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Title :

Effects of Ce4+ And Cd2+ Substitutions on Superconducting Fluctuation Behavior, Ultrasonic Velocity and Elastic Properties of Fe- Doped (Tl, Bi)-1212 High Temperature Superconductors

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In this study, two series of superconductor compounds with starting composition $Tl_{0.9}Bi_{0.1}Sr_{2-x}Ce_xCa_{0.9}Y_{0.1}Cu_{1.99}Fe_{0.01}O_{7-\delta}$ (x = 0–0.20) and $Tl_{0.9}Bi_{0.1}Sr_{1.8}Yb_{0.2}Ca_{1-x}Cd_xCu_{1.99}Fe_{0.01}O_{7-\delta}$ (x = 0–0.4) ceramics were prepared using the conventional solidstate synthesis method to elucidate their physical properties. For Ce-substituted of $Tl_{0.9}Bi_{0.1}Sr_{2-x}Ce_xCa_{0.9}Y_{0.1}Cu_{1.9}9Fe_{0.01}O_{7-\delta}$ (x = 0–0.20) samples, the zero critical temperature, $T_{c\ zero}$ increased from 65.4 K (x = 0.05) to 71.0 K (x = 0.10), but slightly decreased for x > 0.10 indicating the optimum value of average copper valence was achieved at x = 0.10. Excess conductivity analysis using the Aslamazov Larkin, AL and Lawrence–Doniach, LD models revealed two dimensional, 2D to threedimensional, 3D transition of superconducting fluctuation behavior, SFB with the highest transition temperature, $T_{2D\text{-}3D}$ at x = 0.10. FTIR analysis in conjunction with XRD results showed softening of FeO_2/CuO_2 planar oxygen mode which is suggested to be related to possible increase of interplane coupling, J and this is supported by computed results based on the LD model. The enhanced J increases superconducting coherence length along c-axis, ξc(0), and hence lowers anisotropy, γ resulting in enhanced superconducting properties. For $Tl_{0.9}Bi_{0.1}Sr_{1.8}Yb_{0.2}Ca_{1-x}Cd_xCu_{1.99}Fe_{0.01}O_{7-\delta}$ (x = 0–0.4) ceramics, substitution of Cd caused $T_{c\ zero}$ increasing from 40.0 K (x = 0) to 76.4 K (x = 0.3) before decreasing to 74.8 K (x = 0.4) with increasing Cd_{2+} contents. FTIR analysis in conjunction with XRD results indicates improved J that is evidenced in the form of decreased c-axis length and softening of the apical oxygen mode with Cd concentration. Excess conductivity analyses showed cross-over between 2D to 3D SFB transition for all the samples (x = 0.1–0.4) with the highest T_{2D-3D} was observed at x = 0.3. Similar calculation revealed longest value of ξc(0) and the highest J at x = 0.3. Ultrasonic velocity measurements was performed on longitudinal and shear velocities at 9 MHz in temperature ranges of 80–280 K and 80– 220 K, respectively, for $Tl_{0.9}Bi_{0.1}Sr_{1.8}Yb_{0.2}Ca_{1-x}Cd_xCu_{1.99}Fe_{0.01}O_{7-\delta}$ (x = 0-0.4) and $Tl_{0.9}Bi_{0.1}Sr_{2-x}Ce_xCa_{0.9}Y_{0.1}Cu_{1.99}Fe_{0.01}O_{7-\delta}$ (x = 0-0.2) ceramics to study the influence of Cd and Ce substitutions on elastic properties and elastic anomaly. For the former series, ultrasonic velocity measurements at 80 K showed a non-linear increase in both absolute longitudinal and shear velocities as well as elastic moduli with Cd substitution with the largest increase observed for the x = 0.3 sample. Temperature dependant longitudinal modulus showed elastic anomaly characterized by a step-like slope change at around 230 K for x = 0 & x = 0.3 and at around 250 K for x = 0.4 with the x = 0.3 sample showing the sharpest slope change. For $Tl_{0.9}Bi_{0.1}Sr_{2-x}Ce_xCa_{0.9}Y_{0.1}Cu_{1.99}Fe_{0.01}O_{7-\delta}$ series, Ce was observed to influence elastic moduli at 80 K which showed the largest value obtained at x = 0.10. A longitudinal velocity anomaly was observed at around 260 K for the unsubstituted sample (x = 0). Ce substitution caused the temperature of the elastic anomaly to shift to 250 K (x = 0.1) and 262 K (x = 0.2). The existence of the step-like elastic anomaly was suggested to be due to oxygen ordering taking place in Tl-O planes. The analysis of the elastic behavior in the vicinity of the elastic anomalies using Landau free-energy model for both $Tl_{0.9}Bi_{0.1}Sr_{1.8}Yb_{0.2}Ca_{1-x}Cd_xCu_{1.99}Fe_{0.01}O_{7-\delta}$ (x = 0-0.4) and $Tl_{0.9}Bi_{0.1}Sr_{2-x}Ce_xCa_{0.9}Y_{0.1}Cu_{1.99}Fe_{0.01}O_{7-\delta}$ (x = 0-0.2) series suggests that the anomaly is due to a phase transition which involves oxygen ordering.