Interplay between composition, structure, magnetism and superconductivity in iron-based pnictides

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The generic phase diagram of the so-called 1111-*Ln*Fe*Pn*O family (*Ln*: lanthanide, *Pn*: pnictogen) can be tuned by chemical substitution at different atomic sites of the crystal structure or applied pressure when the antiferromagnetic state is partially or completely suppressed. Nevertheless, the resulting electronic phase diagrams are dramatically materials dependent. Single crystals of *Ln*1111 are still a challenge and they are necessary for direct measurements of anisotropic properties and spectroscopic studies that cannot be performed or are inaccurate on polycrystalline samples. Superconducting poly- and single-crystalline samples of substituted *Ln*FeAsO (*Ln*=La, Pr, Nd, Sm, Gd) were synthesized and grown under high pressure and their structural, magnetic and transport properties are studied. Superconductivity in this family of materials has been induced by partial substitution of O by F, *Ln* by Th or As by P. The availability of *Ln*1111 single crystals made it possible to determine several basic superconducting parameters, such as upper critical fields and their anisotropy γ_H and magnetic penetration depth anisotropy γ_λ. The anisotropy γ_H and γ_λ are different and temperature dependent, what suggests multigap superconductivity. Point-contact Andreev-reflection spectroscopy studies show the existence of two energy gaps, which varies also with doping. Resistivity measurements were performed on $SmFeAsO_{1-x}F_y$ single crystals with in- and out-of-plane current flow in magnetic field up to 65 T. The critical current density at low temperature was almost independent on the magnetic field and current direction and exceeds 10^6 A/cm^2, making Ln1111 a promising candidate for technical application. By comparing our experimental data for $SmFeAsO_{1-x}F_y$, $Sm_{1-x}Th_xFeAsO$, and $SmFeAs_{1-x}P_xO$ systems with various others iron-based superconductors we find the relationship between structural parameters, magnetism and superconductivity.