Tuning superconductivity in FeSe thin films through growth control

Ya-Xun He[1], Jia-Ying Zhang[1], Jun-Yi Ge[1,*]

[1] *Materials Genome Institute, Shanghai University, 200444 Shanghai, People's Republic of China*
Email: junyi_ge@t.shu.edu.cn

The superconductivity of FeSe thin films strongly depends on the growth conditions. This presents both a challenge and an opportunity for tailoring superconducting properties. Pulsed laser deposition (PLD), a versatile technique offering numerous adjustable parameters, allows for systematic investigation and control over film growth. Our study focuses on the crucial role of substrate temperature (T_s) in governing the delicate interplay between Se volatilization and Fe/Se reactive crystallization during PLD growth of FeSe thin films. We demonstrate that T_s effectively modulates film crystallinity, composition ($FeSe_{1+x}$), surface morphology, and consequently, the superconducting properties. A series of FeSe films were grown on CaF_2 (001) substrates at T_s ranging from 25 °C to 750 °C. Structural characterization via XRD and pole figure analysis revealed the evolution of film texture and epitaxy as a function of T_s. AFM measurements provided insights into surface morphology and film thickness. Compositional analysis using EDS quantified the Se content variation (x) with T_s, highlighting the competition between Se incorporation and volatilization. Electrical transport measurements revealed a strong correlation between T_s, film composition, and superconducting transition temperature (T_c). An optimal T_c of 14 K was achieved for a slightly Fe-rich $Fe_{1.01}Se$ film grown at 500 °C, demonstrating the effectiveness of T_s control in optimizing superconductivity. Further investigations into the pinning mechanism of the optimized film revealed dominant contributions from δl pinning and surface pinning. This work provides a comprehensive understanding of the growth mechanism of FeSe thin films and establishes a pathway for precisely tuning superconductivity through controlled growth parameters. Further studies exploring additional PLD parameters and their synergistic effects on superconductivity will be discussed.

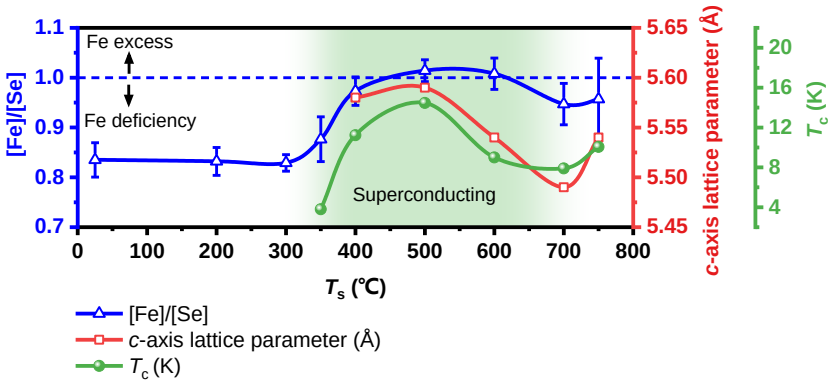

Figure. The T_s dependence of the [Fe]/[Se] ratio, the c-axis lattice parameters and T_c. The dashed line indicates the stoichometric ratio of [Fe]:[Se] = 1, above which excess Fe is normally observed between FeSe layers, while below which Fe deficiency is expected to appear in the lattice. The error bars show standard deviation.

References

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