Cracow Colloquium on f- electron systems

Cracow, 24th - 27th June 2015

Program and abstracts
The compound EuFe$_2$As$_2$ is one of the parent compounds of the iron-based superconductors belonging to the most stable chemically ‘122’ family. The parent compound exhibits development of the iron-based longitudinal incommensurate spin density wave (SDW) at about 192 K with almost simultaneous tetragonal distortion from the rhombohedral symmetry. The SDW propagates along the $a$-axis. Europium orders antiferromagnetically at about 19 K with moments aligned with the $a$-axis. There is no transfer field on iron due to the divalent europium ordering [1]. Upon doping with cobalt in the iron planes one observes gradual suppression of SDW with the emergent superconducting state (SC). Eventually one reaches overdoped region with neither SDW nor SC. Traces of SDW could survive to the overdoped region. The mixed state has some filamentary character with non-magnetic superconducting filaments and normal metal with SDW. Europium partially transforms to trivalent non-magnetic state due to the chemical pressure, while magnetic moments of the remaining divalent Eu tilt in the $a$-$c$ plane preserving anti-ferromagnetic order. One observes some transfer field on iron due to the Eu order. Eu orders in the SC state as well. Eu$^{3+}$ experiences some transfer field from Eu$^{2+}$, too. A tetragonal distortion is suppressed by doping [2]. In order to suppress SDW and create SC one can apply hydrostatic pressure and/or doping of any involved element.

We have studied doubly doped compound in order to look upon europium dilution. The compound CaFe$_2$As$_2$ is a parent compound as well with the SDW onset at about 175 K [1]. Mössbauer spectra of $^{57}$Fe contain two electric quadrupole split components at high temperature. The minor component has very broad lines. The major component has slightly larger spectral shift (isomer shift) and much larger quadrupole splitting at room temperature than the parent compound EuFe$_2$As$_2$ [1]. Hence, the electron density on iron nuclei is lowered due to doping, while the increase in the quadrupole splitting is likely to be caused by the chemical disorder induced by dopants. Traces of SDW order appear in the spectrum collected at 80 K. About 44 % of the sample volume contains SDW, while remainder is free of the iron induced 3d magnetism at 80 K. Spectrum obtained close to the ground state, i.e., at 4.2 K consists of two components as well. About 73 % of the sample volume exhibits SDW and some hyperfine field transferred from the ordered Eu$^{2+}$ magnetic moments. Remainder of the iron nuclei experiences a transferred hyperfine field of about 1.1 T due to the divalent europium magnetic order. The latter minor component does not exhibit 3d magnetic order and it is responsible for filamentary superconductivity typical for ‘Eu-122’ iron-based superconductors [2].

$^{151}$Eu Mössbauer spectra were obtained at three temperatures. Dominant contribution to the spectrum is due to Eu$^{2+}$ ions – about 92 %. Remainder is due to non-magnetic Eu$^{3+}$ ions. Spectral shifts (isomer shifts) are typical for above ionic configurations and comparable...
to shifts in the parent compound EuFe$_2$As$_2$ [2]. Quadrupole coupling constants of the axially symmetric electric field gradient (EFG) tensor $\varepsilon = \frac{1}{2}(c/E_0)eQ_{zz}$ behave similarly in the non-magnetic region [2]. The hyperfine magnetic field $B=26.9(1)$ T is seen in the spectrum collected at 4.2 K on the Eu$^{2+}$ ions. It is slightly smaller than the field of 27.4(1) T in the parent EuFe$_2$As$_2$ [2]. Both fields are practically saturation fields. Hence, a decrease is likely to be due to the magnetic dilution of the divalent Eu ions caused by Ca-substitution. The anomaly in the quadrupole coupling constant and line width observed at 4.2 K for trivalent europium is likely to be an artefact caused by the transferred hyperfine magnetic field from the ordered divalent Eu$^{2+}$ ions. The angle between hyperfine field on Eu$^{2+}$ and the main component of EFG on the same ion amounts to 30(4)$^\circ$ at 4.2 K. The main component of EFG is oriented along the c-axis, while the hyperfine field is aligned with the Eu$^{2+}$ magnetic moment. Hence, the magnetic moment of divalent europium is tilted by 30(4)$^\circ$ from the c-axis, while in the parent compound is perpendicular to the c-axis [2]. For superconducting Eu(Fe$_{1.63}$Co$_{0.37}$)As$_2$ with similar Co concentration one has $\theta = 44(1)^\circ$ at 4.2 K, while for the overdoped Eu(Fe$_{1.42}$Co$_{0.58}$)As$_2$ one gets $\theta = 29(3)^\circ$ at 4.2 K [2]. Therefore, a dilution of the europium by calcium has similar effect to dilution of iron by cobalt as far as Eu behavior is concerned. Both dopants lead to the reorientation of the Eu$^{2+}$ magnetic moment toward the c-axis.

This project was financially supported by the National Science Center of Poland under the Grant No. DEC-2011/03/B/ST3/00446.

References

Email of the presenting author: kamilakom@op.pl