EQUILIBRIUM PRESSURES OF TITANIUM OVER TITANIUM TRITIDE

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Introduction

Tritium-facing equipment and some structural components of nuclear reactors accumulate tritium as a result of neutron irradiation. When the equipment and structural components are dismantled and replaced, they are ranked among high-level radioactive waste. Ref. [1] proposes a process flow to convert large-size high-level radioactive waste to low-level waste by thermal detritiation of structural components. Tritium released during thermal detritiation is absorbed by hydride-forming metals. This allows reducing the amount of high-level waste by a factor of 30 and more, which results in a considerable reduction of disposal costs.

The least expensive hydride-forming material is titanium sponge produced by magnesium-thermic reduction.

Different authors measured equilibrium pressures over titanium hydride with different degrees of saturation [2,3], but as equilibrium pressures of isotopes are considered to be sensitive to impurities, it was necessary now to measure equilibrium pressures of tritium over titanium tritide at different temperatures for the materials being produced.

Results and Discussion

Titanium sponge produced by magnesium-thermic reduction was used as a starting material. Titanium was crushed in a ball drum in the argon atmosphere. The average particle size of the titanium powder was about 40 μm. The mass fraction of impurities in it was: oxygen 0.64%, nitrogen 0.17%, carbon 0.11%, chlorine 0.02%, total fraction of magnesium, aluminum, iron, nickel and chrome 0.19%. Tritium and hydrogen were produced by thermal decomposition of titanium tritide and titanium hydride, respectively. The volume fraction in the gas phase of hydrogen was about 100%, and of tritium, 98%, the rest being deuterium and hydrogen.

Measurements of equilibrium pressures over titanium tritide and hydride were taken in a glass vacuum unit. A 0.500 g sample of titanium was placed into a quartz ampoule. The sample was activated at a temperature of 573K with constant evacuation (pressure did not exceed 10^{-2}Pa) for 1 hour. Evacuation was stopped. Then, the ampoule with the sample was filled with gas, and the temperature of the sample was increased to 773K and maintained for 2 hours. Following this, the temperature of the sample under the gas pressure was reduced to room temperature (~293K) at a rate of no more than 5 degrees per minute. Saturation of the sample corresponded to the atomic ratio of T/Ti = 1.97-1.98, H/Ti = 1.97-1.98. Gas pressure in the ampoule with the sample after titanium saturation was about 40kPa.

The temperature of the sample was increased to 673K, and pressure in the ampoule was raised. The sample was held at this temperature for at least 2 hours, and pressure in the unit was measured. In the sequel, part of the gas was removed from the unit, and sample saturation was decreased by no more than the atomic ratio of T/Ti=0.1. After each gas removal, the sample was held at a temperature of 673K for at least 2 hours. Pressure monitoring at tritide saturation below the atomic ratio of T/Ti=0.2 was performed by means of a PMT-2 thermocouple lamp. The same procedure was used to obtain isotherms for titanium hydride at a temperature of 673K and for titanium tritide and hydride at a temperature of 773K. The resulting isotherms are shown in Fig. 1 and 2.

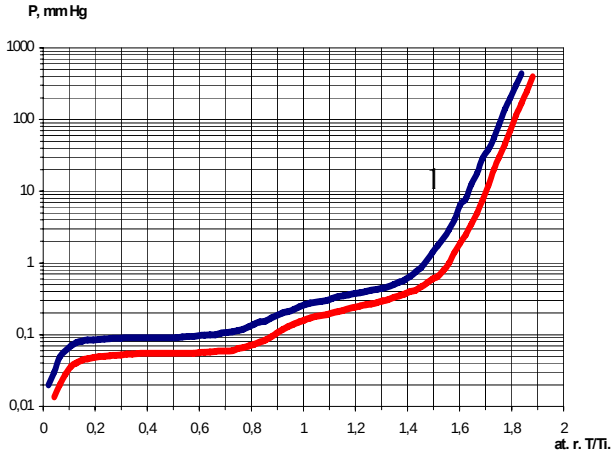

Fig.1. Isotherms of Ti - (T_2; H_2) systems at a temperature of 400^0C: 1 – tritium, 2 – hydrogen.

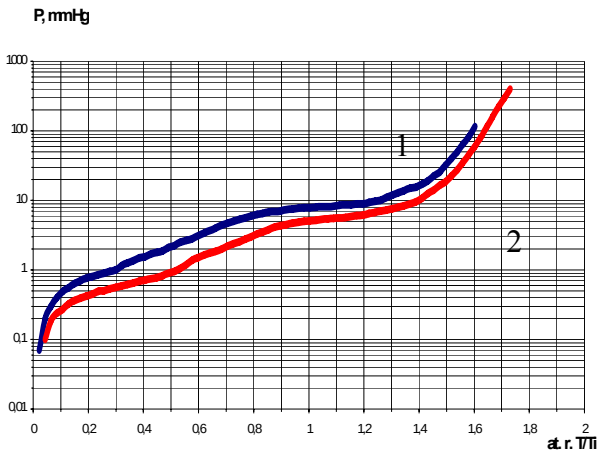

Fig.2. Isotherms of Ti - (T_2; H_2) systems at a temperature of 500^0C: 1 – tritium, 2 – hydrogen.

The plots shown in Fig. 1 and 2 contain no data for high degrees of titanium saturation (above the atomic ratio of T/Ti=1.8), because the units, on which the experiments were conducted, are intended for pressures below 10^5 Pa. Therefore, for safety reasons, titanium was not held at elevated temperatures (773-673K) for long periods. The equilibrium pressure over titanium tritide is approximately 1.5 times higher than that over titanium hydride in all the tested range.

Based on the equilibrium pressures, we made an assessment of existence limits of the α, β and δ phases which have hcp, bcc and fcc lattices, respectively, at a temperature of 673K. The table 1 shows the estimated existence limits of tritide phases and for comparison presents existence limits of titanium hydride phases from Ref. [3].

The data given in the table suggest that the existence limits of the tritide phases at a temperature of 673K are nearly the same as those of the hydride phases given in Ref. [3]. The range of the bcc β-phase of titanium tritide is slightly shifted (0.7-1.1).

Table 1.
Existence limits of titanium tritide phases.

Phase	Titanium tritide, at.ratio T/Ti	Titanium hydride, at.ratio T/Ti /3/
α	0-0.15	0-0.10
α+β	0.15-0.,7	0.10-0.55
β	0.7-1.1	0.55-0.9
β+δ	1.1-1.4	0.9-1.45
δ	1.4-2.0	1.45-2.0

Conclusions

Equilibrium pressures were measured over magnesium-thermic titanium tritide with impurities (Mg + Al + Fe + Ni + Cr <0.2% wt.)

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References

1. Sten'gach A.V., Golubeva V.N., Tarasova A.I., Maslennikova O.B., Purieva A.P. Application of nano-disperse carbon and hydride-forming metals for detritiation of structural materials // Hydrogen Materials Science and Chemistry of Carbon Materials, ICHMS Conference Proceedings, 2007. Ukraine, Kiev, 2007, pp.1092-1093 (in Russian).

2. Kolachev B.A., Livanov V.A., Bukhanova A.A. Phase diagram of the Ti-O_2-H_2 system // Transactions of Institutes of Higher Education. Non-Ferrous Metallurgy, 1966, No.3, p.94 (in Russian).

3. Fadeev N.V., Boiko E.B. Equilibrium pressure of hydrogen in the Ti-H system // Transactions of the Soviet Academy of Sciences. Metallurgy, 1991, No.2, p.20 (in Russian).