Reviewing High-Pressure Growth Effects on Iron-based Superconductors

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The high-pressure growth technique is a valuable tool in the research field due to its ability to stabilize new phases and control structural parameters that significantly affect the electronic and magnetic properties [1]. We report a comprehensive study of the superconducting properties of three different families of FBS [2-6]: 1111 (*RE*FeAsO: *RE* = La, Ce, Sm), 1144 ($CaKFe_4As_4$), and 11 ($FeSe_{1-x}Te_x$ ($x = 0.5$)), which provide the highest critical transition temperature (T_c) of ~58 K as a doped family, ~35 K as a stoichiometric family, and ~14 K as the simplest FBS family, respectively, by using the high gas pressure and high-temperature synthesis (HP-HTS) method. This technique can produce an inert gas pressure of up to 1.8 GPa in a cylinder chamber with a large sample space (~15 cm) and a three-zone furnace capable of reaching 1700°C [5].

We have optimized the growth conditions for these FBS families by preparing various polycrystalline F-doped (Sm/Gd)FeAsO, Fe(Se,Te), and $CaKFe_4As_4$ samples in a broad pressure range (0-1.5 GPa) using HP-HTS and CSP methods. We then present a comparative study based on the T_c, sample quality, grain connectivity, and J_c to understand the effects of growth pressure on their superconducting properties. All prepared samples are characterized by structural, microstructural, transport, and magnetic measurements to reach the final conclusions. Interestingly, the high-pressure synthesis of these samples has enhanced the T_c by 2–3 K for $CaKFe_4As_4$ [4] and Fe(Se,Te) [6] bulks, whereas it is almost constant for the 1111 family [2]. The sample quality, sample density, and grain connections of all these families are improved, and their critical current density (J_c) value is enhanced by two orders of magnitude (~10^5 A/cm^2, 5 K, 0 T) compared to that of CSP (~10^2–10^3 A/cm^2, 5 K, 0 T).

Our studies prove that the high-pressure synthesis method can be a unique way to explore FBS materials by improving the sample quality, enhancing their superconducting properties, and advancing the development of their magnetic applications.

References:

[1] S. J. Singh and M. I. Sturza, *Crystals* **12**, 20 (2022).
[2] M. Azam et al., *IEEE Trans. Appl. Supercond.* **34**, 7300205 (2023) and **34**, 7300405 (2023).
[3] S. J. Singh and A. Morawski, *Jenny Stanford Publishing*: New York, NY, USA, 2021; pp. 283–314.
[4] M. Manasa et al., *IEEE Trans. Appl. Supercond.* **34**, 7300605 (2023), *J. Phys. Chem. Solids* **190**, 111996 (2024).
[5] M. Azam et al., *Crystals* **13** (10), 1525 (2023).
[6] M. Manasa et al., *Ceramics International* **50** (1), 714-725 (2024) and *Materials* **16** (15), 5358 (2023).

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