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THE HYPERFINE INTERACTIONS IN THE INVAR ALLOYS ON Fe-Pt BASE

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Abstract. — The measurements of Mössbauer effect on Fe$^{57}$ were performed in the ternary alloys Fe$_{70}$(Pt$_{1-x}$(Rh, Re)$_x$)$_{30}$, where $x$ varies from 0 to 10 %, and in the binary alloys Fe$_{57}$, where some peculiarities of Mössbauer spectra obtained show the splitting of lines, corresponding to the existence of two values of effective fields on Fe$^{57}$, which may be due to the coexistence of ferro- and antiferromagnetic phases in alloys. This is also confirmed by the measurements of temperature dependence of the intensity of resonance line of $\gamma$-photons by the motionless source and adsorber.

The specific properties of invar alloys attract the attention already for a long time, but physical nature of these properties remained unclear. The essential contribution to the interpretation of iron-nickel invar alloys properties was made by investigations of Kondorsky and Sedov [1] where some peculiarities of these alloys were explained by the assumption of «latent antiferromagnetism » in $\gamma$-iron.

In several works of Nakamura [2] this hypothesis was confirmed by the Mössbauer effect measurements in some invar alloys. In these investigations it was shown that Mössbauer spectra contain central paramagnetic line at the temperatures much lower than Curie point. It was assumed that this central line is due to antiferromagnetic phase with the Néel point lower than the temperature of measurements. The studies of magnetization made by Chikazumi [3], in particular on some Fe-Pt-Re alloys proved the existence of sharp drop of magnetization in very narrow band of external electrons' concentration (the number of electrons in open shells per atom).

In the present investigation the measurements of Mössbauer effect on Fe$^{57}$ were performed in the ternary alloys Fe$_{70}$(Pt$_{1-x}$(Rh, Re)$_x$)$_{30}$ where $x$ varies from 0 to 10 %. The third component concentration 0, 3, 5 and 10 % was chosen to pass through the critical value of external electrons' concentration.

The measurements were performed on conventional Mössbauer spectrometer with multichannel analyser, working in the constant acceleration mode. The source was Co$^{57}$ in stainless steel. The alloys investigated were prepared by alloying the pure metals in an arc furnace in the atmosphere of purified Ar. The purity of components was not worse than 99.9 %, Iron was used with natural abundance of Fe$^{57}$.

The X-rays analysis of the specimens proved that they were homogeneous single phased with face-centered cubic lattice.

Besides the measurements of Mössbauer spectra there were performed the measurements of intensity of central line $\gamma$-photons with the motionless source and adsorber. These measurements permitted to accomplish with high accuracy the magnetic phase analysis of the specimens. The temperature dependence of magnetization was also measured by conventional balance technique. Figure 1 shows the Mössbauer spectra of binary alloy Fe$_{20}$Pt$_{30}$ and ternary alloys with 3, 5 and 10 % of Rh. The binary alloy spectrum consists of well resolved conventional sextet with broadened lines. There exists also a weak central line, corresponding to small amount of paramagnetic phase. The remarkable feature of 3 and 5 % Rh alloys spectra is the splitting of lines, which is most pronounced in 5 % Rh alloy. The intensity of central line increases with Rh concentration. In the alloy containing 10 % Rh the central line dominates in the
spectrum, the intensity of split lines getting quite weak. The spectra of Fe$_{70}$(Pt$_{1-x}$Re$_x$)$_{30}$ alloys, shown in figure 2 have in essential the same peculiarities, but intensive central line is present already in 5 \% Re alloy, and at 10 \% Re the intensity of split lines is already so weak that they disappear in the noise. Figure 3 shows the temperature dependence of resonance line $\gamma$-photons which went through the motionless adsorber (specimen) for Fe$_{70}$Pt$_{30}$ and Fe$_{70}$Pt$_{25}$Rh$_{15}$. It is clear from the curves that alloys contain two magnetic ordered phases. In the opposite, the temperature dependence of magnetization does not show any anomalies. The values of effective magnetic field on Fe$^{57}$ nuclei $H'$ and $H''$ calculated for split lines of Fe$_{70}$(Pt$_{1-x}$Rh$_x$)$_{30}$ alloys spectra are shown in figure 4 for different values of $x$.

There is no common viewpoint at present on the origin of magnetic properties of invar alloys, but in several theoretical and experimental works was assumed the coexistence of ferro- and antiferromagnetic phase in these alloys [1, 2]. Weiss [4] proposed the idea about the existence of two electronic states in $\gamma$-iron which may correspond in invars to the two magnetic phases mentioned above. To explain the unusually high values of electron specific heat in iron-nickel invars Beck [5] also assumed the coexistence of ferro- and antiferromagnetism.

Thus the existence of two values of effective magnetic field on Fe$^{57}$ in our alloys may be the direct sequence of the presence in these alloys both ferro- and antiferromagnetic states, at the temperature of measurements. It is also confirmed by the temperature dependence of resonance line $\gamma$-photons intensity shown in figure 3. The maxima between critical points on these curves may be caused by orienting influence of long-range exchange interaction between dispersed ferromagnetic phase and disordered spins of antiferromagnetic phase above Néel point.

References