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A fully gapped superconducting state in small cuprate islands

MIKAEL FOGELSTRÖM, DAVID GUSTAFSSON, Department of Microtechnology and Nanoscience, Chalmers, Göteborg, Sweden, DMITRI GOLUBEV, Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), Eggenstein-Leopoldshafen, Germany, ANNICA BLACK-SCHAFFER, Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden, TORD CLAESON, SERGEY KUBATKIN, THILO BAUCH, FLORIANA LOMBARDI, Department of Microtechnology and Nanoscience, Chalmers, Göteborg, Sweden — We present a spectroscopic technique, based on an high-Tc superconducting nanoscale device that allows an unprecedented energy resolution thanks to Coulomb blockade effects, a regime practically inaccessible earlier in these materials. We found that the energy required to add an extra electron depends on the parity (odd/even) of excess electrons on the island and increases with magnetic field. This is inconsistent with a pure $d_{x^2-y^2}$ wave symmetry and demonstrates a complex order parameter component that needs to be encompassed in any theoretical model for high-Tc superconductivity. To address this inconsistency, we investigate subdominant order parameters stabilizing at low temperatures in nano-scale high-T_c cuprate islands. Using complementary quasi-classical and tight-binding Bogoliubov-de Gennes methods, we show on distinctly different properties dependent on the symmetry being $d_{x^2-y^2} + is$ or $d_{x^2-y^2} + id_{xy}$. We find that a surface-induced $d_{x^2-y^2} + is$ phase creates a global spectroscopic gap which increases with applied magnetic field, consistent with experimental observation.

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