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Second Order Nlo, Third Order Nlo and Other Studies of Potassium Sodium Tartrate Tetrahydrate Crystals

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Abstract: Sodium potassium tartrate tetrahydrate (SPTT) crystal is also called as the Rochelle salt. Since many studies like, third order NLO studies, LDT studies and impedance studies of SPTT crystals have not been reported in the literature, an investigation has been carried out to grow and study SPTT crystals here. Rochelle salt is highly water soluble material and hence it can be crystallized by the method of solvent evaporation. AR grade chemical of sodium potassium tartrate tetrahydrate (SPTT) salt was purchased and re-crytallization was carried out twice for further purification. Single crystals of SPTT have been grown by solution growth method with slow evaporation technique. The saturated solution of SPTT was prepared using the re-crystallized salt at 30°C by constant stirring for 2 hours. The solution was then filtered in a breaker and seed crystals were prepared after a period of 15 days. Big-sized crystals were grown using the seed crystals in the supersaturated aqueous solution of SPTT.

I. INTRODUCTION

Sodium potassium tartrate tetrahydrate (SPTT) crystal is also called as the Rochelle salt. Since many studies like, third order NLO studies, LDT studies of SPTT crystals have not been reported in the literature[7-11], an investigation has been carried out to grow and study SPTT crystals here. Rochelle salt is a highly water soluble material and hence can be crystallized by the method of solvent evaporation.

A saturated solution of this is highly basic and at acidic conditions it undergoes either chemical reaction or decomposition. Growth of Rochelle salt crystals must take place at temperature below 40 °C above which sodium tartrate is deposited. In this work, growth and various studies of SPTT crystals are done and the results are discussed.

II. EXPERIMENTAL METHOD OF CRYSTAL GROWTH

AR grade chemical of sodium potassium tartrate tetrahydrate (SPTT) salt was purchased and re-crytallization was carried out twice for further purification. Single crystals of SPTT have been grown by solution growth method with slow evaporation technique. The saturated solution of SPTT was prepared using the re-crystallized salt at 30°C by constant stirring for 2 hours. The solution was then filtered in a beaker and seed crystals were prepared after a period of 15 days. Big-sized crystals were grown using the seed crystals and supersaturated aqueous solution of SPTT. Here the growth vessels were covered with perforated polythene papers and they were kept in a vibration free platform at an average room temperature 30°C. The solvent gradually evaporates leading to supersaturation. The excess of the solute was deposited on the seed crystals and the crystals grew into reasonable size crystals. The grown crystal of SPTT is shown in the fig1.1

Fig.1 : Grown crystal of sodium potassium tartrate tetrahydrate (SPTT)

A. Second Order Nlo Studies

The analysis of second order nonlinearity like second harmonic generation (SHG) of the grown crystal was performed by Kurtz and Perry Powder method [293]. A Q-switched Nd:YAG laser (λ=1064 nm), pulse energy of 4 mJ, pulse width of 8 ns and repetition rate of 10 Hz was used as the source. SHG was confirmed by emission of green light (λ=532 nm). The SHG efficiency of SPTT sample is found to be 0.94 times as that of KDP.

B. Third Order Nlo Studies

Z-scan technique was used to study the third order NLO behaviour of crystals. This is a simple and sensitive single beam technique for measuring the change in phase induced on a laser beam upon propagation through a nonlinear material. Additionally, it helps to determine nonlinear absorption coefficient and nonlinear optical refraction for optical materials. The beam was focused using a convex lens and the focal point has been taken at Z=0. The sample is placed at the focus point of the lens and then moved along the Z-axis through a distance of ± Z_0 which is called Rayleigh length. The normalized transmission of the crystal is measured at positions with respect to the focus of the beam. There are two modes in the Z-scan analysis namely, open and closed aperture modes. In the closed aperture method, an aperture is placed in front of the detector to prevent some of the light from reaching the detector. Hence, only the central region of the cone of light reaches the detector. The detector is now sensitive to any focusing or defocusing that a sample may induce. In the open aperture method, the aperture is removed to allow all the light to reach the detector and hence sets the normalized transmittance. This method is used in order to measure the nonlinear absorption which arises due to absorption of two photons. The optically transparent SPTT crystal of about 1 mm thickness and He-Ne laser of wavelength 632.8 nm were used in this experiment. The obtained open and closed aperture Z-scan curves are presented in Fig.2 and Fig.3 respectively. The Z-scan curves are characterized by a prefocal transmittance maximum (peak) followed by a postfocal transmittance minimum (valley) intensity. The transmitance difference between peak and valley (ΔT_{p-v}), linear transmittance aperture (S), the third-order nonlinear refractive index (n_2) of the crystal, the nonlinear absorption coefficient (β) and the third order nonlinear optical susceptibility (χ3**)** were determined as per the procedure given in the literature [10-15]. In closed aperture Z-scan curve, the prefocal transmittance peak is followed by the post focal valley which is the characteristics of negative nonlinearity. The nonlinear refractive index n_2 was calculated to be -4.362 x 10^{-11} m^2/W. As the material has a negative nonlinear refractive index, it results in self-defocusing of the material. The value of nonlinear absorption coefficient (β)estimated from the open aperture Z-scan curve was 5.894 x 10^{-4} m/W. The third order nonlinear susceptibility of SPTT crystal was found to be 6.851 x 10^{-7} esu

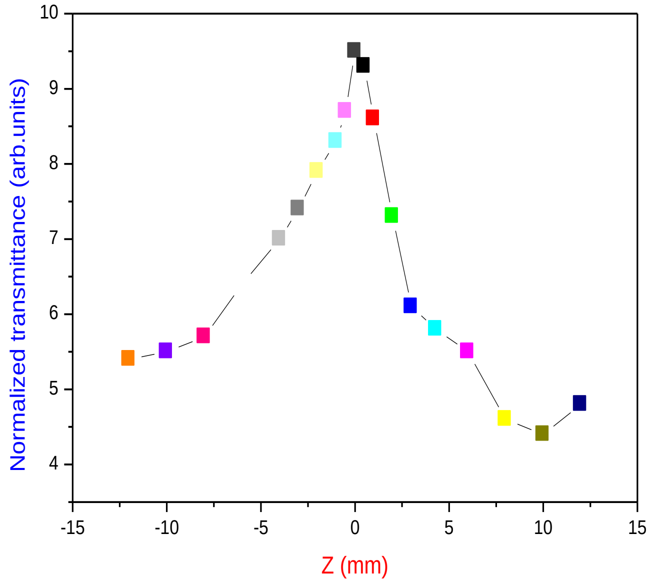

Fig. 2 : Plot of transmittance versus position (Z) of PTT crystal in open aperture mode

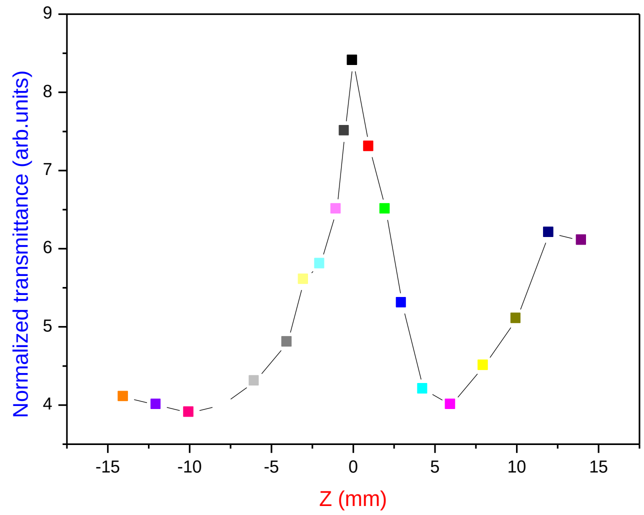

Fig. 3 : Plot of transmittance versus position (Z) of SPTT crystal in closed aperture mode

C. Laser Damage Threshold (LDT) Studies

The value of LDT is one of the important device related properties of NLO crystals. The laser damage in the crystals are caused by various physical processes such as electron avalanche, multiphoton absorption and photoionization for the transparent materials whereas in case of high absorbing materials, the damage threshold is mainly due to the temperature rise, which leads to strain-induced fracture. It also depends upon the specific properties of material, pulse width, and wavelength of laser used. Laser damage threshold (LDT) studies for the samples were carried out using an Nd:YAG laser (1064 nm, 18 ns pulse width). As given in the previous chapters, the values of LDT have been determined using the formula $P = E/\tau\pi r^2$ where τ is the pulse width in ns, E is the input energy in mJ, r is radius of the spot in mm. The obtained value of LDT for SPTT crystal is 0.362 GW/cm^2 and this value is more than LDT value of KDP crystal [298].

D. XRD Studies

The grown SPTT crystal was subjected to single crystal XRD studies and the unit cell parameters were found. The single crystal X-ray diffraction data was collected using Bruker Kappa Apex II X-ray diffractrometer with MoK_α radiation (λ=0.71069Å). The obtained single crystal XRD data are given in the table 6.1. Single crystal XRD analysis indicates that SPTT crystal crystallizes in orthorhombic structure with the space group $P2_1\ 2_12_1$. The number of molecules per unit cell was found to be 4.

Table 1: Lattice parameters of SPTT crystal

Sample	**Lattice constants**	**Volume of the unit cell**
SPTT crystal	a = 9.388 (5) Å b = 10.821(3) Å , c = 8.950 (4) Å α = 90 o, β = 90o, γ = 90 o	909.22(2) Å3

CONCLUSION

Single crystal XRD analysis indicates that SPTT crystal crystallizes in orthorhombic structure with the space group $P2_12_12_1$ and the number of molecules per unit cell was found to be 4. . From the optical results, it is observed that the grown crystals are optically transparent in the visible region and it is an essential condition for SHG emission. Second harmonic generation (SHG) study was carried out by modified experimental set up of Kurtz and Perry.. The measured values of SHG efficiency of SPTT crystal is0.940. Hence, the samples of this work are the second harmonic generators and second order NLO crystals. Laser damage threshold (LDT) is an important material parameter and it is essential for using the crystal as an NLO element in various applications involving large laser input power like frequency doubling, optical parametric processes, etc and it was measured using a Nd:YAG laser with wavelength of 1064 nm and 18 ns pulse width. The values of LDT obtained for, SPTT crystal **is**, 0.362 GW/cm^2.

Third order NLO studies were carried out by Z-scan technique for samples using a He-Ne laser of wavelength 632.8 nm. Using open aperture and closed aperture Z-scan curves, the third-order nonlinear refractive index, the nonlinear absorption coefficient and the third order nonlinear optical suceptibility were determined.

For SPTT crystal, the obtained value of nonlinear refractive index was calculated to be -4.362 x 10^{-11} m^2/W. As the material has a negative nonlinear refractive index, it results in self-defocusing of the material. The value of nonlinear absorption coefficient was estimated to be 5.894 x 10^{-4} m/W and the third order nonlinear susceptibility of SPTT crystal was found to be 6.851 x 10^{-7} esu

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