Giant magnetoelectric effect in manganite heterostructures and the ferromagnetic-insulator phase in manganites.

Sanjukta Paul

*Saha Institute of Nuclear Physics, Kolkata, India.*

We demonstrate that manganite heterostructures of the form (Insulator)/(LaMnO$_3$)$_n$/Interface/(CaMnO$_3$)$_n$/(Insulator) show strong coupling between electric and magnetic orders as charges leak from LaMnO$_3$ to CaMnO$_3$ due to repulsion. Here, an effective nearest-neighbor electron-electron (electron-hole) repulsion (attraction) is generated by cooperative electron-phonon interaction. Double exchange, when a particle virtually hops to its unoccupied neighboring site and back, produces magnetic polarons that polarize antiferromagnetic regions. Thus a striking giant magnetoelectric effect ensues when an external electrical field enhances the electron leakage across the interface. The Ferromagnetic Insulator (FMI) region thus expands at the expense of the A-AFM region of the LaMnO$_3$ and G-AFM domain of CaMnO$_3$. To further explore the FMI region and understand the coexistence of ferromagnetism and insulating behavior in manganites, we propose a localized-band model involving effective intermediate-range electron-hole attraction originating from cooperative effects of the electron-lattice interaction. Coalescing and percolating of magnetic polarons formed due to virtual hopping of holes build up the FMI region. Ferromagnetism gets more pronounced when the holes (doping) increase or when the ratio hopping/polaronic-energy dominates over superexchange-coupling/hopping.


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