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Evidence for coexistence of superconductivity and magnetism in single crystals of Co-doped SrFe₂As₂

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Abstract

In order to investigate whether magnetism and superconductivity coexist in Co-doped SrFe₂As₂, we have prepared single crystals of SrFe_{2-x}Co_xAs₂, $x = 0$ and 0.4, and characterized them via x-ray diffraction, electrical resistivity in zero and applied field up to 9 T as well as at ambient and applied pressure up to 1.6 GPa, and magnetic susceptibility. At $x = 0.4$, there is both magnetic and resistive evidence for a spin density wave transition at 120 K, while $T_c = 19.5$ K—indicating coexistent magnetism and superconductivity. A discussion of how these results compare with reported results, both in SrFe_{2-x}Co_xAs₂ and in other doped 122 compounds, is given.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

The recent discoveries of ever-mounting transition temperatures in the superconducting iron arsenide two-dimensional layered compounds, coupled with the goal of understanding the pairing mechanism(s) of this newly discovered class of superconducting compounds, has led to a surge of activity in materials-based condensed matter physics. From a superconducting transition temperature $T_c = 26$ K in LaFeAs(O_{1-x}F_x) [1] the value is now up to $T_c = 55$ K in SmFeAs(O_{1-x}F_x) [2]. Of particular help in the quest for understanding this new physics has been the widening range of compounds in which the ‘iron arsenide (FeAs)’ based superconductivity has been found, moving from the rather difficult materials synthesis of the original 1111 compounds with F doping to the more easily prepared 122 compounds (non-superconducting prototype BaFe₂As₂) discovered by Rotter *et al* [3]. These latter compounds, as was pointed out

by Ni *et al* [4], can be rather easily grown from a Sn flux as well as from an FeAs ‘self-flux’ [5]. Thus, much of the recent effort for elucidating the physics has focused on these 122 compounds, with both polycrystalline and single crystal work. Single crystals of course allow greater homogeneity and the possibility of following the anisotropy of the fundamental properties—often important in distinguishing the underlying mechanisms of superconductivity [6].

A central question³ for deciding on the superconducting pairing mechanism in these FeAs superconductors has been the interplay/relationship between the ubiquitous magnetic behavior in the undoped, non-superconducting starting compounds (either the 1111 family or AFe₂As₂, where A = Ca, Sr, Ba, and Eu) which is then suppressed by the doping. In the 122 family, K/Na/Cs, or hole doping, on the A site or Co/Ni—electron doping [5]—on the Fe site induces superconductivity. Whether the magnetic (spin density

³ See, for example Han *et al* [7], who state ‘our result strongly suggests the magnetic fluctuation as the pairing mechanism for the superconducting ground state’ in these Fe-based superconductors.

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Table 1. Survey of previous doping results in 122 FeAs superconductors. Units of temperature are kelvin; results are for either single or polycrystalline samples. It is worth noting that some authors, well focused on the difficulty of answering the coexistence question precisely, have used a more precise determination of T_{SDW} (e.g., Wang *et al* [21] used specific heat; Zhang *et al* [16] used band splitting measured by photoemission).

$A_{1-x}A'_xFe_{2-y}Co_yAs_2$ ($A' = K, Na$)	Dopant $_{x,y}$	T_{SDW}	T_c	Coexistence (yes/no)	Single/poly	Reference
A = Ca	Co _{0.06}	None	17	No	Single	[14]
	Na _{0.5}	None	20	No	Poly	[15]
A = Sr	K _{0.2}	135	25	Yes	Single	[16]
	K _{0.4}	None	38	No	Single	[17]
	K _{0.4}	None	20 ^a	No	Poly	[18]
	Na _{0.5}	160	35	Yes	Single	[19]
	Co _{0.2}	None	19.2	No	Poly	[12]
A = Ba	K _{0.5}	70	37	Yes	Single	[19]
	K _{0.2,0.3}	120,100	7,14	Yes	Poly	[20]
	Co _{0.17}	75	9	Yes	Single	[21]
	Co _{0.10}	35–50(split)	20	Yes	Single	[22]
	Co _{0.16}	None	22	No	Single	[5, 23]
A = Eu	K _{0.5}	None	32	No	Poly	[24]
	Pressure	115	30	Yes	Single	[25]

^a Annealed polycrystalline Sr_{0.6}K_{0.4}Fe₂As₂ changes T_c from 38 to 20 K. In the unannealed state, there is an anomaly in ρ at 200 K indicative of SDW and $T_c = 38$ K [18].

wave, ‘SDW’) behavior is coupled to the occurrence of superconductivity in SrFe₂As₂ doped with Co is a main subject of the present work, using single crystals prepared in Sn flux.

The question ‘does the SDW coexist with superconductivity in FeAs superconductors?’ might seem straightforward to answer. However, even in just the 122 compounds, there exist at present four starting compounds AFe₂As₂ (A = Ca, Sr, Ba, and Eu) with both hole (including work on Na, K and Cs) and electron (Co and Ni) doping, and as well the very important materials aspects of both single and polycrystalline samples. Even a cursory review of the current status of this 4(Ca, Sr, Ba, Eu) \times 2(hole/electron) \times 2(single/poly) ‘phase space’ for just the 122 compounds already reveals both large differences but also serious conflicts between the various results. The rate at which doping depresses T_{SDW} and induces superconductivity varies widely between the various A atoms and either hole or electron dopants, which is a sign of the richness of this new class of materials. However, there are also conflicts in some results on the same A atom and the same dopant, which involve disagreements in concentration dependence of, e.g., T_{SDW} , in whether the SDW transition is first or second order in, e.g., SrFe₂As₂ [8–11], and even in the quite fundamental question of coexistence of magnetism and superconductivity itself (see table 1). Our work on the electron-doped SrFe₂As₂ is the first to be done on single crystals in this compound (with one report on polycrystalline samples [12] and one on thin films [13]), bringing an initial data set for the 4 \times 2 \times 2 set closer to completion. SrFe₂As₂ single crystals show a structural phase transition from a high-temperature tetragonal phase to a low-temperature orthorhombic phase at the same temperature as the SDW, $T_0 = 198$ K [11], similar to the behavior observed in the BaFe₂As₂ compound [4].

As summarized in table 1, the relation between magnetic behavior and superconductivity in the 122 FeAs superconductors has been addressed quite thoroughly for A = Ba, but somewhat less so for A = Ca, Sr, and Eu. There is

also growing work on electron doping (primarily Co replacing Fe) for all the A species listed. As detailed in table 1, at present the question of whether magnetism in the form of a SDW coexists with superconductivity in doped AFe₂As₂ is still controversial.

Some of the disagreement in resolving the issue of coexistence of magnetism and superconductivity in the doped 122 AFe₂As₂ materials made apparent by the summary in table 1 can be resolved as merely based on interpretation. For example, some authors (e.g. see [17, 18]) have stated that the SDW transition is suppressed based on the lack of sharp structure in ρ versus T data, although a shoulder that might be indicative of a weak transition exists in their data. However, some of the disagreements appear to be fundamentally unresolvable at this time. One example of this involves contrasting T_{SDW} versus x results even in high quality single crystals of BaFe_{2-x}Co_xAs₂ by Wang *et al* [21] and by Chu *et al* [22]. Such disagreement is independent of any interpretation.

Two important lessons to be drawn from the summary in table 1 on single crystal SrFe_{2-x}Co_xAs₂ are the following. (1) A fine gradation in composition in BaFe_{2-x}Co_xAs₂ was shown to be necessary for determining whether T_{SDW} has been suppressed to $T = 0$ when superconductivity first appears [21–23]. (2) Some of the work on polycrystalline samples has been found to disagree with single crystal work, partly at least for reasons still under discussion, thus obscuring any possible conclusions. In general, although single crystals grown in Sn flux can have small inclusions of Sn [4], single crystals should be more homogeneous than sintered polycrystalline material. In order to address point (1), we are working on single crystals of SrFe_{2-x}Co_xAs₂, $x = 0.1, 0.2, 0.3$ and 0.5 in addition to the work on $x = 0$ and 0.4 reported here. However, as will be discussed below, T_{SDW} is suppressed much less rapidly with Co in SrFe_{2-x}Co_xAs₂ than in BaFe_{2-x}Co_xAs₂, and

our present work on $x = 0$ and 0.4 is sufficient to show the coexistence of magnetism and superconductivity in $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$ —contradicting conclusions based on polycrystalline $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$ [12] (see table 1).

2. Experimental details

Single crystals of Co-doped SrFe_2As_2 were grown using high-temperature solution growth techniques with a Sn flux [4]. Stoichiometric amounts of the elemental Sr, Fe, Co and As were added to Sn with the ratio of $[\text{SrFe}_{2-x}\text{Co}_x\text{As}_2]:\text{Sn} = 1:20$ and placed in an alumina crucible, which was sealed in a silica ampoule in vacuum. All the handling of the elements was performed in a glove box with an Ar atmosphere (oxygen < 1 ppm, $\text{H}_2\text{O} < 1$ ppm). The sealed crucible was heated to 700°C (duration of 4 h), then to 1100°C (duration of 4 h). After this, the sample was slowly cooled down to 500°C at the rate of 4°C h^{-1} and then the plate-like single crystals of typical dimensions $10 \times 10 \times 0.5 \text{ mm}^3$ were removed from the Sn flux by centrifuging [4].

Resistivity measurements were made by a standard four-wire ac method, using a Quantum Design PPMSTM system in fields up to 9 T. Due to the large flat faces of the crystals, where the c -axis is perpendicular to the face, alignment of the field either parallel to the c -axis or in the ab -plane was straightforward. Magnetic susceptibility measurements were performed in the same Quantum Design PPMSTM system. Resistivity under hydrostatic pressure has been measured in a piston-type cell made of maraging steel with a pressure medium of Fluorinert.

3. Results and discussion

X-ray diffraction measurements were carried out on a single crystal from both of the compositions $x = 0$ and 0.4 . As shown in figure 1, only $(00l)$ reflections with even l appear, indicating that the c -axis is perpendicular to the crystal plate. The addition of Co decreased the c -axis lattice parameter in these single crystals. However, for reasons that will become clear below in the discussion of the resistivity data for $x = 0.4$, in order to investigate possible crystal inhomogeneity and impurities below the rather shallow penetration of the x-ray beam (\sim a few μm) in the single crystals, we undertook x-ray diffraction of powders made of individual single crystals. These data, shown also in figure 1, provide a measurement of both the a - and c -axis lattice parameters and are more characteristic of the bulk of the crystal. These powder diffraction lattice parameter results agree with the single crystal results. The results for $x = 0$ were $a = b = 3.928(3) \text{ \AA}$, $c = 12.392(9) \text{ \AA}$, while $a = b = 3.925(3) \text{ \AA}$, $c = 12.33(1) \text{ \AA}$ for $x = 0.4$. For $x = 0$, the c -axis lattice parameter is consistent with some previous reports on poly- [8] and single crystal materials [17], but is slightly larger than the polycrystalline results of Leithe-Jasper *et al* [12]. With Co doping, it has been shown that the c -axis lattice parameter decreases linearly with Co concentration [12, 21, 22].

Considering the inconsistency in the absolute value of the c -axis lattice parameters in the literature, we focused here on a

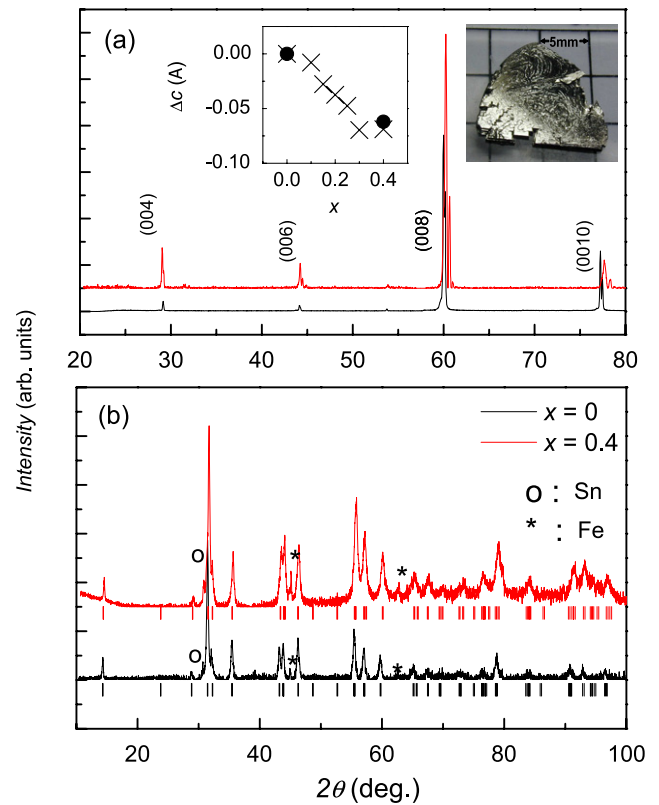


Figure 1. X-ray diffraction patterns for (a) single crystal and (b) crushed powder of $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$ with $x = 0$ and 0.4 . The upper left inset shows the decrease of the c -axis lattice constant (Δc) in the single crystals of the present work due to Co doping (solid circle). For comparison, we also plot the Δc versus x for polycrystalline $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$ (\times symbols) [12]. The upper middle inset shows a photo of an $x = 0.4$ single crystal. Note the marked second phase lines in the powder pattern (b), where in addition to a small amount of Sn inclusion from the flux some excess Fe is seen.

comparison of the *change* (contraction) of the c -axis in our Co-doped crystals with that found in polycrystalline works [12] (see figure 1). According to Leithe-Jasper *et al*, a c -axis contraction of $-0.07(1) \text{ \AA}$ is expected for $x = 0.4$, which is comparable with our result of $-0.06(2) \text{ \AA}$ for our Co-doped single crystal. This provides a bulk proof for the presence of approximately $x = 0.4$ Co in our Co-doped single crystals.

Resistivity and susceptibility data for $x = 0$ and 0.4 are shown in figure 2. Discussing the normal state properties first, as shown clearly in figure 2, our single crystals for $x = 0.4$ show differing resistivity behaviors below T_{SDW} : one crystal (S2) shows evidence for strong scattering below T_{SDW} while other crystals (S1 and S3) show only a slight change in slope (marked by the arrows). (We have measured a total of six different single crystals out of the same growth batch for $x = 0.4$, and the strong increase in ρ below T_{SDW} is found in two samples. We are continuing to investigate this.) This sample dependence is of course reminiscent of early sample dependence problems in ρ in $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$. However, in both crystals (as well in all the other crystals measured from this $x = 0.4$ batch), the superconducting transition is consistently at $T_c = 19.5 \text{ K}$. Clearly, the magnetic anomaly for $\text{SrFe}_{1.6}\text{Co}_{0.4}\text{As}_2$ is clearer evidence for an SDW

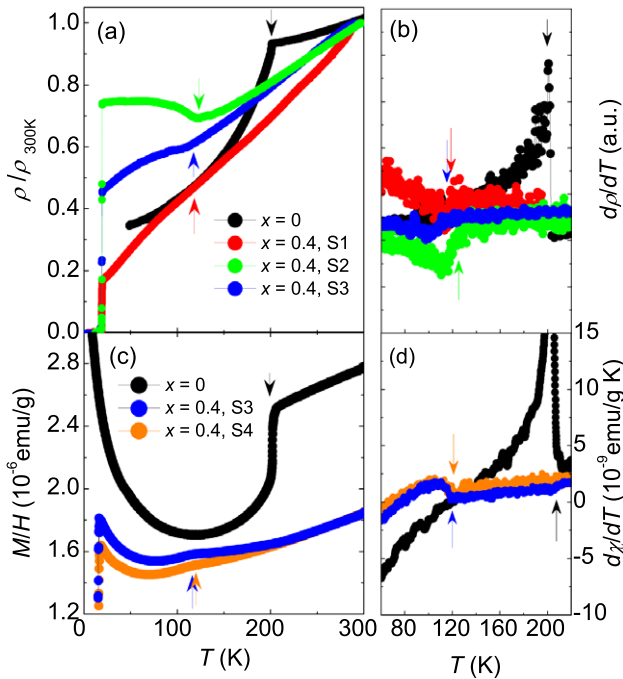


Figure 2. Resistivity versus temperature (a) for single crystal $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$, $x = 0$ and 0.4 (three samples from the same growth batch, labeled as S1, S2 and S3), showing the anomalies at T_{SDW} (202 K for $x = 0$ and ≈ 120 K for $x = 0.4$). On an expanded plot, shown in (b), a kink in the derivative of the resistivity is marked by the arrow. The plot in (c) shows the M/H (measured in 7 T) for $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$, $x = 0$ and 0.4 (two samples S3 and S4). The SDW anomalies for both $x = 0$ and 0.4 are clearly seen in the derivative of susceptibility in (d).

transition at 120 K than the slight change of slope/broad hump in the resistivity data that is characteristic of most of our samples. In the polycrystalline work on $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$ [12], the resistivity curve for a non-superconducting sample of $x = 0.1$ increases below $T \sim 130$ K, similar to the S2 data for the $x = 0.4$ single crystal in figure 2. The polycrystalline resistivity data [12] for $x \geq 0.2$ ($T_c = 19.2$ K for $x = 0.2$) show positive curvature versus temperature between T_c and 300 K, i.e. unlike both the S2 and S1 resistivity curves for our single crystal $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$ shown in figure 2. Thus, if it were not for the good agreement in the lattice contraction for the same compositions ($x = 0$ and 0.4) in the present single crystal work compared to the polycrystalline work [12], the difference in the behavior of both T_{SDW} and T_c would have called the comparability of the Co compositions into question. As it is, it would be useful for magnetic susceptibility data to higher temperatures than 25 K (the upper limit in [12]) to be measured on the polycrystalline samples. At this time it is not clear why there is disagreement between $T_{\text{SDW}}(x)$ results determined by resistivity data on poly-[12] and single crystalline (present work) samples of $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$.

The different size of the resistivity anomaly for the Co-doped SrFe_2As_2 crystals indicates the possible role of disorder in the SDW transition. As shown in figure 2(b), the SDW transition temperature determined by the kink in the derivative of the resistivity curve is almost the same for the three samples S1, S2 and S3, consistent with the magnetization

data (figure 2(d)). This finding suggests that the different size of the SDW anomaly is not simply due to the chemical inhomogeneity, i.e. coexisting multi-phases with different T_{SDW} values. In general, the long-range density wave order is quite sensitive to the presence of disorder or impurity [26]. As often found in several spin/charge-density-wave systems such as disordered $\text{K}_{0.3}\text{MoO}_3$ [27], Cr [28] and α -uranium [29], the resistivity/susceptibility anomaly is significantly broadened by a small amount of impurities, which hinders the long-range coherency from being fully developed. In particular, the magnetic order in the iron pnictides is known to be quite fragile; the energy difference between the in-plane stripe-like AFM structure and other AFM structure is relatively small, and also the two-dimensional nature of the system leads to a very weak interlayer magnetic coupling [30, 31]. Therefore, Co substitution at the Fe sites would suppress the SDW anomaly not only because the electron doping breaks the conditions for Fermi surface nesting, but also because it introduces disorders in the FeAs network. Moreover, the size of the SDW anomaly at a fixed doping level can also be sensitive to the degree of disorder in each crystal piece, which in turn can cause the different resistivity upturns shown in figure 2(a).

As stated in section 1, the field of FeAs superconductivity is in a state of flux at present. The variation of the resistivity seen in our single crystals for $x = 0.4$, and the disagreement between our single crystal compositional dependence of T_{SDW} and T_c compared to polycrystalline [12] results, is perhaps one reason why some of these open questions must remain open until better understanding of sample quality is achieved.

The superconducting transition temperature for $x = 0.4$ $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$ single crystals is 19.5 K, which is comparable with the maximum T_c achieved by Co doping in polycrystalline SrFe_2As_2 [12] and coexists with the magnetic transition at $T_{\text{SDW}} \approx 120$ K. Our work in progress on other compositions confirms this result, adding one more piece to the conclusion that is becoming clearer (see table 1 and references therein) that—contrary to early conclusions—magnetism and superconductivity clearly coexist in these 122 FeAs superconductors. In comparison with Co-doped BaFe_2As_2 , the magnetic phase is more robust in Co-doped SrFe_2As_2 . For BaFe_2As_2 , the T_{SDW} is decreased rapidly with a relatively small amount of Co substitution, i.e. $x = 0.12$, which is sufficient to fully suppress the SDW transition and induce the maximum $T_c \approx 24$ K. In contrast, we still observe the clear magnetic transition at $T_{\text{SDW}} \approx 120$ K with $x = 0.4$ in $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$ with $T_c \approx 20$ K. This result may be related to the higher $T_{\text{SDW}} \approx 202$ K in SrFe_2As_2 than that of BaFe_2As_2 ($T_{\text{SDW}} \approx 140$ K).

The temperature dependence of $H_{c2}(T)$, defined by 90% of the resistive transition, is shown in the inset of figure 3. Both H_{c2}^{ab} and H_{c2}^c showed almost linear temperature dependence with slopes of $dH_{c2}^{ab}/dT = -3.9$ T K⁻¹ and $dH_{c2}^c/dT = -2.2$ T K⁻¹. The zero temperature upper critical fields can be estimated using the Werthamer–Helfand–Hohenberg formula, $H_{c2}(0) = -0.69T_c(dH_{c2}/dT)|_{T_c}$, yielding $H_{c2}^{ab}(0) = 30$ T and $H_{c2}^c(0) = 53$ T. The corresponding coherence lengths are 33 Å and 19 Å along the ab -plane and the c -axis, respectively. The c -axis coherence length is comparable with the distance

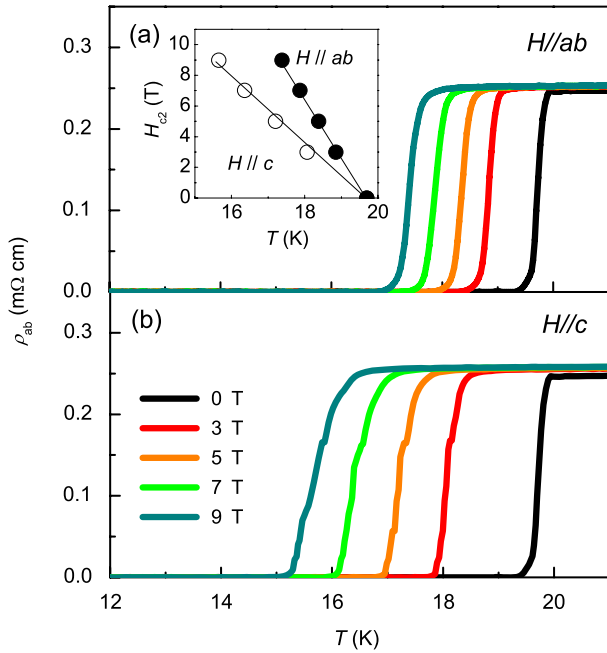


Figure 3. Temperature dependence of the ab -plane resistivity of single crystal $\text{SrFe}_{1.6}\text{Co}_{0.4}\text{As}_2$ with different magnetic fields along the ab -plane (a) and the c -axis (b). The inset shows the $H_{c2}(T)$ curves near T_c for the two field directions, $H \parallel c$ and $H \parallel ab$.

between two adjacent FeAs layers, $d \sim 6 \text{ \AA}$, indicating the quasi-two-dimensionality of the superconductivity. The anisotropy parameter $\Gamma = H_{c2}^{ab}/H_{c2}^c$ derived from the data in figure 3 is $\Gamma \approx 1.7$, which is comparable with $\Gamma \approx 1.5$ – 2 of K- or Co-doped BaFe_2As_2 and K-doped SrFe_2As_2 [17] but significantly lower than $\Gamma \approx 5$ – 10 in the 1111 oxypnictides.

Recent studies on the upper critical fields for K- or Co-doped BaFe_2As_2 single crystals as well as Co-doped SrFe_2As_2 film showed that $\Gamma(T)$ is reduced with decrease of temperature, indicating nearly isotropic orbital limiting effects with peculiar multi-band electronic structures [32–34]. The Γ value near T_c for Co-doped BaFe_2As_2 also shows an interesting doping dependence. The Γ near T_c is ~ 1.5 for the ‘underdoped’ samples, showing both the SDW and superconducting transitions, while the much higher $\Gamma \sim 2.5$ was obtained in the ‘overdoped’ samples, with only a superconducting transition [33]. Our Co-doped SrFe_2As_2 crystal showing both transitions also has a relatively small Γ near T_c , consistent with the results of Co-doped BaFe_2As_2 . Further study on Γ for other Co-doped SrFe_2As_2 crystals with different doping levels would be highly desirable.

As a final characterization of the superconductivity we observe in our single crystals of $\text{SrFe}_{1.6}\text{Co}_{0.4}\text{As}_2$, we present the pressure dependence of T_c in figure 4. Gooch *et al* [35] reported on $T_c(P)$ in polycrystalline $\text{Sr}_{0.6}\text{K}_{0.4}\text{Fe}_2\text{As}_2$, $T_c^{\text{onset}} = 37 \text{ K}$, and find an increase in T_c^{onset} at 0.9 GPa of about 1.2 K, or about 3%, compared to our result for electron-doped SrFe_2As_2 where T_c increases by about 1.8 K, or about 9% with 0.9 GPa. Gooch *et al* also see some saturation in the rise of T_c with pressure in their 1.7 GPa data, comparable to what we observe (see inset to figure 4). From previous pressure

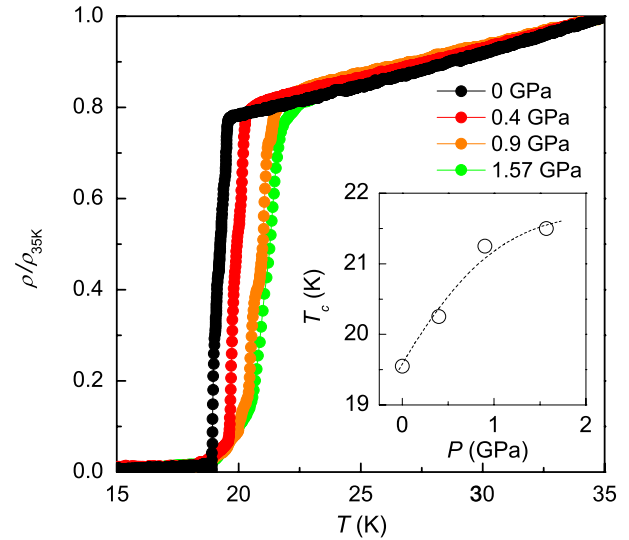


Figure 4. Superconducting transition temperatures for single crystal $\text{SrFe}_{1.6}\text{Co}_{0.4}\text{As}_2$ determined by the resistivity as a function of hydrostatic pressure.

work on the K-doped AFe_2As_2 ($A = \text{Ba}, \text{Sr}$) compounds, it has been found that the pressure dependence of T_c reflects the ‘dome’ shape of the doping dependence of T_c [35]. The underdoped and overdoped samples show positive and negative pressure dependence, respectively, while almost no pressure dependence of T_c is observed in the optimally doped sample. As mentioned already, our $x = 0.4$ crystal shows $T_c = 19.5 \text{ K}$, close to the maximum T_c of Co-doped polycrystalline SrFe_2As_2 [12], thus in the optimal doping regime. The sizable pressure dependence of T_c in our crystal, therefore, suggests that there is still room for improving the superconducting transition temperature by further tuning, e.g. using external pressure. Similar behavior has been also observed in optimally Co-doped BaFe_2As_2 [36]. This different behavior between K-doped and Co-doped 122 compounds indicates that the pressure dependence of T_c is not just determined by the doping level of the FeAs layer but also reflects more complex interplay with other parameters such as the degree of hybridization between the Fe and As states that can be tuned by, e.g., a bonding angle of the Fe–As–Fe network [37].

4. Summary and conclusion

Our present work on single crystal $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$ ($x = 0$ and 0.4) shows clear signatures in both electrical resistivity and magnetization curves for the presence of a spin density wave at 202 and 120 K, respectively. The $x = 0.4$ sample shows superconductivity at 19.5 K, which—in the spirit of the work on the FeAs superconductors to date (see table 1)—allows the conclusion that superconductivity is coexistent with magnetism (SDW) in single crystal $\text{SrFe}_{1.6}\text{Co}_{0.4}\text{As}_2$. Of course, a microscopic determination of the coexistence below T_c is further required. Both the single crystal and powder x-ray diffraction characterizations of our samples show internal consistency as well as agreement of the lattice contraction with Co doping, compared to the

polycrystalline work on $\text{SrFe}_{2-x}\text{Co}_x\text{As}_2$ [12]. In contrast, our compositional dependences of both T_{SDW} and T_c disagree with the polycrystalline data in [12] which does not report magnetic susceptibility. The anisotropy of the upper critical field H_{c2} in our single crystals of $\text{SrFe}_{1.6}\text{Co}_{0.4}\text{As}_2$ is consistent with K- or Co-doped BaFe_2As_2 and K-doped SrFe_2As_2 [17]. The pressure dependence of T_c of our single crystalline $\text{SrFe}_{1.6}\text{Co}_{0.4}\text{As}_2$ is, when expressed as a percentage of $T_c(P = 0)$, much larger than that observed [35] in K-doped SrFe_2As_2 .

An important conclusion that can be drawn from our present work is that even in single crystals there appears to be significant sample dependence at least in the resistivity below T_{SDW} , while T_{SDW} and T_c themselves did not show any sample dependence. Our results clearly show sample dependence in the resistivity, as well as an unexplained difference between our single crystal and reference [12]'s polycrystalline values of T_{SDW} and T_c as a function of Co concentration. This may be a useful cautionary note about the rush to draw firm conclusions in the early stages of the fascinating study of superconductivity in the 122 FeAs compounds.

Acknowledgments

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