UNIVERSITI TEKNOLOGI MARA

THE DOCTORAL RESEARCH ABSTRACTS

Volume: 7, Issue 7 May 2015

SEVENTH ISSUE

INSTITUTE of GRADUATE STUDIES

Leading You To Greater Heights, Degree by Degree

IGS Biannual Publication

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Title :
Ultrasonic Velocity and Elastic Anomaly in Charge-Ordered $Nd_{0.5}Ca_{0.5}Mn_{1-x}Cr_xO_3$, $Nd_{0.3}La_{0.2}Ca_{0.5-y}Sr_yMnO_3$ and $Dy_{0.5-z}Er_zBa_{0.5}CoO_3$ Magnetic Ceramics

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Three series of charge-ordered compounds $Nd_{0.5}Ca_{0.5}Mn_{1-x}Cr_xO_3$ (NCMCO) ($0 \le x \le 0.05$), $Nd_{0.3}La_{0.2}Ca_{0.5-y}Sr_yMnO_3$ (NLCSMO) ($0 \le y \le 0.05$) and $Dy_{0.5-z}Er_zBa_{0.5}CoO_3$ (DEBCO) ($0 \le z \le 0.05$) ceramics were prepared using the solid-state reaction method. For NCMCO series, resistivity and susceptibility measurements for the x=0 sample showed an insulating behavior and an anti-ferromagnetic (AFM) transition at 230 K as well as a charge-ordering (CO) transition at 280 K. The substitution of Cr induces a ferromagnetic-paramagnetic (FM-PM) and metal-insulator (MI) transition as well as gradually suppressing the CO state due to weakening of the Jahn-Teller (JT) effect. Quenching to reduce the oxygen content of the x=0.05 sample caused the MI transition temperature to shift to lower temperatures most likely due to oxygen reduction. On the other hand, both longitudinal and shear velocities at 100 K increased significantly with Cr substitution indicating improvement in elastic properties. However, quenching of the x=0.05 sample slightly decreased both velocities and related elastic moduli. A step-like longitudinal velocity anomaly characterized by a slope change suggests the existence of CO state for x=0, 0.02 and 0.05 samples. The step-like anomaly shifts to lower temperatures from 266 K (x=0) to 222 K (x=0.05) with Cr substitution indicating the weakening of the CO state. Absence of the step-like anomaly for the quenched x=0.05 sample suggests suppression of the CO state due to oxygen reduction. For the NLCSMO series, resistivity and susceptibility measurements showed all samples exhibit MI behavior accompanied by FM-PM transition where the MI transition temperature, T_{MI} and FM-PM transition temperature, T_C increased with Sr content indicating the enhancement of double-exchange mechanism. Analysis of the resistivity change with respect to temperature, $d\ln\rho/dT^{-1}$ versus T indicates onset of CO state where its CO transition temperature, T_{CO} decreased with Sr content indicating weakening of the CO state. On the other hand, both absolute longitudinal and shear velocities as well as elastic moduli measured at 80 K increased significantly with Sr doping indicating improvement in elastic properties. A longitudinal velocity anomaly characterized by a slope change around the vicinity of T_{CO} was observed for all samples. The longitudinal elastic anomaly is attributed to the JT effect of Mn^{3+} ions. For the DEBCO series, resistivity and susceptibility measurements for the z=0 sample exhibited an insulating behavior and an AFM transition, T_N at 198 K as well as FM transition, T_C at 260 K. Increasing of Er content suppressed the FM and AFM state may be due to the increase in size disorder arising from the size mismatch between A-site cations. On the other hand, both absolute velocities and related elastic moduli measured at 210 K decreased with Er content in conjunction with the declining in the FM domain indicating a weakening in elastic properties. A longitudinal velocity anomaly characterized by a drop in velocity upon cooling before hardening with further cooling was observed for all samples. This abnormal elastic anomaly can be attributed due to JT distortion of intermediate-spin Co^{3+} ions. Analysis of the elastic anomaly using the mean-field theory in the NCMCO, NLCSMO and DEBCO series suggests involvement of the JT effect which transforms from dynamic to static type with decreasing temperature. The elastic anomaly shifted to lower temperature from 266 K (x=0) to 222 K (x=0.05) for NCMCO, 222 K (y=0) to 205 K (y=0.05) for NLCSMO and 129 K (z=0) to 124 K (z=0.05) for DEBCO, indicating a weakening of the static JT effect.