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Dilute superconductivity and ferroelectricity in strontium titanate

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During the last decade, strontium titanate has been essentially used and studied in two contexts: its interface with other insulators and as a substrate for other materials such as FeSe. Nevertheless, the bulk material itself is the heart of interesting physics, widely studied in the seventies, it saw in the last years a renewed impetus. Superconductivity in this semiconductor was discovered as early as 1964 [1], where a superconducting ground state survives when there remains less than one electron per 10000 atoms and the average distance between pairing electrons is about thirty atomic distances. The persistence of superconductivity in such a context presents several interconnected challenges [2]. How can Cooper pairs survive when the characteristic energy scale of electronic quasiparticles is as small as the Debye energy and the electrons become slow as phonons? How can there be enough density of states to provide a critical temperature of detectable amplitude? Add to these mysteries, the parent and insulating compound is known to be close to a ferroelectric instability that never settles due to quantum fluctuations. However, this phase can be stabilized through the addition of calcium, and, following the example of $BaTiO_3$, $Sr_{1-x}Ca_xTiO_{3-\delta}$ becomes a ferroelectric-metal upon doping. More excitingly, when the temperature is decreased, a superconducting transition is observed in the ferroelectric state making strontium titanate the first material where ferroelectricity and superconductivity coexist.

We will hence review a number of recent experiments, which have explored this superconductor during the last few years [3, 4, 5] and have documented a possible link to a ferroelectric instability, which is intertwined with the superconducting order.

[1] J. F. Schooley, W. R. Hosler and M. L. Cohen "Superconductivity in semiconducting SrTiO3" Phys. Rev. Lett. **12**, 474 (1964)
[2] X. Lin *et al.* "Fermi surface of the most dilute superconductor" Phys. Rev. X **3**, 021002 (2003)
[3] A. G. Swartz *et al.* "Strong polaronic behavior in a weak-coupling superconductor" arXiv:1608.05621 (2016)
[4] C. W. Rischau *et al.* "A ferroelectric quantum phase transition inside the superconducting dome of $Sr_{1-x}Ca_xTiO_{3-\delta}$" Nature Physics, **13**, 643 (2017)
[5] A. Stucky *et al.* "Isotope effect in superconducting n-doped $SrTiO_3$" Scientific Reports **6**, 37582 (2016)