Materials with multifold functionalities such as ferroelectricity, magnetism\textsuperscript{1,2}, and ferroelasticity have been receiving everlasting attention due to miniaturization of sensors, development of multistate high-density storage technologies, and integration of multifunctional devices/systems\textsuperscript{3,4}. One of the driving forces along these lines is an exploration of magnetoelectric (ME) multiferroic (MF) materials in which multifold ferroic functionalities i.e. (anti-)ferromagnetism and (anti-)ferroelectricity coexist and inter-coupled, resulting promising potential applications. But the co-existence of (anti)ferroelectricity and (anti)ferromagnetism is rare due to their opposing mechanisms of origin. In perovskite type materials (ABO\textsubscript{3}), one possible way to combine these two order parameters is the introduction of lone-pair cation at the A-site which drives off-center displacement and partially filled “d” shell cations at the B-site which contributes to the magnetism\textsuperscript{5,6}. Though there exist many lone pair based magnetoelectric MFs, the coupling between the electric and magnetic degrees of freedom is weak in most of the cases and that prevents one to use them for practical applications. In lone pair based MFs, presence of $d^0$ cations at the B-site with properties like spin-state transition, orbital ordering etc. can enhance the ME coupling abnormally\textsuperscript{3,6}. With these starting ideas, we have designed new series of MF materials where two mechanisms for ferroelectricity ($6\times^2$ lone-pair electrons, Ti$^{4+}$ cations with $d^0$-ness) coexist, such as $x$BaTiO$_3$-(1-$x$)BiCoO$_3$\textsuperscript{7}, $x$PbTiO$_3$-(1-$x$)BiCoO$_3$\textsuperscript{8}, PbTi$_3$, $x$V$_2$O$_5$, Bi$_2$XTiO$_6$ (X = Mn, Fe, Ni)$^{10,12}$ along with magnetism from cation with partially filled 3d shell i.e. Fe$^{3+}$, Co$^{3+}$, V$^{4+}$ etc. Our results show that these compounds have the tendency to show giant ME coupling i.e. the applied electric field can make magnetic-to-nonmagnetic transition and conversely a ferroelectric-to-paraelectric phase transition can be obtained by an external magnetic field. In this talk, I will discuss about the mechanism behind such strong coupling in the studied materials. This work demonstrates that the cooperative effect of strong lattice coupling with different order parameters on the ME properties would be important to develop next generation memory devices, sensors, magnetic switches etc.

**References:**


All are welcome