Change of the charge modulation at critical temperature in iron-based superconductors as seen by Mössbauer spectroscopy

A. Blachowski, A.K. Jasek, A. Pierzga, K. Komędera, K. Ruebenbauer

Mössbauer Spectroscopy Laboratory, Pedagogical University, Kraków, Poland

Iron-based superconductors Ba$_{0.6}$K$_{0.4}$Fe$_2$As$_2$ [1] belonging to the ‘122’ family (critical temperature $T_c = 38$ K) and SmFeAsO$_{0.91}$F$_{0.09}$ [2] belonging to the ‘1111’ family ($T_c = 47$ K) were investigated by Mössbauer spectroscopy versus temperature with particular attention paid to the region of superconducting transition. Spectra display quasi-continuous distribution of quadrupole doublets in the whole temperature range. A distribution is caused by the spatial modulation of the electric field gradient, i.e., by the electric field gradient wave (EFGW), the latter being a consequence of the incommensurate modulation of the charge density on the iron nuclei, i.e., the charge density wave (CDW). CDW is seen as the line broadening. Shape and amplitude of EFGW and CDW are strongly perturbed at the superconducting transition. Namely, all modulations strongly vary at critical temperatures due to the superconducting gap opening and subsequent formation of the Cooper pairs. Dispersion of the CDW and EFGW shape behave in the opposite ways for these two superconductors. These differences follow the manner of doping above compounds to achieve superconductivity. The ‘122’ superconductor is hole doped, while the ‘1111’ superconductor is electron doped. Hence, the Fermi surface moves opposite way for above cases and it seems that d electrons contribute significantly to the Cooper pair formation in both compounds as EFGW is perturbed within the temperature region of the superconducting gap formation.

57Fe Mössbauer spectra obtained across transition from the superconducting state to the normal state

$\text{Ba}_{0.6}\text{K}_{0.4}\text{Fe}_2\text{As}_2$ ($T_c \approx 38$ K)

$\text{SmFeAsO}_{0.91}\text{F}_{0.09}$ ($T_c \approx 47$ K)

The Mössbauer spectroscopy is sensitive to the superconducting transition in the iron-based superconductors via change of the electron charge density modulation. The charge modulation incommensurate with the lattice period is seen via dispersion of the isomer shift and via distribution of the electric field gradient. The first effect is caused by the s electrons and is often called CDW effect. The second effect is due to the non-s electrons (mainly d electrons) and is called EFGW. On the other hand, spectral parameters dependent on the lattice dynamics like recoilless fraction and SOD are insensitive to the transition, as the lattice dynamics remains practically unchanged across superconducting transition.

References


Resistivity and magnetic susceptibility vs. temperature for SmFeAsO$_{0.91}$F$_{0.09}$.