence and lyoluminescence characterization of $Li_2BaP_2O_7$:Eu phosphor**,** Rad. Meas., 60, 2014, 16-22.