Effects of post-annealing and Co substitution on superconducting properties of (Ca,Pr)Fe$_2$As$_2$ single crystals

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Abstract

RE doped CaFe$_2$As$_2$ system has been attracting various interests due to its high $T_c$ reaching 49 K and anomalous superconducting properties, such as weak diamagnetism at high temperatures above ~20 K and very low $J_c$, implying the absence of bulk superconductivity.

In order to clarify the origin of anomalous superconductivity in this system, Pr doped and Pr,Co co-doped CaFe$_2$As$_2$ single crystals were grown using FeAs flux method with nominal compositions of (Ca$_{1-x}$Pr$_x$)(Fe$_{1-y}$Co$_y$)$_4$As$_4$. These samples showed two-step transitions at $T_{c1} = 30$–42 K and $T_{c2} < 16$ K. In addition, post-annealing was performed for these crystals in evacuated quartz ampoules at various temperatures. As a result, we found that samples annealed at 400°C have longer $c$-axes than those of as-grown ones, indicating existence of the lattice strain in as-grown crystals and this strain is released by annealing at ~400°C. Along with the release of the strain, superconducting properties changed drastically. Some of the co-doped samples showed large diamagnetic signal below $T_{c2}$ after annealing, suggesting appearance of bulk superconductivity. However, the superconducting volume fraction above $T_{c2}$ was always very low, indicating that 40 K-class superconductivity in this system is originated from the local superconductivity in the crystal.