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Research Article

Studies on Mechanical and Electrical Properties of L-Alaninium Succinate NLO Active Single Crystal

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Abstract

L-Alaninium Succinate (LAS) single crystals were grown by slow evaporation method. The Vicker's microhardness test was carried out on the grown crystal. The dielectric studies are carried out and the nature of variation of dielectric constant and dielectric loss in the frequency range of 50 Hz to 5 MHz at different temperatures (30°C, 60°C and 90°C) is studied and reported. Photoconductivity measurements were carried out on the grown crystal reveals the negative photoconducting nature.

Keywords*: Single Crystal, Growth from solution, Microhardness, Dielectric constant, Dielectric loss and Photoconductivity Studies*

1. Introduction

The design of optoelectronics and photonic devices relies heavily in the development of nonlinear optical (NLO) materials with higher efficiency (Balamurugaraj *et al* 2013; Talebian *et al* 2012). So the materials possessing large second order nonlinear susceptibility with favorable in thermal and mechanical stability are intensively used in many device applications (Vimalan *et al* 2010; Jiang *et al* 1999; Zyss *et al* 1981). The rapid development of optical communication systems has led to a demand for nonlinear optical materials with high optical quality. The organic materials which exhibit very large second order nonlinearity with high laser damage threshold find applications in the field of frequency conversion, image processing, data storage, fiber optic communication etc (Gupta *et al* 2001; Newman *et al* 1990). An organic crystal with delocalized π-electrons usually displays a large NLO response which makes it attractive for applications in integrated optics (Prasad *et al* 1991. These crystals in general composed of aromatic molecules that are substituted with π-electron donors and acceptors which exhibit intermolecular charge transfer (Koll *et al* 2003).In the present paper of L-alanine succinate single crystal was grown from by slow evaporation method and the crystals were characterized by microhardness, dielectric, and photoconductivity studies.

2. Experimental Procedure

The L-alanine succinate single crystal was synthesized from commercially available L-alanine and succinic acid, taken in the equimolar ratio. The calculated amounts of the reactants were thoroughly dissolved in double distilled water and stirred well for about two hours to get saturation solution. The solution was filtered and allowed to crystallize by slow evaporation technique. Tiny seed crystals with good transparency were obtained due to the spontaneous nucleation. Among them, defect free seed crystal was suspended in the mother solution, which was allowed to evaporate at a room temperature. Bulk crystals with perfect external morphology are harvested within a period of 20 days. Good quality of single crystals was chosen for various characterizations.

3. Microhardness Studies

Microhardness studies for the grown L-alanine succinate single crystal was performed at room temperature to determine microhardness number and hence the mechanical strength and this study play an important role in the fabrication of opto-electronic devices. The hardness of a material is a measure of its resistance to plastic deformation. Vickers hardness indentations were made on the flat polished face of the crystal at room temperature for loads 10, 25 and 50 g using Vicker's hardness tester fitted with Vicker's diamond intender and attached to an incident light microscope. Crack initiation and material chipping became significant beyond 50 g of the applied load and hardness test thus could not be carried out further. The lengths of the two diagonals of the indentations were measured and the Vickers hardness number was calculated using the formula,

$$H_v = 1.8544 P / d^2 \quad (1)$$

where Hv is the Vicker's hardness number in kg mm^{-2}, P is the intender load in kg and d is the diagonal length of the

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impression in mm. The variation of Hv with applied load is shown in Fig. 1. It is evident from the plot that the microhardness of the crystal decreases with increasing load. The decrease in the microhardness values of LAS with increasing load is in agreement with the normal indentation size effect (ISE).

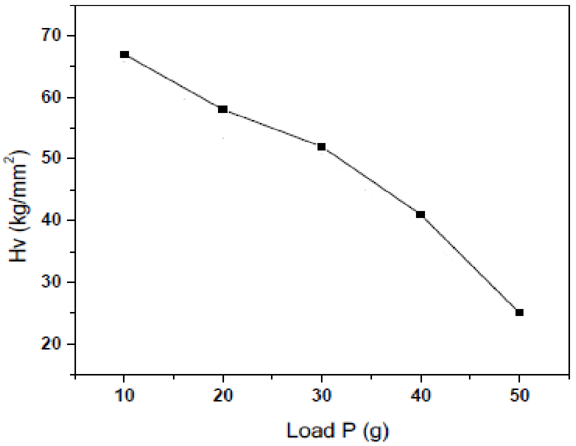

Fig. 1 Variation of hardness number *Hv* with Load P

4. Dielectric Properties

The dielectric constant and the dielectric loss of L-alanine succinate single crystal were measured in the frequency range from 50 Hz to 5 MHz. Figs 2 and 3 show the variation of dielectric constant and dielectric loss with log frequency under different temperatures from 30ºC to 90ºC respectively. To determine the dielectric constant, we use the interactive Hamiltonian which is given by,

$$H = U_s + \frac{1}{2}\sum_i k_i \vec{r}_i^{\,2} + \frac{1}{2}\sum_{i\neq j}\left(\vec{\mu}_{0i} + e_i\vec{r}_i\right).T_{ij}.\left(\vec{\mu}_{0j} + e_j\vec{r}_j\right) - \sum_i\left(\vec{\mu}_{0i} + e_i\vec{r}_i\right).\vec{E}_0 \qquad (2)$$

where Us is a short range interaction energy between the molecules which is not further specified, $\vec{r}_i$ is an internal coordinate, which oscillates harmonically with spring constant k_i, $\vec{\mu}_{0i}$ is the permanent dipole moment of molecule i, and $e_i\vec{r}$ the induced moment, so that the third term represents the dipole–dipole interaction, T_{ij} being the dipole tensor, and the last term is the dipole interaction energy with an external field. Finally the tensor T is given by

$$T_{ij} = \frac{1}{4\pi\varepsilon_0 R_{ij}^3}\left(1 - 3\hat{R}_{ij}\hat{R}_{ij}\right) \qquad (3)$$

where $\hat{R}_{ij}$ denotes the connecting vector between the particles i and j. The force on the coordinate $\vec{r}_i$ is for a given field $\vec{E}_0$ given by

$$k_i\vec{r}_i + e_i\sum_{j\neq i} T_{ij} \qquad (4)$$

Where only took the dipolar part due to the other polarizabilities, not due to the permanent dipoles. It is observed from the plot (Fig. 2) that the dielectric constant decreases exponentially with increasing frequency and then attains almost a constant value in the high frequency region. It is also observed that as the temperature increases, the value of the dielectric constant also increases. The same trend is observed in the case of dielectric loss versus frequency (Fig.3). The dielectric constant has high values in the lower frequency region and then decreases with the applied frequency. The very high value of dielectric constant at low frequencies may be due to the presence of all the four polarizations namely, space charge, orientation, electronic and ionic polarization and its low value at higher frequencies may be due to the loss of significance of these polarizations gradually. From the plot, it is also observed that dielectric constant increases with increasing temperature, attributed to space charge polarization near the grain boundary interfaces, which depends on the purity and perfection of the sample (Balarew *et al* 1984). The characteristic of low dielectric constant and dielectric loss with high frequency for a given sample suggests that the sample possesses enhanced optical quality with lesser defects and this parameter is highly important for making this material suitable for various nonlinear optical applications.

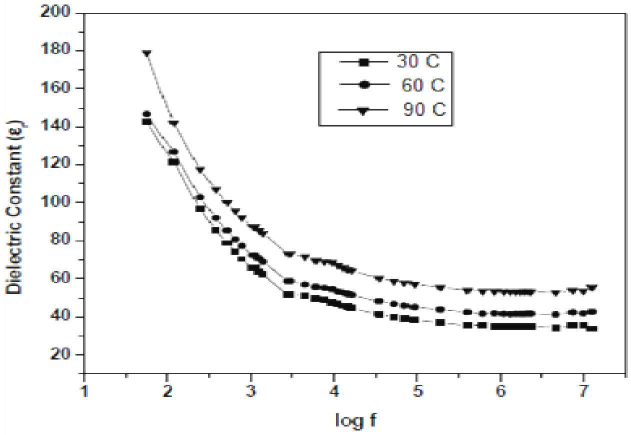

Fig. 2 Variation of dielectric constant with frequency

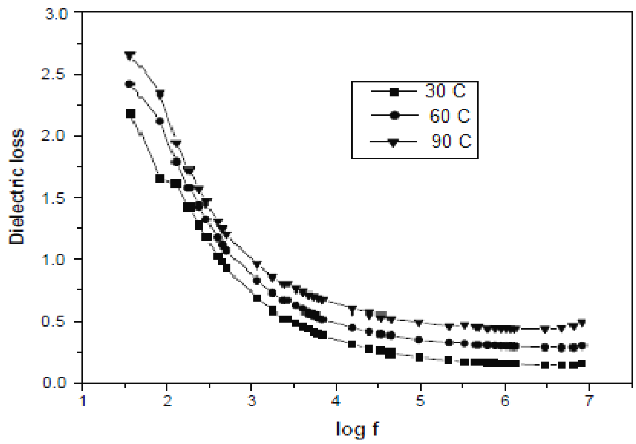

Fig.3 Variation of different loss with frequency

5. Photoconductivity Studies

Photoconductivity studies were carried out at room temperature for L-alanine succinate crystals, using Keithley 485 picoammeter. The dark current was recorded for the samples by keeping them unexposed to any radiation. The light from the halogen lamp (100 W) containing iodine vapour is focused on the respective samples and the photo currents of the samples were measured. The DC inputs were increased in steps and the photo currents were measured. Fig.4. shows the variation of both dark current (I_d) and photocurrent (I_p) with applied field. It is seen from the plots that both I_d and I_p of the sample increase linearly with applied field. It is observed from the plot that the dark current is always higher than the photo current, thus confirming the negative photoconductivity nature of the material. This phenomenon can be attributed to generation of mobile charge carriers by the absorption of photons. Generally, this may be attributed to the loss of water molecules in the crystal. However, the negative photoconductivity in this case may be due to the reduction in the number of charge carriers or their lifetime in the presence of radiation [11]. Decrease in lifetime with illumination, could be due to the trapping process and increase in carrier velocity according to the relation,

$$\tau = (vsN)^{-1} \quad (5)$$

where v is the thermal velocity of the carriers, s is the capture cross section of the recombination centers and N is the carrier concentration. As intense light falls on the sample, the lifetime decreases (Ashraf *et al* 2004). In Stockmann model, a two level scheme is proposed to explain negative photoconductivity (Joshi *et al* 1990).

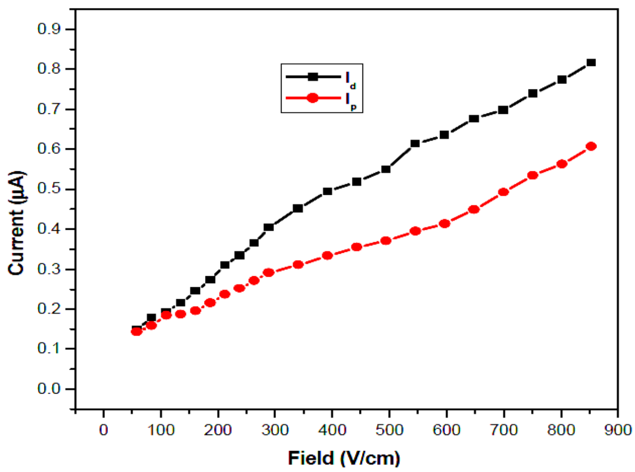

Fig.4 Field dependence of photo and dark conductivity

6. Conclusion

Single crystals of L-alaninium succinate (LAS) were grown by slow evaporation technique. The mechanical behavior is studied by Vickers hardness method. Dielectric measurements were carried to analyze the dielectric constant and dielectric loss at different frequencies and different temperatures. The characteristics of low dielectric loss for the sample suggest that it possesses enhanced optical quality with lesser defects and this parameter is of vital significance for nonlinear optical applications. Photoconductivity investigations reveal the negative photoconducting nature of the L-alaninium succinate material.

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