STRUCTURE AND PHASE TRANSFORMATIONS DURING AGING OF COLD WORKED Ti–Nb ALLOYS

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Several titanium alloys are used after cold deformation and aging, especially superconducting alloys of the Ti–Nb system. Phase transformations in these alloys have been investigated after quenching and tempering.

This work concerns the phase transformations that occur in the process of plastic deformation and during aging of cold worked Ti–Nb alloys (25–50% Nb) with up to 7.5% Zr, up to 1% Fe, up to 5% Mo, and up to 5% V.

The alloys were cold-hearth melted in vacuum (~10⁻³ mm Hg) with a water-cooled copper hearth.

The alloys contained 0.03–0.06% O, 0.002–0.005% N, 0.01–0.03% C.

The alloys were first hot rolled to plates 3.5 mm thick and then, after water quenching from 750°C, cold rolled to thicknesses of 1.3–0.1 mm.

Aging after cold rolling was conducted in vacuum (~1·10⁻⁵ mm Hg) for 4 h. The method of investigation was described in [1].

It was shown in [1, 2] that body-centered tetragonal τ phase with lattice constant a matching the lattice constant a of α" phase in the same alloy is formed in the process of cold plastic deformation. During deformation of the alloy containing α" phase the latter disappears.

Fig. 1. Dilatometric curves for Ti + 33% Nb (1) and Ti + 35% Nb + 7.5% Zr (2). ——) Quenched samples; ———) cold rolled samples (65% reduction) in rolling direction; ———) across the rolling direction.

The tetragonality (c/a) of τ phase decreases from 1.14 to 1.08 with increasing amounts of niobium from 25 to 40% and remains almost unchanged with zirconium and vanadium additions within the limits investigated.

The formation of τ phase leads to a substantial increase in hardness after cold deformation. For the alloy with 30% Nb the hardness rises from HB 195 to HB 290. For the alloy with 45% Nb, where τ phase is not formed, the hardness changes from HB 155 to HB 180.

With heating to 250°C, τ phase disappears. A strong anisotropy of the change in the length during heating to this temperature is observed in all alloys containing τ phase [1] — the length decreases in the rolling direction and increases in the transverse direction (Fig. 1). This is evidently due to the fact that the orientation of axis c of the tetragonal phase is close to the rolling direction.

This is probably also the explanation for the anisotropy of changes in electrical resistivity and temperature — ρ decreases in the rolling direction and increases in the transverse direction with heating to 100°C.

It was impossible to make a quantitative phase analysis by means of x-ray diffraction due to the texture of these alloys. From the change in the hardness and the character of the dilatometric curves it can be concluded that the amount of τ phase in cold worked alloys decreases with increasing niobium additions from 25 to 40%, decreases somewhat with the addition of zirconium, and decreases greatly with the addition of iron and molybdenum.

Thus, the reduction of the length in the rolling direction during heating of cold worked alloys with 65% reduction was 1.5% for the alloy with 35% Nb, and 0.6% for Ti-33Nb-2V and Ti-34.6Nb-0.4Fe alloys. This effect is eliminated with the addition of 5% V, 5% Mo, or 0.5% Fe to the alloy containing 35% Nb.

Raising the aging temperature of the cold worked alloys to 300°C or higher leads primarily to precipitation of α phase (the formation of metastable ω phase is suppressed). The intensity of the lines of ω phase increases little with increasing aging temperatures. After 65% reduction the lines of ω phase remain on the x-ray diffraction line profile of the alloy with 30% Nb only at 250°C, and up to 300°C with the addition of 7.5% Zr.

After cold rolling with 98% reduction the lines of α phase on the x-ray patterns for samples with 25-40% Nb and additions of zirconium and vanadium appear after aging at 250-300°C. The intensity of lines of α phase decreases with an increase of the niobium content from 30 to 40%, decreases somewhat with the addition of zirconium and vanadium, and decreases considerably with the addition of molybdenum.