

The Rise of T_c : A Promising Paradigm via Interfacial Mechanism

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A tribute to those with courage in the search for higher T_c in the last 25 years:

Ralph Waldo Emerson once said “Whatever course you decide upon, there is always someone to tell you that you are wrong. There are always difficulties arising that tempt you to believe that your critics are right. To map out a course of action and to follow it to the end requires courage.”

Abstract. Following the seminal detection of superconductivity at 35 K in the first cuprate high temperature superconductor Ba-doped ternary LCO (La214) by Mueller and Bednorz in 1986, the discovery of the first liquid nitrogen superconductor quaternary YBCO (Y123) with a transition temperature T_c of 93 K by Chu, Wu, and colleagues in 1987 has ushered in the modern era of high temperature superconductivity (HTS). In the ensuing 25 years, great progress has been made in all areas of HTS research and development, from materials to physics to devices. However, the T_c remains at 134 K in quaternary HBCCO (Hg1223) at ambient pressure achieved in 1993 by Schilling et al. and at 164 K in the same compound under high pressure in the same year by Gao et al. A holistic multidisciplinary enlightened empirical approach has been proposed to search for superconductors with higher T_c , which includes the discovery of new compounds empirically and the realization of novel mechanisms proposed by theorists. Recently, we have observed nonbulk superconductivity in single crystalline rare-earth doped Ca122 samples with an onset T_c of 49 K, higher than the T_c of any known compounds formed of the constituent elements at ambient or under high pressures. Subsequent systematic structural, electrical, magnetic, and calorimetric investigations suggest that the observation may be attributed to an interface-induced T_c , thus suggesting a possible new paradigm for higher T_c . In this presentation, our results will be presented and discussed, following a brief recollection of a few events in our lab in the continuing search for higher T_c , even though a number of review articles have appeared.



1. Introduction

Superconductivity is intellectually challenging and technologically promising. It provides the never-ending lure to scientists and technologists and the never-ending inspiration to those in the frontiers of science from quarks to Majorana fermions. As a result, superconductivity is considered a subject of pursuit only 101 years young. One of the major driving forces for its vitality is the continued quest for superconductivity at higher T_c .

The T_c -rise with time is shown in figure 1. T_c was 4 K in Hg when superconductivity was first discovered by Kamerlingh Onnes at Leiden in 1911 after liquefying gas helium [1], rose steadily but only slowly to 23 K in Nb_3Ge thin film by Gavalier et al. of Westinghouse and Testardi et al. of Bell Labs in 1973 [2], after improving the stoichiometry of the compound, and stayed there until 1986. However, it jumped to 35 K in the mixed-phase La-Ba-Cu-O samples when Mueller and Bednorz (MB) at Zurich decided to dive into the new path of perovskite oxides for a higher T_c in 1986 [3]. The genie of this seminal discovery was formally let out of the bottle on December 4 at the 1986 Fall MRS meeting in Boston when I announced our reproduction at Houston of the Zurich result at the end of my formal presentation on the oxide BPBO superconductor and, during the ensuing Q&A, Kitazawa of Tokyo immediately revealed their identification of the superconducting phase as La214 in MB's samples [4]. The world caught fire afterward, busily working around the clock on the new La214 superconductor, in spite of the initial skepticism expressed by many except for a lucky few, including my group.

In an attempt to understand the cause of the observation and to explore the possibility of further raising the T_c , we decided to determine the effect of the inter-atomic distance on the 35 K superconductivity in the La-Ba-Cu-O samples by the application of pressure. To our great surprise, the T_c increases rapidly at a rate about ten times that observed in previously known superconductors to a new record first at 40.2 K [5], and then at 52.5 K [6], exceeding the T_c -ceiling of ~ 30 K predicted by theory [7] and thus raising the prospect that higher T_c is possible through high pressure and/or chemical replacement. It should be noted that unstable resistive and ac magnetic anomalies were also detected above 77 K before the MRS meeting in some mixed-phase samples of La-Ba-Cu-O of ours [8], suggestive of superconductivity above the liquid nitrogen temperature for the first time. I shared

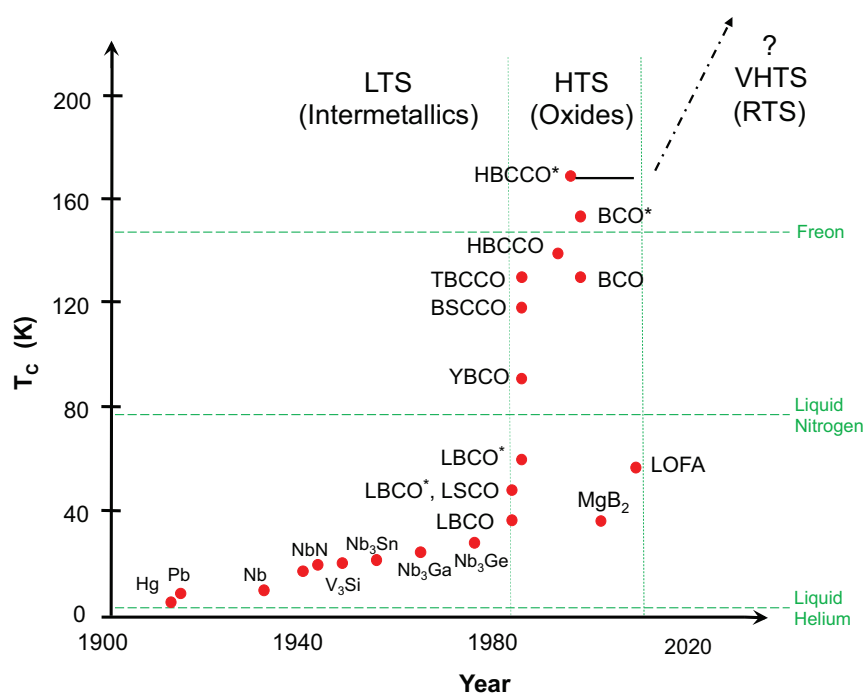


Figure 1. T_c -rise with time (*—under pressure).

the preliminary data at the MRS meeting at Boston with my former student M. K. Wu and invited him to join the search.

Like many in the field who believe that the best way to study the physics of materials is to use single-crystal samples, we tried but failed to grow single crystals of La214 following Kitazawa's phase identification. Unfortunately, two-thirds of our Pt-crucibles for crystal growth were destroyed. However, during this period of time, we found that as the polycrystalline samples were made purer with La214, the appearance of the high temperature resistive anomalies became less frequent. We decided to skip the study of single-crystalline La214 and tried to achieve higher T_c directly by stabilizing the resistive and magnetic anomalies detected sporadically by us above 77 K via chemical replacement and pressure application [9]. Replacements of Ba by the smaller isovalent Ca and Sr and of La by the smaller non-magnetic rare-earth (R) elements, Y, Yb, and Lu (thinking to avoid the magnetic ones, based on the conventional wisdom but finding out later that this was unnecessary as shown below), were proposed and attempted. Substitution of Ba by Sr indeed leads to a T_c increase but not by Ca. A resistive drop in the Y-Ba-Cu-O above 77 K was observed on January 28, 1987, and the superconducting state in these samples was firmly established by detecting the Meissner effect in these samples the very next day. Stable superconductivity with a T_c of 93 K above the liquid nitrogen temperature of 77 K was finally achieved in YBCO [10]. A subsequent high pressure test demonstrated that the newly discovered 93 K T_c YBCO belongs to a new material family different from that of La214 [11]. The crystal structure of YBCO was quickly determined in collaboration with Hazen et al. of Geophysical Laboratories at Washington DC to be $\text{YBa}_2\text{Cu}_3\text{O}_7$ (Y123) [12]. To probe the role of Y^{3+} in YBCO, a standard technique was employed by examining the effect of a small replacement of the Y^{3+} by a magnetic R^{3+} element such as Gd. We found the T_c was hardly affected and concluded that the role of Y in YBCO is to stabilize the crystal structure and not to participate in the superconducting process. We therefore replaced the Y in YBCO completely by R and obtained the new superconducting family of RBCO ($\text{RBa}_2\text{Cu}_3\text{O}_7$ or R123) for all Rs except Ce and Pr, with a T_c up to 98 K [13]. Extending the replacement of Y with the trivalent ions beyond the R^{3+} s, two more superconducting families BSCCO [$\text{Bi}_2\text{Sr}_2\text{Ca}_{n-1}\text{Cu}_n\text{O}_{2n+4}$ for $n = 1, 2, 3, \dots$ or $\text{Bi}22(n-1)n$] with a T_c up to 105 K for $n = 3$ and TBCCO [$\text{Tl}_2\text{Ba}_2\text{Ca}_{n-1}\text{Cu}_n\text{O}_{2n+4}$ for $n = 1, 2, 3, \dots$ or $\text{Tl}22(n-1)n$] with a T_c up to 125 K for $n = 3$ were discovered by Maeda et al. in Tsukuba [14] and Sheng and Hermann in Arkansas [15], respectively, in 1988. Five years later in 1993, Schilling et al. [16] in Zurich replaced the trivalent R with Hg and raised the T_c to the current record of 134 K in HBCCO [$\text{HgBa}_2\text{Ca}_{n-1}\text{Cu}_n\text{O}_{2n+3}$ for $n = 1, 2, 3, \dots$] for $n = 3$ at ambient, which was subsequently raised by the application of pressure at ~ 30 GPa to 164 K by Gao et al. of Houston and Mao et al. at Geophysical Laboratories at Washington DC [17].

In the last 25 years, a large number of cuprate HTSs has been discovered. They belong to the above families and their derivatives. These cuprate HTSs display a layered structure and can be represented by a generic formula, $\text{A}_m\text{E}_2\text{R}_{n-1}\text{Cu}_n\text{O}_{2n+m+2}$, with $m = 1$ or 2 ; $n = 1, 2, 3, \dots$; $\text{A} = \text{Bi}, \text{Tl}, \text{Pb}, \text{or Cu}$; $\text{E} = \text{Ca}, \text{Sr}, \text{or Ba}$; and $\text{R} = \text{Ca}$ or a rare-earth element. The generic formula can be rewritten as $\text{A}_m\text{E}_2\text{R}_{n-1}\text{Cu}_n\text{O}_{2n+m+2} = [(\text{EO})(\text{AO})_m(\text{EO})] + [(\text{CuO}_2)\text{R}_{n-1}(\text{CuO}_2)_{n-1}]$ that consists of two main alternately stacked blocks, namely the active block $[(\text{CuO}_2)\text{R}_{n-1}(\text{CuO}_2)_{n-1}]$, where supercurrent flows along the CuO_2 -planes, and the charge-reservoir block $[(\text{EO})(\text{AO})_m(\text{EO})]$, where doping takes place to introduce charge-carriers without defects to the CuO_2 -planes. The active block comprises n (CuO_2)-layers interleaved by $(n-1)$ R-layers, while the charge-reservoir block consists of m (AO)-layers bracketed by 2 (EO)-layers, as shown in figure 2. Almost every cuprate HTS can be designated as $\text{Am}2(n-1)n$ with the (AO)-layer or $0m2(n-1)n$ without the (AO)-layer. Their parents are an antiferromagnetic Mott-insulator and made superconducting through doping. T_c increases with n up to 3 and decreases beyond due to the inhomogeneous doping and proximity effect for $n > 3$. In spite of the large number and their higher T_c , YBCO remains to be the choice HTS for science and application due to its higher J_c in high field, higher chemical stability and physical robustness, ease in epitaxial film growth and lower cost. As a result, it has been included in the 2000 White House Millennium Time Capsule "to honor the past

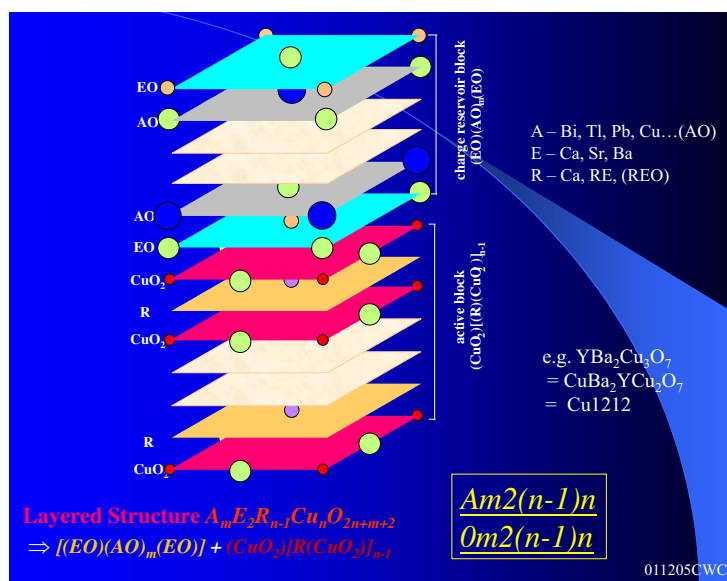


Figure 2. The schematic crystal structure and generic formula of the cuprate layered HTSs.

and imagine the future” as a tribute to the ingenuity of the Americans in the 20th century. Hope the full potential of YBCO can be realized long before our grandchildren open the time capsule in 2100.

In 2008, the layered Fe-based superconductor F-doped LaFeAsO (1111) with a $T_c \sim 26$ K was discovered by Hosono et al. at Tokyo [18], leading to the second explosion of superconductivity research activities in the hope of raising the T_c further because of the existence of a large number of compounds with similar structure and the unraveling of the role of magnetism due to the existence of a large amount of the magnetic Fe in them. Indeed, a new class of Fe-based pnictide and chalcogenide superconductors has been found with a maximum T_c of 56 K in the ensuing years. They all possess the FeAs or FeSe-layers and may be grouped into the following families as shown in figure 3: the RFeAsO (1111) with R = rare-earth elements and a maximum T_c of 56 K [19]; the AFe₂As₂, A’Fe₂As₂, and AFe₂Se₂ (122) with A = alkaline and A’ = alkaline-earth elements and a maximum T_c of 38 K [20] in general and 49 K in special cases [21] (see below); AFeAs (111) with A = Li and Na and a maximum T_c of 25 K [22]; and FeSe (11) with a maximum T_c of 10 K [23] and 46 K [24] in bulk and single-layer form, respectively (see below).

2. Search for superconductors of higher T_c

Indeed, in the last 25 years, T_c has undergone a dramatic rise to the current record of 134 K at ambient [16] and 164 K under pressure [17]. Unfortunately, it has stagnated at these values since 1993. However, the intrinsic scientific lure and potential technological implication of superconductivity at a higher T_c have kept its search unabated. The ultimate goal is to discover a superconductor with a higher T_c , preferably at room temperature. It should be pointed out that the term of room temperature superconductor (RTS) can be a relative one. A superconductor is an RTS if its T_c is equal to the ambient temperature of the environment where a superconductor is tested and used, i.e. it can be the liquid nitrogen boiling point, the liquid natural gas boiling point, or 300 K around which we live. Therefore, there are two ways to achieve RTS: one is to increase the T_c and the other is to lower the ambient temperature. For practitioners in the HTS-field, we would like to raise the T_c to 300 K. Three questions immediately follow: the first is whether it is possible to achieve 300 K superconductivity. My answer is a simple “yes,” because we have learned the following over the past 25 years: there is no evidence, experimental or theoretical, to show that room temperature superconductivity is impossible; whatever physics law doesn’t say won’t happen will happen; and history repeats itself always. The second is whether the effort to search for RTS is worth it in view of the potential challenge to use RTS

for power or large current applications because of its possible small current carrying capability due to the small flux pinning force associated with its short coherence length $\xi \propto 1/T_c$ as a result of the high T_c . This is particularly true for a highly anisotropic superconductor, which has generally been considered to favor high T_c . However, a reduction in the anisotropy of an RTS can provide relief to such an impasse to a large extent. In addition, small-current applications of HTS can have equal, if not more, impacts on lives in this increasingly electricity-dependent society. The third question is how to find it. We believe a holistic multidisciplinary enlightened empirical approach, where knowledge and experience in different fields, insight, imagination, courage, and even luck play important roles, can be most fruitful [25].

In the general approach mentioned above, two paths have been adopted to raise T_c : to realize novel mechanisms inspired by theoretical models and to discover new compounds guided by experience and insight empirically. Among the many theoretical mechanisms proposed for higher T_c , interfacial mechanism in different forms has been the one most explored theoretically and experimentally since 1964 when Little and Ginzburg [26] first proposed it. However, an analytic study was not made until 1973 when Allender, Bray, and Bardeen (ABB) [27] considered a model system that consists of an interface between a thin metal-layer and a semiconductor. Their realistic estimations showed that a substantial T_c -enhancement is possible via the exchange of excitons with a higher characteristic energy should the stringent requirements on the interfaces and materials be met, although questions have also been raised [28]. As was pointed out by ABB, the realization of interfacial mechanism might not only lead to a substantial T_c -enhancement but would also be a notable achievement by itself. Numerous experiments inspired by the general concept of interface-induced T_c -enhancement have subsequently been carried out on samples with heterostructures that consist of insulating, semiconducting, metallic, and superconducting bilayers, trilayers, or superlattices [29]. Some have reported the observation of interfacial superconductivity with enhanced T_c . However, evidence for its existence remains elusive due to the technical difficulties in direct diagnoses. Interfacial superconductivity has often been inferred from the higher T_c detected in the artificially made layered samples as compared to that in the starting materials of the layers under ambient conditions without detailed information about the superconducting state. Even the T_c reported in these heterostructural samples appears to be often achievable in the original materials through either doping or straining.

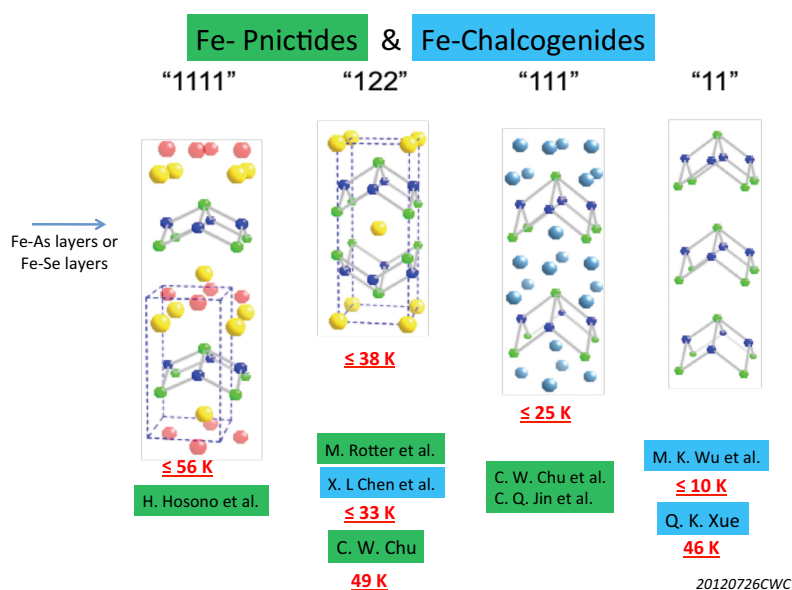


Figure 3. The schematic crystal structures of the four families of Fe-pnictide (green) and Fe-chalcogenides (blue) superconductors with their maximum T_c s.

3. Possible evidence for interface-enhanced T_c in rare-earth doped Ca122

Recently, non-bulk superconductivity was detected in Pr-doped single-crystalline CaFe_2As_2 [$(\text{Ca}_{1-x}\text{Pr}_x)\text{Fe}_2\text{As}_2$ or $(\text{Ca},\text{Pr})122$] with an onset- T_c (T_c^{on}) up to ~ 49 K [21]. Such a T_c^{on} is much higher than the T_c previously known for compounds at ambient or high pressure that contain one or more of the constituent elements Pr, Ca, Fe, and As. In addition, it exceeds that expected from the phonon-mediated superconductor [7]. These authors, therefore, conjectured that the enhanced T_c^{on} of 49 K may have occurred at the interfaces associated with strains and/or defects without further elaboration.

We have therefore examined systematically the rare-earth (R) doped single crystals of $(\text{Ca}_{1-x}\text{R}_x)\text{Fe}_2\text{As}_2$ [$(\text{Ca},\text{R})122$] with $\text{R} = \text{La}, \text{Ce}, \text{Pr},$ and Nd to determine whether the enhanced- T_c is a mere effect of doping in small segregated regions of the sample and, if not, what the morphology of the superconducting body is. Quality crystals with x up to their solubility limits were subsequently grown by the self-flux technique in an Ar inert atmosphere. Wavelength-dispersive-spectrometry (WDS) analysis shows they are chemically homogeneous. All $(\text{Ca},\text{R})122$ crystals display a T_c^{on} between 42 K for $\text{R} = \text{Nd}$ and 49 K for $\text{R} = \text{Pr}$ and show similar transport and magnetic behavior. They also display two sequential superconducting transitions resistively in the otherwise homogeneous single-crystalline

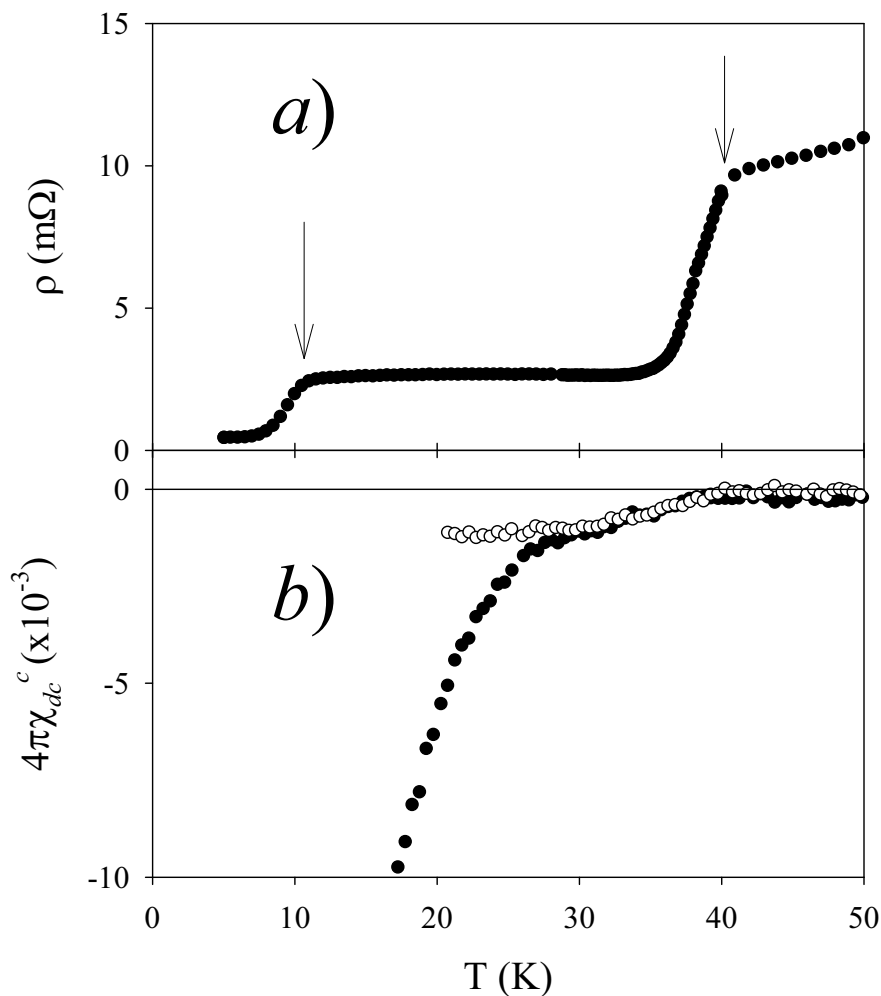


Figure 4. (a) $\rho(T)$ at ambient and 3 mA and (b) $\chi_{\text{dc}}(T)$ at 1 Oe of single-crystalline $(\text{Ca},\text{Nd})122$, where arrows in (a) show the two superconducting transitions.

samples: one with a T_c^{on} at ~ 42 K and the other with a $T_c^{on} \sim 12$ K, as exemplified by the resistance $\rho(T)$ and low field dc magnetic susceptibility $\chi_{dc}(T)$ for $\text{Ca}_{0.93}\text{Nd}_{0.07}\text{Fe}_2\text{As}_2$ shown in figures 4a and 4b, respectively. A dc magnetic field was found to broaden the $\rho(T)$ -transition and shifts it toward lower temperature but cannot suppress it completely down to 4 K at 5 T, indicating a Type-II characteristic for the superconducting state, while the diamagnetic transition in $\chi_{dc}(T)$ was observed to disappear in less than 1 kOe, suggesting a large magnetic background of the sample, similar to [21]. Because of the slightly higher T_c^{on} at 49 K and 24 K for the two transitions, respectively, for $R = \text{Pr}$, we shall discuss only $(\text{Ca},\text{Pr})_{122}$ hereafter. The two transitions were recovered in the ac-susceptibilities in an ac field H_{ac} of 0.5 Oe along the c -axis (χ_{ac}^c) and the ab -direction (χ_{ac}^{ab}) shown in figure 5. The two transitions exhibit drastically different responses to the magnetic fields as previously reported for $R = \text{Pr}$. This is clear from the rapid suppression of the diamagnetic transition at 47 K to below 20 K by a dc-bias field H_{dc} of only ~ 300 Oe (figure 5), suggesting that the superconducting body consists of Josephson Junction Arrays (JJAs). The magnetic anisotropy $\eta = \chi_{ac}^c / \chi_{ac}^{ab}$ is large and exhibits a drastic drop at ~ 20 K, coinciding with the entering into the low temperature phase, as displayed in the inset of figure 5.

We have determined the x -dependence of T_c^{on} on $(\text{Ca}_{1-x}\text{R}_x)\text{Fe}_2\text{As}_2$ single crystals for x up to its maximum solubility of 0.13. T_c^{on} is found to be x -insensitive to within ± 2 K throughout the superconducting region of $x = 0.06$ –0.13, as shown in figure 6. In contrast to $T_c^{on}(x)$, the upper-limit of the superconducting volume-fraction f , estimated as the zero-field-cooled dc diamagnetic $4\pi\chi_{dc}^{ab}$ at

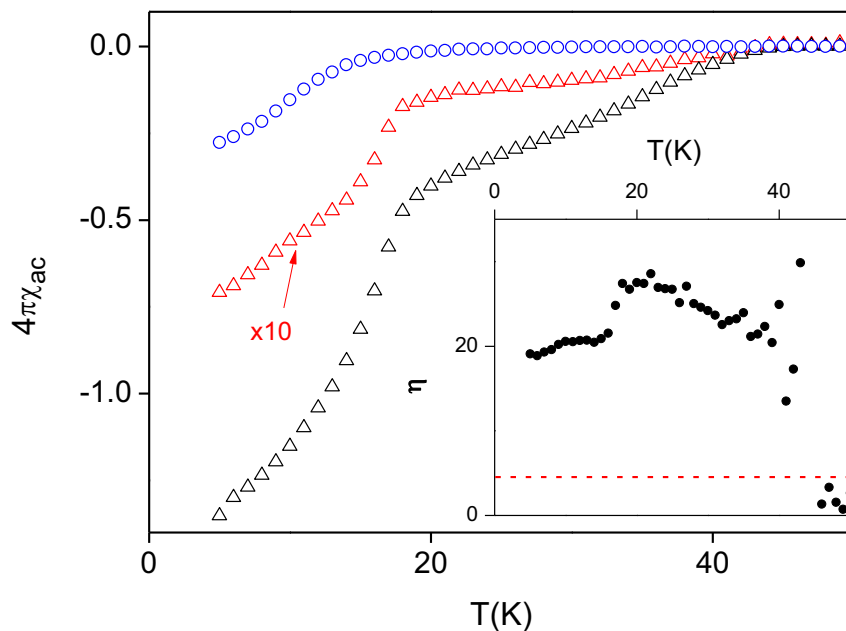


Figure 5. The temperature dependences of the magnetic susceptibilities for single-crystalline $\text{Ca}_{0.87}\text{Pr}_{0.13}\text{Fe}_2\text{As}_2$: red triangles— $10 \times 4\pi\chi_{ac}^{ab}$ at $H_{ac} = 0.5$ Oe and $H_{dc} = 0$; blue circles— $4\pi\chi_{ac}^{ab}$ at $H_{ac} = 0.5$ Oe and $H_{dc} = 300$ Oe; and black triangles— $4\pi\chi_{ac}^c$ at $H_{ac} = 0.5$ Oe and $H_{dc} = 0$. Inset: $\eta = \chi_{ac}^c / \chi_{ac}^{ab}$.

5 K and $H_{dc} = 2$ Oe, was also obtained and shown in the same figure. f increases rapidly with x but, even at the solubility limit of $x = 0.13$, is still far below 10% of that of a perfect superconductor, demonstrating that the superconducting state is indeed non-bulk, consistent with the previous report [21] and the negligible specific heat anomaly at the transition detected by us. The combined observations of the x -independent T_c^{on} and the rapidly increasing f with x in contrast to the large x -range of $0.06 < x \leq 0.13$ for superconductivity and the excellent chemical homogeneity of the samples suggest that the non-bulk superconductivity in $(Ca,R)122$ cannot be caused by local chemical-doping, *i.e.* small inclusions of a bulk superconducting phase in the sample. These unusual observations, however, can be attributed to an x -dependent defect morphology, consistent with the picture of interface superconductivity.

To elucidate the morphology of such an unusual superconducting body in the single-crystalline $(Ca,R)122$, we have examined the field effects on χ_{ac}^{ab} in a total field $H_t = H_{ac} + H_{dc}$ between 10^{-3} and 10^3 Oe on another crystal. $4\pi\chi_{ac}^{ab}(H_t)$ and $4\pi\chi_{ac}^c(H_t)$ at 25 K without the interference of the low T_c^{on} -phase is shown in figure 7. It is evident that as H_t increases, the magnitude of the diamagnetic $4\pi\chi_{ac}^{ab}$ or f^{ab} remains constant at $f_1^{ab} \sim 1.6 \times 10^{-3}$ for $H_t \leq H_{t1} \sim 10$ Oe; decreases for $H_t > H_{t1}$, representing the beginning of flux penetration into the sample along the ab -direction; and finally levels off at $f_2^{ab} \sim 2 \times 10^{-4}$ for $H_{t2} \geq 500$ Oe, presumably $< H_{c1}$. The much larger $4\pi\chi_{ac}^c(H_t)$ or $f^c \sim 63 \times 4\pi\chi_{ac}^{ab}(H_t)$ exhibits a similar behavior: a constant $f_1^c \sim 100 \times 10^{-3}$ for $H_t \leq H_{t1} \sim 0.4$ Oe that decreases linearly until $H_t \sim 5$ Oe and nonlinearly beyond. An unusually large magnetic anisotropy $\eta \sim 63$ at low field and 25 K is thus evident, in contrast to the geometric anisotropy ~ 4 of the sample, suggesting that the superconducting body must be composed of sparsely populated domains made of Josephson-coupled thin superconducting platelets, which have a large aspect ratio $\sim \eta$. This is consistent with the low superconducting screening and flux penetration threshold H_{t1} observed along both directions. Similar

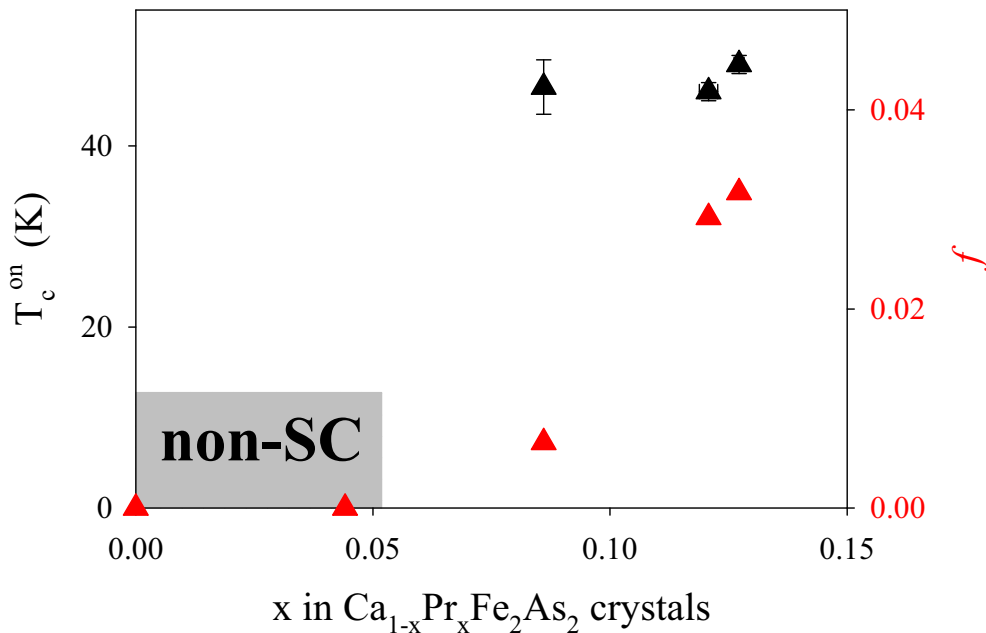


Figure 6. The x -dependences of T_c^{on} : black triangles—for the high T_c^{on} transition; and red triangles—for the superconducting volume-fraction, for $x = 0$ – 0.13 of $(Ca_{1-x}Pr_x)Fe_2As_2$ single crystals.

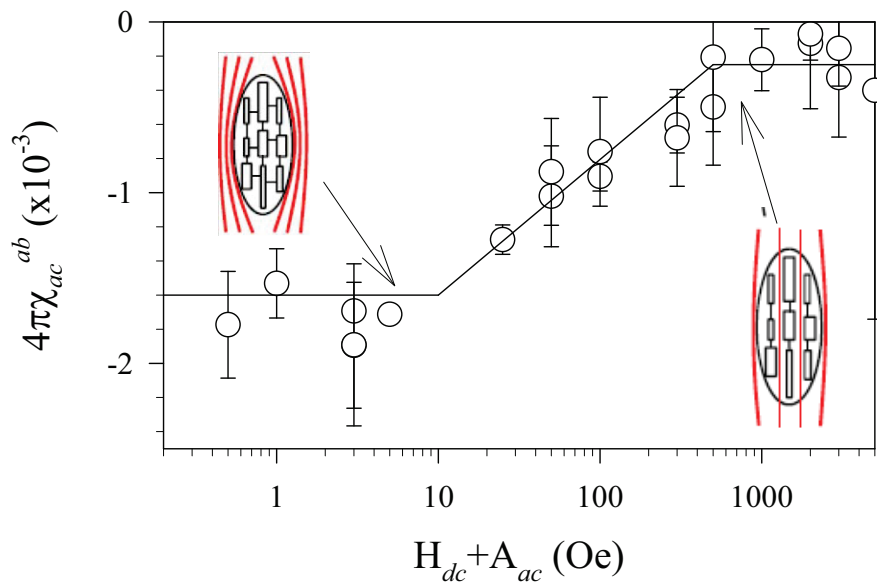


Figure 7. The field effects on $4\pi\chi_{ac}^{ab}$ at 25 K between 10^{-3} and 10^3 Oe.

field effects on $4\pi\chi_{ac}^{ab}(H_t)$ and $4\pi\chi_{ac}^c(H_t)$ at lower temperatures have also been observed.

The above field-dependences of $4\pi\chi_{ac}^{ab}(H_t)$ and $4\pi\chi_{ac}^c(H_t)$ are reminiscent of field-penetration into granular ceramic superconductors [30] and can thus be so understood in terms of a superconducting morphology in the sample proposed in figure 8. In such a sample, penetration occurs in two stages of vortex creation: first the Josephson vortices within the weak-links between the superconducting platelets in low field and then Abrikosov vortices at a higher field within the individual platelets. In our samples, as H_t increases, f is initially a constant for $H_t < H_{t1} \sim 10$ Oe when the sample is shielded by the JJAs; decreases as $H_t > H_{t1}$ when the Josephson vortices form and enter the sample; and finally stops decreasing at $H_{t2} \sim 500$ Oe when all weak-links between the superconducting platelets are decoupled and before the Abrikosov vortices can enter the platelets when H_{t2} is smaller than the effective lower critical field H_{c1} of the platelet, as presumably is the case.

In an attempt to estimate the thickness of the superconducting platelets, we examined the suppression of the superconducting screening in a thin long sample with the field parallel to the ab -

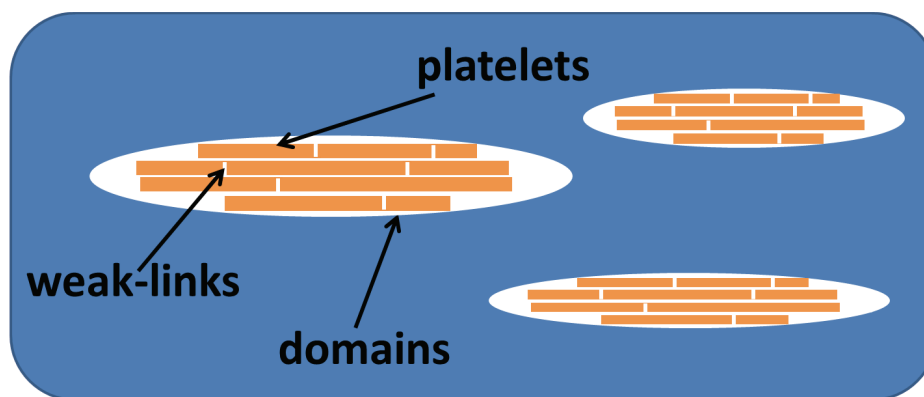


Figure 8. The proposed morphology for the non-bulk highly anisotropic superconducting body in the $(\text{Ca}_{0.87}\text{Pr}_{0.13})\text{Fe}_2\text{As}_2$ single crystal, which is composed of interfaces between alternately stacked perfect and defected Fe_2As_2 layers.

axis from that of an ideal sample. The expected suppression factor is $S = 1/[1 - \frac{2\lambda}{d} \cdot \tanh(\frac{d}{2\lambda})]$ for a thin sheet with a thickness d , where λ is the penetration depth [31]. The large $S \sim f(<H_{c1})/f(>H_{c2}) = 8$ for the superconducting platelets offers a model-insensitive way to estimate the thickness of the platelets d , leading to an upper limit of $d < 1.3\lambda$. For known bulk Fe-pnictide superconductors, the reported λ varies between 0.2 and 0.6 μm . The estimated d for the superconducting platelets is thus on the order of sub-microns, consistent with the dimension-induced, unusually large $H_{c1} > 500$ Oe along the ab -direction suggested by figure 7. Dense interfaces may also exist within the platelets that consist of alternately stacked perfect and defect-infested Fe_2As_2 layers, similar to the case of the $\text{K}_x\text{Fe}_{2-y}\text{Se}_2$ system. This is in agreement with our preliminary finding that f is proportional to the superparamagnetic cluster density in the samples investigated [32]. It is therefore rather natural for us to attribute the enhanced T_c^{on} observed to the interfaces between the closely packed perfect and defect-infested Fe_2As_2 layers. The defects may arise from As-deficiencies that usually occur in pure or slightly doped AeFe_2As_2 samples for Ae = alkaline earth elements [32].

4. Conclusion

In the present study we have provided the most convincing evidence for interface-enhanced T_c to date. This may also be able to account for the non-bulk superconductivity previously observed in the undoped Ba122, Sr122, and Ca122 single crystals below ~ 20 K and other systems. The full deployment of the interface mechanism in other artificially made or naturally assembled material systems may lead to higher T_c . Detailed investigations on the nature of these defects will help further reveal the working of interfaces and are currently underway in our lab.

Acknowledgments

The work in Houston is supported in part by U.S. Air Force Office of Scientific Research contract FA9550-09-1-0656, U.S. Air Force Research Laboratory subcontract R15901 (CONTACT) through Rice University, the T. L. L. Temple Foundation, the John J. and Rebecca Moores Endowment, and the State of Texas through the Texas Center for Superconductivity at the University of Houston.

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