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Block JD, Sector III, Salt Lake, Kolkata 700 106

DEPARTMENTAL SEMINAR

Condensed Matter and Materials Physics

30th July 2025 **4.00 PM** **ONLINE / FERMION**

SPEAKER

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TITLE OF THE TALK

Unveiling the Unexpected in SrTiO3 : Polar Metal States as a Superconductivity Enhancer

HOST FACULTY

Prof. Priya Mahadevan, Senior Professor
Dept. of Condensed Matter & Materials Physics
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Unveiling the Unexpected in $SrTiO_3$: Polar Metal States as a Superconductivity Enhancer

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Nb:(Sr,Ba)TiO_3, achieved by substituting Ti^{4+} with Nb^{5+} in the ferroelectric (Sr,Ba)TiO_3 matrix, exhibits metallic behaviour. Remarkably, the broken spatial inversion symmetry characteristic of ferroelectrics persists up to an electron concentration of $n < n^*$, defining the so-called "polar metal" state. In this regime, electrical resistance increases below a characteristic temperature T_K [1]. The fact that T_K and the resistivity upturn remain unaffected under an applied magnetic field rules out the influence of magnetic impurities. The value of T_K rises monotonically as n decreases, converging with the Curie temperature of the ferroelectric matrix when n approaches zero [2].

The superconducting transition temperature T_c of Nb:(Sr,Ba)TiO_3 exhibits a dome-shaped dependence on carrier concentration, mirroring that of Nb:$SrTiO_3$ (Fig. 1, bottom). Intriguingly, despite substantial shifts in n^* with varying Ba concentrations, the peak of the superconducting dome consistently resides around 10^{20} cm^{-3} (Fig. 1, middle). While increasing Ba content significantly enhances the peak T_c, the difference ΔT_c—defined as the T_c of Nb:(Sr,Ba)TiO_3 minus that of Nb:$SrTiO_3$— remains minimal (below 0.1 K) near n^* (Fig. 1, top). However, ΔT_c dramatically increases in the low carrier density regime ($n < n^*$), where screening effects are weak.

These results suggest the broken spatial inversion symmetry not only fails to suppress superconductivity but actively enhances it in $n < n^*$. Notably, even at an ultralow carrier density of 3.8×10^{17} cm^{-3} with 7.5 % Ba substitution, superconductivity emerges at 0.4 K, yielding an unusually large T_c/T_F ratio of approximately 0.04. This discovery challenges conventional understanding and calls for a re-evaluation of the microscopic models describing superconductivity in $SrTiO_3$.

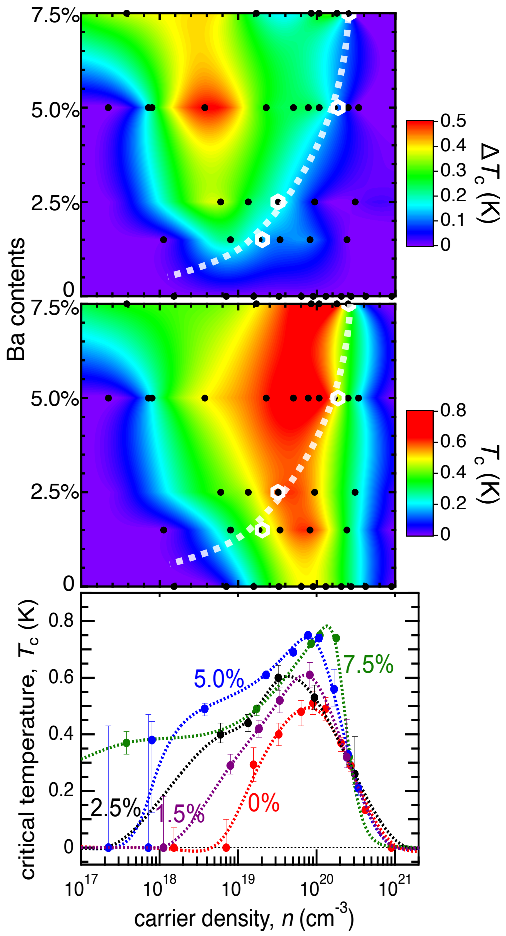

Figure 1: Density plots of ΔT_c (top) and T_c (middle) as functions of carrier concentration n at 5 K and Ba substitution. The white hexagon marks n^*, while the white dashed line delineates the boundary between polar and non-polar metallic regions. Experimental data points are indicated by black circles. In the superconducting dome (bottom panel), the error bars represent the onset and completion temperatures of the superconducting transition.

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[1] Y. Tomioka et al., *Nature Commun.* **10**, 738 (2019).
[2] Y. Tomioka et al., *npj Quantum Mater.* **7**, 1 (2022).