The recent discovery of superconductivity in the iron oxypnictides \( \text{LnO}_{1-x}\text{F}_x\text{FeAs} \) (\( \text{Ln} = \text{La, Sm, Nd, etc.} \)) with transition temperatures \( (T_c) \) well beyond the McMillan limit for BCS superconductors has rejuvenated intensive research on unconventional superconductivity \[1, 2, 3, 4, 5, 6, 7\]. In some ways, the layered structure of an iron-based superconductor resembles the high-\( T_c \) cuprates: \( \text{LnO}_{1-x}\text{F}_x\text{FeAs} \) layers act as the charge reservoir, and \( \text{FeAs} \) layers act as the conducting layers. Moreover, neutron diffraction measurements show that the ground state of the parent compound \( \text{LaOFeAs} \) is a spin density wave (SDW) \[8\]. This makes the phase diagrams of both groups observed a spectral weight suppression which was related to superconducting gaps of about 4 ~ 5meV for LOFFA's, and a superconducting gap of about 1 meV for LOFFP. Intriguingly, they are all about \( 2k_BT_c \).

Photoemission is sensitive to surface and sample quality, systematics thus needs to be collected before reaching a robust conclusion when dealing with polycrystals. However, so far only one doping of each material was measured in individual studies. In this paper, we report systematic AIPES measurement of polycrystalline \( \text{SmO}_{1-x}\text{F}_x\text{FeAs} \) (SOFFA) with a variety of dopings (\( x = 0, 0.12, 0.15, 0.2 \)). At high temperatures, we observed a DOS suppression over a large energy scale of 80 meV, whose onset temperature is even higher than 300K. At low temperatures, a V-shaped lineshape around the energy scale of 10 meV was observed in the symmetrized spectra. Surprisingly, we found that both}

![Resistivity graph](image-url)
kinds of suppressions are doping-independent, very different from the pseudogap behaviors in cuprates. The low energy suppression scale of 10 meV corresponds to \(2k_B T_{c, \text{max}}\), where \(T_{c, \text{max}}\) is the maximum \(T_c\) of 54K for SOFFA’s. Considering similar correlations in LOFFA and LOFFFP, it suggests that the 10 meV suppression reflects an intrinsic pseudogap in the normal state, which evolves into the superconducting gap at low temperatures. However, it is not clear at this stage whether the 80 meV scale is related to an intrinsic pseudogap effect, or caused by extrinsic effects such as inhomogeneities and domain boundaries of the polycrystal.

Polycrystalline SmO_{1-x}F_xFeAs (x=0, 0.12, 0.15, 0.2) have been synthesized through solid state reaction, the detailed information about the synthesis and characterization of the sample has been described elsewhere\(^{13}\). Resistivity data (Fig.1) clearly indicate the superconducting transition occurs at 25K, 42K, 47K, and 54K for x=0.12, 0.15, 0.2(\#2), and 0.2(\#1) respectively. The Meissner volumes were estimated to be 50 \(\sim\) 60% according to the susceptibility measurements, which is among the best for the polycrystalline samples synthesized so far. The resistivity of the parent compound exhibits a similar peak at around 150K similar to that observed in LOFFA, indicative of a possible SDW and/or structure phase transition in SOFFA\(^{8}\).

Photoemission measurements were performed at beam line 5-4 of Stanford Synchrotron Radiation Laboratory (SSRL) and beam line 9 of Hiroshima Synchrotron Radiation Center (HiSOR), data were taken with Scienta R4000 electron analyzers. The overall energy resolution was set to 7 meV. The sample rod was cracked \textit{in-situ} and then measured in ultra-high vacuum (~3 \(\times\) 10\(^{-11}\) mbar).

We emphasize that all the sample surfaces prepared in this way show consistent results, and the data measured with 22.7 eV photons agree with those measured with more bulk sensitive 8eV photons (shown in Fig.4), indicative of the high sample quality.

The AIPES spectra of SmO_{1-x}F_xFeAs are shown in Fig.2, which measure the DOS. There is a broad low energy feature around 0.22 eV below \(E_F\), whose position seems to be quite doping independent. The low energy feature was attributed to Fe 3d states in various band calculations\(^{16, 17, 18, 19, 20}\). Our data, especially the peak at 0.22 eV and the flat DOS between 0.5 eV to 3 eV binding energy (see inset of Fig.2)\(^{21}\), agree best with the calculation that considers an antiferromagnetic ground state\(^{19, 20}\). On the other hand, this low energy feature does not show up in dynamical mean field theory calculation\(^{22}\).

The evolution of DOS near \(E_F\) is studied as a function of doping and temperature. As shown in Fig.3(a1-d1), the lineshape evolution above and below \(E_F\) clearly differs from the symmetrical Fermi-Dirac distribution function normally observed on a polycrystalline metal. The spectra \([n(\omega)]\) are symmetrized to remove the thermal broadening effects\(^{23}\), and the resulting \(n(\omega)+n(-\omega)\) are shown in Fig.3(a2-d2) respectively. This has been commonly practiced in the study of gap in cuprate superconductors. In this way, a spectra weight suppression with decreasing temperature is clearly revealed, which occurs at the highest measured temperature over the energy range of \(\pm 80 \text{ meV}\). With decreasing temperature, further suppressions of the DOS happen in a smoothly shrinking energy window around \(E_F\), as shown by the arrows and summarized in Fig.3e. This resembles the anisotropic pseudogap opening behavior in cuprates, where gap of larger size opens at higher temperature\(^{23}\). It also indicates the maximum gap could well exceed 80 meV. However, unlike the cuprates, the suppression has no doping dependence. All AIPES spectra exhibit similar behavior in the entire investigated doping range. As quantified in Fig.3f, the DOS at \(E_F\) has almost the same linear temperature dependence when normalized by their values at 300K.

To study the superconducting state, high resolution AIPES spectra were measured with 1 meV steps near the Fermi energy at low temperatures in Fig.4(a1-d1). The insets in Fig.4(a1-d1) show the enlargement near \(E_F\), the cross-points indicate a leading-edge gap of 1 \(\sim\) 4 meV fluctuating with sample. The corresponding symmetrized angle-integrated spectra are shown in Fig.4(a2-d2). There is clearly an additional abrupt drop of DOS at a fixed characteristic energy scale of 10 meV at low temperatures (see Fig.3c), which eventually causes a V-shaped DOS near \(E_F\) at the lowest temperatures. The 10 meV energy scale itself is quite intriguing, since it is about \(2k_B T_{c, \text{max}}\) for SmO_{1-x}F_xFeAs. Similar low energy scales of \(2k_B T_c\) have been observed for LOFFA\(^{12, 13}\).
and LOFFP[13], therefore it is likely an intrinsic pseudogap related to pairing fluctuation in the normal state. This gap might have started to open above 100K, but the thermal broadening prevents it being observed. If the pseudogap/superconducting gap transition in optimally doped cuprates could apply here, it naturally evolves into the superconducting gap once the system enters the superconducting state. It is remarkable that such a pseudogap is doping independent and very small in SOFFA, compared with the large and doping dependent pseudogap in cuprates. Furthermore, the V-shaped DOS with finite value at $E_F$ indicates an anisotropic gap with nodes or Fermi arc in the superconducting state[21].

The doping-independent DOS suppressions do raise the question whether they are artifacts from the polycrystalline nature of the sample. Although the Meissner ratio is 50~60% for the superconducting samples, as high as currently one could get, still there are 40~50% non-superconducting part in the polycrystal, which might come from the domain boundary or inhomogeneity of the fluorine dopants or oxygen vacancies. It is not surprising if this portion of the polycrystal could be independent of doping, and cause the observed 30% spectral weight suppression at $E_F$. Furthermore, the quite large DOS around $E_F$ at 10K could be also attributed to the non-superconducting portion besides the possible nodes or Fermi arc of the superconducting portion, which naturally explains the fluctuating leading edge gaps as well. However, for the suppression at 10 meV energy scale, its correlation with $T_{c_{\text{max}}}$ in several systems indicates that it should be an intrinsic effects from the bulk part of the polycrystal. For the suppression at 80 meV energy scale, there is no strong evidence to exclude the extrinsic polycrystalline effects, except the fact that this energy scale is smoothly connected to the 10 meV scale as shown in Fig.3e.

To summarize, we have found doping independent behavior of the spectral weight suppression
FIG. 4: (color online) Temperature dependence of the SmO$_{1-x}$F$_x$FeAs AIPES spectrum near $E_F$ at low temperatures for (a1) $x = 0.2$, $T_c = 54K$, (b1) $x = 0.2$, $T_c = 47K$, (c1) $x = 0.12$, $T_c = 25K$ and (d1) $x = 0$ respectively. The corresponding symmetrized spectra are shown in (a2-d2) respectively. Data in (b1-d1) were taken with 22.7 eV photons at SSRL, while data in (a1) were taken with 8 eV photons at HiSOR.

SmO$_{1-x}$F$_x$FeAs. A large “pseudogap” of 80 meV is observed from the highest measured temperature, whose origin is currently unclear, and debatably, could be extrinsic. A smaller gap of 10 meV becomes observable below 100K, which is likely an intrinsic pseudogap in the normal state, and would become a superconducting gap once in the superconducting state. Therefore, the pseudogap behavior in iron oxyynitrides is very different from that in cuprate superconductors. Moreover, our data alert that the results obtained from polycrystalline iron oxynitrides have to be interpreted with caution.

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Note added: During the preparation of this manuscript, we noticed another work on SmO$_{1-x}$F$_x$FeAs is posted online[24].

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