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Exotic Superconducting State Embedded in the Hidden Order Phase of URu_2Si_2[1]

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The heavy-Fermion compound URu_2Si_2 has mystified researchers since the superconducting state ($T_c = 1.5$ K) is embedded within the "hidden order" phase ($T_h = 17.5$ K). According to several experimental observations, most of the carriers disappear below T_h resulting in a density one order of magnitude smaller than in other heavy-Fermion superconductors. Superconductivity with such a low density is remarkable since the superfluid density is very low in some way reminiscent of underdoped cuprates; the superconductivity by itself is an exceptional case of pairing among heavy electrons with a long Fermi-wavelength in a nearly semimetallic system. Moreover, pressure studies reveal that the superconductivity coexists with the hidden order but is suppressed by antiferromagnetic ordering. Here, we report charge and thermal transport measurements on ultraclean single crystals of URu_2Si_2 ($RRR \sim 700$) down to 30 mK ($T_c/50$), which reveal a number of unprecedented superconducting properties. The uniqueness is best highlighted by field-induced superconductor-insulator-like first-order transition at the upper critical fields, which is a direct consequence of the electronic structure imposed by the hidden order. The results provide strong evidence for a new type of unconventional superconductivity with two distinct gaps having different nodal topology. We propose a gap function with chiral d-wave form $\Delta_k \propto k_z(k_x \pm ik_y)$ [1]. We also report a distinct flux line lattice melting transition with outstanding characters and a formation of the quasiparticle Bloch state in the periodic flux line lattice in this ultraclean system [2]. The intriguing superconducting state of URu_2Si_2 adds a unique and exciting example to the list of unconventional superconductors.

[1] Y. Kasahara *et al.* Phys. Rev. Lett. **99**, 116402 (2007). [2] R. Okazaki *et al.* arXiv:0710.2382

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