Coexistence of spatially decoupled unconventional superconducting condensates in 4Hb-TaSSe

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Materials exhibiting multiple superconducting phases are exceptionally rare in nature. The few known examples of multiphase superconductors display complex phase diagrams, where distinct phases can be independently induced by means of external stimuli such as pressure or magnetic fields. Here we report the coexistence of two superconducting condensates with different spatial localization in the van der Waals 4Hb-TaSSe polytype. Its layered structure consisting of alternating layers of the T-type and H-type polymorphs enables the development of two effectively decoupled superconducting phases with marked distinct microscopic properties. Using high-resolution quasiparticle tunneling and Andreev reflection spectroscopy in the two polymorph layers, we identify two different superconducting gaps in size in each layer, with signatures compatible with weakly coupled condensates, potentially of different pairing symmetry. The coexistence of these condensates is further corroborated by our measured critical temperatures and upper critical magnetic fields, which significantly differ in each polymorph layer. We explore the possible superconducting ground states using a minimal model based on ab initio calculations that captures many of the experimental features (1). Lastly, I will compare this phenomenology with that occurring in related layered compounds showing conventional superconductivity (1). Our results challenge the current understanding of superconductivity in low-dimensional superconductors and open new pathways for customizable superconducting devices that could independently operate several superconducting states.

References

(1) H. Guo, S. Sajan, et al. In preparation (2025).
(2) S. Sajan, H. Guo, et al. Nano Letters, in press (2025).

Figures

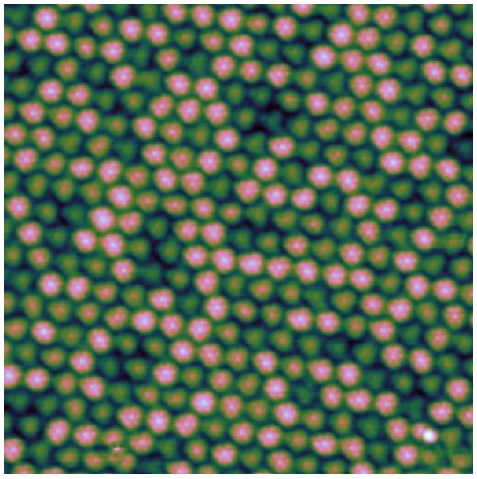

Figure 1: Topographic image of the 1T-layer of the $4H_b$-TaSSe superconductor.