**International Journal of Scientific Research in Physics and Applied Sciences** **Research Paper**
Vol.7, Issue.1, pp.46-51, February (2019) **E-ISSN:** 2348-3423
*DOI: https://doi.org/10.26438/ijsrpas/v7i1.4651*

# Investigation on new NLO material L-histidine potassium pentaborate ($LHKB_5$)

**C.Karnan[1], A.R.Prabakaran[2*]**

[1,2] Department of Physics, Pachaiyappa's College, Chennai 600 030, India

**Corresponding Author: arprabakaran6095@gmail.com*

**Available online at: www.isroset.org**

Received: 05/Feb/2019, Accepted: 17/Feb/2019, Online: 28/Feb/2019

***Abstract-*** A new nonlinear optical crystal L-histidine potassium pentaborate single crystal was grown from aqueous solution by the slow evaporation solution growth technique to analyse its suitability for NLO device applications. It belongs to the orthorhombic crystal system which is confirmed by single crystal X-ray diffraction analysis. The UV-visible analysis was carried out on $LHKB_5$ crystal to find out cut-off wavelength and the energy gap of the material was found to be 245 nm and 5.05 eV. The presence of L-histidine potassium pentaborate on grown material was confirmed by FTIR analysis. TG-DSC analysis determines that the material has two stages of decomposition and it has three stages of weight loss. From DTA curve a sharp endothermic peak at 192.45°C shows good crystallinity and corresponds to the melting of the grown crystal. The mechanical strength of the material is calculated using Vicker's microhardness. Grown crystal shows that the material is very much suitable for a second harmonic generation and frequency conversion applications.

***Keywords*:** X-ray diffraction, FT-IR, Optical, TG-DSC and microhardness.

## I. INTRODUCTION

In recent trends, the research on new NLO materials has aroused much interest in modern material science for the growth of novel single crystal which finds a variety of applications to perform functions like optical switching, electro optic shutters and optical memory storage devices, photonics, frequency conversion and optoelectronic technology [1-4]. The semi organic crystals are superior in high optical nonlinearity, resistance to laser induced damage, a high degree of design chemical flexibility and with good mechanical strength and have high thermal stability [6, 7].Amino acids are potential substance for NLO applications and were subjected to extensive analysis by several researchers for their nonlinear properties. Since they contain proton donor carboxylic group, proton acceptor ($-NH_2$) group in them and Zwitter ionic nature favors crystal hardness and crystallizes with a non-centrosymmetric space group [8-10]. Among the amino acids family, L-histidine molecule consists of the planar imidazole ring in the histidine structure which helps in possessing high nonlinear optical efficiency [11]. A number of L-histidine complexes were reported earlier which shows good NLO property, namely L-histidine maleates [12], L-histidinehydrochloride[13] and $Tb^{3+}$ doped L-histidine hydrochloride monohydrate crystal [14]. The electronegative value between boron and oxygen are higher, they can exhibit different structure. A boron atom may coordinate to triangular or tetrahedral shape in complex formation. The borates crystals possess high damage threshold and high optical quality. Some of the borate crystals which have been reported earlier are ($KB_5$), (APB), ($K_3CdB_5O_{10}$) and ($LAKB_5$) [15-19]. In the present investigation the new semi organic crystal of L-histidine potassium pentaborate crystals have been grown by slow evaporation solution growth technique from aqueous solution. The grown $LHKB_5$ crystals were characterized by single crystal XRD, FTIR, UV-visible, TG-DSC and microhardness properties were reported for the first time.

## II. EXPERIMENTAL DETAILS

The analytical reagent (AR) grade materials of potassium carbonate (Merck) and boric acid (Merck) were taken in the ratio 1:10 for the synthesis of potassium pentaborate using deionized water as solvent. The resultant product of potassium pentaborate was found as homogeneous mixture which is then mixed with 1 mole of L-histidine (LOBA). The solution was continuously stirred for 5hours to obtain homogeneous mixture of L-histidine pentaborate ($LHKB_5$). After that, colorless solution was obtained which reaches saturation point. The saturated solution was passed through Wattmann filter paper twice to remove impurities and allowed for crystallization at room temperature. After one week a good quality seed crystals were obtained. The seed crystals were immersed in a mother solution and allowed to crystallize at room temperature. The $LHKB_5$single crystals were harvested from the mother

© 2019, IJSRPAS All Rights Reserved 

solution over a period of 28 days. Fig. 1 shows the reaction of synthesized $LHKB_5$ crystal. The grown $LHKB_5$ crystal is depicted in fig.2.

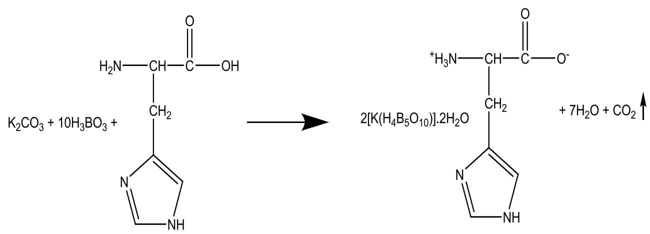


Fig. 1. Reaction scheme of $LHKB_5$

Fig. 2. Grown crystal of $LHKB_5$

## III. CHARACTERIZATION METHOD

L-histidine pentaborate crystals were characterized using varioustechniques like single crystal X-ray diffraction, Fourier Transform Infrared (FTIR), UV-VIS spectral, TG-DSC, microhardness and nonlinear optical (NLO) studies. Single crystal X-ray diffraction is carried using BRUKER APEX 2 with MoKα (λ=0.71073Å) radiation The Perkin Elmer Spectrum1 FTIR spectrum by KBr pellet technique between the range 4000-400$cm^{-1}$. The UV-VIS absorption was analyzed using Perkin Elmer LAMDA 950 between the ranges 200-800. TG-DSC was carried using NETZSCH STA 449 F3 Jupiter thermal analysis is used to measure the thermal stability of the crystals. The microhardness analysis was carried using a Vicker's microhardness analyzer. The second harmonic generation was detected using Kurtz Perry powder technique.

## IV. RESULTS AND DISCUSSION

### A. Single crystal X-ray diffraction studies

The grown $LHKB_5$ crystals were subjected to single crystal X-ray diffraction analysis affirms that the title material belongs to orthorhombic crystal system. The unit cell parameters of title compound are a=9.13Å, b=11.22Å, c=11.12Å, α=β=γ=90° and volume (V) = 1138Å [3]. The cell parameters of some of earlier reported $KB_5$ crystals are compared with $LHKB_5$ and it is depicted in table.1. The inclusion of L-histidine in $KB_5$ shows small variation in lattice parameters value.

Table .1 Cell parameters values of $KB_5$ and $LHKB_5$

| Cell parameters | $KB_5$ [25] | $LHKB_5$ [Present work] |
|---|---|---|
| a (Å) | 11.13 | 9.13 |
| b (Å) | 11.23 | 11.22 |
| c (Å) | 9.10 | 11.12 |
| Volume $(Å)^3$ | 1137 | 1138 |

### B. Vibrational analysis of Potassium pentaborate

The $LHKB_5$ crystal were subjected to FTIR spectrum to confirm the presence of various functional groups. Fig.3 shows the FTIR spectrum of $LHKB_5$. The peaks observed at 3445 $cm^{-1}$ is correspond to O-H stretching vibration [ 17, 22]. The peak at 3061 $cm^{-1}$ is mainly due to OH stretch of $(B_5O_6(OH)_4)^-$ and confirms that all the OH groups are present in hydrogen bonding [18,22]. The B-O asymmetric stretching vibrations are observed at 1350 $cm^{-1}$ and 1249 $cm^{-1}$ [22]. The band assignments at 1101, 1025 and 782 cm-1 are due to tetrahedral boron [23]. The symmetric stretching of B-O in $BO_3$ is assigned due to sharp peak at 925 $cm^{-1}$[24]. The O-B-O ring bending vibration occurring at 455 and 593 $cm^{-1}$[22, 25].

### Vibrational analysis of L-histidine

The presence of L-histidine in the $LHKB_5$ crystals was analyzed using Vibrational analysis data, the peak observed at 3377 $cm^{-1}$ is due to $NH^{3+}$ asymmetric stretching vibration. The band occurring at 2663 $cm^{-1}$ assigned due to $CH_2$stretching vibration [10]. The band observed at 2176 $cm^{-1}$ is due to asymmetrical bending vibration of $NH_3^+$. The peak observed at 1654 $cm^{-1}$ was attributed due to C=N stretching vibration of the imidazole ring [1]. The presence of the carboxylic acid group in L-histidine was confirmed by band observed at 1434 $cm^{-1}$ is due to weak $COO^-$ stretching. The weak C-H bending vibration was observed by a sharp peak at 694 $cm^{-1}$. Torsional oscillation of $NH_3^+$ was observed at 508 $cm^{-1}$.The obtained vibrations were compared with some standard FTIR spectra and are in good agreement with [26-28]. FTIR spectrum of $LHKB_5$ was depicted in Fig.3.

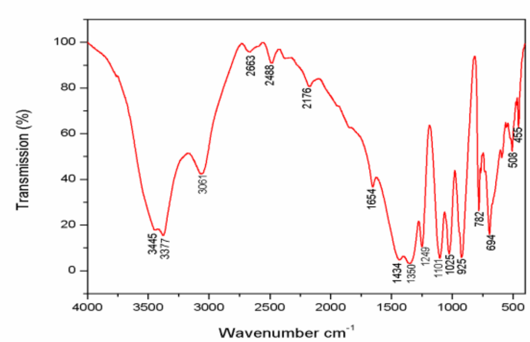


Fig. 3 FTIR spectrum of $LHKB_5$

Table.2 Tentative assignment of various functional groups

© 2019, IJSRPAS All Rights Reserved 

| Assignments | Wavenumber $cm^{-1}$ |
|---|---|
| O-H stretching | 3445, 3377 |
| OH stretch of $(B_5O_6(OH)_4)^-$ | 3061 |
| B-O asymmetric stretching | 1350, 1249 |
| tetrahedral boron | 1101, 1025, 782 |
| B-O in $BO_3$ symmetric stretching | 925 |
| O-B-O ring bending | 455,593 |
| NH stretching | 2663 |
| $NH_3^+$ asymmetrical bending | 2176 |
| $COO^-$ strong band | 1654 |
| $COO^-$ weak band | 1434 |
| C-H bending | 694 |
| $NH_3^+$ torsional oscillation | 508 |

**C. Optical analysis**

The optical absorption of a single crystal is essential for device fabrications. The title material was subjected to UV-VIS absorption spectrum analysis between the range 200-800 nm. The plot of absorption spectra of $LHKB_5$ crystal is depicted in fig.4. The lower cut-off wavelength of $LHKB_5$ crystal was found to be 245 nm from the absorption spectrum. The low absorption of title material shows suitability for optoelectronic device fabrications. The $LHKB_5$ has low absorption between 245 to 800 nm shows its suitability for second harmonic generation. The measured absorption (A) was used to calculate the absorption coefficient (α) utilizing relation [20].

$$\alpha = \frac{2.3042A}{t} \quad \text{-----(1)}$$

Where t is a thickness of the crystal and A is the absorption. The optical energy gap can be measured using the expression [21].

$$(\alpha h\nu)^2 = A(E_g - h\nu) \quad \text{-------(2)}$$

Where A is a constant, ν is the frequency of incident radiation, h Planck's constant and Eg energy gap. A plot between the energy gap (hν) and with the product of the absorption coefficient and the energy gap is depicted in fig.5. The measured energy gap of title material was 5.05 eV. The $LHKB_5$ has low absorption in the entire visible region and has a high value of energy gap shows that $LHKB_5$ crystal is suitable for device fabrications.

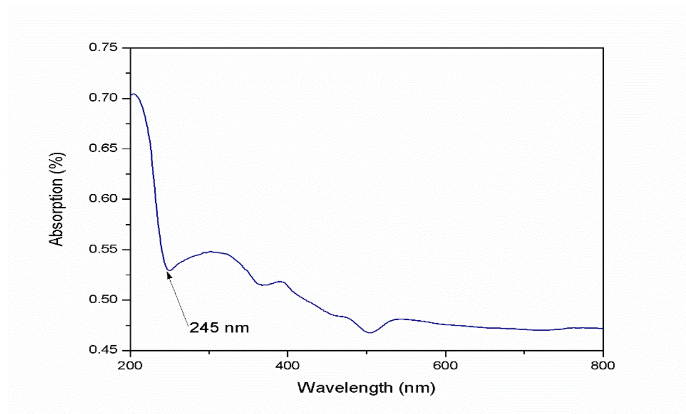


Fig. 4 The absorption spectra of $LHKB_5$.

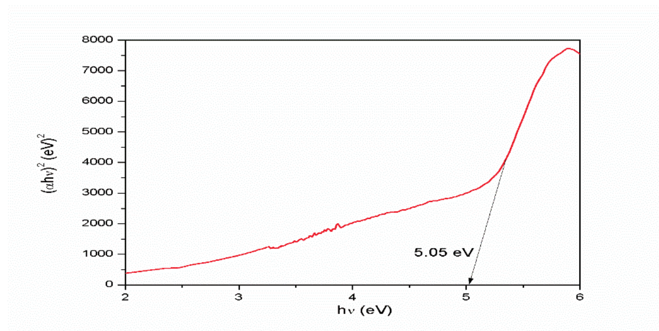


Fig. 5 Tauc's plot of $LHKB_5$ crystals.

**D. Thermal analysis**

In the field of optical switching and optoelectronic device fabrications there is a huge need for thermally stable materials, which can with stand at high temperature when they are exposed to laser continuously [29].Thermogravemetric(TG) and Differential scanning (DSC) studies were carried concomitantly on $LHKB_5$ powder sample 4.739 mg. Fig.6.shows the thermograms of $LHKB_5$.From TG curve it shows three stage of decomposition first stage weight loss of 16.31% between the temperatures ranges 169.44°C to 220.20°C due to vaporization of water molecules in the lattice points of the crystals. From DSC curve a sharp exothermic peaks observed at 198.35°C due to decomposition of L-histidine and anhydrous potassium pentaborate. Second stage weight loss of about 7.01% between temperatures 220.20°C to 416.71°C due to liberation of volatile substance such as $CO_2$, $H_2O$ and $NH_3$ in L-histidine and potassium pentaborate. The decomposition of borate in potassium pentaborate was observed from DSC curve at 787.29°C due to sharp exothermic peak. Third stage of weight loss of 30.17% was obtained at the range of 1084.44°C to 1400°C due to removal of borate from potassium pentaborate. The total mass change of 53.40% is occurring between 169.44°C to 1400°C. The final residue of 47.52% was left about 1400°C. From TG-DSC curve confirms that material can tolerate heat of 198.35°C which is very much essential for optoelectronic device fabrication. DTA curve of $LHKB_5$ was depicted at

© 2019, IJSRPAS All Rights Reserved 

fig.7. The endothermic peak of the DTA analysis was observed at 192.45°C which corresponds to melting point of the material. The good degree of crystalline nature and purity of $LHKB_5$ crystals were confirmed by sharp exothermic peak [2].

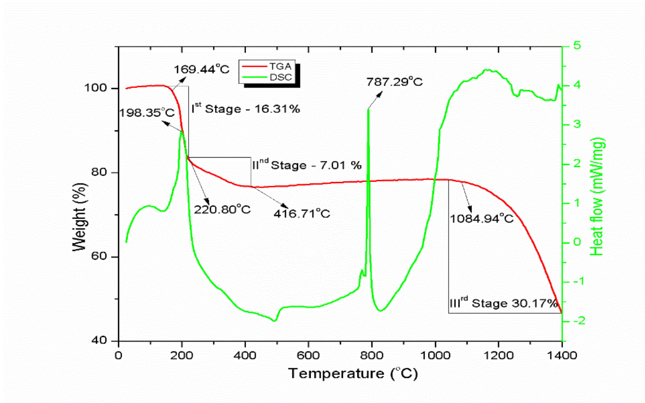


Fig. 6 TG-DSC curve of $LHKB_5$ crystals.

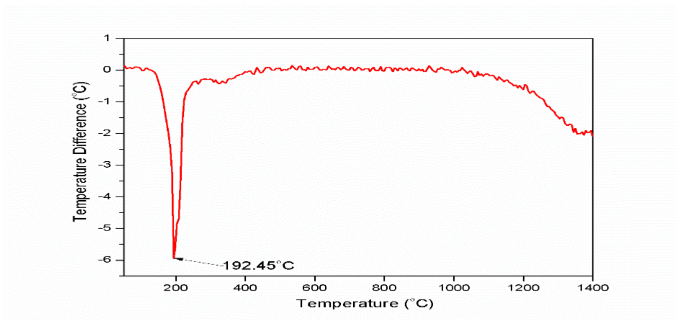


Fig. 7 DTA curve of $LHKB_5$ crystals.

**E. Microhardness Measurement**

The Vicker's diamond pyramidal indenter microhardness analyzer was used to contemplate the mechanical quality of L-histidine potassium pentaborate crystal. In the field of optoelectronic device fabrication, the mechanical quality of the material plays a fundamental role. Using different loads from 10g to 100g with a consistent space-time of 10 s for all loads the indentations were made utilizing a Vicker's pyramidal indenter [30]. The hardness of the L-histidine potassium pentaborate crystal can be determined to utilize the relation [19].

$$Hv = \frac{1.854p}{d^2}(kg/mm^2) \quad \text{-------(3)}$$

Where d is the diagonal length in mm and P is the applied load in kg. Fig. 8. demonstrates the variety of connected load with a Vicker's hardness number for title material. Reverse indentation size effect (RISE) is noticed on $LHKB_5$ crystal due to the increase of hardness ($H_v$) as the load (P) is increased [31]. To distinguish the material quality the estimation of the work hardening coefficient is fundamental. Meyer's index (n) value for the soft material is more noteworthy than 1.6 and for hard material under 1.6. Meyer's index (n) can be resolved to utilize the relation [32].

$$P = Kd^n \quad \text{-----------(4)}$$

$$LogP = LogK + nLogd \quad \text{----------(5)}$$

Where n is Meyer's index and K is a constant for a crystal. Meyer's index (n) is assessed from the fig. 9. Variation between log d and log P, by a linear fit. The slope value n=3.09 was distinguished from linear fit, in this manner affirming that the LHKB5 crystal has a place with the soft category. L-histidine potassium pentaborate crystal has a great mechanical strength which is essential for optoelectronic device fabrications.

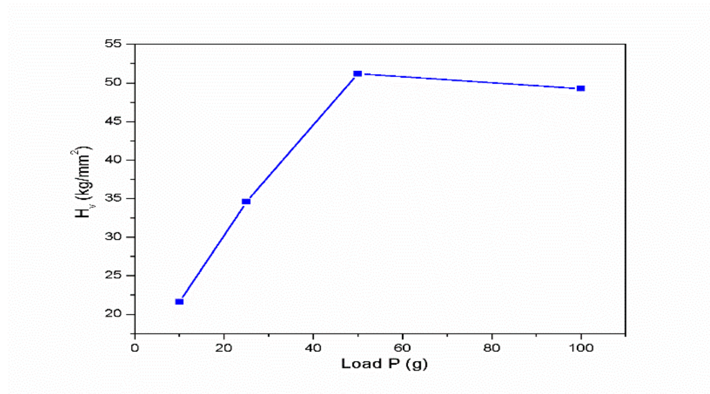


Fig. 8 Variation of Vicker's hardness number and applied load for $LHKB_5$ crystal.

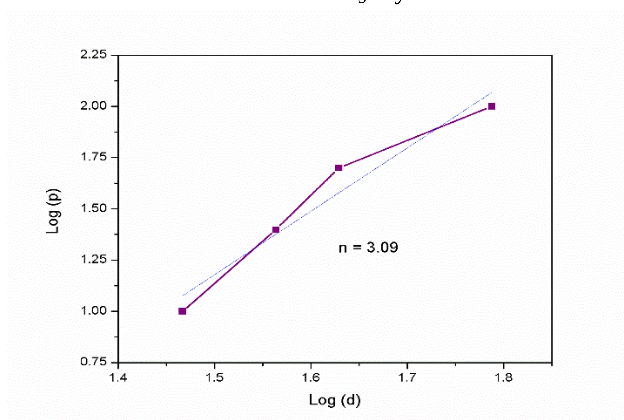


Fig. 9 Variation of log d and log p for $LHKB_5$ crystal.

**F. Kurtz-Perry Powder Second Harmonic Generation Studies**

The grown crystals of L-histidine potassium pentaborate was subjected to Kurtz-Perry [33] powder second harmonic generation (SHG) test to confirm the nonlinear optical (NLO) property. The sample were taken in a powder form and tightly packed between glass slides Nd: YAG Q-switched laser beam of wavelength 1064 nm was made to fall on the powder sample at a repetition rate of 10 Hz with a pulse width of 6 ns. The input energy of 0.61 J was made to fall on the powder samples which exposed to laser radiation. The second harmonic generation in the crystal was confirmed by the emission of green light from the sample. The reference material of potassium dihydrogen phosphate crystals was taken in the powder form to compare the SHG efficiency with $LHKB_5$. The output power of standard KDP

© 2019, IJSRPAS All Rights Reserved 

is 7.501mJ and title material emitted output power of 15.752mJ. The efficiency of $LHKB_5$ crystals was found to be 2.1 times greater than that of the KDP crystals.

## V. CONCLUSION

The single crystal of L-histidine potassium pentaborate was grown from aqueous solution by employing a solvent evaporation technique at room temperature. X-ray diffraction studies affirm that the crystal belongs to the orthorhombic crystal system and lattice parameter values are reported. Presence of L-histidine potassium pentaborate functional groups vibrations were confirmed by the FTIR spectrum. From the UV absorption spectrum, energy gap and cut-off wavelength were found to be 5.05 eV and 245 nm. TG-DSC curve shows two stages of decomposition at 198.35°C and 782.29°C of the material and the endothermic peak of the DTA analysis are observed at 192.45°C which corresponds to the melting point of the material. The good degree at crystalline nature and purity of $LHKB_5$ crystals were confirmed by a sharp endothermic peak at 192.45°C from DTA curve. From the hardness study, material has Meyer's index n=3.04 which shows that title material belongs to soft crystal category.SHG efficiency confirms that the crystal has 2.1 times greater efficiency than reference material standard KDP. The studies carried out on title material conclude that the material has high thermal stability and SHG efficiency which is essential for device fabrication. Thus, various studies carried on L-histidine potassium pentaborate crystal suggest that the material has great potential for nonlinear optoelectronics device fabrication.

**Compliance with Ethical Standards:**

**Funding:** There is no funding involved with the current study.

**Conflict of Interest:** There is no conflict of interest in the work was declared by author.

## REFERENCES

[1] V. RejeenaRajan, Merin George, Javeesh Alex, D. Sajan, G. Vinitha, Growth , effect of protonation and hydrogen bonding interactions of L-histidine nitrate monohydrate, a potential semi organic third order nonlinear optical material, Optical Materials, **86**, **198-212, 2018**.

[2] S. Kandhan, P. Krishnan, R. Jagan, S. Aravindhan, S. Srinivasan, S. Gunasekaran, Structural, optical and piezoelectric investigation on new Brucinium Chlorate di-hydrate NLO single crystal for optoelectronic, piezo-sensor, transducer and OLED applications, Optical Materials **84**, **556-563, 2018**.

[3] S. Masilamani, A. Mohamed Musthafa, Chemical analysis, FTIR and microhardness study to find out nonlinear optical property of L-asparagine lithium chloride: a semiorganic crystal, Microchemical Journal **110**, **749-752, 2013**.

[4] R. Subhashini, S. Arjunan, Synthesis and physicochemical properties of bis(L-asparaginato) Zinc(II): A promosing new semiorganic crystal with high laser damage threshold for shorter wavelength generation, Optics and Laser Technology **101, 248-256, 2018**.

[5] N.R. Rajagopalan, P. Krishnamoorthy, K. Jayamoorthy, A strategic approach to physico-chemical analysis of bis (thiourea) lead chloride – A reliable semi-organic nonlinear optical crystal, Optics & Laser technology **89, 6-15, 2017**.

[6] P. Prabhu, B. Vijayabhaskaran, G. Vasuki, C. Ramachandra Raja, Growth, structural, optical and thermal properties of a new semiorganic NLO crystal: L-propyl mercury (II) chloride, Optics and Laser technology **98**, **12-18, 2018**.

[7] K. Mohanraj, D. Balasubramanian, N. Jhansi, Structural, mechanical, electrical and optical properties of a new lithium boro phthalate NLO crystal synthesized by a slow evaporation method, Optics and Laser Technology **2017**, http://dx.doi.org/10.1016/j.optlastec.2017.06.001.

[8] K. Ramya, N.T. Saraswathi, C. Ramachandra Raja, Growth and characterization of an organic nonlinear optical material: Optics & Laser Technology **84**, **102-106, 2016**.

[9] A.S.J. Lucia Rose, P. selvarajan, S. Perumal, Growth, structural, spectral, mechanical and dielectric characterization of RbCl-doped L-alanine hydrogen chloride monohydrate single crystals, Physica B,**406, 412-417, 2011**.

[10] M. Krishna Mohan, S. Ponnusamy, C. Muthamizhchelvan, Spectral, optical, etching, second harmonic generation (SHG) and laser damage threshold studies of nonlinear optical crystals of L-Histidine bromide, Applied Surface Science **2018**, https://doi.org/101016/j.apsusc.2018.01.073.

[11] S. Sahaya Jude Dhas, S. Jerome Das, Spectral, optical, thermal and optical and mechanical studies on L-Histidine Oxalate crystals, Arabian Journal of Chemistry, **2013**, http://dx.doi.org/10.1016/j.arabjc.2012.12.019.

[12] M.Fleck, V.V. Ghazaryan, L.S. Bezhanova, A.K. Atanesyan, A.M. Petrosyan, New crystals of L-histidine maleates, Journal of Molecular Structure **1035**, **407-415, 2013**.

[13] P. Anandan, M. Arivanandhan, Y. Hayakawa, D. RajanBabu, R.Jayavel, G. Ravi, Investigations on the growth aspects and characterization of semiorganic nonlinear optical single crystals of L-histidine and its hydrochloride derivative, SpectrochimicaActa Part A: Molecular and Biomolecular Spectroscopy, **121**, **508-513, 2014**.

[14] S. Rajalakshmi, K. Ramachandra RAO, B. Brahmaji, K. Samatha, T.K. Visweswara Rao, G. Bhagavannarayana, Optical investigations on $Tb^{3+}$ doped L-Histidine hydrochloride mono hydrate single crystals grown by low temperature solution techniques, Optical Materials,**54**, **74-83, 2016**.

[15] S.A. Rajasekar, K. Thamizharasan, A. Joseph Arul Pragasam, J. Packiam Julius, P. Sagayaraj, Growth and characterization of pure and doped potassium pentaborate ($KB_5$) single crystals, Journal of Crystal Growth,**247**, **199-206, 2003**.

[16] Hongwei Yu, Shilie Pan, Hongping Wu, Jian Han, Xiaoyu Dong, Zhongxiang Zhou, Synthesis, structure characterization and optical properties of a new tripotassium cadmium pentaborate $K_3CdB_5O_{10}$, Journal of Solid State Chemistry **184**, **1644-1648, 2011**.

[17] T. Balakrishnan, G. Bhagavannarayana, K. Ramamurthi, Growth, structural, optical, thermal, and mechanical properties of ammonium pentaborate single crystal, SpectrochimicaActa Part A,**71, 578-583, 2018**.

[18] S. Abraham Rajasekar, K. Thamizharasan, Joe G.M. Jesudurai, D. PremAnand, P. Sagayaraj, The role of metallic dopants on the optical and photoconductivity properties of pure and doped potassium pentaborate ($KB_5$) single crystals. Materials Chemistry and Physics **84**, **157-161, 2004**.

© 2019, IJSRPAS All Rights Reserved 

[19] R. PoornashriMathangi, A.R. Prabakaran, S. NaliniJayanthi and K.Thamizharasan, Structural, optical and mechanical studies on a novel nonlinear optical material: L-Arginine Potassium Penta Borate (LAKB$_5$), Materials Today Proceedings **5**, **17730-17736, 2018**.

[20] OllaaM.Mailoud, AdlyH.Elsayed, A.H. Abo-Elazm, H.A. Fetouh, Synthesis and study the structure, optical, thermal and dielectric properties of promising Glycine Copper Nitrate (GCN) single crystals, Results in Physics,**10, 512-520, 2018**.

[21] P.Karuppasamy, V.Sivasubramani, M.SenthilPandian and P.Ramasamy, Growth and characterization of semi-organic third-order nonlinear optical (NLO) potassium 3,5-dinitrobenzoate (KDNB) single crystals, RSC Adv., **6**, **109105-109123/109105, 2016.**

[22] S. Benita JebaSilviya, C.K. Mahadevan, T. Balu, A. Moses Ezil Raj, S. Balakumar, S.G. Jebastin Andrews, Urea doped crystals formed with potassium-sodium pentaborate ($K_{0.5}Na_{0.5}B_5$), Surfaces and Interfaces, **2018**, doi: 10.1016/j.surfin.2018.02.003

[23] Huan-Xin Liu, Yun-Xiao Liang, Xiao Jiang, Synthesis, crystal structure and NLO property of a nonmetal pentaborate $[C_6H_{13}N_2][B_5O_6(OH)_4]$, Journal of Solid State Chemistry **181**, **3243-3247, 2008**.

[24] R. Arivuselvi, P. Ramesh Babu, Investigation of inorganic nonlinear optical Potassium Penta Borate Tetra hydrate (PPBTH) single crystals grown by slow evaporation method, Physica B: Physics of Condensed Matter **2018**, https://doi.org/10.1016/j.physb.2017.12.051

[25] C. Ramki, R. EzhilVizhi, Investigation on the growth, optical, mechanical and dielectric properties of an inorganic potassium pentaborate dehydrate ($KH_4B_5O_{10}.2H_2O$) single crystal, Materials Chemistry and Physics **2018**, https://doi.org/10.1016/j.matchemphys.2018.10.034

[26] Ralph L. Shriner, Christine K.F. Hermann, Terence C. Morrill, David Y. Curtin, Reynold C. Fuson, The Systematic Identification of Organic Compounds, Jhon Wiley & Sons, inc. **2004**.

[27] Robert M. Silverstein, Francis X. Webster, David J. Kiemle, Spectrometric Identification of Organic Compounds, Jhon Wiley & Sons, inc. **2005**.

[28] G.Socrates, Infrared Characteristic Group Frequencies, A Wiley-Interscience publication, **2001**.

[29] K. Senthil, S. Kalainathan, Y. Kondo, F. Hamada, M. Yamada, Investigation on the crystal growth, molecular structure and nonlinear optical susceptibilities of 2-[2-(4-Ethoxy-phenyl)-Vinyl]-1-ethyl-stilbazolium iodide (EESI) by Z-scan technique using He-Ne laser for third-order nonlinear optical applications, Optics & Laser Technology **2016**, https://doi.org/10.1016/j.optlastec.2016.10.019

[30] P. Rajasekar, K. Thamizharasan, Effect of cobalt ($Co^{2+}$) concentration on structural, optical, thermal and mechanical propertirs of potassium acid phthalate (KAP) crystals, J Mater Sci: Mater Electron **29, 1777-1784, 2018**.

[31] P. Sangeetha, P. Jayaprakash, M.Nageshwari, M. Peer Mohamed, G. Vinitha, M. Lydia Caroline, Growth and characterization of L-phenylalanine nitric acid (LPN) and tris L-(phenylalanine) nitrate (TPLPN) as second and third order nonlinear optical materials, Chinese Journal of Physics **2017**, https://doi.org/10.1016/j.cjph.2017.12.026.

[32] M. Suresh, S. AsathBahdur, S. Athimoolam, Synthesis, growth and characterization of a new hydrogen bonded organic tosylate crystal: L-alanium P-toluenesulfonate for second order nonlinear optical applications, J Mater Sci: Mater Electron **2016**, DOI 10.1007/s10854-016-4334-7.

[33] S.K. Kurtz, T.T. Perry, J. Appl. Phys. **39, 3798–3813, 1968.**


## AUTHORS PROFILE

Mr. C.Karnan pursued B.Sc., in physics from Govt. Arts College for Men (Autonomous), Nandanam, Chennai, Tamil Nadu, India. B.Ed., in education from Jaya College of Education, Thiruvallur, Tamil Nadu, India. M.Sc., in physics from Pachaiyappa's college, Chennai, Tamil Nadu, India. He is currently pursuing Ph.D as Full-time research scholar in Pachaiyappa's college, Chennai, Tamil Nadu, India. His main research work focuses on Material science.

Dr.A.R. Prabakaran pursued M.Sc., in physics from Pachaiyappa's college, Chennai, Tamil Nadu, India. Ph.D in physics from Pondicherry University, Pondicherry, India. He has rich experience in teaching and research for three decades. He has published more than 45 research papers. He has guided 4 students for their Ph.D and 6 students are pursuing under his guidance.

© 2019, IJSRPAS All Rights Reserved 