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Abstract

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L. N. Bystrov, L. I. Ivanov

Investigation of the Effect of γ-Irradiation on the Aging Rate of Beryllium Bronze

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In recent years, considerable attention has been paid to the question of the effect of ionizing radiation on the properties of metals and alloys and on the processes occurring in them. However, the overwhelming majority of studies have dealt with the effect of neutron irradiation, while the effect of γ-irradiation has been investigated much less. In the works published so far, the question of the dependence of the effect on the dose of γ-irradiation has not been studied.

The present investigation is devoted to the study of the influence of γ-irradiation of 1.25 MeV on the aging process of an alloy Cu + 2.5% Be, quenched from 800° into water. The degree of aging was estimated from the magnitude of the change in the electrical resistance of the specimens, which was measured at the temperature of liquid nitrogen, −196°. The choice of temperature was made on the basis that, first, high temperature stability during measurements is thereby ensured, and, second, since the component of electrical resistance of interest to us does not depend on temperature, it is advantageous to carry out the measurement at lower temperatures in order to reduce the phonon component of the electrical resistance.

The electrical resistance was measured by a potentiometric method using PPTN-1 potentiometers and an M21/4 galvanometer. The specimens for measuring electrical resistance were wound in the form of a spiral from wire 2 mm in diameter. The electrical resistance of the specimens at −196° was approximately 10^{-2} ohm, so that, at an operating current of 2 A, the voltage drop across the specimen was about $2 \cdot 10^{-2}$ V (the full scale of the PPTN-1 potentiometer). Under these conditions the relative measurement error did not exceed $\pm 10^{-5}$.

For the measurements, 2 specimens were prepared, one of which was subjected to repeated irradiation on a cobalt source (dose rate at the location of the specimen 490 r/sec), while the other served as a witness specimen.

After each irradiation, the electrical resistance was measured both for the irradiated specimen and for the witness, which was under identical thermal conditions (room temperature). The criterion for the effect of γ-irradiation was the magnitude of the change in relative electrical resistance $\Delta(R_{\text{irr}}/R_{\text{nonirr}})$.

Fig. 1. Dependence of the electrical resistance of the witness specimen and of the relative electrical resistance of the irradiated specimen on the irradiation dose D and annealing time τ

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After the integral irradiation dose had reached $125 \cdot 10^7$ r, isothermal annealing of both specimens was carried out under strictly identical conditions, at a temperature of 120°.

The experimental results are presented in Fig. 1, in which the lower curve shows the change in the electrical resistance of the witness specimen during the test. As can be seen from Fig. 1, prolonged holding at room temperature (about 1.5 months) practically did not change the magnitude of the electrical resistance of the unirradiated specimen. This means that, under normal conditions at room temperature, the aging process in beryllium bronze practically does not occur. Annealing at 120° causes a monotonically decaying increase in the electrical resistance of the witness, which indicates the occurrence of the aging process.

The upper curve of the graph corresponds to the change in relative electrical resistance $\Delta(R_{\mathrm{irr}}/R_{\mathrm{nonirr}})$ as a function of irradiation dose and of time-

of isothermal annealing at 120°. It can be seen that the relative electrical resistance of the irradiated specimen increases as the irradiation dose is increased, and this increase is linear in character. At the maximum dose, $\sim 125 \cdot 10^{-7}$ r, the relative electrical resistance increases by approximately 0.7%.

The magnitude of the change in relative electrical resistance rises sharply during the first minutes of annealing, reaching a maximum ($\sim 1.3\%$) after 80–100 min of annealing. This indicates that the process of thermal aging of the preliminarily irradiated specimen proceeds, in the initial period, considerably faster than that of the unirradiated specimen. Further annealing leads to a slow, damped decrease in the relative electrical resistance.

Fig. 1. Dependence of the electrical resistance of the witness specimen and of the relative electrical resistance of the irradiated specimen on the irradiation dose D and annealing time τ

The results obtained can be explained as follows. Preliminary γ-irradiation of the specimen, associated with the appearance of an excess concentration of vacancies and interstitial atoms, leads mainly to the appearance of centers (nuclei) of a new equilibrium phase; however, the growth of the nuclei is extremely slow because the rate of diffusion at room temperature is small.

This is also confirmed by the fact that the dependence of the increase in electrical resistance on the irradiation dose is linear in character. A linear increase in electrical resistance during irradiation indicates that increasing the irradiation dose leads only to quantitative changes (for example, to an increase in the number of nuclei of the new phase, which are scattering centers for conduction electrons). If the process of growth of the nuclei of the new phase were also proceeding in parallel on an appreciable scale, the curve for the dependence of the change in electrical resistance would have a more complex character, as is observed, for example, in the case of thermal aging.

Thus, it may be considered that the difference between preliminarily irradiated and unirradiated specimens consists in the fact that the former contains a certain number (proportional to the irradiation dose) of prepared nuclei of the new phase. This also affects the character of the subsequent thermal aging. In the initial period of annealing, in a specimen containing ready nuclei, intensive growth of the equilibrium phase takes place, as a result of which the relative electrical resistance rises sharply. However, after the nuclei prepared by irradiation prove to be exhausted, the rate of aging of the unirradiated specimen begins

prevail, since it is somewhat farther from the equilibrium state (has aged less). As a result, the relative electrical resistance decreases slightly.

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Institute of Metallurgy
named after A. A. Baikov

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Note: Figure translations are in progress. See original paper for figures.