Mössbauer study of YFe$_2$Ge$_2$

K. Komędra$^1$, J. Gatlik$^2$, A. Blachowski$^3$, J. Żukowski$^2$, Z. Bukowski$^3$

$^1$Mössbauer Spectroscopy Laboratory, Institute of Physics, Pedagogical University, Kraków, Poland
$^2$Academic Centre for Materials and Nanotechnology, AGH University of Science and Technology, Kraków, Poland
$^3$Institute of Low Temperature and Structure Research, Polish Academy of Sciences, Wroclaw, Poland

artur.blachowski@up.krakow.pl

Introduction

The YFe$_2$Ge$_2$ crystallize in the body-centered tetragonal ThCr$_2$Si$_2$-type structure (space group I4/mmm) isostuctural to the A$\text{Fe}_2$A$\text{S}_2$ (A = Ca, Ba, Eu, K) iron-pnictide parent compounds and superconductors, see Fig. 1. The YFe$_2$Ge$_2$ possesses a shorter inter-layer distance and does not show long range magnetic order. Superconductivity with $T_c$ = 1.8 K is strongly dependent on the sample quality (disorder caused by Fe deficiency on the Fe site) [1]. Coexistence of ferromagnetic and stripe-type antiferromagnetic spin fluctuations within the Fe plane was recently found by neutron scattering measurements [2]. It is known that spin fluctuations can provide the pairing force for magnetic unconventional superconductivity.

Results

$^{57}$Fe Mössbauer spectroscopy measurements were performed versus temperature down to 1.5 K for the YFe$_2$Ge$_2$ powdered single crystals grown out of Sn flux, see Fig. 2. Spectra at room temperature (RT) and at 80 K have a shape of broadened pseudo-single line with quasi-continuous distribution of quadrupole doubllets. A distribution is caused by the spatial modulation of the electric field gradient, which can be interpreted as consequence of the incommensurate modulation of the charge density on the Fe nuclei, i.e., the charge density wave (CDW). The isomer shift (IS) at RT is equal to 0.34 mm/s, which is significantly less than 0.39 mm/s for Ba$_2$KFe$_2$As$_2$ superconductor and 0.43 mm/s for BaFe$_2$As$_2$ parent compound. It means that d-electrons density is significantly lowered in YFe$_2$Ge$_2$ in comparison to mentioned compounds, so the system can be considered as strongly hole-doped, like KFe$_2$As$_2$ superconductor with IS = 0.31 mm/s at RT. The Debye temperature $\theta_B = 422(5)$ K for the YFe$_2$Ge$_2$ was calculated from temperature (80 K - 300 K) dependence of the Mössbauer spectra centre shift. This value is typical for ‘122’ iron-pnictide compounds, see Fig. 3.

Fig. 2. $^{57}$Fe Mössbauer spectra of YFe$_2$Ge$_2$.
Shape of the EFGW/CDW (electric field gradient wave / charge density wave) versus phase angle and corresponding normalized distribution of the quadrupole coupling constant $c$ are shown for spectra at 294 K and 80 K. Symbol $\alpha$ stands for the amplitude of EFGW, while $\beta$ denotes the shape parameter of EFGW.
Shape of the SDW (spin density wave / hyperfine field modulation) versus phase angle and corresponding normalized distribution of the hyperfine magnetic field $B$ are shown for spectra at 4.2 K and 1.5 K. Amplitudes of the dominant harmonics $h$, the average amplitude of SDW and the average magnetic field $<B>$ are shown as well.

Fig. 3. The Debye temperature $\theta_B$ for YFe$_2$Ge$_2$ calculated from temperature dependence of the Mössbauer spectra centre shift. The solid line represents the best-fit to the experimental data in terms of the Debye model for the phonon spectrum.

Conclusion

Spectra at 4.2 K and 1.5 K have wide broadening caused by the spatial modulation of a weak hyperfine magnetic field with the average values about 1.3 and 1.5 Tesla, respectively. The magnetic nature of the spectra close to the ground state can be interpreted as consequence of the spin fluctuations and indicates that the system is close to magnetic instabilities.