Research Article 2019, **4**(4), 162-164 Advanced Materials Proceedings

Synthesis, Crystallization and Optical Properties of Potassium Nitrate Added L-alanine Single Crystals for Optoelectronic Device Applications

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DOI: 10.5185/amp.2019.0023
www.vbripress.com/amp

Abstract

Current work, L-alanine single crystals in the presence of potassium nitrate were grown by slow evaporation method. The unit cell parameters and crystalline structure of the L-alanine crystal were analysed using powder XRD (PXRD) technique. The numerous functional groups and vibrational modes of the grown crystal were identified by FTIR analysis. The linear optical analysis has been employed in the wavelength range 200-2500 nm to find out the optical transparency of the grown crystal. Nonlinear optical efficiency of the grown crystal is 1.12 times superior to the reference crystalline material KDP. The negative photoconductivity of the grown crystal was exposed by photoconductivity analysis. Copyright © VBRI Press.

Keywords: Semi organic single crystals, L-alanine potassium nitrate, optoelectronic material.

Introduction

L-alanine is a hydrophobic and non-polar organic compound under amino acid family composed of optically active molecule. The recent researches are focused to grow semi organic crystals with high non-linear optical (NLO) efficiency and high optical transparency in the UV-Vis and near infra-red regions which are very essential properties for the fabrication of various optoelectronics devices such as frequency converter, optical switch, telecommunication devices, optical storage devices, displays, optical-fiber amplifiers [**1**]. The very low thermal stability of organic materials prohibits their application in device fabrications. Consequently, inorganic materials exhibit higher mechanical and thermal stabilities. Owing to this, new materials have been developed which merge the excellence of both organic and inorganic materials bestowing rise to metal organic materials. These semi organic materials have chemical flexibility of organic materials and also have high thermal and mechanical stabilities of inorganic materials [**2**]. Owing to the excellent optical properties of semi organic crystals, they are playing a significant role in the field of frequency doubling, imaging systems, optical wave guides, optical signal processing, and telecommunication and laser science. Thus, in the present communication, the grown potassium nitrate added L-alanine crystals have been employed with various optical studies to acquire its favourable properties to recognize its promising applications in optoelectronics production.

Experimental

The commercially available L-alanine (Merck) and Potassium Nitrate (Merck) chemicals were blended in 1:2 molar ratio in a 250 ml beaker using 100 ml doubly distilled water. The prepared solutions were agitated for 6 hours to prevail clear homogeneous solution. The prepared solution was strained using Whatman filter circles in a 300 ml crystallization dish and top peripheral of the crystallization dish is closed with cling film sheet to evade the levigate particles fall in it. Then, the dish was reserved in a clean crystal growth chamber and permitted for spontaneous nucleation at ambient temperature. In next15 days of slow evaporation, the solution attains supersaturation and tiny crystals were grown from the solution and they are permitted for supplementary growth to reach device quality crystals and collected in a growth time span of 29 days. The snap of the grown potassium nitrate added L-alanine crystals (LAPN) is presented in **Fig. 1**.

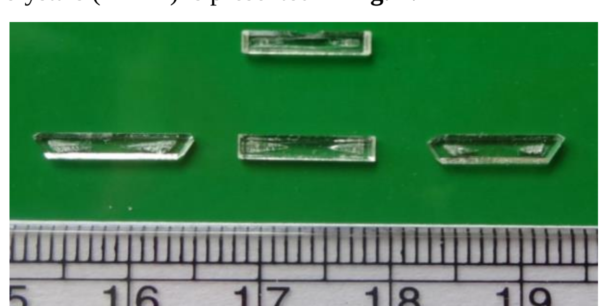

Fig. 1. The snap of the grown LAPN single crystals.

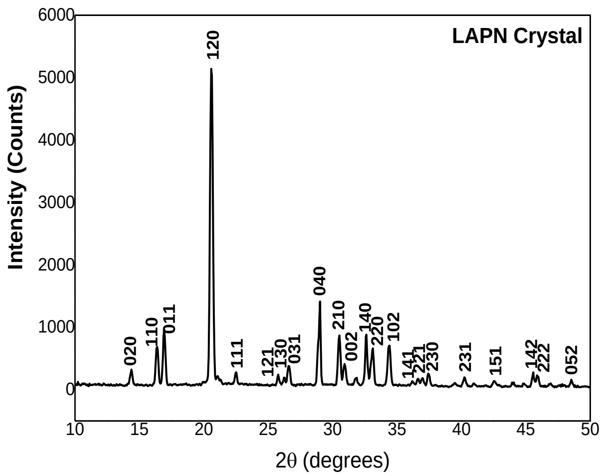

Fig. 2. Powder X-ray diffractogram of the grown LAPN crystal.

Results and discussion

Powder X-ray diffraction study

The grown crystals were grounded and employed to PXRD study by bruker AXS D8 X-ray diffractometer. The obtained PXRD pattern of potassium nitrate added L-alanine single crystal is depicted in **Fig. 2**. The PXRD pattern affirmed that the grown crystal belongs to orthorhombic crystal structure with the P212121 non-centrosymmetric space group. The lattice parameter values of grown crystals are evaluated and are a = 5.421 Å, b = 6.413 Å, c = 9.191 Å and $\alpha = \beta = \gamma = 90°$. The sharp and strong peaks acquired in the PXRD pattern affirms good crystalline nature of the grown single crystals and the acquired peaks point are good coincides with the literature work [**2**].

FTIR spectroscopic analysis

The FTIR spectrum within the frequency range from 400-4000 cm^{-1} of the LAPN single crystal has been examined by Perkin Elmer FTIR spectrophotometer and the resulted spectrum is depicted in **Fig. 3**. The peak at 2245 cm^{-1}confirms the CH_3 stretching mode of vibration at the same time the presence of ammonium group is affirmed by the peaks observed at 1589, 1512 cm^{-1}. The asymmetric CH_3^+ bending mode of vibrations is assigned to absorption peak at 1458cm^{-1}. The symmetric stretching of $C\text{-}COO^-$ is assigned to the peak at 1412 cm^{-1}. The NO_3 stretching modes correspond to the vibration peaks at 1358, 1111, 849 and 772 cm^{-1}. C-H and N-H bending modes of vibrations are seen at 1304 cm^{-1}. The peaks at 1234 and 1150 cm^{-1} are assigned to the $NH3^+$ rocking. The torsional oscillation of NH_3^+ is confirmed at 1011 and 918 cm^{-1} are due to the overtones of torsional oscillation of NH_3^+. The presence of COO^- in plane deformation is evident at 648 cm^{-1}. The peak observed at 540 cm^{-1} is evident to torsional oscillation of NH_3^+. The peak at 486 cm^{-1} reveals the presence of the NH_3^+ in plane rocking. The obtained spectrum affirms the presence of nitro group in the grown LAPN single crystal [**2**].

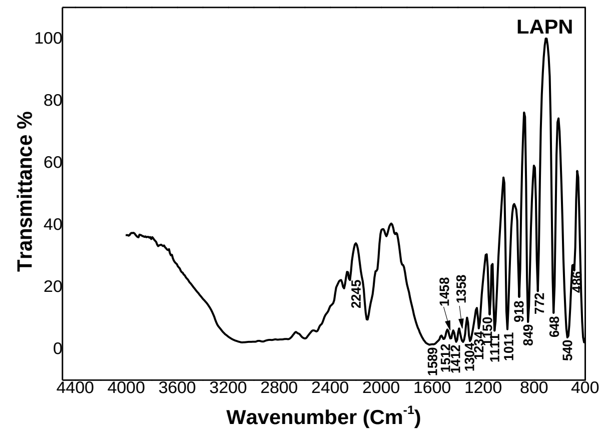

Fig. 3. FTIR Spectrum of the grown LAPN single crystal.

Linear optical spectroscopic study

The linear optical transmittance spectrum of the LAPN crystal was employed in the wavelength range of 200 and 2500 nm by Varian (Model-Cary 5000) UV-Vis-NIR spectrophotometer. The optical transmittance spectrum shows lower cut off wavelength at 270 nm. Consequently it is clear that the grown LAPN single crystal has an optical transmittance window between 270 and 2500 nm. Also, grown LAPN single crystal possesses the optical transparency of about 70 % which is shown in **Fig. 4**.The grown LAPN crystals have good optical transparency in the entire visible, NIR regions which was confirmed from linear optical transmittance spectrum. The bandgap energy of the LAPN crystal is 4.593 eV which was calculated using Planck's energy equation ($E_g = \frac{hc}{\lambda min}$ nm) by the lower cut-off wavelength [**3**].

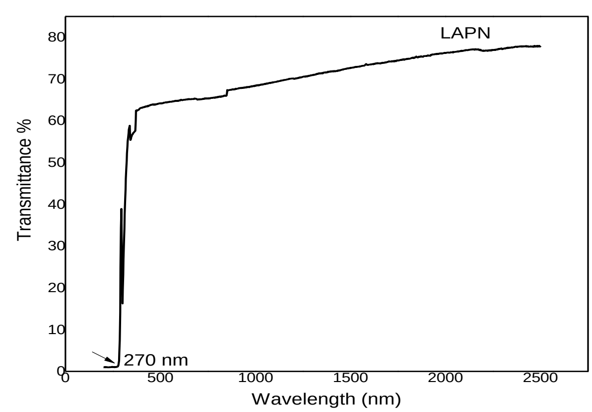

Fig. 4. Linear optical spectrum of the grown LAPN single crystal.

SHG efficiency analysis

The Kurtz-perry powder technique was made to find out the second order nonlinear optical productivity of the grown LAPN crystals [**4**]. The finely powdered grown crystal in identical particle size of about 150 μm is orderly packed in a micro-capillary glass tube of steady bore. The fundamental Q-switched Nd: YAG laser beam of 1064 nm was used to find out SHG efficiency of grown LAPN crystal. The SHG output of wavelength 532 nm was tested using a photomultiplier tube. The second order nonlinear optical productivity of the LAPN crystals (38 mV) is 1.12 times superior to the reference crystalline material KDP (34 mV).

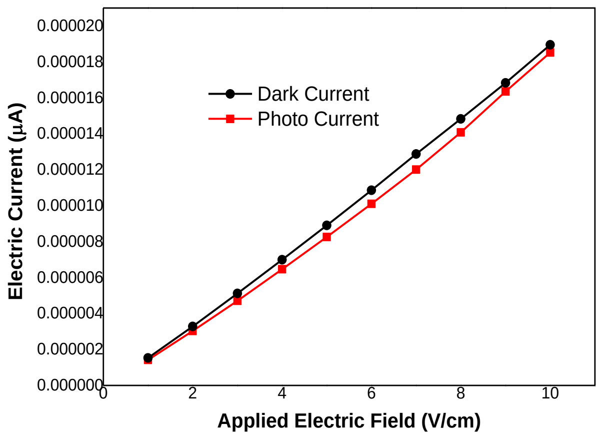

Fig. 5. Photoconductivity response of the grown LAPN single crystal.

Photo conductivity analysis

The photoconductivity analysis on grown LAPN single crystals is a noteworthy observable fact in which it confirms gain or loss of charge carriers with applied electric voltage (V). This analysis was examined at room temperature by connecting the grown crystal in series to Keithley Model 6517B electrometer and DC power supply. Grown LAPN crystal surface was coated using silver paste to make contact between electrodes and finally it was reserved in vacuum. Dark current and photo current were measured by applying voltage (V) to the electrodes without permitting any peripheral radiations fall on the crystal. The nature of photocurrent and dark current with increasing voltage is depicted in **Fig. 5**. As dark current has high magnitude than photo current at every applied voltage. It proves the negative photoconductivity by the grown LAPN crystals, which obtained owing to decrease in lifetime as well as abridged transfer of charge carriers in the presence of radiation. In agreement to the stockmann model, the energy state with elevated seizing cross-section close up to the valence band traps electrons from the conduction band and holes from the valence band reducing the mobility of charge carriers, which is most important mechanism accountable for negative photoconductivity [**2**].

Conclusion

Optically transparent LAPN single crystals have been grown by employing slow evaporation technique. Orthorhombic crystal system and P212121 space group was affirmed by powder XRD studies. The diverse functional groups of LAPN crystals were notorious by FTIR analysis. The linear optical spectrum of LAPN crystals confirms the wide transparent window upto NIR region. The NLO productivity of the grown LAPN crystals is 1.12 times superior to the reference crystalline powder KDP. The negative photoconducting nature of the grown LAPN single crystal was inveterate from photoconductivity study. It is a noteworthy factor for the materials having nonlinear optical belongings. Consequently the grown LAPN single crystals with obvious optical properties revealed its further most trust worthiness in manipulative devices for optoelectronics industry.

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