Friend or Foe? How Disorder Can Enhance Superconductivity

Maciej M. Maśka[1,*] and Marcin Mierzejewski[1]

[1]Wrocław University of Science and Technology
[*]*maciej.maska@pwr.edu.pl*

Disorder is usually regarded as detrimental to superconductivity. Impurities and structural defects scatter electrons, can break Cooper pairs, and may eventually destroy the superconducting state. This conventional picture suggests that superconductors should be as clean and homogeneous as possible. In strongly correlated materials, however, disorder can also modify the microscopic interactions responsible for pairing, opening a route to enhancement rather than suppression.

I will revisit a mechanism proposed for cuprate superconductors [1], motivated by scanning-tunneling experiments showing a positive correlation between the superconducting gap and the positions of oxygen dopants [2]. The electrostatic potential of the dopants produces spatial variations of the local atomic energies. Strong Coulomb repulsion limits the associated charge redistribution, but these energy variations modify the virtual hopping processes responsible for antiferromagnetic superexchange. Although disorder affects the two possible virtual processes differently, their combined contribution enhances the effective exchange interaction. If superexchange provides the pairing interaction, disorder can therefore strengthen local pairing and increase the superconducting gap.

I will discuss the consequences of this mechanism for nanoscale inhomogeneity in cuprates and its relation to tunneling experiments. Finally, I will briefly mention more recent examples, including disordered quasiskutterudites [3], which suggest that the constructive role of disorder is not restricted to cuprates or to a single microscopic pairing mechanism.

References

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