First investigation of superconducting phase diagram in the simplest iron-based superconductor

-Pressure induced superconductor-metal phase transition in $FeSe_{0.5}Te_{0.5}$-

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The research group of Dr. K. Horigane and Prof. K. Yamada in WPI has revealed the superconducting phase diagram of the simplest iron-based superconductor including the pressure-induced metallic phase for the first time.

The research result is published in Journal of Physical Society of Japan (JPSJ) in June 2009. This work was selected as a paper of Editor's Choice in JPSJ.

<Background>

Since the discovery of iron-based high-temperature superconductor $LaFeAs(O_{1-x}F_x)$, a lot of iron-based superconductors have been made to search for new superconducting materials and the recent observations of superconducting transition temperature, T_c, are raised up to 55K in $LaFeAs(O_{1-x}F_x)$. T_c of iron-based superconductor is as high as that of cuprate superconductor, therefore extensive attentions have been paid to elucidate the mechanism of superconductivity. Recently, superconductivity was discovered in FeSe with T_c=8K. The crystal structure of this system is composed of a stack of FeSe conduction layers, which is the simplest crystal structure in iron-based superconductor (Fig.1-(a)). Moreover, T_c was dramatically enhanced in FeSe under high pressure. From these characteristic properties, FeSe is considered to be a good candidate to enhance the T_c and understand the mechanism of superconductivity. However, several problems make difficult to research in this system.

(1) It is difficult to make a single phase FeSe sample.
(2) The crystal structure is changed from superconducting α-FeSe phase to non superconducting hexagonal phase.
(3) Zero resistivity cannot be observed by using diamond anvil cell (DAC)

<Research>

The research group of Tohoku University has revealed the superconducting phase diagram of the simplest iron-based superconductor including the pressure-induced metallic phase for the first time in Te substituted $FeSe_{0.5}Te_{0.5}$. By using cubic anvil cell, we have also succeeded in observing the zero resistivity with precise pressure. Figure 1-(b) shows the temperature dependence of the resistivity of $FeSe_{0.5}Te_{0.5}$ at various pressures up to 7.5GPa. T_c^{onset}(T_c^{offset}) was enhanced from 13.5K(12.5K) to

26.2K(21.5K) at 2GPa. In a comparison with the previous reports on the $FeSe_{1-x}Te_x$ system, the present T_c^{offset} is the highest value for this system. In $FeSe_{0.5}Te_{0.5}$, the α-phase can be easily formed and $\triangle T_c(T_c^{onset}-T_c^{offset})$ is almost constant value above 2GPa, indicating structural transition by applying pressure is suppressed in this system. Moreover, it is clear that T_c is connected smoothly between FeSe and $FeSe_{0.5}Te_{0.5}$ and show a general curve (Fig.2). Therefore, our result is the first observation of a phase transition from the superconducting to metallic phase on the P-T_c phase diagram in the FeSe system.

<Future aspect>

Our researches open the new research field in iron-based superconducting systems. By comparing the difficulties of metallic phase and researching structural parameters, we expected to elucidate the mechanism of superconductivity

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<Figure>

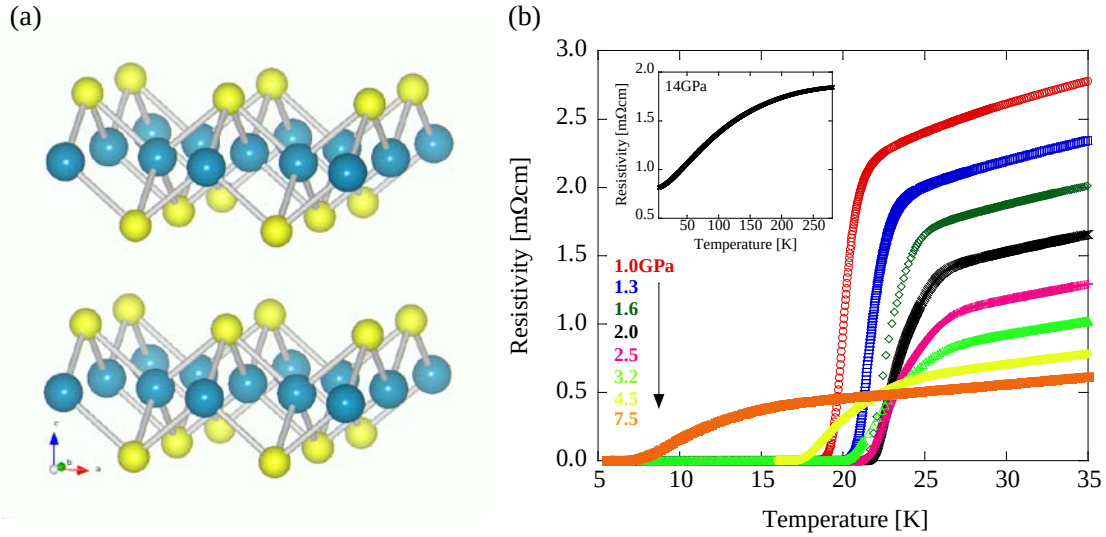

Figure 1 : (a) Crystal structure of FeSe (Fe : blue, Se: yellow). (b) Superconducting transition in $FeSe_{0.5}Te_{0.5}$ under high pressure. T_c^{onset} was enhanced from 13.5K to 26K at P=2GPa. Inset show the metallic phase at P=14GPa.

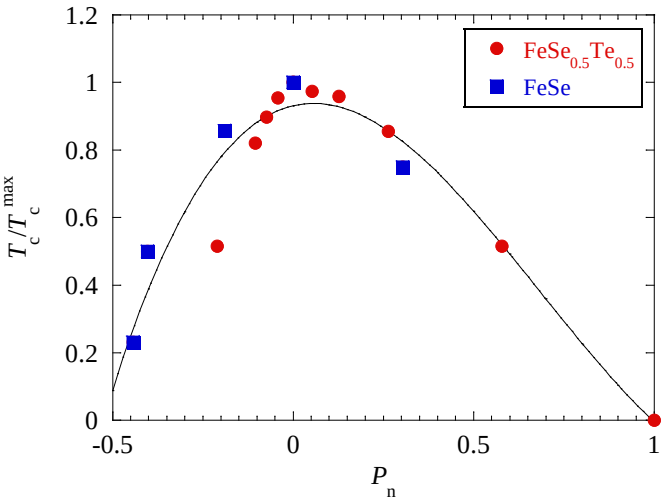

Figure 2 : Pressure dependence of T_c. Normalized pressure P_n is represented by the equation $P_n = (P\text{-}P^*)/(P_c\text{-}P^*)$, where P^* and P_c are pressures with maximum T_c and T_c=0, respectively.