Pressure Effects on the Magnetic Superconductor $Eu(Fe_{0.88}Ir_{0.12})_2As_2$

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The observation of high-T_C superconductivity in FeAs based 122-type compounds (AFe_2As_2) has triggered an enormous scientific interest. Here, we investigate the rich playground among electronic, magnetic and structural properties of the $Eu(Fe_{0.88}Ir_{0.12})_2As_2$ compound using x-ray absorption spectroscopy and single crystal diffraction techniques under high pressure and at room/low temperatures. The aforementioned Eu-based material orders ferromagnetic (FM) below $T_{FM} \sim 17$ K at ambient pressure, where small or complete absences of magnetic moments are observed at the Fe/Ir sites. Therefore the magnetism is dominated by the Eu^{2+} ions. In addition, macroscopic measurements surprisingly display a bulk superconductivity emerging below 22 K in which magnetism and superconductivity coexist at low temperatures.

Our X-ray absorption spectroscopy (XAS) measurements reveal that the Eu^{2+} ions have the magnetic state diminished followed by an enhancement of the amount of the non-magnetic Eu^{3+} ions. The collapse of the magnetic state starts arising around 3-5 GPa in which it can be seen as a delocalization of the $4f^7$ shell electrons. Consequently a charge transfer between the Eu magnetic ions and the dense orbital environment can be expected. In addition, we observe that around 15 GPa the x-ray magnetic circular dichroism (XMCD) is reduced drastically to 20 % in which the average oxidation state for the Eu ions is approximately +2.3.

To probe the lattice, high-pressure single crystal x-ray diffraction measurements were performed at room and at low temperatures. As observed in the XAS measurements, around 3-5 GPa a first transition from tetragonal (T) to collapsed-tetragonal (cT) is observed. This isostructural transition is mainly stimulated by the compression of the Eu ions. However, the cT phase is rapidly suppressed in which above 8-12 GPa the system transits to an orthorhombic (Or) phase with a strong temperature dependence. In this range of pressure and above, the Eu oxidation seems to be very close to the saturation value which makes the As-Fe/Ir-As and As-Eu-As layer distances play important role in the properties of the system. Consequently, the layer distance might directly affect the superconductivity and the magnetism in the system.

These results open up new possibilities for exploring how the structural, electronic and magnetic properties can be coupled to superconductivity in the 122 family.