BL-8A, 8B/2013S2-002

# Bipartite magnetic parent phases in the iron oxypnictide superconductor

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A new class of high-$T_c$ superconductor iron-based materials has been widely studied since the discovery in 2008. In the first obtained iron-based superconductor, ZrCuSiAs-type LaFeAsO, the superconductivity emerges via doping the carrier to the non-doped parent compound with magnetic- and structural-ordered states. An advanced doping method using a hydrogen anion instead of fluorine in LaFeAsO surpassed the doping limit of fluorine, and uncovered the second superconducting phase (SC2) ($T_{c,max}$ = 36 K at $x$ ~ 0.35), following to the first dome (SC1) ($T_{c,max}$ = 26 K at $x$ ~ 0.1) [1]. To determine whether a certain hidden phase exists beyond the SC2 region, we performed X-ray powder diffraction measurements for $LaFeAsO_{1-x}H_x$ on the beamlines of 8A/8B at KEK-PF.

Figure 1(a) shows the X-ray profile of the $(2, 2, 0)_T$ reflection in the non-superconducting state with $x$ = 0.51. On cooling, the peak of $(2, 2, 0)_T$ was broadened, while, any broadening of the $(0, 0, 6)_T$ and $(2, 0, 0)_T$ peaks were not observed [2]. The experimental findings suggest that the tetragonal-orthorhombic structural transition emerges clearly in $x$ = 0.51. Figure 1(b) shows the temperature dependence of the lattice parameters for $x$ = 0.51. The $a$-axis length splits in two below the structural transition of $T_s$ ~ 95 K, and the $c$-axis shows an upturn at $T_s$. The X-ray powder-diffraction structural analysis with RIETAN-FP program [3] using high-resolution synchrotron radiation source provides the interesting result that the $x$ = 0.51 compound crystallizes in an orthorhombic non-centrosymmetric *Aem*2 structure below $T_s$ in contrast to the centrosymmetric *Cmme* structure for $x$ = 0. Across the structural transition, only the As atoms moves slightly in $x$ = 0, while, the Fe and As atoms move in antiphase in $x$ = 0.51 as shown in the inset of Fig. 1(c) .

In the neutron powder diffraction measurement for x = 0.51, we observed magnetic peaks below $T_N$ = 89 K with the propagation vector of $\mathbf{q}$ = (1/2, 1/2, 0). The magnetic structure analysis reveals an exceptional stripe-type arrangement among the iron-pnictides as shown in the inset of Fig. 1(d). The magnetic moment 1.2 $\mu_B$ per iron atom is significantly larger than the value of 0.63 $\mu_B$ for $x$ = 0. In the muon spin relaxation measurements, we observed that the value of $T_N$ and the magnetic volume fraction decrease in unison with decreasing the hydrogen contents from $x$ = 0.51.

Figure 1(d) illustrates the comprehended phase diagram of $LaFeAsO_{1-x}H_x$ [2]. We note a new antiferromagnetic phase with the structural transition next to the superconducting phase that can be regarded as the doped parent phase by the analogy of the non-doped antiferromagnetic ordered phase with the structural transition. This is unexpected result because the magnetic and electronic interactions are usually perceived as being weak by highly carrier-doping. We would account that in the iron-pnictides the parent compound not only refers to the non-doped compound but also more generally indicates a certain critical phase of the magnetic and electronic correlations. We can, moreover, definitely state that the two SC domes come from carrier-doping to the left- and right-hand parent compounds towards the intermediate region of the phase diagram.

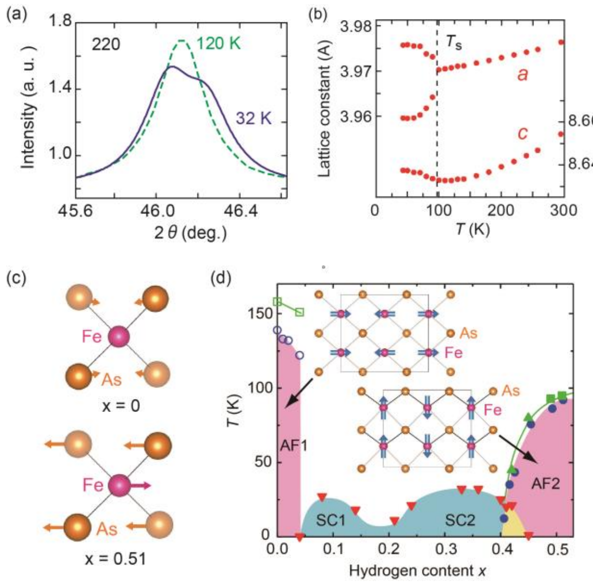


Fig.1 (a) X-ray profiles of $(2, 2, 0)_T$ reflections for $LaFeAsO_{0.49}H_{0.51}$ at 120 K and 32 K. (b) Temperature dependence of the lattice constant for $LaFeAsO_{0.49}H_{0.51}$. (c) Schematic of the atom displacements across the structural transition for $x$ = 0 and 0.51. (d) Phase diagram of $LaFeAsO_{1-x}H_x$. AF1 and AF2 represent the original and the advanced parent phases, respectively.

References

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