



The Properties, Advantage, Disadvantage and Applications of Iron-Based Superconductors: A Review Work

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Abstract: With a higher transition temperature (T_c), the recent discovery of iron-based superconductors has evoked eagerness for extensive research on these materials because they form the second high-temperature superconductor family after the copper oxide superconductors and impart an expectation for materials. Including an unconventional pairing mechanism and superconducting properties preferable for application such as a high upper critical field and small anisotropy, they have peculiar physical properties. The new star in the world of solid state physics are iron-based superconductors. Due to the discovery of superconductivity in iron-based materials, it has exposed a new family of high-temperature superconductors with properties that are both similar to and different than those of the copper-oxide family of superconductors. These materials promise to provide a rich playground to study the fundamentals of superconductivity with transition temperatures approaching the boiling point of liquid nitrogen, while advancing the prospects for widespread technological applications. In this paper, we review the properties and applications of iron-based superconductors. The advantages and disadvantages of iron-based superconductors over high T_c superconductors and cuprate-based superconductors have been also studied.

Keywords: Iron-based superconductors; Superconductors; Properties; Applications.

1. INTRODUCTION

Superconductivity is a phenomenon in which the resistance of the material to the electric current flow is zero. The first discovery of the phenomenon was made by Kamerlingh Onnes in 1911 in mercury (Hg). In 1986, a new class of “high temperature” superconductors was discovered that completely contradicted this rule. These were oxides in which the crystal structure contained sheets of copper and oxygen—called “cuprates” [1]. Oxides typically aren’t even conductors let alone superconductors, but more surprising was that the copper ions carry a magnetic spin (like a compass needle), which is the kiss of death for conventional superconductors. Moreover, it turns out that the magnetism is not only tolerated in the cuprates, but appears to play a key role in the Cooper pairing. All known “high temperature” superconductors exhibited two essential ingredients up until 2008: copper-oxygen planes of atoms, and magnetic moments on the copper. In that time, it was thought that these two properties were essential to achieve “high T_c ” superconductivity. Then the iron-based superconductors with high T_c were discovered [2, 3]. Its properties are controlled by the atomic structure and bonding of a material and for the iron systems there are four different structure types that have been identified so far, typified by LaFeAsO, SrFe₂As₂, LiFeAs, and Fe (Te-Se). The structure for the first two types has the highest T_c ’s. A layer of Fe and As atoms (like the Cu-O layer for the cuprates) is the common structural feature, which is separated by a non-iron layer such as La-O (for LaFeAsO) or Sr (for SrFe₂As₂). Due to several good reasons FeSC are so interesting. First of all, they assure interesting physics that stems from the coexistence of superconductivity and magnetism. Second, with their multi-band electronic structure they provide a much wider variety of compounds for research and they offer the hope of finally discovering the mechanism of high temperature superconductivity and finding the way to increase T_c . Lastly, for applications the FeSC are quite promising. They are attractive for electrical power and magnetic applications because of much higher T_c than cuprates and high isotropic critical currents, while the coexistence of magnetism and superconductivity makes them interesting for spintronics [15, 16].

In this paper, we review the properties and applications of iron-based superconductors. The advantages and disadvantages of iron-based superconductors over high T_c superconductors and

cuprate-based superconductors have been also studied. In section 2, iron-based superconductors are given; section 3 discusses about the different properties of superconductors; advantages and disadvantages of superconductors was discussed in section 4, section 5 gives the application of iron-based superconductors. Finally, the summary and conclusions are given in section 6.

2. FEAS-BASED SUPERCONDUCTORS

When another completely different family of superconductors was discovered by the group of Hideo Hosono in 2006 [4], the condensed-matter community got stirred up once again. At a relatively low temperature of $\sim 4\text{K}$, the Japanese group reported observation of a superconducting transition in LaFePO. With a limited attention from the community, this original discovery received certain. Two years later the general excitement came, when the same group reported superconductivity at a temperature of 26 K, higher that of most conventional superconductors in a closely related compound LaFeAsO_{1-x}F_x at a doping level of $x = 0.12$ [5], with the parent compound LaFeAsO being non-superconducting at routinely attainable cryogenic temperatures. Due to this latter discovery, there was a rise to the explosive growth of research of these materials all over the world, which lead to reports of high-temperature superconductivity in several new classes of compounds in this family, such as SmFeAsO_{0.9}F_{0.1} [6] ($T_c \approx 55\text{K}$) and Ba_{0.6}K_{0.4}Fe₂As₂ [7] ($T_c \approx 38\text{K}$). With the discovery of superconductivity at 4 K in LaFePO in 2006, iron-based superconductors started and great interests have been drawn since 2008 when T_c was raised to 26 K in LaFeAsO_{1-x}F_x by replacing phosphorous with arsenic, and some of oxygen with fluorine [3]. So far, iron-based superconductors have been extended to a large variety of materials including four prototypical families of iron-based superconductors, “1111” system RFeAsO (R: the rare earth element) including LaFeAsO [16], SmFeAsO [17], PrFeAsO [18] etc.; “122” type BaFe₂As₂ [19], SrFe₂As₂ [20] or CaFe₂As₂ [21]; “111” type LiFeAs [22-24], NaFeAs [25,26,27] and LiFeP [28], as shown in Figure 1, and further variations such as 42622-type iron pnictides [8-11] and 122-type iron chalcogenides [12-15]. Doping or applied pressure will transform the compounds into superconductivity [29]. A list of oxypnictide and non-oxypnictide iron-based superconductors is given in Table 1.

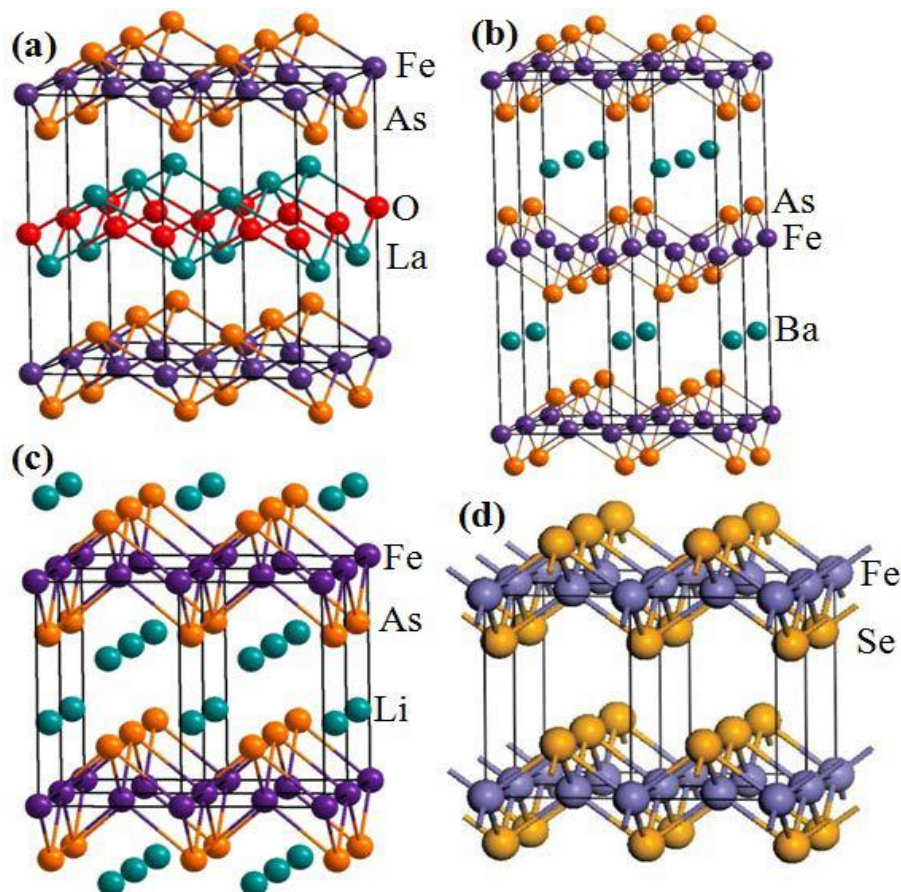


Figure1. Four families of iron-based superconductors, (a) 1111, (b) 122, (c) 111, (d) 11 types

Table1. Oxypnictide and Non-oxypnictide Superconductors with transition temperature

Oxypnictide	T_c (K)	Non- Oxypnictide	T_c (K)
$\text{LaO}_{0.89}\text{F}_{0.11}\text{FeAs}$	26	$\text{Ba}_{0.6}\text{K}_{0.4}\text{Fe}_2\text{As}_2$	38
$\text{LaO}_{0.9}\text{F}_{0.2}\text{FeAs}$	28.5	$\text{Ca}_{0.6}\text{Na}_{0.4}\text{Fe}_2\text{As}_2$	26
$\text{CeFeAsO}_{0.84}\text{F}_{0.16}$	41	$\text{CaFe}_{0.9}\text{Co}_{0.1}\text{AsF}$	22
$\text{SmFeAsO}_{0.9}\text{F}_{0.1}$	43	$\text{Sr}_{0.5}\text{Sm}_{0.5}\text{FeAsF}$	56
$\text{La}_{0.5}\text{Y}_{0.5}\text{FeAsO}_{0.6}$	43.1	LiFeAs	18
$\text{NdFeAsO}_{0.89}\text{F}_{0.11}$	52	NaFeAs	9-25
$\text{PrFeAsO}_{0.89}\text{F}_{0.11}$	52	FeSe	< 27
ErFeAsO_{1-y}	45		
Al-32522 (CaAlOFeAs)	30 (As), 16.6 (P)		
Al-42622 (CaAlOFeAs)	28.5 (As), 17.2 (P)		
$\text{GdFeAsO}_{0.85}$	53.5		
$\text{BaFe}_{1.8}\text{Co}_{0.2}\text{As}_2$	25.3		
$\text{SmFeAsO}_{-0.85}$	55		

3. DIFFERENT PROPERTIES OF IRON-BASED SUPERCONDUCTORS

3.1. 1111-Type Family

LaFePO and $\text{LaFeAsO}_{1-x}\text{F}_x$ and LnFeAsO are included to the 1111-type family with various lanthanide elements (Ln). The atomic structure of the 1111 family consists of negatively charged FeP or FeAs layers, where Fe atoms form a planar square lattice, and positively charged LnO layers, as shown in Figure 2(a). Electrons are conducting in FeP or FeAs layers with or without doping. The electrical resistivity of pure LaFePO drops at 4 K and that of F-doped LaFePO drops at higher temperature as shown in the Figs. 3(a) and (b). From Figure 3(c), these superconducting transitions are confirmed by magnetic susceptibility. It is clear that decrease of the resistivity starts at ~ 10 K in F-doped LaFePO .

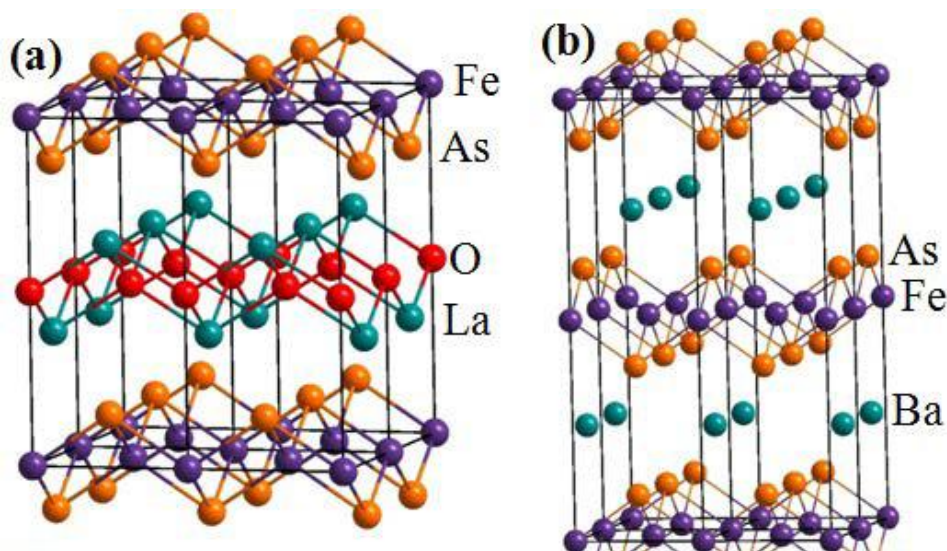


Figure2. Crystal structures of 1111 (LaFeAsO) type superconductors

Figure 4(a) shows that unlike LaFePO , undoped LaFeAsO does not show superconductivity. $\text{LaFeAsO}_{0.89}\text{F}_{0.11}$ becomes superconducting with doping of F replacing O in part. T_c increases when small pressure is applied to $\text{LaFeAsO}_{0.89}\text{F}_{0.11}$, reaching a maximum value of $T_c = 43$ K at 4 GPa and then it decreases to $T_c = 9$ K at 30 GPa [30]. T_c higher than 40 K is achieved in $\text{SmFeAsO}_{1-x}\text{F}_x$ at ambient pressure [31].

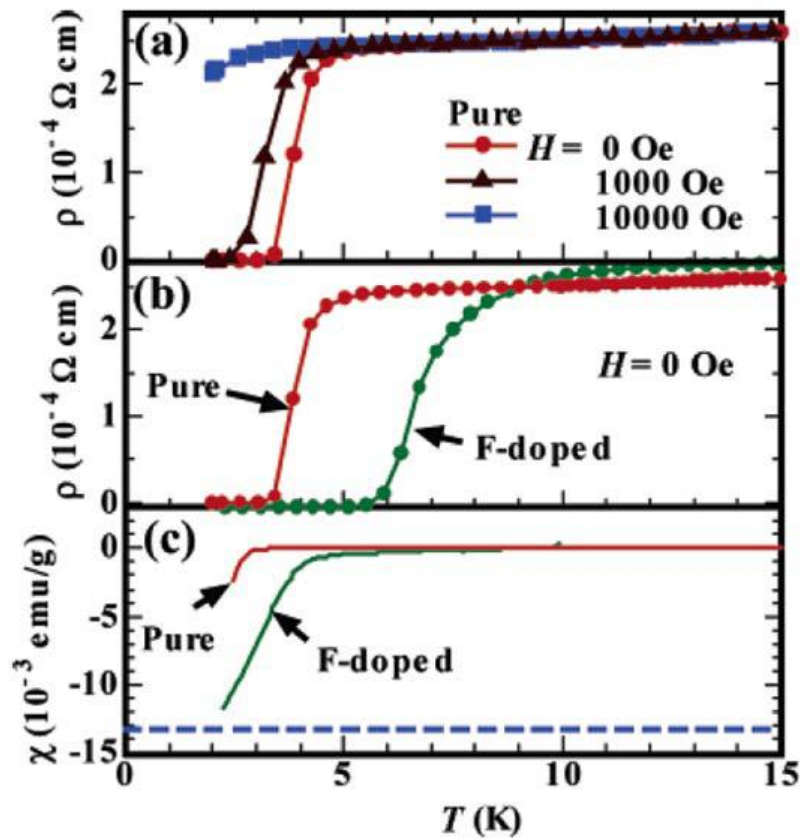


Figure3. (a) Electrical resistivity, ρ , vs. temperature, T , for pure LaFePO at various magnetic field, H . (b) ρ vs T and (c) magnetic susceptibility, χ , vs T for pure and F-doped LaFePO [32]

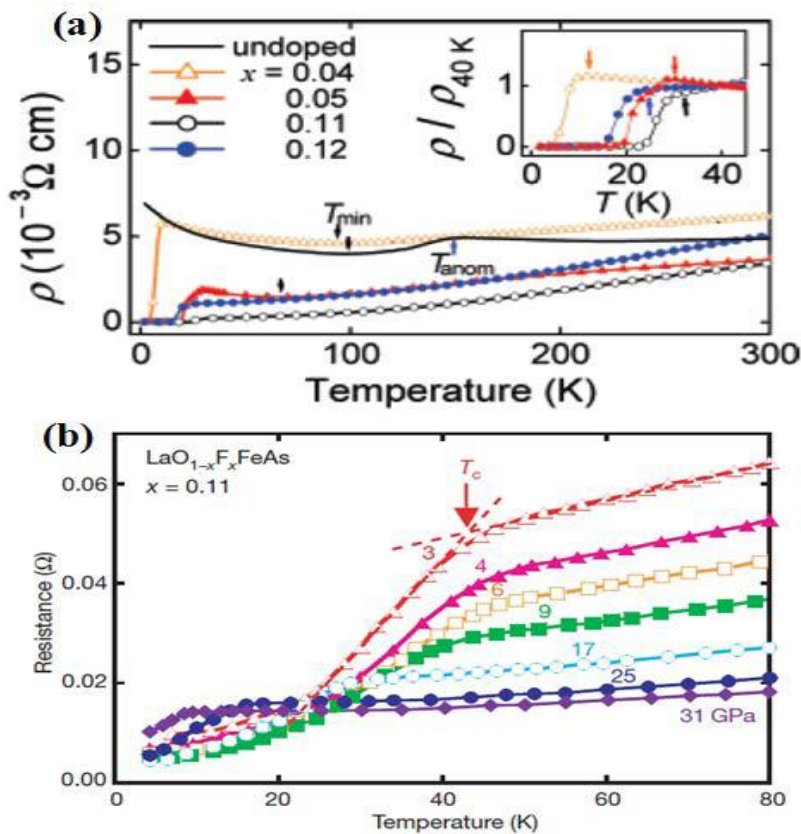


Figure4. (a) Electrical resistivity, ρ , vs temperature in LaFeAsO_{1-x}F_x for $x = 0.0, 0.04, 0.05, 0.11, \text{ and } 0.12$. (b) Temperature dependence of electrical resistance above 3 GPa in LaFeAsO_{0.89}F_{0.11}. The maximum T_c is 43 K at 4 GPa

For 1111-type materials, the reported values of T_c include 4 K in LaFePO [2], 26 K in LaFeAsO_{0.89}F_{0.11} [3], 41 K in CeFeAsO_{0.84}F_{0.16} [33], 52 K in PrFeAsO_{0.89}F_{0.11} [34], 54.3 K in NdFeAsO_{1-y} [35], 55 K in SmFeAsO_{0.9}F_{0.1} [36], and 54 K in GdFeAsO_{1-y} [35].

3.2. 122-Type Family

After the discovery of 1111-type family, 122 types ($Ba_{1-x}K_xFe_2As_2$) with T_c of 38 K [43] was found, followed by 111 types (LiFeAs) with T_c of 18 K [44]. The 122- and 111-type families have simpler structures than the 1111-type family. With FeAs or FeP layers in 1111-, 122-, and 111-type materials, the ‘blocking layer’ which separates FeAs or FeP is different for each type: rare-earth oxide or fluoride (for example, LaO or SrF) for the 1111-type family, alkaline-earth metals (for example, Ba) for the 122-type family, and alkali metals (for example, Li) for the 111-type family. 122 type iron-based superconductors are shown in the Figure 5. For the 122-type materials, the reported values of T_c include 38 K in Ba_{0.6}K_{0.4}Fe₂As₂ [43], 32 K in Sr_{0.6}K_{0.4}Fe₂As₂ [45], 26 K in Sr_{0.6}Na_{0.4}Fe₂As₂ [46], and 21 K in Ca_{0.6}Na_{0.4}Fe₂As₂ [45]. For representative iron-based superconductors, the structure, composition, dopant species, and T_c values are summarized in Table2.

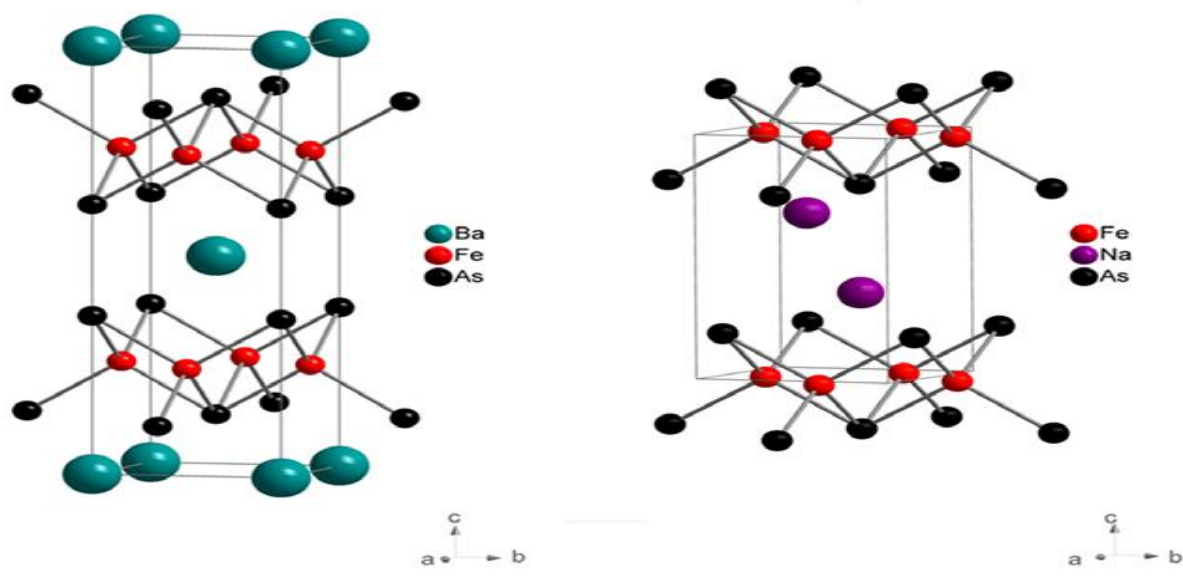


Figure5. Crystal structures of 122 ($Ba_{1-x}K_xFe_2As_2$) type superconductors

3.3. 111-Type Family

The 111 family yields many interesting results as it is highly reactive with air and consequently, more challenging to study. LiFeAs (the main representative of the family) [62, 63] is the most ‘‘arpesable’’ compound [64–66]. It grows in good quality single crystals [67] that cleave between the two Li layers, thus revealing a non-polar surface with protected topmost FeAs layer; it is stoichiometric. The ‘‘111’’ type compounds such as AFeAs (A: alkaline elements) with the highest T_c of 18K [71] have the CeFeSi structure (space group P4/nmm) with each Ae element of the 122 type compounds substituted by two Ae elements. Another member of the 111 family is NaFeAs [Fig 7]. Three successive phase transitions at around 52, 41, and 23 K was shown by it, which correspond to structural, magnetic, and superconducting transitions, respectively [68,69]. This compound shows less reaction with the environment than LiFeAs but exposure to air strongly affects T_c [68]. Replacing Fe by either Co or Ni suppresses the magnetism and enhances superconductivity [69]. For representative iron-based superconductors, the structure, composition, dopant species, and T_c values are summarized in Table2.

Table2. Structure, composition, dopant species, and T_c values for representative iron-based superconductors

Structure	Composition	Dopant (Site)	T_c (K)
1111	LnFePO (Ln = La, Sm, Gd)	F (O)	7
		Vacancy (O)	28-55
	RFeAsO (R = Y, La-Ho)	F (O)	26-55
		Co (Fe)	7-18
122	AeFe ₂ As ₂ (Ae = Ca, Sr, Ba)	A (Ae)	20-38
		Co (Fe)	20-23
		P (As)	30
111	K _x Fe _{2-y} Se ₂ ^{a)}		30
	Li _x FeAs		18
11	Fe _{1+x} Se		9
		Te (Se)	8 (37 ^{b)}
21113	Sr ₂ ScFePO ₃		14 (21 ^{c)}
			7
			17
32225	Sr ₂ VFeAsO ₃		37 (46 ^{b)}
		Ti (Sc)	45

3.4. 11-Type Family

11 type compounds have the lowest T_c among the iron-based superconductors. A significant increase in T_c due to their simplest crystal structure and the pressure-induced straightforwardly lead to motivation for fabricating epitaxial films on lattice-mismatched substrates, which may show strain-induced T_c enhancement. The 11-type materials started with FeSe having T_c of 8 K at ambient pressure [54] and 36.7 K with applied pressure of 8.9 GPa [55]. FeTe_{1-x}Se_x and FeTe_{1-x}S_x are also included to this family. Among iron-based superconductors, these materials have the simplest structure, in which iron-chalcogenide layers are simply stacked together. For 11-type materials, the reported values of T_c include 8 K in FeSe at ambient pressure [54] and 36.7 K in FeSe under pressure of 8.9 GPa [23], as mentioned above, and 14 K in FeTe_{0.5}Se_{0.5} [56], 2 K in Fe_{1.13}Te_{0.85}S_{0.1} [57], and 10 K in FeTe_{0.8}S_{0.2} [58]. The 11 type compound also has a γH similar to or slightly smaller than that for the 122 type compounds. Observation of clear broadening of the resistive transition was reported in spite of such a small γH [48]. Table 2 shows the superconducting properties are. The anisotropy factor correlates well with the distance between the CuO₂ planes or the thickness of the blocking layer in copper oxide superconductors, that is, a thinner blocking layer leads to smaller anisotropy [60]. This is also the case for the iron-based superconductors. Recently, with a thick perovskite-like blocking layer substantially larger anisotropy was observed for the compounds, and an inverse correlation between the irreversibility fields H_{irr} and γ , as seen in copper oxides, was also reported by Ogino and his colleagues [61]. Figs. 7 & 8 shows the crystal structures and phase diagram of 11-type superconductors respectively.

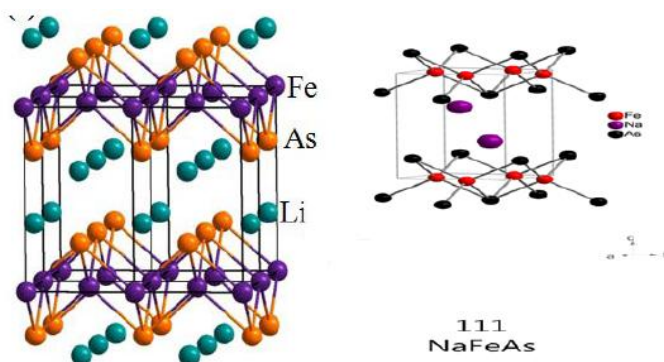


Figure6. Crystal structures of 111 type superconductors

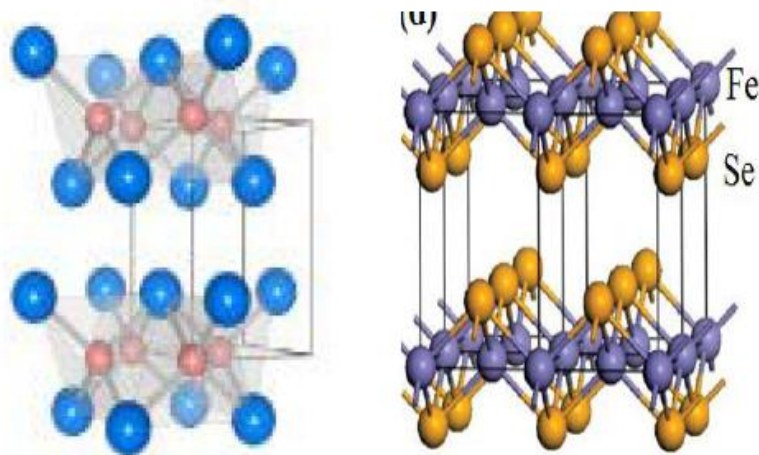


Figure7. The crystal structures of 11-type superconductors

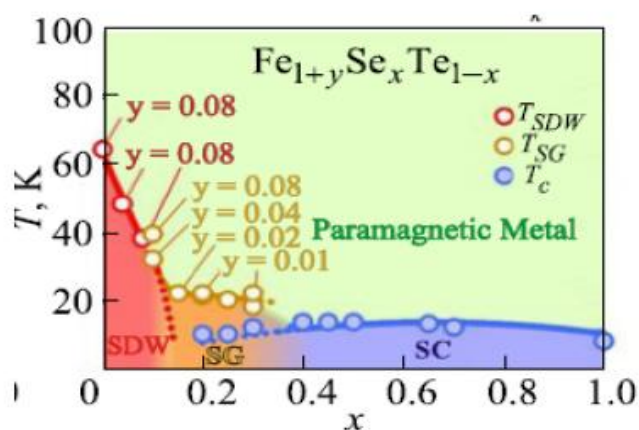


Figure8. Phase diagram of 11-type SC

Table3. Superconducting properties of representative iron-based superconductors

Material	T_c (K)	$\mu_0(-dH_{c2}^{ c}/dT)_{T_c}$ (TK ⁻¹)	$\mu_0 H_{c2}^{ c}(0)$ (T)	Anisotropy factor, γ_H	Coherence length, ξ_{ab} (nm)	ξ_c (nm)	Energy gap, Δ (meV)
RFeAs(O,F) (R = Nd, Sm)	47-55	0.8-2.5	80-100*	5-10	1.8-2.3	0.26	4-7, 10-18
(Ba,K)Fe ₂ As ₂	37-38	4-5	70-135*	1.5-2	1.5	1.0	1.8-4.6, 9-11
Ba(Fe,Co) ₂ As ₂	22-23	2.5	47-50	1.5-1.9	2.4	1.3	1.9-4.4, 5-7.4
Fe(Se,Te)	14-16	14	~ 50	1.1-1.9	1.2	0.63	~2.3

*Ambiguity exists as described in the text.

3.5. Typical Phase Diagram and Superconducting Properties for 122-Type Family

Figure 9(a) shows a set of experimental phase diagram [47-50] for the Ba-based 122 system, which captures the main traits of 122-type family. The systematic replacement of either the alkaline-earth metal (Ba), transition metal (Fe), or pnictogen (As) with different elements almost universally suppresses the non-superconducting antiferromagnetic state of parent compounds to a superconducting nonmagnetic state in BaFe_2As_2 . For the iron-based superconductor systems, this phase transition from the antiferromagnetic state to the superconducting state is generic property which can also be produced by applied external pressure [51]. Except that the undoped parent compound of copper-oxide materials is an antiferromagnetic Mott insulator it is remarkable that the phase diagram of the iron-based superconductor system is very similar to that of copper-oxide materials [52] shown in Figure 9(b).

At low temperatures, the 122 type compounds such as $(\text{Ba,K})\text{Fe}_2\text{As}_2$ and $\text{Ba}(\text{Fe,Co})_2\text{As}_2$ have a much smaller γH of approximately 1.5 [49] which is comparable to that for MgB_2 and suggests a minimal thermal fluctuation effect. In fact the resistive transition of 122 type compound single crystals exhibits an almost parallel shift of the resistive transition in magnetic fields [47,49] although slight broadening was reported in $\text{Ba}(\text{Fe,Co})_2\text{As}_2$ thin films [53]. The superconducting properties of 122-types in details are listed in table 3.

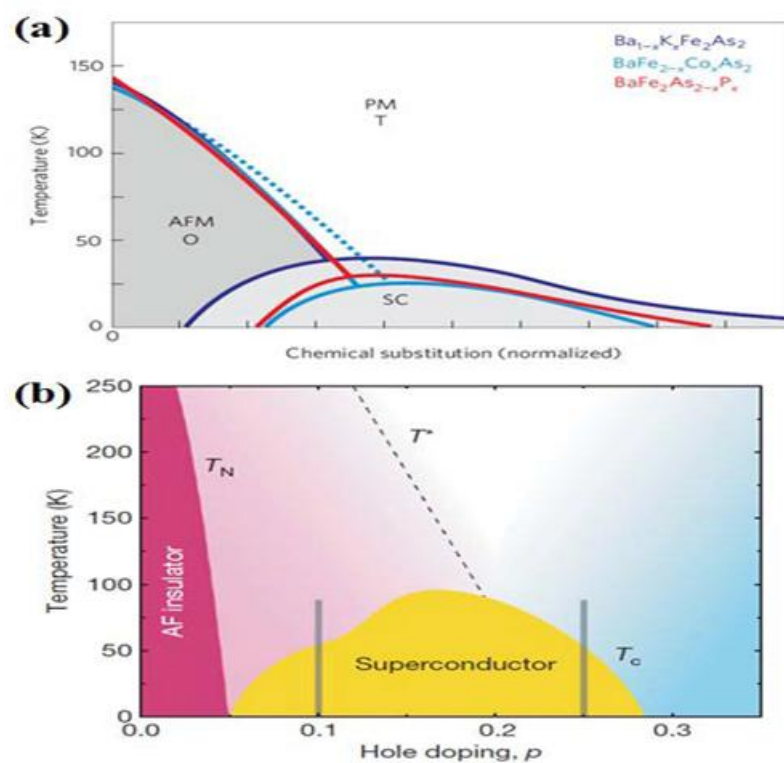


Figure 9. (a) For K [47], Co [31] and P [49] doping phase diagram of the BaFe_2As_2 system shown. Tetragonal (T) to orthorhombic (O) structural phase transitions in Co doped samples indicated by the dotted line. (b) Doping dependent antiferromagnetic transition temperature, T_N , superconducting transition temperature, T_c , and pseudogap crossover temperature, T^* , in YBCO [52]

4. ADVANTAGE AND DISADVANTAGE OF IRON-BASED SUPERCONDUCTOR

A quarter century has passed since the discovery of copper oxide high-temperature superconductors. There are many technical hurdles in their application to superconducting wires and tapes as well as electronic devices because of their unique physical properties such as the metal-insulator transition, the d-wave symmetry of the order parameter, the unusual normal metal states, and the weak links at grain boundaries. Owing to the increased understanding of their properties and many technical breakthroughs, however, developments of electric power devices such as cables, magnets, and motors using long-length superconducting tapes with Bi- and Y-based superconductors [$(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{-Cu}_3\text{O}_y$ and $\text{YBa}_2\text{Cu}_3\text{O}_y$] have recently become a reality [94]. Electronic devices such as band-pass

filters and superconducting quantum interference devices (SQUIDs) with Y-based superconductor thin films have also been commercialized to some extent. In spite of these successes of copper oxide superconductors, mostly for use at liquid nitrogen temperature, there has been a continuing demand for new superconductors with a higher transition temperature (T_c) and superior properties in high magnetic fields. The discovery of the iron-based or iron-pnictide superconductor LaFeAs(O,F) with a T_c above 26K by the Tokyo Institute of Technology (TIT) group in 2008 [95] has renewed the worldwide enthusiasm for the search for new superconductors. The most striking impact of this discovery is that superconductivity occurs in materials including iron (Fe), well known as a typical ferromagnetic element, which usually breaks Cooper pairs. The other significant characteristic of this superconductor is that there are a variety of materials having similar structures, and many new superconductors have been discovered in this family in the last three years. Thus there is the possibility of finding new superconductors with superior properties, though the highest T_c in this family of materials remains 55K reported in June 2008, which is still below liquid nitrogen temperature.

Much of the interest on iron based superconductors is because the new compounds are very different from the cuprates and may help lead to a theory of non-BCS-theory superconductivity. A subset of iron-based superconductors with properties similar to the oxypnictides, known as the 122 iron arsenides, attracted attention in 2008 due to their relative ease of synthesis. Similarly to superconducting cuprates, the properties of iron based superconductors change dramatically with doping. Parent compounds of FeSC are usually metals (unlike the cuprates) but, similarly to cuprates, are ordered antiferromagnetically that often termed as a spin-density wave (SDW). The superconductivity (SC) emerges upon either hole or electron doping. In general, the phase diagram is similar to the cuprates.

5. APPLICATIONS

5.1. Applications of Iron-Based Superconductors in Wire and Tape

For the wires fabrication, the power-in-tube (PIT) method has been applied which is based on high-temperature superconductors such as Bi-based copper oxides and MgB₂, and now-a-days km-length commercial wires are available [75]. The trial fabrication of F-La1111 and F-Sm1111 wires was reported by Gao and coworkers [76, 77] after the discovery of high- T_c iron-based superconductors. Using La(Sm), As, LaF₃ (SmF₃), Fe, and Fe₂O₃ as starting materials, they employed an in situ PIT method. With an inner Ti sheath a Ta tube or a Fe tube was used to prevent the reaction between the tubes and the 1111 type compounds. They obtained a wire as shown in Figure 10 after swaging the tubes containing the raw materials and heat treatment at above 1150 °C. Figure 11 shows that they could not observe a high transport I_c , magnetization measurements revealed that the core material of the wire with a T_c as high as 52K had a self-field J_c of approximately 4000 A/cm² at 5K and a weak magnetic field dependence of J_c , indicating an encouraging first step toward fabrication of practical wires. By the PIT method the fabrication of K-Sr122 wires was also subsequently reported by the same group [78]. They improved the wire fabrication process to obtain a high transport I_c . To prevent the reaction with the raw materials they employed Ag inner sheath and added Ag to the raw materials to enhance grain growth. This improved process led to the successful observation of a transport J_c of 1200 A/cm² at 4.2K for K-Sr122 wires [79]. Using K-Sr122 powder, they employed an ex situ PIT method recently and increased the transport J_c to 3750 A/cm² at 4.2 K [80]. F-Sm1111 wires with a transport J_c of 2700 A/cm² were also fabricated by employing a similar method and annealing at relatively low temperatures of 850–900°C [81]. By an ex situ PIT method with the addition of Ag, Togano and his colleagues reported the successful fabrication of Ag-sheathed K-Ba122 wires with a large transport I_c of as high as 60.7A at 4.2 K, which corresponds to a self-field J_c of 1.0×10^4 A/cm² [82]. The wires exhibited a transport J_c of 1.1×10^3 A/cm² even in a field of 10 T, as shown in Figure 16. By an ex situ PIT method using a binder composed of SmF₃, SmAs, and FeAs, high self-field transport J_c at 4.2K of approximately 4000 A/cm² has also been reported for F-Sm1111 wires fabricated [83]. On the other hand, further improvement of the transport J_c is required to realize practical wires. The texturing of grains in wires appears to be necessary to some extent considering the weak-link behavior of high-angle GBs. Furthermore, a recent TEM study on a polycrystalline K-Sr122 sample indicated the existence of nanometer-scale amorphous layers and oxygen enrichment at the grain boundaries [84].

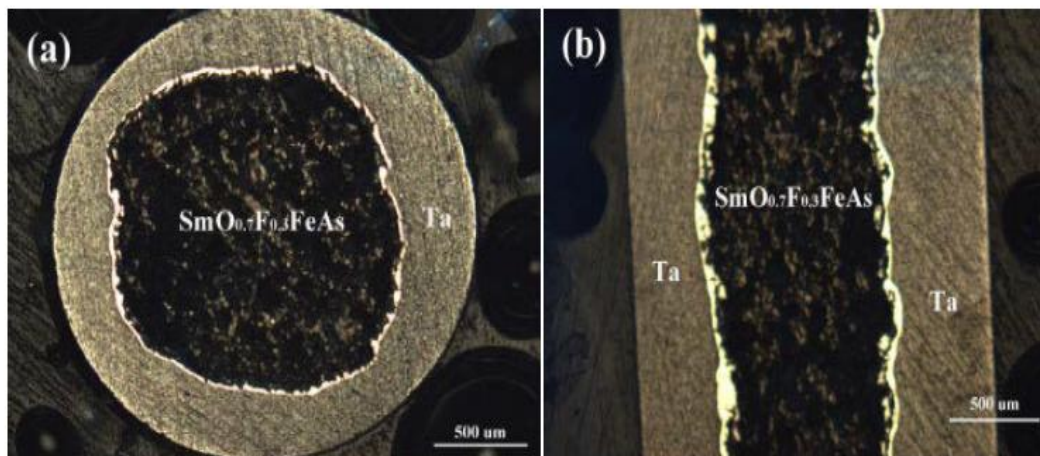


Figure10. (Color online) Optical images of a typical (a) transverse and (b) longitudinal cross section of the first successfully fabricated $SmFeAsO_{1-x}F_x$ (F-Sm1111) PIT wires after heat treatment

By an in situ PIT method, Mizuguchi and his colleagues reported the fabrication of wires based on the 11 type compound Fe (Se,Te) [85]. The Fe sheath played the role of a raw material for synthesizing superconducting phases as well as the sheath was also reported by them. By an ex situ PIT method, their group also reported the fabrication of Fe (Se,Te) wires and obtained a transport J_c of about 100 A/cm² at 4.2 K [86]. Moreover, Ozaki and his colleagues [87] has recently reported a higher J_c of approximately 1000 A/cm² in FeSe PIT wires.

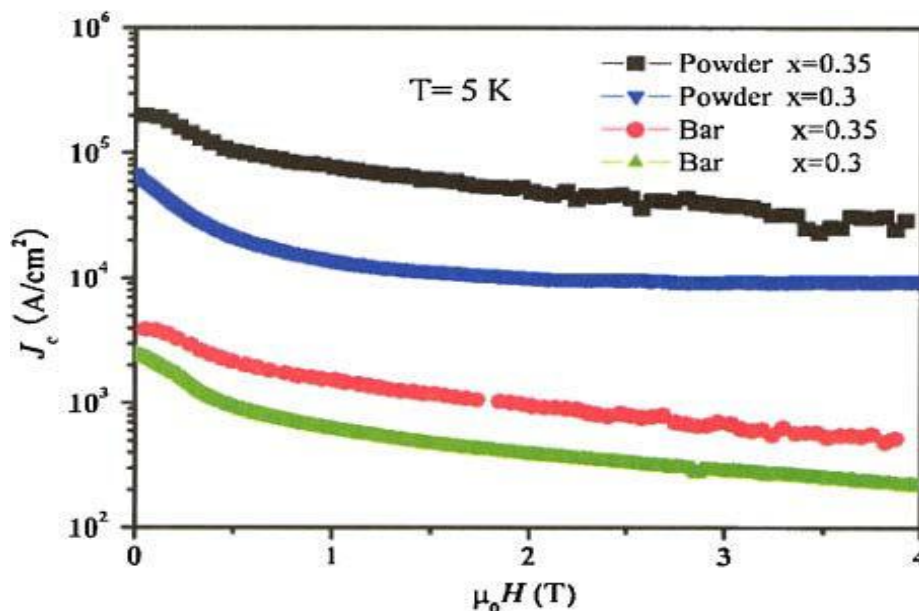


Figure11. Magnetic field dependence of J_c at 5K for a bar and powder of F-Sm1111 PIT wires

5.2. Films on Technical Substrates

It has recently been reported that after high- J_c epitaxial thin films, especially those of 122 and 11 type compounds, were prepared on various singlecrystal substrates, the trial fabrication of their thin films on technical substrates such as flexible metal tapes with biaxially textured buffer layers. Iida and his colleagues realized the biaxially textured growth of Co-Ba122 thin films on IBAD-MgO-buffered Hastelloy substrates by employing the Fe buffer architecture [88] which is typically used for the fabrication of coated conductors. The films exhibited in-plane misorientation $\Delta\Phi$ of about 5.1° , which was slightly smaller than that of the homoepitaxial MgO/IBAD- MgO layer. A broader transition width and a substantially lower self-field J_c than those for films on MgO single-crystal substrates was also shown by them, as shown in Figure13.

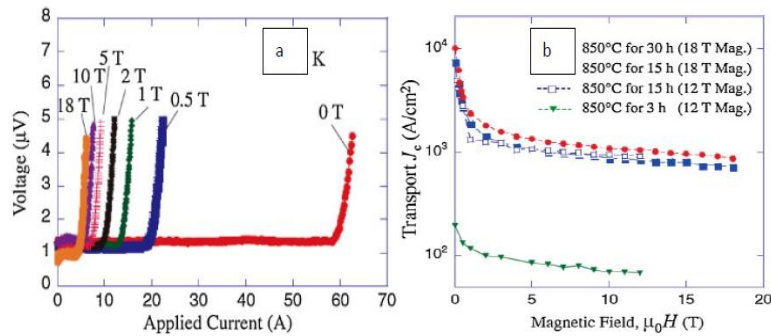


Figure12. (Color online) (a) For a K-Ba122 PIT wire heat-treated at 850 °C for 30 h typical voltage vs applied current curves measured. (b) Transport J_c as a function of applied magnetic field for the wires heat treated at 850 °C for 3, 15, and 30 h. Using an 18 T superconducting magnet, measurement was carried out in liquid helium (4.2 K).

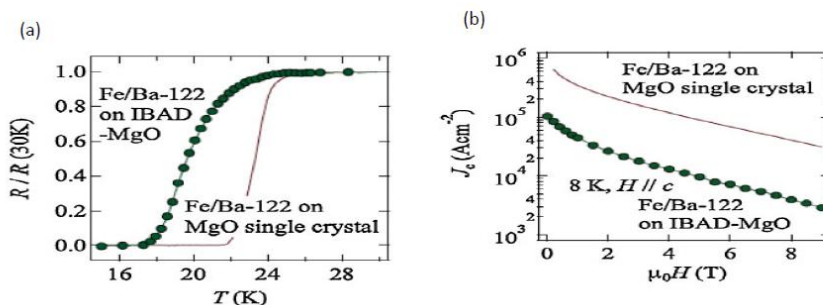


Figure13. (Color online) (a) Normalized resistance of a Co-Ba122 thin film on IBAD-MgO. The data were normalized to the value at 30 K. The resistance of a film on an MgO single-crystal substrate is also plotted for comparison. (b) J_c - H characteristics for the Co-Ba122 thin film on IBAD-MgO at 8K.

Alternatively, Katase and his colleagues directly prepared biaxially textured Co-Ba122 thin films on IBAD-MgO buffered Hastelloy substrates [89]. Fascinatingly, the films showed a small in-plane misorientation $\Delta\Phi$ of approximately 3° , despite the two times larger misorientation of the MgO base layers ($\Delta\Phi = 7.3^\circ$). Figure 14 shows how they exhibited a resistive transition as sharp as that for films on MgO single crystal substrates and high self-field J_c values of 1.2–3.6 MA/cm² at 2K. These results mean that using less well textured templates with a large $\Delta\Phi$, high- J_c Co-Ba122 coated conductors can be fabricated by a rather simple low-cost process, although further technical challenges are required toward realizing practical tapes such as an improvement in the vortex pinning properties by the introduction of suitable pinning centers and the enhancement of material T_c values. Li et al [90] has also been reported the fabrication of Fe (Se,Te) 11 type compound thin films on IBAD-MgO-buffered Hastelloy substrates and rolling-assisted biaxially textured substrates (RABiTS).

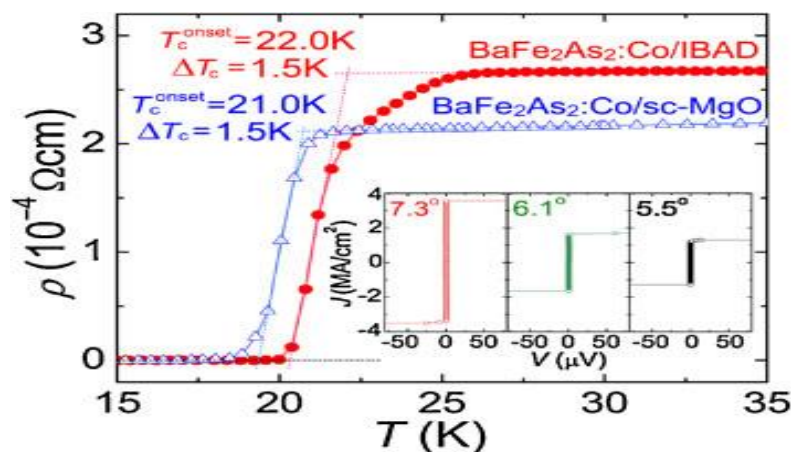


Figure14. ρ - T curves for Co-Ba122 thin films on IBAD-MgO substrate (circles) and single-crystal MgO (triangles). The inset shows the J - V characteristics at 2K of the films on IBAD-MgO with (left) $\Delta\Phi_{MgO} = 7.3^\circ$, (middle) 6.1° , and (right) 5.5°

For the Fe (Se,Te) films, they found an enhancement of T_c onset up to 20K. A nearly isotropic J_c of over 10^4 A/cm² at 4.2K under a magnetic field as high as 25 T, indicating the high potential of the iron-based superconductor for future high field applications has also been reported by them [91]. At low temperatures, Co-doped Ba122 films with a high self-field J_c of over 1MA/cm² have been demonstrated. By optimizing flux pinning centers and/or microstructures, further improvement of J_c preferably in high magnetic fields and at moderately high temperatures is required for the development of practical wires or tapes. Using Co-doped Ba122 with a T_c of approximately 22 K, although most of the above-mentioned demonstrations have been carried out, the application of iron-based superconductors with higher T_c values but similarly small anisotropy is desirable.

6. SUMMARY AND CONCLUSION

In review, we say that the iron-based superconductors promise interesting physics and applications. In this paper, we review the properties and applications of iron-based superconductors. The advantages and disadvantages of iron-based superconductors over high TC superconductors and cuprate-based superconductors have been also studied. Electronic structures and magnetic properties of iron-based superconductors are quite well understood. The iron-based superconductors provide an excellent chance to understand an unconventional superconductivity which might be helpful to reveal the origin of high- T_c superconductivity in copper oxides, Since electron-phonon interaction is too weak to explain the superconducting transition temperature as high as 55 K,. Finally we have studied the applications of iron-based superconductors in wire and tapes which will help to produce industrial products. For the researcher to do research and discover many new practical and possible applications of iron-based superconductors the topics described in this overview will be helpful. Based on iron, the discovery of this new class of superconductors has tremendously revitalized the field of superconductivity, and should provide many more surprises and promises for the future.

REFERENCES

- [1] J. G. Bednorz and K. A. Müller, "Possible high T_c superconductivity in the Ba-La-Cu-O system", Z. Phys. B 64, 189-193 (1986).
- [2] Y. Kamihara and his colleagues, "Iron-based layered superconductor: LaOFeP", J. Am. Chem. Soc. 128, 10012-10013 (2006).
- [3] Y. Kamihara, T. Watanabe, M. Hirano, and H. Hosono, "Iron-based layered superconductor La[O_{1-x}F_x]FeAs ($x = 0.05-0.12$) with $T_c = 26$ K", J. Am. Chem. Soc. 130, 3296-3297 (2008).
- [4] Kamihara, Y., and his colleagues (2006). Iron-based layered superconductor: LaOFeP. Journal of the American Chemical Society, 128, 10012–10013.
- [5] Kamihara, Y., Watanabe, T., Hirano, M., & Hosono, H. (2008). Iron-based layered superconductor La [O_{1-x}F_x]FeAs ($x = 0.05 - 0.12$) with $T_c = 26$ K. Journal of the American Chemical Society, 130, 3296.
- [6] Zhi-An, R., and his colleagues (2008). Superconductivity at 55 K in iron-based F-doped 1 ayered quaternary compound Sm[O_{1-x}F_x]FeAs. Chinese Physics Letters, 25, 2215.
- [7] Rotter, M., Tegel, M., & Johrendt, D. (2008). Superconductivity at 38 K in the iron arsenide (Ba_{1-x}K_x)Fe₂As₂. Physical Review Letters, 101, 107006.
- [8] H. Ogino and his colleagues, "Superconductivity at 17 K in (Fe₂P₂)(Sr₄Sc₂O₆): a new superconducting layered pnictide oxide with a thick perovskite oxide layer", Supercond. Sci. Technol. 22, 075008 (2009).
- [9] X. Zhu and his colleagues, "Transition of stoichiometric Sr₂VO₃FeAs to a superconducting state at 37.2 K", Phys. Rev. B 79, 220512(R) (2009).
- [10] S. Sato and his colleagues, "Superconductivity in a new iron pnictide oxide (Fe₂As₂)(Sr₄(Mg,Ti)₂O₆)", Supercond. Sci. Technol. 23, 045001 (2010).
- [11] K.-W. Lee and W. E. Pickett, "Sr₂VO₃FeAs: a nanolayered bimetallic iron pnictide superconductor", Euro. Phys. Lett. 89, 57008 (2010).
- [12] J. Guo and his colleagues, "Superconductivity in the iron selenide K_xFe₂Se₂ ($0 \leq x \leq 1.0$)", Phys. Rev. B 82, 180520(R) (2010).
- [13] Y. Zhang and his colleagues, "Nodeless superconducting gap in A_xFe₂Se₂ (A=K, Cs) revealed by angle-resolved photoemission spectroscopy", Nature Mater. 10, 273-277 (2011).
- [14] D. Mou and his colleagues, "Distinct Fermi surface topology and nodeless superconducting gap in a (Tl_{0.58}Rb_{0.42})Fe_{1.72}Se₂ superconductor", Phys. Rev. Lett. 106, 107001 (2011).

- [15] A. F. Wang and his colleagues, "Superconductivity at 32 K in single-crystalline $\text{RbxFe}_2\text{-ySe}_2$ ", *Phys. Rev. B* 83, 060512(R) (2011).
- [16] Kamihara, Yoichi; Watanabe, Takumi; Hirano, Masahiro and Hosono, Hideo (2008). "Iron-Based Layered Superconductor $\text{La}[\text{O}_{1-x}\text{Fx}]\text{FeAs}$ ($x = 0.05\text{--}0.12$) with $T_c = 26$ K". *Journal of the American Chemical Society* 130 (11): 3296–3297. doi:10.1021/ja800073m. PMID 18293989
- [17] Chen, X. H.; Wu, T.; Wu, G.; Liu, R. H.; Chen, H. and Fang, D. F. (2008). "Superconductivity at 43 K in $\text{SmFeAsO}_{1-x}\text{Fx}$ ". *Nature* 453 (7196): 761–762. Bibcode:2008Natur.453..761C. doi:10.1038/nature07045. PMID 18500328.
- [18] Ren, Zhi-An; Che, Guang-Can; Dong, Xiao-Li; Yang, Jie; Lu, Wei; Yi, Wei; Shen, Xiao-Li; Li, Zheng-Cai; Sun, Li-Ling; Zhou, Fang; Zhao, Zhong-Xian (2008). "Superconductivity and phase diagram in iron-based arsenic-oxides $\text{ReFeAsO}_{1-\delta}$ (Re = rare-earth metal) without fluorine doping". *EPL (Europhysics Letters)* 83: 17002. arXiv:0804.2582. Bibcode:2008EL.....8317002R. doi:10.1209/0295-5075/83/17002.
- [19] Rotter, Marianne; Tegel, Marcus and Johrendt, Dirk (2008). "Superconductivity at 38 K in the Iron Arsenide $(\text{Ba}_{1-x}\text{K}_x)\text{Fe}_2\text{As}_2$ ". *Physical Review Letters* 101 (10): 107006. arXiv:0805.4630. Bibcode:2008PhRvL.101j7006R. doi:10.1103/PhysRevLett.101.107006. PMID 18851249.
- [20] Sasmal, K.; Lorenz, Bernd; Guloy, Arnold M.; Chen, Feng; Xue, Yu-Yi; Chu, Ching-Wu (2008). "Superconducting Fe-Based Compounds $(\text{A}_{1-x}\text{Srx})\text{Fe}_2\text{As}_2$ with $\text{A}=\text{K}$ and Cs with Transition Temperatures up to 37 K". *Physical Review Letters* 101 (10): 107007. Bibcode:2008PhRvL.101j7007S. doi:10.1103/physrevlett.101.107007. PMID 18851250.
- [21] Shirage, Parasharam Maruti; Miyazawa, Kiichi; Kito, Hijiri; Eisaki, Hiroshi; Iyo, Akira (2008). "Superconductivity at 26 K in $(\text{Ca}_{1-x}\text{Nax})\text{Fe}_2\text{As}_2$ ". *Applied Physics Express* 1: 081702. Bibcode:2008APExp...1h1702M. doi:10.1143/APEX.1.081702.
- [22] Wang, X.C.; Liu, Q.Q.; Lv, Y.X.; Gao, W.B.; Yang, L.X.; Yu, R.C.; Li, F.Y.; Jin, C.Q. (2008). "The superconductivity at 18 K in LiFeAs system". *Solid State Communications* 148 (11–12): 538–540. arXiv:0806.4688. Bibcode:2008SSCom.148..538W. doi:10.1016/j.ssc.2008.09.057.
- [23] Pitcher, Michael J.; Parker, Dinah R.; Adamson, Paul; Herkelrath, Sebastian J. C.; Boothroyd, Andrew T.; Ibberson, Richard M.; Brunelli, Michela; Clarke, Simon J. (2008). "Structure and superconductivity of LiFeAs ". *Chemical Communications* (45): 5918–20. doi:10.1039/b813153h. PMID 19030538.
- [24] Tapp, Joshua H.; Tang, Zhongjia; Lv, Bing; Sasmal, Kalyan; Lorenz, Bernd; Chu, Paul C. W.; Guloy, Arnold M. (2008). " LiFeAs : An intrinsic FeAs -based superconductor with $T_c=18$ K". *Physical Review B* 78 (6): 060505. arXiv:0807.2274. Bibcode:2008PhRvB..78f0505T. doi:10.1103/PhysRevB.78.060505.
- [25] Chu, C.W.; Chen, F.; Gooch, M.; Guloy, A.M.; Lorenz, B.; Lv, B.; Sasmal, K.; Tang, Z.J.; Tapp, J.H.; Xue, Y.Y. (2009). "The synthesis and characterization of LiFeAs and NaFeAs ". *Physica C: Superconductivity* 469 (9–12): 326–331. arXiv:0902.0806. Bibcode:2009PhyC..469.326C. doi:10.1016/j.physc.2009.03.016.
- [26] Parker, Dinah R.; Pitcher, Michael J. and Clarke, Simon J. (2008). "Structure and superconductivity of the layered iron arsenide NaFeAs ". *Chemical Communications* 2189 (16): 2189. arXiv:0810.3214. doi:10.1039/B818911K.
- [27] Zhang, S. J.; Wang, X. C.; Liu, Q. Q.; Lv, Y. X.; Yu, X. H.; Lin, Z. J.; Zhao, Y. S.; Wang, L.; Ding, Y.; Mao, H. K.; Jin, C. Q. (2009). "Superconductivity at 31 K in the "111"-type iron arsenide superconductor $\text{Na}_{1-x}\text{FeAs}$ induced by pressure". *EPL (Europhysics Letters)* 88 (4): 47008. Bibcode:2009EL.....8847008Z. doi:10.1209/0295-5075/88/47008.
- [28] Deng, Z.; Wang, X. C.; Liu, Q. Q.; Zhang, S. J.; Lv, Y. X.; Zhu, J. L.; Yu, R. C.; Jin, C. Q. (2009). "A new "111" type iron pnictide superconductor LiFeP ". *EPL (Europhysics Letters)* 87 (3): 37004. Bibcode:2009EL.....8737004D.
- [29] Stewart, G. R. (2011). "Superconductivity in iron compounds". *Rev. Mod. Phys.* 83 (4): 1589. Bibcode:2011RvMP...83.1589S. doi:10.1103/revmodphys.83.1589.
- [30] H. Takahashi and his colleagues, "Superconductivity at 43 K in an iron-based layered compound $\text{LaO}_{1-x}\text{FxFeAs}$ ", *Nature (London)* 453, 376-378 (2008).
- [31] X. H. Chen and his colleagues, "Superconductivity at 43 K in $\text{SmFeAsO}_{1-x}\text{Fx}$ ", *Nature (London)* 453, 761-762 (2008)
- [32] Kamihara and his colleagues, *J. Am. Chem. Soc.* 128, 10012 (2006).
- [33] G. F. Chen and his colleagues, "Superconductivity at 41 K and its competition with spin-density-wave instability in layered $\text{CeO}_{1-x}\text{FxFeAs}$ ", *Phys. Rev. Lett.* 100, 247002 (2008).
- [34] Z. A. Ren and his colleagues, "Superconductivity at 52 K in iron based F doped layered quaternary compound $\text{Pr}[\text{O}_{1-x}\text{Fx}]\text{FeAs}$ ", *Mater. Res. Innov.* 12, 105-106 (2008).

- [35] K. Miyazawa and his colleagues, “Superconductivity above 50 K in LnFeAsO_{1-y} (Ln=Nd, Sm, Gd, Tb, and Dy) synthesized by high-pressure technique”, *J. Phys. Soc. Jpn.* 78, 034712 (2009).
- [36] Z.-A. Ren and his colleagues, “Superconductivity at 55 K in iron-based F-doped layered quaternary compound Sm[O_{1-x}F_x]FeAs”, *Chin. Phys. Lett.* 25, 2215-2216 (2008).
- [37] C. de la Cruz and his colleagues, “Magnetic order close to superconductivity in the iron-based layered LaO_{1-x}F_xFeAs systems”, *Nature (London)* 453, 899-902 (2008).
- [38] N. Qureshi and his colleagues, “Crystal and magnetic structure of the oxypnictide superconductor LaFeAsO_{1-x}F_x: a neutron-diffraction study”, *Phys. Rev. B* 82, 184521 (2010).
- [39] J. Zhao and his colleagues, “Structural and magnetic phase diagram of CeFeAsO_{1-x}F_x and its relation to high-temperature superconductivity”, *Nature Mater* 7, 953-959 (2008).
- [40] M. Putti, I. Pallecchi, E. Bellingeri, M. R. Cimberle, M. Tropeano, C. Ferdeghini, A. Palenzona, C. Tarantini, A. Yamamoto, J. Jiang, J. Jaroszynski, F. Kametani, D. Abraimov, A. Polyanskii, J. D. Weiss, E. E. Hellstrom, A. Gurevich, D. C. Larbalestier, R. Jin, B. C. Sales, A. S. Sefat, M. A. McGuire, D. Mandrus, P. Cheng, Y. Jia, H. H. Wen, S. Lee, and C. B. Eom: *Supercond. Sci. Technol.* 23 (2010) 034003.
- [41] J. Jaroszynski, F. Hunte, L. Balicas, Y.-J. Jo, I. Raic̃ević, A. Gurevich, D. C. Larbalestier, F. F. Balakirev, L. Fang, P. Cheng, Y. Jia, and H. H. Wen: *Phys. Rev. B* 78 (2008) 174523.
- [42] Z. S. Wang, H. Q. Luo, C. Ren, and H. H. Wen: *Phys. Rev. B* 78 (2008) 140501.
- [43] M. Rotter, M. Tegel, and D. Johrendt, “Superconductivity at 38 K in the iron arsenide (Ba_{1-x}K_x)Fe₂As₂”, *Phys. Rev. Lett.* 101, 107006 (2008).
- [44] X. C. Wang and his colleagues, “The superconductivity at 18 K in LiFeAs system”, *Solid State Commun.* 148, 538-540 (2008).
- [45] R. Mittal and his colleagues, “Phonon dynamics in Sr_{0.6}K_{0.4}Fe₂As₂ and Ca_{0.6}Na_{0.4}Fe₂As₂ from neutron scattering and lattice-dynamical calculations”, *Phys. Rev. B* 78, 224518 (2008).
- [46] R. Cortes-Gil and S. J. Clarke, “Structure, magnetism, and superconductivity of the layered iron arsenides Sr_{1-x}Na_xFe₂As₂”, *Chem. Mater.* 23, 1009-1016 (2011).
- [47] F.-C. Hsu and his colleagues, “Superconductivity in the PbO-type structure α -FeSe”, *Proc. Natl. Acad. Sci. U.S.A.* 105, 14262-14264 (2008).
- [48] M. Rotter, M. Pangerl, M. Tegel, and D. Johrendt, “Superconductivity and crystal structures of (Ba_{1-x}K_x)Fe₂As₂ (x=0–1)”, *Angew. Chem. Int. Ed.* 47, 7949-7952 (2008). “Superconductivity and crystal structures of (Ba_{1-x}K_x) Fe₂As₂ (x=0–1)”, *Angew. Chem. Int. Ed.* 47, 7949-7952 (2008).
- [49] N. Ni and his colleagues, “Effects of Co substitution on thermodynamic and transport properties and anisotropic ρ_{c2} in Ba(Fe_{1-x}Co_x)₂As₂ single crystals”, *Phys. Rev. B* 78, 214515 (2008).
- [50] S. Jiang and his colleagues, “Superconductivity up to 30 K in the vicinity of the quantum critical point in BaFe₂(As_{1-x}P_x)₂”, *J. Phys.: Condens. Matter* 21, 382203 (2009).
- [51] J. Paglione and R. L. Greene, “High-temperature superconductivity in iron-based materials”, *Nature Phys.* 6, 645-658 (2010).
- [52] T. Park and his colleagues, “Pressure-induced superconductivity in CaFe₂As₂”, *J. Phys.: Condens. Matter* 20, 322204 (2008).
- [53] N. Doiron-Leyraud and his colleagues, “Quantum oscillations and the Fermi surface in an underdoped high-T_c superconductor”, *Nature (London)* 447, 565-568(2007).
- [54] B. Maiorov, T. Katase, S. A. Baily, H. Hiramatsu, T. G. Holesinger, H. Hosono, and L. Civale: *Supercond. Sci. Technol.* 24 (2011) 055007.
- [55] F.-C. Hsu and his colleagues, “Superconductivity in the PbO-type structure α -FeSe”, *Proc. Natl. Acad. Sci. U.S.A.* 105, 14262-14264 (2008).
- [56] S. Medvedev and his colleagues, “Electronic and magnetic phase diagram of β -Fe_{1.01}Se with superconductivity at 36.7 K under pressure”, *Nature Mater.* 8, 630-633 (2009).
- [57] B. C. Sales and his colleagues, “Bulk superconductivity at 14 K in single crystals of Fe_{1+y}Te_xSe_{1-x}”, *Phys. Rev. B* 79, 094521 (2009).
- [58] R. Hu, E. S. Bozin, J. B. Warren, and C. Petrovic, “Superconductivity, magnetism, and stoichiometry of single crystals of Fe_{1+y}(Te_{1-x}S_x)_z”, *Phys. Rev. B* 80, 214514 (2009).
- [59] Y. Mizuguchi, F. Tomioka, S. Tsuda, T. Yamaguchi, and Y. Takano, “Superconductivity in S-substituted FeTe”, *Appl. Phys. Lett.* 94, 012503 (2009).
- [60] J. H. Tapp, Z. Tang, B. Lv, K. Sasmal, B. Lorenz, C. W. Chu, and A. M. Guloy: *Phys. Rev. B* 78 (2008) 060505.

- [61] J. Shimoyama, K. Kitazawa, K. Shimizu, S. Ueda, S. Horii, N. Chikumoto, and K. Kishio: *J. Low Temp. Phys.* 131 (2003) 1043.
- [62] H. Ogino, S. Sato, N. Kawaguchi, Y. Shimizu, K. Machida, A. Yamamoto, K. Kishio, and J. Shimoyama: presented at Int. Workshop Novel Superconductors and Super Materials, 2011 (N2S2011)
- [63] X. Wang, Q. Q. Liu, Y. X. Lv, W. B. Gao, L. X. Yang, R. C. Yu, F. Y. Li, and C. Q. Jin, *Solid State Commun.* 148, 538 (2008).
- [64] J. H. app, Zh. Tang, B. Lv, K. Sasmal, B. Lorenz, P. C. W. Chu, and A. M. Guloy, *Phys. Rev. B* 78, 060505 (2008).
- [65] S. V. Borisenko, V. B. Zabolotnyy, D. V. Evtushinsky, T. K. Kim, I. V. Morozov, A. N. Yaresko, A. A. Kordyuk, G. Behr, A. Vasiliev, R. Follath, and B. B uchner, *Phys. Rev. Lett.* 105, 067002 (2010).
- [66] A. A. Kordyuk, V. B. Zabolotnyy, D. V. Evtushinsky, T. K. Kim, I. V. Morozov, M. L. Kulić, R. Follath, G. Behr, B. B uchner, and S. V. Borisenko, *Phys. Rev. B* 83, 134513 (2011).
- [67] S. V. Borisenko, V. B. Zabolotnyy, A. A. Kordyuk, D. V. Evtushinsky, T. K. Kim, I. V. Morozov, R. Follath, and B. B uchner, *Symmetry* 4, 251 (2012).
- [68] I. Morozov, A. Boltalin, O. Volkova, A. Vasiliev, O. Kataeva, U. Stockert, M. Abdel-Hafiez, D. Bombor, A. Bachmann, L. Harnagea, M. Fuchs, H.-J. Grafe, G. Behr, R. Klingeler, S. Borisenko, Ch. Hess, S. Wurmehl, and B. B uchner, *Cryst. Growth Des.* 10, 4428 (2010).
- [69] G. F. Chen, W. Z. Hu, J. L. Luo, and N. L. Wang, *Phys. Rev. Lett.* 102, 227004 (2009).
- [70] S. Li, C. de la Cruz, Q. Huang, G. F. Chen, T.-L. Xia, J. L. Luo, N. L. Wang, and P. Dai, *Phys. Rev. B* 80, 020504 (2009).
- [71] M. A. Tanatar, N. Spyrison, K. Cho, E. C. Blomberg, G. Tan, P. Dai, Ch. Zhang, and R. Prozorov, *Phys. Rev. B* 85, 014510 (2012).
- [72] D. R. Parker, M. J. P. Smith, T. Lancaster, A. J. Steele, I. Franke, P. J. Baker, F. L. Pratt, Michael J. Pitcher, S. J. Blundell, and Simon J. Clarke, *Phys. Rev. Lett.* 104, 057007 (2010).
- [73] C. He, Y. Zhang, B. P. Xie, X. F. Wang, L. X. Yang, B. Zhou, F. Chen, M. Arita, K. Shimada, H. Namatame, M. Taniguchi, X. H. Chen, J. P. Hu, and D. L. Feng, *Phys. Rev. Lett.* 105, 117002 (2010).
- [74] C. He, Y. Zhang, X. F. Wang, J. Jiang, F. Chen, L. X. Yang, Z. R. Ye, Fan Wu, M. Arita, K. Shimada, H. Namatame, M. Taniguchi, X. H. Chen, B. P. Xie, and D. L. Feng, *J. Phys. Chem. Solids* 72, 479 (2011).
- [75] K. Segawa and Y. Ando, *J. Phys. Soc. Jpn.* 78, 104720 (2009). 73B. C. Sales, A. S. Sefat, M. A. McGuire, R. Y. Jin, D. Mandrus
- [76] G. Osabe, N. Ayai, M. Kikuchi, K. Tatamidani, T. Nakashima, J. Fujikami, T. Kagiya, K. Yamazaki, S. Yamade, E. Shizuya, S. Kobayashi, K. Hayashi, K. Sato, J. Shimoyama, H. Kitaguchi, and H. Kumakura: *Physica C* 470 (2010) 1365.
- [77] Z. Gao, L. Wang, Y. Qi, D. Wang, X. Zhang, and Y. Ma: *Supercond. Sci. Technol.* 21 (2008) 105024.
- [78] Z. Gao, L. Wang, Y. Qi, D. Wang, X. Zhang, Y. Ma, H. Yang, and H. Wu: *Supercond. Sci. Technol.* 21 (2008) 112001.
- [79] Y. Qi, X. Zhang, Z. Gao, Z. Zhang, L. Wang, D. Wang, and Y. Ma: *Physica C* 469 (2009) 717.
- [80] L. Wang, Y. Qi, D. Wang, X. Zhang, Z. Gao, Z. Zhang, Y. Ma, S. Awaji, G. Nishijima, and K. Watanabe: *Physica C* 470 (2010) 183.
- [81] Y. Qi, L. Wang, D. Wang, Z. Zhang, Z. Gao, X. Zhang, and Y. Ma: *Supercond. Sci. Technol.* 23 (2010) 055009.
- [82] Y. Ma, L. Wang, Y. Qi, Z. Gao, D. Wang, and X. Zhang: *IEEE Trans. Appl. Supercond.* 21 (2011) 2878.
- [83] K. Togano, A. Matsumoto, and H. Kumakura: *Appl. Phys. Express* 4 (2011) 043101.
- [84] M. Fujioka, T. Kota, M. Matoba, T. Ozaki, Y. Takano, H. Kumakura, and Y. Kamihara: *Appl. Phys. Express* 4 (2011) 063102.
- [85] L. Wang, Y. Ma, Q. Wang, K. Li, X. Zhang, Y. Qi, Z. Gao, X. Zhang, DWang, C. Yao, and C. Wang: *Appl. Phys. Lett.* 98 (2011) 222504
- [86] Y. Mizuguchi, K. Deguchi, S. Tsuda, T. Yamaguchi, H. Takeya, H. Kumakura, and Y. Takano: *Appl. Phys. Express* 2 (2009) 083004.
- [87] T. Ozaki, K. Deguchi, Y. Mizuguchi, H. Kumakura, and Y. Takano: *IEEE Trans. Appl. Supercond.* 21(2011) 2858.
- [88] T. Ozaki, K. Deguchi, Y. Mizuguchi, Y. Kawasaki, T. Tanaka, T. Yamaguchi, H. Kumakura, and Y. Takano: to be published in *J. Appl. Phys.*

- [89] K. Iida, J. Hahnisch, S. Trommler, V. Matias, S. Haindl, F. Kurth, I. L. del Pozo, R. Hühne, M. Kieszun, J. Engelmann, L. Schultz, and B. Holzapfel: *Appl. Phys. Express* 4 (2011) 013103.
- [90] T. Katase, H. Hiramatsu, V. Matias, C. Sheehan, Y. Ishimaru, T. Kamiya, K. Tanabe, and H. Hosono: *Appl. Phys. Lett.* 98 (2011) 242510.
- [91] Q. Li, W. Si, Q. Jie, J. Zhu, S. Solovyov, A. Goyal, and V. Matias: presented at Applied Superconductivity Conf., 2010 (ASC2010).
- [92] W. Si, J. Zhou, Q. Jie, I. Dimitrov, V. Solovyov, P. D. Johnson, J. Jaroszynski, V. Matias, C. Sheehan, and Q. Li: *Appl. Phys. Lett.* 98 (2011) 262509.
- [93] <http://www.superconductors.org/Type1.htm>.
- [94] <http://www.superconductors.org/Type2.htm>.
- [95] K. Tanabe: *Butsuri* 66 (2011) 773 [in Japanese].
- [96] Y. Kamihara, T. Watanabe, M. Hirano, and H. Hosono: *J. Am. Chem. Soc.* 130 (2008) 3296.

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