Diluted Oxide Interfaces with Tunable Ground States

The metallic interface between two oxide insulators, such as LaAlO$_3$/SrTiO$_3$(LAO/STO), provides new opportunities for electronics and spintronics. However, due to the presence of multiple orbital populations, tailoring the interfacial properties such as the ground state and metal-insulator transitions remains challenging. Here, an unforeseen tunability of the phase diagram of LAO/STO is reported by alloying LAO with a ferromagnetic LaMnO$_3$ insulator without forming lattice disorder and at the same time without changing the polarity of the system. By increasing the Mn-doping level, $x$, of LaAl$_{1-x}$Mn$_x$O$_3$ (STO $0 \leq x \leq 1$), the interface undergoes a Lifshitz transition at $x = 0.225$ across a critical carrier density of $n_c = 2.8 \times 10^{13}$ cm$^{-2}$, where a peak $T_{SC} \approx 255$ mK of superconducting transition temperature is observed. Moreover, the LaAl$_{1-x}$Mn$_x$O$_3$ turns ferromagnetic at $x \geq 0.25$. Remarkably, at $x = 0.3$, where the metallic interface is populated by only $d_{xy}$ electrons and just before it becomes insulating, a same device with both signatures of superconductivity and clear anomalous Hall effect ($7.6 \times 10^{12}$ cm$^{-2} < n_s \leq 1.1 \times 10^{13}$ cm$^{-2}$) is achieved reproducibly. This provides a unique and effective way to tailor oxide interfaces for designing on-demand electronic and spintronic devices.