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Hardness study of cesium chloride doped L-threonine single crystal for optical device applications

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Abstract: Single crystal of cesium chloride doped L-threonine (LTCC) was grown by employing slow solvent evaporation of solution growth method at room temperature. An attempt has been made to evaluate the mechanical properties such as Hardness number (Hv), Elastic stiffness constant (C_{11}), Yield strength (σ_V). The hardness value increases with increasing time of indentation at constant load 5g..
Keywords: Hardness : Hardness number (Hv), Stiffness constant (C_{11}), Yield strength (σ_V)

I. INTRODUCTION

L-threonine is an important polar amino acid. It shows higher SHG efficiency as compare to other amino acid family members. Nonlinear optical (NLO) materials with large NLO coefficients have numerous applications in the optoelectronics as an optical elements, in the material processing, harmonic generation, optical communication, information processing. Studies an effect of potassium iodide and cesium chloride doping on the second harmonic generation efficiency, optical and thermal properties of L-threonine crystal were reported [1,2]. Owing to good optical and thermal properties of cesium chloride doped L-threonine single crystal, its hardness has to be study. Hardness is the vital important characteristics of crystal from device fabrication point of view [3]. The hardness properties includes hardness number (Hv), Elastic stiffness constant (C_{11}), Yield strength (σ_V). The values of these provide information about tightening of bond between the adjacent atoms in the crystal, mechanical stability, elasticity and plasticity, molecular composition of the material etc. There are different methods for the hardness testing such as Rockwell, Brinell, Vicker, Knoop, and Berkovich. Vicker micro hardness testing is simple, accurate and commonly used testing method. The hardness value is defined as the ratio of indentation load to projected area of indenter for crystal [4]. In the present communication, cesium chloride doped L-threonine single crystal's hardness properties have been evaluated.

II. MATERIAL AND CRYSTAL GROWTH

The equimolar ratio of cesium chloride and L-threonine were dissolved in double distilled water and using magnetic stirrer, stirred continuously for four hours at a temperature 40^oC to form homogeneous solution. The homogeneous solution then filtered using membrane filter. The filtered solution kept in constant temperature at room temperature for spontaneous crystallization to get seed crystals within 2 days. The seed crystal was hang in the supersaturated solution for 12-15 days in the constant temperature water bath maintained at a 35^oC constant temperature to grow larger size crystal. The fully grown single crystal was harvested for hardness study.

III. RESULT AND DISCUSSION

Hardness study

Hardness is an important characterization to know the mechanical strength of the material. Hardness is the resistance offered by a material to the motion of dislocations and producing deformation under an applied load [3].To obtain transparent flat surface of crystals, it was polished and lapped. The indentation time was changed for same load to calculate the micro-hardness number. Each time, the cracks were initiated on the crystal surface around the indentation for the constant applied load 5g. The variation of micro hardness number with indentation time for same applied load is tabulated in the TABLE. It is noted that hardness value increases with increasing time of indentation. The ability of the material to sustain the applied load for larger period of time without releasing energy has well. Elastic stiffness constant of the crystal is estimated from Wooster's empirical relation $C_{11}=HV^{7/4}$[5]. Elastic stiffness constant gives the broad idea about the tightening of the bonds between adjacent atoms. The elastic stiffness constant value is quite large. The tensile strength of the material is the maximum stress that can be crystal sustain without breaking. The yield point is the maximum stress in which crystal behaves elastically. The tensile strength and yield point of LTCC crystal have been calculated using the relation T=0.2Hv+6 and Y= 0.23Hv-13.5. The increase in the hardness number can be attributed to the electrostatic attraction between the zwitterions present in the molecule. The zwitterionic nature of the molecule favors crystal to have good mechanical strength [6]. For the higher loads cracks was observed on the surface. It may be due to the release of internal stress generated locally by the indentation [7].

IV. Tables

Hardness value, Elastic stiffness constant (C_{11}), Tensile strength (T) and Yield point(Y) with varying Indentation time.

Indentation time (s)	H_v (kg/mm^2)	$C_{11}\times10^{14}$ (Pa)	T(MPa)	Y(MPa)
5	63.7	1436.29	18.74	1.151
10	69.0	1651.91	19.8	2.37
15	87.9	2523.37	23.58	6.717

V. Conclusion

The hardness value increases with increasing time of indentation. Crystal sustains the load without breaking for longer period of time. The bonding between the adjacent atoms in the crystal is good. The crystal sustain load for a longer period of time without going to plastic deformation. Overall, the mechanical stability of the crystal is good. Owing to the good mechanical properties LTCC can be used in optical device applications.

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