The lower-frequency lines corresponding to small changes in the magnetic quantum number, as a rule, are more intense than the higher-frequency lines. The situation is the opposite with the use of double NQR–NMR resonance [7].

LITERATURE CITED


INVESTIGATION OF ELECTRON TRANSMISSION THROUGH THIN METAL FILMS USING ELECTRON NQR SPECTROSCOPY

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Nuclear gamma resonance (NQR) spectroscopy in which conversion and Auger electrons are recorded (electron NQR spectroscopy) is widely used not only to investigate thin surface layers on solids, but also to carry out a layer-by-layer analysis of their surfaces in layers whose thickness is either less than [1] or considerably greater than [2] the mean free path of the conversion electrons. The method of obtaining the distributions of the concentration of resonance atoms and the phase composition over the cross section of the specimens investigated using this method involves determining the electron NQR spectra after layers of known thickness have been removed from the specimen, in which case an integral distribution curve is obtained. To construct the differential curve data are also required on the transmission coefficients of the conversion and Auger electrons through thin layers of different materials.

A considerable amount of experimental material has now been accumulated on the transmission of electrons of different energy through materials [3]. However, at energies less than several tens of keV the data were obtained using a single-direction single-energy electron beam geometry. The specific features of the experiments on the transmission of secondary electrons, connected with nuclear absorption of gamma quanta, are determined by the fact that the conversion and accompanying Auger electrons are generated directly in the material of the target when it is irradiated with gamma quanta, and hence the angular distribution of the electrons formed is isotropic. Thus, several single-energy groups of such electrons are usually generated. In addition, in the case of nonresonant gamma quanta absorption processes, mainly arising from the photoelectric effect, photoelectrons and accompanying Auger electrons are also formed in the target, and the angular distribution of the photoelectrons is nonisotropic. For low-energy gamma quanta their emission-angle distribution \( f(\theta) \) is given by

\[
    f(\theta) \sim \sin^2(\theta),
\]

where \( \theta \) is the angle between the direction of propagation of the gamma quantum and the photoelectron pulse vector [4].

In this paper we present the results of an experimental investigation of the transmission of conversion electrons through films of aluminum, iron, tin, and gold; the absorption of resonant electrons of the Mössbauer nuclide \(^{57}\text{Fe} \) formed when the target is irradiated with gamma quanta from a \(^{57}\text{Co} \) source in a chromium matrix was studied. The experimental specimens were plates of "nonresonant" \(^{56}\text{Fe} \) with dimensions of \( 15 \times 15 \times 0.5 \) cm. 

Fig. 1. a) Experimental arrangement for determining the transmission coefficient of conversion electrons through metal films by electron NGR spectroscopy; b) graph showing the transmission coefficient \( \gamma \) of resonant electrons as a function of the thickness \( S \) of films consisting of aluminum (1), iron-56 (2), tin (3), and gold (4).

Fig. 2. Graph of the transmission coefficient of gamma-resonant electrons as a function of the film thickness \( S \), calculated taking into account the photoelectric effect in the electron-absorbing films (using Eq. (5)).

To record the electrons we used a gas-discharge detector in which the electrodes were in the form of two plane-parallel plates, and the specimen under investigation was the cathode [5]. In this detector the recording probability is practically independent of the angle of emission and the electron energy (in the range from 0 to 20 keV). The angle of incidence of the gamma quanta on the specimen was close to normal. To separate the photoelectrons and resonant electrons electron NGR spectra were obtained, using a YaGRS-4M Mössbauer spectrometer with an AI-4096 multichannel analyzer. The transmission coefficient of the conversion electrons was found from the equation

\[
\tilde{\gamma} = \frac{(A_0 N_0)}{(A_0 N_s)},
\]

where \( A \) is the area under the resonance line of the Mössbauer spectrum which is proportional to the number of recorded resonance electrons, and \( N \) is the number of recorded electrons far from resonance, which is determined by the number of electrons formed due to photoelectric absorption of gamma quanta; the subscripts 0 and \( s \) relate to the spectra obtained from the specimens before and after depositing the metal layer on them. In Fig. 1b we show graphs of \( \gamma \) as a function of the film thickness, expressed in units of surface density. As is well known, in this case the transmission coefficient is practically independent of the charge \( z \) of the nucleus of the absorbing element. However, as can be seen from the figure, the form of the curves obtained differs considerably for materials with different order numbers \( z \). This is obviously due to the fact that for different elements the number of nonresonant photoelectrons formed is different, since the cross section of the photoelectric effect depends very much on \( z \). Hence, the value of \( N_s \) is dependent on the nuclear charge of the deposited metal. In order to take this fact into account, therefore, we have introduced a correction for the photoelectric effect in Eq. (2) in the coatings which absorb the conversion electrons.

To calculate the correction it is necessary to determine the number of photoelectrons emitted from the specimen with the deposited metal film, and without it. If the specimen consists only of iron, then taking into account the fact that at a distance of the order of the mean free path of the photoelectrons in the material, the flux of gamma quanta is hardly attenuated, \( N_0 \) will be proportional to \( \sigma \tilde{\gamma}_{Fe} \):

\[
(\tilde{\gamma} R)_{Fe} = \sum_{\Gamma}^{\Gamma_{Fe}} 3/8 R_{\beta_i} + z \sum_{\Gamma}^{\Gamma_{Fe}} 3/8 R_{\beta_j}.
\]