Why are the $T_c$'s so high in rare-earth doped CaFe$_2$As$_2$ single crystals and ultrathin FeSe epi-films?\(^1\)

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Recent reports of non-bulk superconductivity with unexpectedly high onset-$T_c$'s up to 49 K in the Pr-doped CaFe$_2$As$_2$ [(Ca,Pr)$_{122}$] single crystals \(^1\) and up to 100 K in one-unit-cell (1UC) FeSe epi-films \(^2\), respectively, offer an unusual opportunity to seek an answer to the question posed in the title. Through systematic compositional, structural, resistive, and magnetic investigations on (Ca,R)$_{122}$ single crystals with $R = \text{La, Ce, Pr, and Nd}$, we have observed a doping-level-independent $T_c$, a large magnetic anisotropy, and the existence of mesoscopic-2D structures in these crystals, thus providing evidence consistent with the proposed interface-enhanced $T_c$ in these naturally assembled Fe-based superconductors. Similar resistive and magnetic measurements were also made on the 1-4UC FeSe ultra thin epi-films. We have detected a Meissner state below 1 Oe with extensive weak-links up to $\sim 20$ K, unconnected small superconducting patches up to $\sim 40$ K, and an unusual dispersion of diamagnetic moment with frequency up to 80 K. The unusual frequency dependences of the diamagnetic moment observed in the films at different temperature ranges suggest that collective excitations of electron and/or spin nature may exist in the FeSe films below 20 K and 40-80 K. The experimental results will be presented and the implications discussed.


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