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Abstract

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The Effect of Neutron Irradiation on the Corrosion Behavior of Aluminum in Water

(Presented by Academician V. I. Spitsyn, May 25, 1963)

In one of our previous works (^1) it was shown that irradiation with electrons of energy 0.8 MeV leads to the formation on aluminum, in a solution of trisubstituted sodium chloride, of oxide films of increased thickness. At the same time it was established that this thickened film dissolves in the electrolyte considerably faster than the thinner one obtained in the absence of irradiation. This peculiar action of electron irradiation was explained by the fact that the irradiating particles (electrons), as a result of elastic collisions, displace ions from the lattice sites of the oxide, forming structural defects (vacancies, interstitial ions and atoms). An increase in the number of defects in the structure of the oxide film leads simultaneously to an increase in the ionic conductivity and chemical activity (^2) of the oxide, which accounts for the combination of such diverse effects as acceleration of the growth of the film thickness with a simultaneous increase in the rate of its dissolution in the electrolyte.

Since heavier particles, for example neutrons, have a stronger destructive action (^3), it was to be expected that upon irradiation in a reactor the noted effects would appear still more distinctly. Experiment confirmed this supposition.

Figure 1 shows photographs of transverse microsections of aluminum specimens tested in the reactor. Specimen A was subjected to neutron irradiation, the integral flux of which was 10^{20} n/cm^2. Specimen B was tested in an inactive zone, i.e., the incidence of neutrons on its surface was practically excluded. In all other respects the test conditions of the specimens were completely identical: the specimens were in the same stream of water at a temperature of 96°. As the photographs in Fig. 1 show, neutron irradiation led, under the indicated conditions, to the formation on aluminum of an oxide film whose thickness was 15–16 μ. On specimens not subjected to irradiation, such a film was not detected under the microscope (magnification 200×). However, after treatment in a saturated solution of boric acid with the application of alternating current, carried out for the purpose of separating the oxide film from the metal, it turned out that the unirradiated specimens lost weight and that a certain amount of oxides had separated from their surface. Thus, an oxide film also formed on the unirradiated specimens, but it was so thin that at 200-fold magnification it could not be examined under the microscope. The oxide film separated in boric acid, in the form of a powder, was thoroughly washed and subjected to X-ray structural analysis. Figure 2 presents X-ray diffraction patterns kindly taken and analyzed by Doctor of Chemical Sciences N. A. Shishakov. The X-ray diffraction patterns show the different character of the oxides formed on irradiated and unirradiated aluminum specimens. Neutron irradiation leads to the formation of hydrargillite ($\alpha \cdot Al_2O_3 \cdot 3H_2O$) with a very slight admixture of boehmite ($\gamma \cdot Al_2O_3 \cdot H_2O$), whereas in the absence of irradiation the oxide is pure boehmite. It is characteristic that on the X-ray diffraction patterns of the unirradiated oxide there are observed

Fig. 1. Photographs of transverse polished sections of technical aluminum kept in a water flow at a temperature of 96°.
a –the specimen was subjected to neutron irradiation with an integral flux of 10^{20} n/cm^2; *b* –the neutron flux was absent.

Fig. 2. X-ray diffraction patterns of oxides obtained on technical aluminum under the conditions of Fig. 1.
a –oxide obtained under the action of a neutron flux; *b* –oxide obtained in the absence of a neutron flux.

fairly intense lines of metallic aluminum, which is possibly explained by the nonuniformity of the oxide formed, leading to the etching out of metallic grains when the oxide film is removed from unirradiated specimens.

The increased hydration of oxide films under irradiation can evidently be explained by the active interaction of the destructured oxide with water molecules penetrating into the oxide layer through its defective sites.

Since it was impossible to analyze the water for dissolved aluminum, we determined the amount of aluminum that had passed into solution by the following formula:

$$U = x - y - \frac{(z - y) \cdot 54}{Y},$$

where x is the weight of the specimen before corrosion tests (g/cm^2), y is the weight of the specimen without the film (removed) after corrosion tests (g/cm^2), z is the weight of the specimen with the film after corrosion tests (g/cm^2), Y is the molecular weight of boehmite (for unirradiated specimens) and hydrargillite (for irradiated specimens), and 54 is the atomic weight of 2Al.

The calculations showed that the corrosion (dissolution) rate of aluminum is: 0.01 g/m^2 • h for irradiated aluminum and 0.004 g/m^2 • h for unirradiated aluminum. Thus, as in work (^{1}), irradiation, while promoting thickening of the oxide film, at the same time increases its dissolution rate, according to our data, by approximately a factor of 3. The results presented clearly show that neutron radiation changes the structure of the oxide film and accelerates the corrosion process of aluminum. However, in water at 100° this acceleration is not so significant as to place aluminum among corrosion-unstable materials.

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CITED LITERATURE

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