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Elastic properties of $La_{1.85}$ $Sr_{0.15}$ CuO_4 at high temperature superconductor

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Abstract
Elastic properties at high temperature Superconductors depends on the second order (SOE) and third order (TOE) expressions. The superconductor of $La_{1.85}$ $Sr_{0.15}$ CuO_4 having tetragonal structure have been derived using the finite deformation theory and variation with Einstein temperature (θ_E), Debye temperature (θ_D) for La $_{1.85}$Sr $_{0.15}$ CuO_4 at high temperature superconductor. The derived expression have been used to compute the values of SOE and TOE constant of La $_{1.85}$ $Sr_{0.15}$ CuO_4 material are being presented for the first time.

Keywords: elastic properties, second order (SOE), third order (TOE)

Introduction

Depending upon the response of a superconducting material to and applied magnetic field, superconductors are normally classified into two categories, type Ist in which the expulsion of the magnetic lines of force is complete below the applied critical field and type IInd in which the magnetic field penetration is complete till the upper critical field destroys superconducting [1]. The longitudinal sound velocity in the Barium doped compound with the composition $La_{1.85}$ $Sr_{0.15}$ CuO_4 was measured by Fossheim *et al.* [2] using the pulse method at 24 MHz These authors also observed a sudden drop in the velocity starting from 200 to 240K. This was accompanied by a sharp rise in attenuation which exhibited a broad peak at 100 K. Copper becomes strictly square planer coordinator with Cu-O bonds of about 1.97 Å. They are no epical oxygen the La atom bond to 8 oxygen compare to 9-oxygen for larger Lanthanum in the T-structure.

Our study of elastic constant for the tetragonal phase of La $_{1.85}$ Sr $_{0.15}$ CuO_4 will provide some information about the structural phase transition and doping. Lanthanum Copper Oxide La_2CuO_4 undergoes a structure transformation from a tetragonal to an orthorhombic structure at 530 K. The Strontium and Barium doped superconducting compounds are tetragonal at room temperature. The phase diagram of tetragonal to orthorhombic transition in the Strontium doped compound has been investigator by Moret *et al.* [3-7].

The superconductivity on these compounds is highly sensitive to structure perturbations induced by hydrostatic pressure owing to their anisotropic structure [8-9]. We attribute the deviation from Poission behavior and the C–lattice contraction to tensile strain induced oxygen vacancy formation owing to the reduced oxygen activation energy [10-11]. This is to be compared with a Debye temperature of 292 K determined via specific heat for a superconducting single crystal elastic data are consistent with specific heat data obtained on ceramics [12-14], where values nearer to 360 K are observed. Thus the discrepancy, though suggestive of porosity and ceramic structure effects is certainly real because it is hard to imagine how this compound could a V_l of 7.3 km/s and a V_s of 4.1 km/s, the values predicted by the specific heat data if we use $\sigma = 0.26$. A highly anisotropy structure could, however, limit the specific has contribution from the acoustic phonons. The super conducting phase transition generates a discontinuity in compression elastic constants which can be obtained from a thermodynamic treatment. Observation of such effects are relevant to the interpretation of normal state properties because the discontinuity. ΔV_l is the bulk sound velocity of an isotropic superconductor given by-$\Delta V_l = \frac{V_l \Delta c}{2T_c}\left[\frac{dT_c}{dP}\right]^2$, where Δc is the discontinuity in specific heat at T_c and V_l is the bulk sound speed.

Calculation and Results

Table 1: Value of Einstein Temperature (θ_E) and Debye Temperature (θ_D) for various high temperature superconductors calculated from specific heat data

Compounds	T(K)	$\frac{C}{3R}$	(θ_E)(K)	(θ_D)(K)
$La_{1.85}Sr_{0.15}CuO_4$	10	0.020	80.9	157.3
	15	0.060	98.8	162.8
	20	0.136	107.2	161.0
	25	0.261	107.0	151.3
	30	0.441	97.8	163.0
	35	0.646	82.0	108.5
	40	0.750	75.4	96.1

Table 2: Second Order Elastic Constant (in GPa) of $La_{L85}Sr_{0.15}CuO_4$

C_{ij}	Present
C_{11}	239.89
C_{12}	84.01
C_{13}	55.01
C_{33}	147.06
C_{44}	53.97
C_{66}	80.22

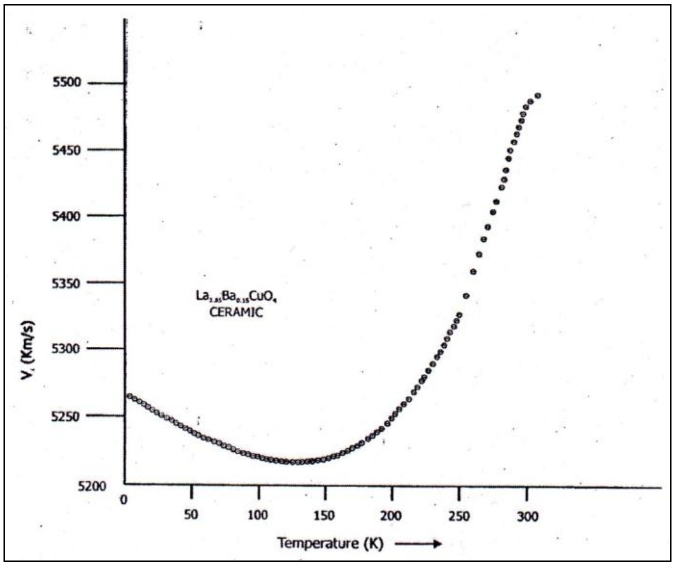

Fig 1: V_l for single crystal $La_{1.85}Sr_{0.15}CuO_4$ ceramic showing the decreases in sound velocity on cooling below 300K.

Result and Discussion

The second order elastic constants thus obtained for $La_{2-x}Sr_xCuO_4$ (x=0.10 to 0.20) are given in above table. A comparison of second order elastic constants calculated using the present method and the measured value for $La_{2-x}Sr_xCuO_4$ superconductors are also given in table. The agreement of second order elastic constants obtained by present method with the some reported experimental value is good.

The third order elastic constants obtained by us are listed. The third order elastic constants are compared with those from [15], where in the values are given as combinations of third order elastic constants. For $C_{11}+6C_{12}+2C_{23}$ and $C_{44}+2C_{66}$ they obtained $-301x10^{11}$Pa and $-6x10^{11}$ Pa respectively. The corresponding values obtained by us are $-90.87x10^{11}$ Pa and $-24.78x10^{11}$ Pa respectively. The CuO planes do not suffer relative displacement when the lattice is strained. All the third order elastic constants of $La_{2-x}Sr_xCuO_4$ (x=0.13 to 0.20) are negative.

The change in elastic properties is undoubtedly related to the tetragonal to orthorhombic transition at T_0. In fact, coupling between the order parameter, and strains can account for this softening quite naturally. However, the acoustic modes remain soft for an extended temperature range below T_0. One major objects of the present study has also been to analysis the elastic behavior on other ceramic materials to find out whether a small bulk modulus and larger pressure dependence are general characteristics of mixed oxides based on copper.

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