Role of electronic and atomic properties in an XY-like spin-glass system
Ni$_{0.4}$Mn$_{0.6}$TiO$_3$

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Abstract
Recent discovery of XY-like spin-glass on single crystal Ni$_{0.4}$Mn$_{0.6}$TiO$_3$ (NMTO) introduces linear magnetoelectric coupling and toroidal moment. Generally, combination of the competing exchange interactions and either site or bond disorder can give rise to a spin glass state. We have used synchrotron techniques like x-ray absorption near-edge structure (XANES), extended x-ray absorption fine structure (EXAFS) and resonant inelastic x-ray scattering (RIXS) to investigate the roles of electronic and atomic properties in the XY-like spin-glass system. Magnetization measurements reveal the signatures of spin-glass behavior in the NMTO with a freezing temperature of $T_{SG} \approx 9.1$ K. RIXS experiments provide the evidence of $d$-$d$ excitations at Ni and Mn $L_3$-edge. These excitations at Ni $L_3$-edge are strongly dependent on the excitation energies; however they are almost independent for Mn $L_3$-edge. Further, these inelastic features show stronger intensities than elastic peaks at Ni $L_3$-edge, which indicate high probability of $d$-$d$ excitations at Ni 3$d$ orbitals. Using temperature dependent XANES, x-ray linear dichroism (XLD) and EXAFS studies along with RIXS, it has been shown that the preferential occupation of orbitals from out-of-plane states ($3d_{3z^2-r^2}$) to in-plane ($3d_{x^2-y^2}$) the due to local disorder of Ni-O bond lengths. We therefore believe that XY-like spin glass state of NMTO is associated with the unoccupied in-plane ($3d_{x^2-y^2}$) states.