Interplay between anisotropic multiband superconductivity and unconventional electronic order in Pd chalcogenides

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The Fe pnictides and chalcogenides often display the coexistence of multiband superconductivity with electronic or magnetic order. For instance, the pressure-induced suppression of the orbital order of FeSe leads to antiferromagnetism and to an enhanced superconducting transition temperature $T_c$. The superconducting phase-diagram of these compounds under an external magnetic field tend to display anomalous phase boundaries as, for example, a linear dependence of the upper critical field $H_{c2}(T)$ on temperature which, in FeSe is claimed to result from an additional superconducting phase at the highest fields and lowest temperatures. Motivated by these compounds, a few years ago we reported the discovery of superconductivity in Pd and chalcogenide based compounds [1,2] like Nb$_2$Pd$_{0.82}$S$_5$. These compounds display extremely large $H_{c2}(T)$ accompanied by a temperature dependent superconducting anisotropy [1,2] akin to what is observed in Fe based superconductors which is claimed to result from multi-band superconductivity. Point contact spectroscopy [3] does provide evidence for multiple superconducting gaps in some of these compounds, while $H_{c2}(T) \propto T$ is detected in Ta$_3$Pd$_4$Te$_{16}$ [4]. Remarkably, one observes anomalies in the resistivity [2] and in thermodynamic variables [5] indicating that superconductivity is preceded by some type of subtle electronic order which apparently does not affect the geometry of their Fermi surfaces [5]. We also find that Pd acts as a tuning parameter, i.e. an increase in its fraction within Nb$_3$Pd$_7$Se$_2$ increases its $T_c$ albeit leading to an extremely anisotropic superconducting state whose $H_{c2}(T)$ display a $T^{1/2}$ dependence in the neighborhood of $T_c$ as observed in monolayer NbSe$_2$ [6] or in the surface of ionic liquid gated MoS$_2$ [7]. This indicates that superconductivity in these single-crystals is two-dimensional in character but unlikely to result from spin momentum locking [6,7]. Here, we review and discuss the properties of this family of superconductors.

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