QUADRUPOLE BROADENING OF THE MOSSBAUER LINE OF Fe^{57} IN DEFORMED COPPER

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The Mossbauer effect may turn out to be useful in the investigation of structure defects in crystals [1, 2]. The Mossbauer method was already used to advantage for the study of charged "impurity ion and vacancy" complexes in ionic crystals [3 - 5]. We know of no published reports indicating that defects have been observed in metals by this method, although similar investigations were made by a number of workers [1, 6].

In metals whose matrices contain Mossbauer atoms, particularly Armco iron, saturation of the material with defects leads practically to no noticeable shift or spreading of the lines. The probability of observing defects should obviously be much higher in the case of impurity Mossbauer atoms that tend to diffuse directly to the defects. In order to observe the defects, we investigated the Mossbauer spectra of a strongly diluted solution of Co^{57} in Cu following deformation and tempering. A low concentration of the Co^{57} atoms was essential in order to exclude the possibility of formation of particles of a new phase, which would make measurement of the local matrix distortions difficult.

The Co^{57} was deposited galvanically on copper of 99.996% purity. Co^{57} sources with activity $\sim$0.1 μCi were prepared from the obtained alloy by annealing and remelting in a vacuum of 10^{-5} Torr. The Co^{57} concentration in the sources was $\sim 5 \times 10^{-6}$ at.%, which is lower than the expected average concentration of the atoms located in the immediate vicinity of the dislocation nucleus; the magnitude of this concentration, in a strongly deformed metal (at a dislocation density 10^{11} - 10^{12} cm^{-2}), amounts to $\sim 10^{-3}$ - 10^{-4} %.[1)]

To produce an increased defect density, the sample was rolled down after remelting from a thickness $\sim$3 to 0.02 mm (99.3% deformation). The Mossbauer spectrum of the source was investigated as a function of the temperature of the tempering following the deformation. The purpose of the tempering was to accelerate the diffusion of the Mossbauer atoms to the defects.

The Co^{57} source in deformed Cu (without tempering) has a single Lorentz line (Fig. 1a), shifted by $-(0.372 \pm 0.003)$ mm/sec relative to the high-energy line of sodium nitroprusside, or by (0.481 ± 0.0004) mm/sec relative to the center of its doublet; this is in good agreement with the data by others [7]. Figure 2 shows plots of the width Γ, the height ε, and the position of the line against the tempering temperature. At each temperature, the tempering lasted 5 hours. The data were obtained for a single sample by the method of four-channel plotting.

As seen from Fig. 2, a noticeable broadening of the line and a decrease of its height are observed during the first stages of the tempering. Both effects are apparently the result of the smearing of the line, since its integral intensity is not changed appreciably. The greatest smearing appears at tempering temperatures 130 - 200°C, and at higher temperatures the width and height of the line return to their initial values. The line position remains unchanged, accurate to ±0.005 mm/sec.

It can be assumed that the observed spreading of the line is the result of localization of the Mossbauer atoms near the defects. This conclusion agrees

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1)Unfortunately, uncontrollable contamination of the copper to 0.02 - 0.1% could occur during the electrolysis and the subsequent treatment of the samples.

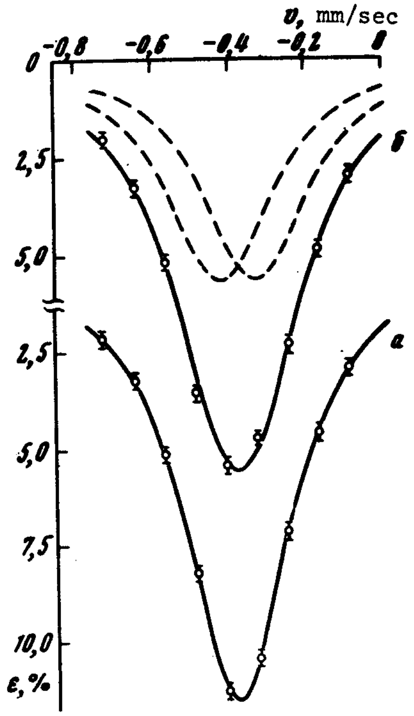

Fig. 1

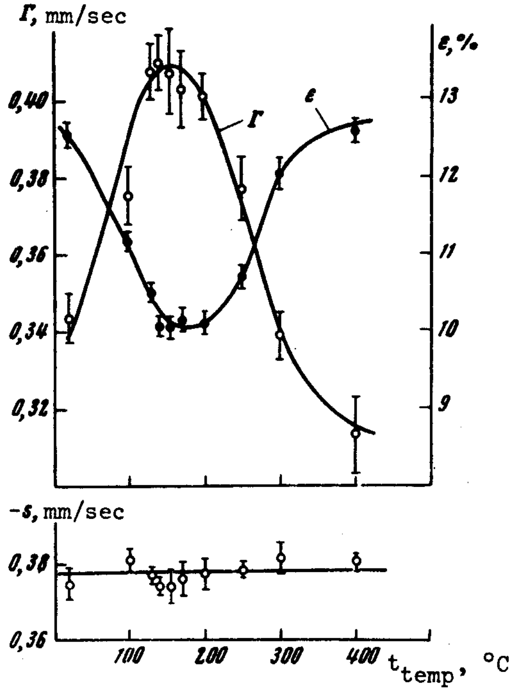

Fig. 2

Fig. 1. Mossbauer spectrum of a source of deformed Cu with Co^{57}: a - prior to tempering, b - after tempering at 170°C. The figure shows half the spectrum with absorber of sodium nitroprusside.

Fig. 2. Width Γ, height ε, and position s of the Co^{57} line in Cu vs. the temperature of tempering after deformation.

with the data of [8], in which, at the same tempering temperatures, a noticeable decrease of the internal friction in Cu was observed, owing to the pinning of the dislocations by impurity atoms.

The line broadening upon tempering can be due, in principle, to two factors: an inhomogeneous isomer shift connected with the inhomogeneous volume deformation of the lattice, and a quadrupole effect due to local anisotropic lattice distortions. In the former case, a line shift should be observed simultaneously, owing to the preferred diffusion of the Co atoms in the compression region. Since no such shift was observed in the experiment, it can be assumed that the main cause of the broadening is the quadrupole splitting of the line. This is indicated also by the shape of the experimental line of a source tempered at 170°C, which, according to a computer analysis by least squares, is described best by a doublet of Lorentz lines with a splitting of ~0.1 mm/sec (see Fig. 1b).

The absence of a line shift after tempering the deformed sample might seemingly contradict the experimental dependence of the isomer shift on the pressure [9]. This, however, can be understood by taking into consideration the known effect of the redistribution of the conduction electrons near the dislocation nucleus. Owing to the transfer of electrons from the compressed regions into the distended ones, the density of the s-electrons near the dislocation may change, compensating for the action of the dilatation on the isomer shift. This probably explains also the weak influence of the defect on the spreading of the line in deformed Armco iron.

Thus, the observed line broadening upon tempering of deformed Cu with Co^{57} impurity must apparently be ascribed to quadrupole splitting of the nuclear levels as a result of the localization of the Mossbauer atoms about the defects in locations with distorted cubic lattice, where the inhomogeneous field of the electric dipole acts simultaneously. It is still impossible to separate these two factors.

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