Spontaneous rotational symmetry breaking in $KTaO_3$ heterointerface superconductors

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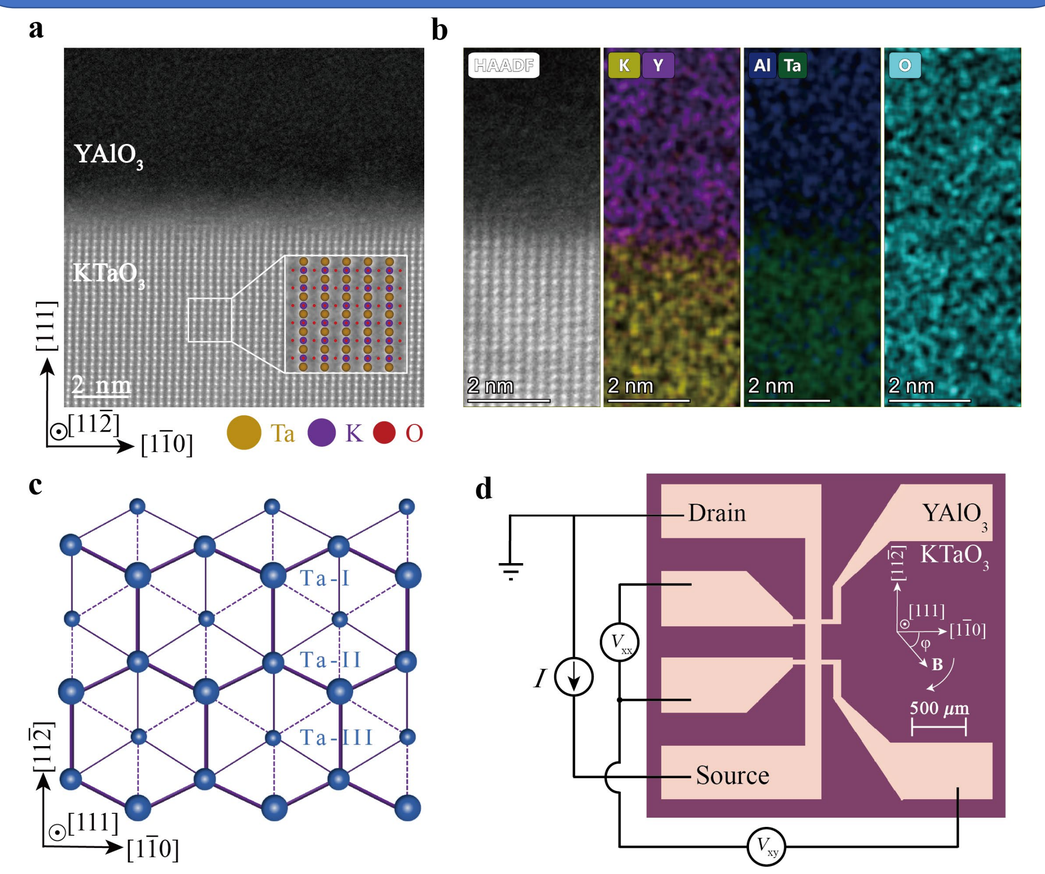
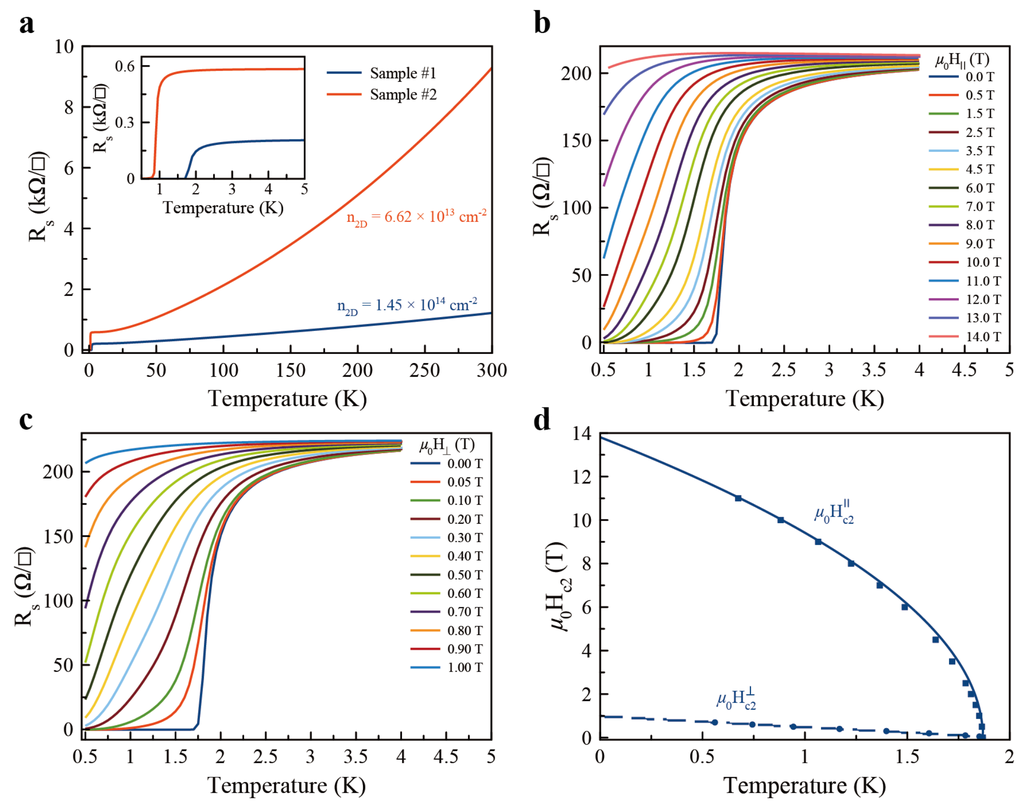
Abstract: Broken symmetries play a fundamental role in superconductivity and influence many of its properties in a profound way. Understanding these symmetry breaking states is essential to elucidate the various exotic quantum behaviors in non-trivial superconductors. Here, we report an experimental observation of spontaneous rotational symmetry breaking of superconductivity at the heterointerface of amorphous (a)-$YAlO_3$/$KTaO_3$(111) with a superconducting transition temperature of 1.86 K. Both the magnetoresistance and superconducting critical field in an in-plane field manifest striking twofold symmetric oscillations deep inside the superconducting state, whereas the anisotropy vanishes in the normal state, demonstrating that it is an intrinsic property of the superconducting phase. We attribute this behavior to the mixed-parity superconducting state, which is an admixture of s-wave and p-wave pairing components induced by strong spin-orbit coupling inherent to inversion symmetry breaking at the heterointerface of a-$YAlO_3$/$KTaO_3$. Our work suggests an unconventional nature of the underlying pairing interaction in the $KTaO_3$ heterointerface superconductors, and brings a new broad of perspective on understanding non-trivial superconducting properties at the artificial heterointerfaces.

Structural and composition characterizations



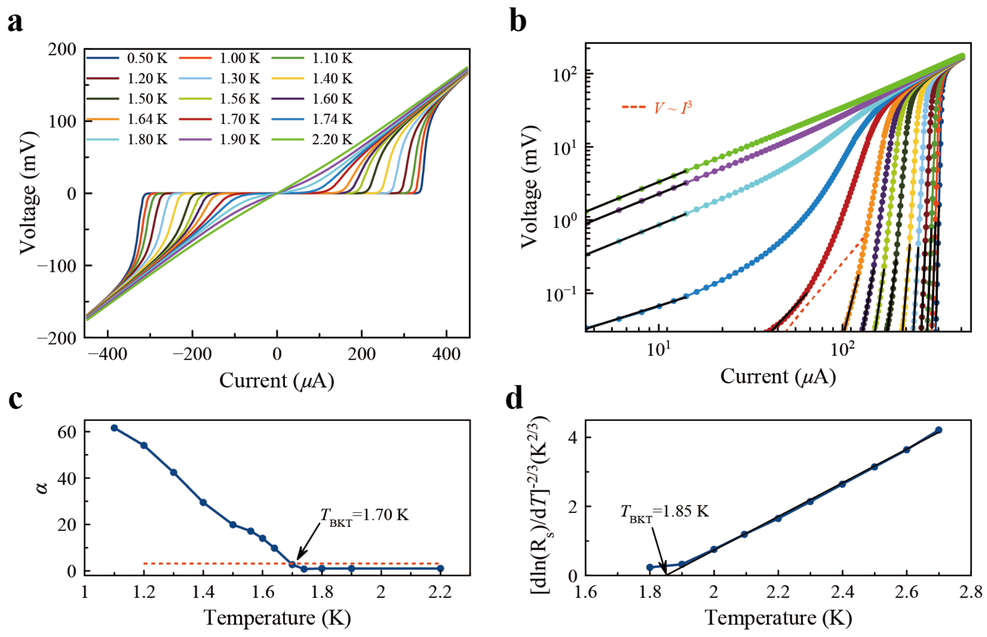
- The homogeneous and amorphous phase $YAlO_3$ thin film is grown on the $KTaO_3$(111) substrate.
- The abrupt and smooth interface between $KTaO_3$ single-crystal substrate and a-$YAlO_3$ film.

Superconducting properties



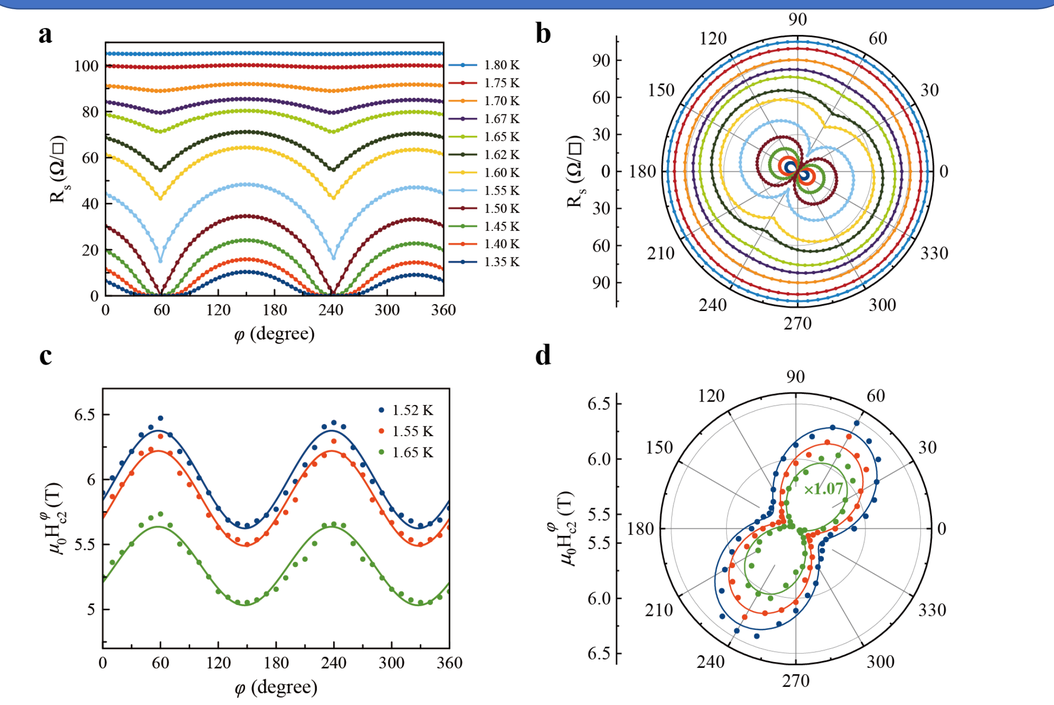
- The superconducting transition temperature T_c = 1.86 K.
- High values of $\mu_0 H_{c2}^{||}$ excessing Pauli-paramagnetic pairbreaking field $B_p \approx 3.46$ T.
- A two-dimensional nature of superconductivity.

Two-dimensional superconducting behavior



- The Berezinskii-Kosterlitz-Thouless (BKT) transition is determined using current-voltage (I-V) measurements as a function of temperature T.
- The maximal value of I_c is ~330 μA at 0.5 K, which is substantially larger than that previously observed in the $KTaO_3$ heterointerfaces.

In-plane twofold symmetric oscillations



- The twofold rotational symmetry of the superconductivity.
- In the a-$YAlO_3$/$KTaO_3$ the lack of inversion symmetry, however, tends to mix spin-singlet and spin-triplet driven by strong spin-orbit coupling.
- Due to the absence of a mirror plane parallel to the interface of a-$YAlO_3$/$KTaO_3$, the point group of a-$YAlO_3$/$KTaO_3$ is C_{3v}.

In summary, we have experimentally observed spontaneous rotational symmetry breaking from threefold to twofold in the superconducting state of $KTaO_3$(111) heterointerfaces with respect to an application of in-plane magnetic field. This in-plane anisotropic superconductivity is theoretically attributed to the intrinsic nature of mixed-parity unconventional superconductivity with an admixture of s-wave and p-wave pairing components, bringing with it fresh new insights into the study of emergent fascinating and non-trivial superconducting properties at the heterointerfaces with inversion symmetry breaking.

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