# Superconducting gap symmetry in 2DEG at the (111) $KTaO_3$ interfaces

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Since the discovery of superconductivity in a two-dimensional electron gas (2DEG) at the $LaAlO_3/SrTiO_3$ (LAO/STO) interface [1], transition metal oxides have emerged as a versatile platform for investigating the interplay of strong spin–orbit coupling, reduced dimensionality, and topology. A particularly compelling realization is provided by (111)-oriented $KTaO_3$ (KTO) interfaces, which exhibit gate-tunable critical temperatures up to $T_c^{max} \approx 2$ K [2] — an order of magnitude higher than in LAO/STO or (001)-oriented KTO — together with markedly enhanced spin–orbit coupling [3]. Strikingly, experiments in (111) KTO reveal a pronounced twofold anisotropy [4] of the in–plane critical field, while its magnitude reaches $H_{c2,\|}^{max} \approx 55$ T [5]. Together, these observations suggest an unconventional superconducting state governed by strong spin–orbit coupling, raising questions about the superconducting gap symmetry.

Here, we develop a group–theoretical framework for studying superconductivity in the 2DEG at the (111) $KTaO_3$ interface. We classify the symmetry of the order parameter in the presence of real-space intra- and interlayer coupling, and relate the resulting symmetry classes to microscopic pairing mechanisms. This approach builds upon our previous work, where it yielded semi-quantitative agreement with experimental observations in LAO/STO [6, 7]. We demonstrate that long-range pairing gives rise to V-shaped superconducting density of states and naturally accounts for the doubled coherence peaks observed in tunneling spectra. Finally, calculations of the critical temperature as functions of chemical potential reproduce experimentally observed $T_c^{max} \approx 2$ K. Our results provide a direct link between the symmetry of the order parameter, microscopic pairing scenarios, and experimentally accessible superconducting properties.

**Acknowledgments** *This work is financed by the Horizon Europe EIC Pathfinder under the grant IQARO number 101115190 titled "Spin-orbitronic quantum bits in reconfigurable 2D-oxides". Computing infrastructure PLGrid (HPC Center: ACK Cyfronet AGH) within computational grant no. PLG/2026/019641 was used.*

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