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Short Communication

Synthesis and Second Harmonic Generation Study of Nd^{3+} Doped Lithium Alumino-Borate Non-Linear Optical Material

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Abstract

A polycrystalline neodymium doped lithium aluminum borate ($Li_2Al_{2(1-x)}Nd_{2(x)}B_2O_7$, Nd:LABO) with x=0 and 0.03 has been synthesized by simple solid-state technique. The obtained Nd: LABO polycrystalline was characterized by powder X-ray diffraction and second harmonic generation efficiency measurement. The second harmonic generation efficiency of the polycrystalline material was obtained by the classic Kurtz and Perry powder technique using a fundamental wavelength 1064 nm of Nd:YAG laser in comparison with potassium dihydrogen phosphate.

Keywords: Nd: LABO, Powder X-ray diffraction, Second harmonic generation.

Introduction

Recently, several new nonlinear optical (NLO) crystals in borate category have been developed. The grown NLO crystals required to have high NLO coefficient, non-hygroscopic nature, high transparency at wavelength of interest, moderate birefringence for phase matching, high laser damage threshold and good mechanical stability[1-3]. As per the literature survey, grown NLO crystals are of choice from borate based two families- beryllium borates and alluminium borates.

Belonging to these families, $Sr_2Be_2B_2O_7$ (SBBO)[4-6], $Ba_2Be_2B_2O_7$ (TBO)[7], $BaAl_2B_2O_7$ (BABO)[8,9], $K_2Al_2B_2O_7$ (KABO)[10-15] and $Na_2Al_2B_2O_7$ (NABO)[16-18] have been reported as promising NLO crystals. KABO has excellent NLO properties with a wide spectral transparency range and large birefringence. Ye et al. were first to reported KABO[10]. Thereafter, many researchers have reported the crystal structure, linear optical and NLO properties of KABO crystal[11-15].

The crystal structure and other properties of NABO have been studied by many researchers[16-18]. Ahman et al.[19] reported the phase $LiAl_7B_4O_{17}$ and recently Palaspagar et al.[20] have reported photoluminescence properties of Eu^{3+} doped $Li_2Al_2B_2O_7$ (LABO) phosphor. Dagdale et al.[21] have reported the synthesis and optical properties of polycrystalline LABO.

In this study, the $Li_2Al_{2(1-x)}Nd_{2(x)}B_2O_7$ with x = 0 (LABO) and 0.03 (Nd:LABO) polycrystalline have been synthesized by solid-state technique.

The phase has been confirmed using powder X-ray diffraction (XRD) analysis and second-harmonic generation (SHG) study has also been presented.

Materials and Methods

Analytical grade chemicals lithium carbonate (Li_2CO_3) and neodymium oxide (Nd_2O_3) were purchased from LOBA Chemie, India, Aluminum oxides (Al_2O_3) and boric acid (H_3BO_3) were purchased from s d Fine-Chem, India. The chemicals were used as it is as received without further purification.

The aluminum borate material $Li_2Al_{2(1-x)}Nd_{2(x)}B_2O_7$ with x = 0 and 0.03 were prepared by solid-state reaction technique. The appropriate amounts of starting chemicals Li_2CO_3, Nd_2O_3, Al_2O_3 and H_3BO_3 were taken and mixed thoroughly by grinding to make homogeneous mixtures. The homogeneous mixtures were transferred to platinum crucibles and kept in resistively heated muffle furnace.

Firstly, it was heated at 550°C for 5h to decompose the carbonate and boric acid. After that the samples were crushed to make powder and for proper mixing. Then it was heated at 850 °C in air atmosphere for 10 h with intermittent grinding. Since, the LABO compound decomposes at high temperatures, the reaction temperature was carefully controlled.

The expected reaction takes place is given below.

$$Li_2CO_3 + (x\text{-}1)Al_2O_3 + (x)Nd_2O_3 + 2H_3BO_3 \rightarrow Li_2Al_{2(1-x)}Nd_{2(x)}B_2O_7 + CO_2\uparrow + 3H_2O\uparrow$$

The phase and crystallanity of the polycrystalline samples were confirmed by powder XRD. Powder XRD measurement was carried out on a X-ray Diffractometer (Rigaku, Miniflex-II, Japan). SHG measurement of powdered samples was carried out by using Kurtz and Perry powder technique[22].

Results and Discussion

Powder XRD study: The crystals structure of the material was studied by recording and analyzing powder XRD data. Powder XRD patterns of the LABO and Nd: LABO powders were recorded using a CuKα (λ =1.504 Å) radiations over a range 10-90° for 2θ at a scan rate of 10°/min. The software PowderX[23] was used to analyze data and index obtained peaks. Obtained powder XRD patterns are shown in Figure-1. The LABO crystallizes in the trigonal crystal system and the unit cell parameters are a = 15.723 Å, c = 10.596Å and α = β = γ = 90° [21].

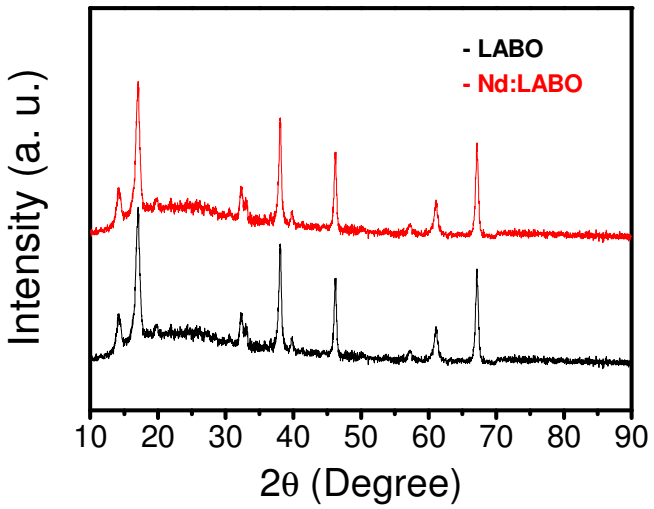

Figure-1
Powder XRD pattern of LABO and Nd: LABO

SHG study: The LABO and Nd: LABO polycrystalline materials were subjected to the SHG study to decide the SHG efficiency in comparison with potassium dihydrogen phosphate (KDP) by using an analogues experimental setup as Kurtz and Perry powder technique[22]. The setup consists of a Q-switched Nd: YAG laser emitting fundamental wavelength at 1064 nm. The pulse rate of Nd: YAG laser was 10 Hz, pulse diameter was 6 mm and pulse energy was 120 mW. A laser beam was passed through an iris diaphragm to shaping beam and removing flash lamp component around it. Interference filter was used to remove other wavelengths present with laser beam. The laser beam was made to incident on a sample surface and output signal was collected at an angle 90° after passing through 532 nm interference filters to filter out IR components. The collected signal was fed to optical fiber based UV-vis spectrophotometer to measure intensity. The experimental setup for SHG measurement was reported in our previous publication[21]. The intensities of light at 532 nm for samples and KDP polycrystalline material were measured and compared. The SHG in the powder samples was confirmed from green radiation emission[24]. The SHG efficiencies of polycrystalline LABO and Nd:LABO were 1.3 and 1.4 times higher as compare to standard material KDP as shown in Figure-2.

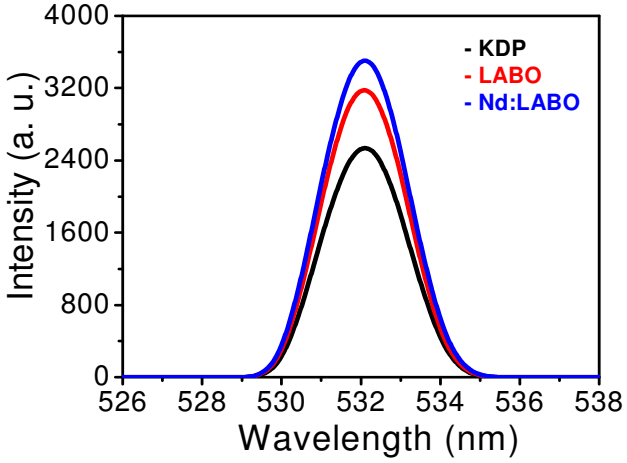

Figure-2
Spectra for KDP, LABO and Nd:LABO after SHG

Conclusion

In the present report, polycrystalline material LABO and Nd:LABO were successfully synthesized by a simple solid-state technique. The phase of the LABO and Nd:LABO was studies by powder XRD analysis. The SHG test was carried and it is found that the LABO and Nd: LABO has ~1.3 and 1.4 times more SHG efficiency as compare to KDP.

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References

1. Atuchin V.V., Bazarov B.G., Grossman V.G., Molokeev M.S. and Bazarov Z.G. (2013). Structural field of $K_2Al_2B_2O_7$-family crystals. *Proc. of SPIE.,* 8772, 87721O-1-8.
2. Dagdale S.R. (2015). Synthesis and Optical Study of Novel Nd^{3+}:$Na_2Mg_2ZnB_4O_{10}$ Single Crystal. *OIIRJ.*, 5(3), 105-110.
3. Dagdale S.R., Pahurkar V.G. and Muley G.G. (2016). Review Article High Temperature Crystal Growth: An Overview. *Macromolecular Symposia,* 362(1), 139-141.
4. Chen C.T., Wang Y.B., Wu B.C., Wu K.C., Zeng W.L. and Yu L.H. (1995). Design and synthesis of an ultraviolet-transparent nonlinear optical crystal $Sr_2Be_2B_2O_7$. *Nature,* 373(6512), 322-324.
5. Lin Z., Wang Z., Chen C., Chan S.K. and Lee M.H. (2003). Mechanism for linear and nonlinear optical effects in crystals of the $S_{r2}B_{e2B2O7}$ family. *J. Appl. Phys.,* 93(12), 9717-9723.

6. Meng X.Y., Wen X.H. and Liu G.L. (2008). Structure and Stacking Faults in $S_{r2}B_{e2B2O7}$ Crystal. *J. Korean Phys. Soc.*, 52(4), 1277-1280.

7. Qi H. and Chen C.T. (2001). A new UV-nonlinear optical material $Ba_2Be_2B_2O_7$. *Chem. Lett.,* 30(1), 354-356.

8. Ye N., Zeng W.R., Wu B.C., Huang X.Y. and Chen C.T. (1998). Crystal structure of barium aluminium borate, $BaAl_2B_2O_7$. *Z. Kristallogr, New Cryst. Struct.*, 213, 452.

9. Yamada K. (1994). Japan Kokai Tokyo Koho. Japanese Patent No., 09.61, 864.

10. Ye N., Zeng W.R., Jiang J., Wu B.C., Chen C.T., Feng,B. and Zhaang X. (2000). New nonlinear optical crystal $K_2Al_2B_2O_7$. *J. Opt. Soc. Am. B*., 17(5), 764-768.

11. Hu X.B., Wang J.Y., Zhang C.Q. and Xu X.G. (2004). Raman study of phonons in $K_2Al_2B_2O_7$ crystals. *Appl. Phys. Lett.*, 85(12), 2241-2243.

12. Hu Z.G., Higashiyama T., Yoshimura M., Mori Y. and Sasaki T. (1999). Redetermination of the crystal structure of dipotassium dialuminum borate, $K_2AI_2B_2O_7$, a new non-linear optical material. *Z. Kristallogr. New Cryst. Struct,.* 214, 433-434.

13. Hu Z.G., Higashiyama T., Yoshimura M., Yap Y.K., Mori Y. and Sasaki T. (1998). A New Nonlinear Optical Borate Crystal $K_2Al_2B_2O_7$ (KAB). *Jpn. J. Appl. Phys*., 37(10A), L 1093-L1094.

14. Kaduk J.A., Satek L.C. and Mckenna S.T. (1999). Crystal structures of metal aluminum borates. *Rigaku J.,* 16(2), 17-30.

15. Hu Z.G., Ushiyama N., Yap Y.K., Yoshimura M., Mori Y. and Sasaki T. (2002). The crystal growth and nonlinear optical properties of $K_2Al_2B_2O_7$. *J. Cryst. Growth*, 237-239, 654-657.

16. Rza-Zade P.F., Guseinova S.G. and Ganf K.L., Abdullaev G.K. and Samedov F.R. (1971). English translation ofIzv. Akad. Nauk SSR. *Inorg. Mater.,* 7, 1135.

17. He M., Chen X.L., Zhou T., Hu B.Q., Xu Y.P. and Xu T. (2001). Crystal structure and infrared spectra of $Na_2Al_2B_2O_7$. *J. Alloys Compd.,* 327, 210-214.

18. He M., Kienle L., Simon A., Chen X.L. and Duppel V. (2004). Re-examination of the crystal structure of $N_{a2}A_{l2B2O7}$: stacking faults and twinning. *J. Solid State Chem*., 177(9), 3212–3218.

19. Ahman J., Svensson G. and Grins J. (1997). Lithium aluminium borate, $LiAl_7B_4O_{17}$. *J. Acta Chemica Scandinavica.,* 51, 1045-1050.

20. Palaspagar R.S., Gawande A.B., Sonekar R.P. and Omanwar S.K. (2014). Combustion synthesis and photoluminescence properties of a novel E^{u3+} doped lithium alumino-borate phosphor. *J. Luminescence* 154, 58–61.

21. Dagdale S.R. and Muley G.G. (2016). Synthesis and Optical Properties of Polycrystalline $Li_2Al_2B_2O_7$ (LABO). AIP Conf. Proc., 1728, 020436-1-4.

22. Kurtz S.K. and Perry T.T. (1968). A powder technique for the evaluation of nonlinear optical materials. *J. Appl. Phys*., 39(8), 3798-3813.

23. Dong C. (1998). Institute of Physics National Lab. for Superconductivity. P.O. Box 603, Beijing 100080 PowderX Nov. 16.

24. Dagdale S.R. and Muley G.G. (2016). Synthesis and characterization of a novel nonlinear optical material $Mg_2Na_2ZnB_4O_{10}$. *Procedia Technology*, 682-688.