Optical Properties of Di-sodium Hydrogen Phosphate (DSHP) Single Crystal

R. N. Shaikh, Mohd Anis, S. S. Hussaini

Crystal Growth Laboratory, Department of Physics,
Milliya Arts, Science and Management Science College, Beed-431122, Maharashtra, India

Abstract

A single crystal of di-sodium hydrogen phosphate (DSHP) was grown by the slow evaporation technique at room temperature. The optical transmission study reveals the wide transparency of grown crystal in the entire visible region, which is an essential requirement for NLO applications. The cut off wavelength has been found to be 281 nm and the optical band gap is found to be 5.5eV. The vital optical constants necessary for designing optical devices were also studied.

Keywords: *Crystal growth, DSHP, UV-Visible, Optical properties*

1. INTRODUCTION

The new nonlinear optical frequency conversion materials have a significant impact on laser technology, optical communication and optical data storage. Second order nonlinear optical (SONLO) materials have recently attracted much attention because of their potential application in emerging optoelectronics technology [1-5]. Many phosphate group NLO materials like potassium dihydrogen phosphate (KDP), ammonium dihydrogen phosphate (ADP), potassium titanyl phosphate (KTP), etc. have been widely studied for Nd: YAG laser applications. Disodium hydrogen phosphate (DSHP) is an interesting and promising inorganic NLO material of phosphate group. However it's XRD, FT-IR and thermal properties has been reported by Gunasekaran et al [6].The powder XRD, FT-IR and electrical properties of DSHP has been reported by Jhon et al [7]. However investigation on optical properties of DSHP is avoided in literature. Hence, in the present work the DSHP crystal has been grown by the slow evaporation method and is characterized by UV-visible spectral analysis and its detailed optical parameters were reported for NLO applications.

2. EXPERIMENTAL

2.1. Synthesis and crystal growth

The AR grade DSHP salt was dissolved in double distilled water at room temperature. The solution was stirred well for six hours constantly using magnetic stirrer to ensure homogeneous concentration over the entire volume of the solution, then solution was filtered using Whatman filter paper. The homogeneous saturated solutionwas kept in glass vessels for slow evaporation. The transparent seed crystals were harvested within 6-7 days.

2.2. Linear optical studies

The grown crystals were subjected to spectral analysis for studying the linear optical properties. The transmission spectrum was recordedusing Shimadzu UV-2450 Spectro-photometer in the range 200-900 nm. The optical absorption coefficient (α) was calculated using the relation

$$\alpha = \frac{2.303 \log\left[\frac{1}{T}\right]}{t}$$

where, T is the Transmittance and t is the thickness of the crystal. The various optical constants were also calculated [8].

3. RESULTS AND DISCUSSION

3.1. Linear optical properties

The transparent behaviour of DSHP inthe entire UV-visible region is clearly illustrated by its UV–visible spectrum shown in Fig.1.It is also supported by the transmittance spectrum showing 89% transmittance in the entire UV-visible region. This is due to delocalization of electrons of bonded oxygen along P=O which is expected to largely destroy the double bond character. The UV cut off Wavelength for the grown crystal was found to be

281nm. The high transmittance and lower cut-off wavelength of DSHP crystals were essential optical parameters for applications in SHG transmission devices [9]. The energy dependence of the absorption coefficient suggests the occurrence of direct band gap and hence it obeys the relation for high photon energy,

$$\alpha h\upsilon = A(h\nu - E_g)^{\frac{1}{2}}$$

where, E_g is the optical band gap and A is a constant. The variation of $(\alpha h\upsilon)^2$ versus $h\upsilon$ in the fundamental absorption region is plotted in Fig. 2 and E_g is evaluated by the extrapolation of the linear part. The band gap is found to be 5.5 eV. As a consequence of wide band gap and high transmittance in the visible region makes it potential candidate for optoelectronic applications [10]. From the recorded transmission spectra, the linear optical constants of DSHP as a function of photon energy is plotted (Figs. 3-8).

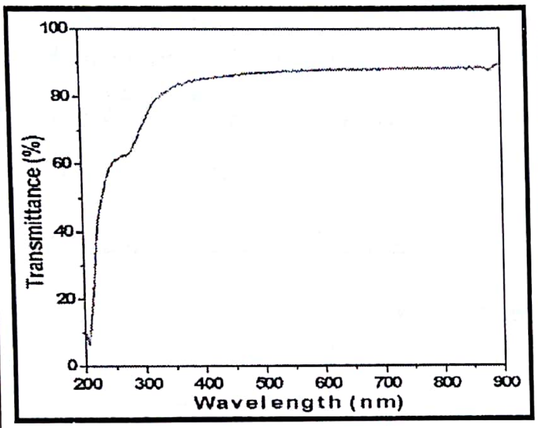

Fig.2. Tauc's plot of DSHP crystal

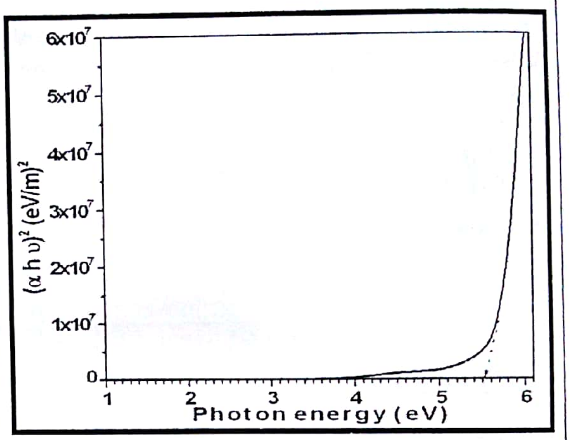

Fig.2.Tauc's plot of DSHP crystal.

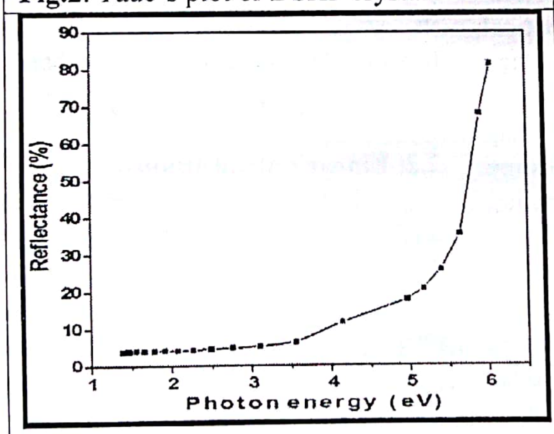

Fig. 3. Plot of reflectance vs. $h\upsilon$

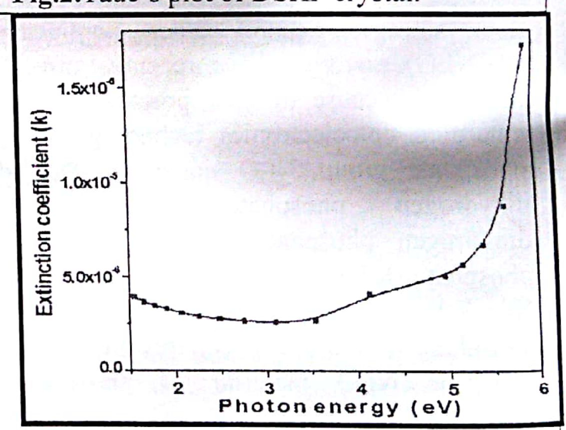

Fig.4. Plot of extinction coefficient vs. $h\upsilon$.

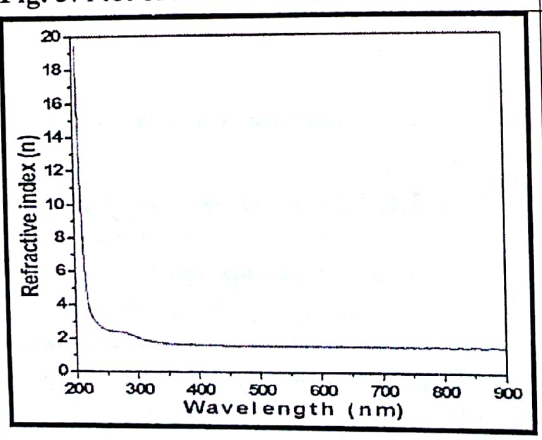

Fig. 5. Plot of refractive index vs. wavelength

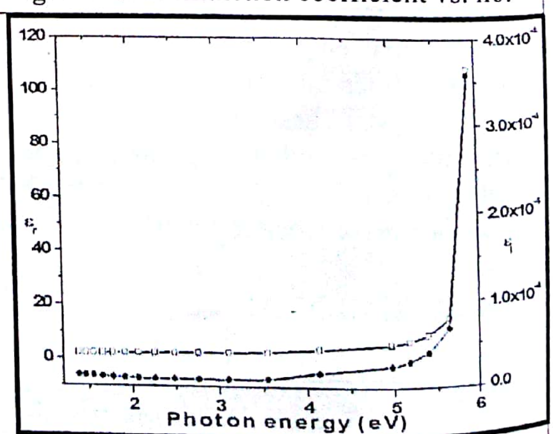

Fig. 6. Plot of real and imaginary part of dielectric constant.

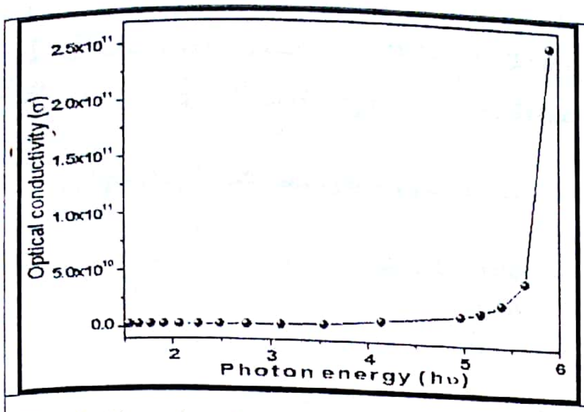

Fig. 7. Plot of optical conductivity vs. hυ.

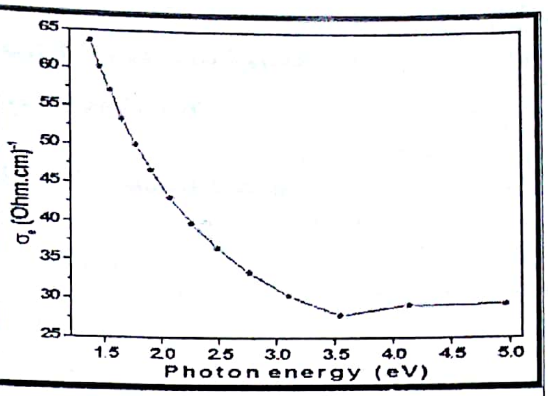

Fig. 8. Plot of electrical conductivity vs. hυ

For understanding the interaction of light with matter, it is very essential to study the refractive index and the extinction coefficient. The refractive index of the material at 900 nm is 1.48. Also the extinction coefficient shows exponential decay as the photon energy decreases. Refractive index being the measure of percentage of intensity of light reflected, the reflectance shows an increasing value along the photon energy.

From **Fig**. 3 and 4, it is clear that the reflectance and the extinction coefficient depend upon the absorption coefficient. The internal energy of the device depends on this absorption coefficient. The high transmission, low reflectance and low refractive index of DSHP in the UV-vis. region makes the material a prominent one for antireflection coating in solar thermal devices and NLO applications [11]. The low extinction value and electrical conductivity show the semiconducting nature of the material. The high magnitude of optical conductivity ($10^{11} s^{-1}$) confirms the presence of very high photo response nature of the material [11]. This makes the material more prominent for device applications in information processing and computing

4. CONCLUSION

The DSHP crystal has been grown from aqueous solution by slow evaporation technique. The high transmittance, lower cut-off wavelength and wide band gap (5.5eV) are suitable for optoelectronics applications. The high transmission, low reflectance and low refractive index in the UV-Vis region make the material a prominent one for antireflection coating in solar thermal devices. The low extinction and electrical conductivity value shows the semiconducting nature of the material. The high magnitude of optical conductivity confirms the presence of very high photo response nature of the material.

5. ACKNOWLEDGMENT

The authors are thankful to the DST (DST/SR/S2/LOP-22/2010), and UGC (UGC / 41-591/2012/SR), New Delhi, for financial assistance.

REFERENCES

[1].N.R. Dhumane, S.S. Hussaini, M.D. Shirsat et al Cryst. Res. Technol. 41 (2006) 897.
[2].M.D. Shirsat, S.S. Hussaini, N.R. Dhumane et al Cryst. Res. Technol. 43 (2008)756.
[3].N.R. Dhumane, S.S. Hussaini, M.D. Shirsat et al J. Optical mater. 31 (2008) 328.
[4].S.S. Hussaini, M.D. Shirsat et al Cryst. Res. Technol. 42 (2007)1110.
[5].R.Rajasekaran, P. Ramasamy, J. Cryst.Growth, 252 (2002) 317.
[6].M. Gunasekaran, P. Ramasamy, C.W. Lan, J. Cryst. Growth 244 (2002) 194.
[7]. N.J. John, P. Selvarajan, S. Benita JebaSilviya, and C.K. Mahadevan, J. Mater. & Manuf. Proc., 22 (2007) 379.
[8].R. Hanumantharao, S. Kalainathan et al Spectrochim. Acta A, 103 (2013) 388.
[9].S.A. Martin BrittoDhas, S. Natarajan et al Opt. Comm., 278 (2007) 434.
[10].Sagadevan Suresh. J. Appl. Sci. andTechn.3, (2013) 340.
[11].T. C. SabariGirisun, S. Dhanuskodi,Cryst. Res. Technol., 44 (2009) 1297.