Deuterium interaction with low–activated chromium-manganese austenitic steel with increased contamination of carbide particles

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Austenitic nickel steels and reduced activation ferritic-martensitic steels are considered as structural materials for fusion reactors. The main disadvantages of austenitic steels are a high activation and a very slow decrease in activity induced by neutron irradiation. The disadvantage of reduced activation ferritic-martensitic steels lies in their magnetic properties, which can cause difficulties when using them in strong magnetic fields of tokamaks, and especially during transients. Low-activation nickel-free austenitic steels could serve as an alternative. The development of such steels started in the last half of the 20th century in several countries. After a time, these works were stopped due to phase instability during prolonged heating.

New reduced activation austenitic chromium-manganese steel (MAAHMS) [1] was recently developed in Russia as a potential structural material for nuclear and fusion reactors. MAAHMS demonstrates the stability of its microstructure and mechanical properties under conditions of prolonged aging at 700 °C.

The retention and transport of hydrogen isotopes in fusion reactor materials is a very important aspect of ensuring safety. The interaction of hydrogen isotopes with chromium-manganese steels has not been studied before. Our work presents the results of a study of deuterium retention and transport in the new steel. The object of this study is melting No. 4 of MAAHMS with a high content of carbide particles. The structural material of fusion reactors will contact with gaseous hydrogen isotopes and in some cases can be exposed to plasma irradiation. Therefore, the deuterium retention in MAAHMS was investigated after exposure in D_2 gas and after irradiation with deuterium plasma.

Some of the samples were irradiated with deuterium plasma for 14 hours at a temperature of 200 ° C to a dose of 10^{25} D/m^2, with a bias potential of 100 eV. Some of the samples were saturated in deuterium gas at a pressure of 5 atmospheres and at the same temperature for 24 hours. Deuterium retention in MAAXMS was investigated by thermal desorption spectroscopy at a sample heating rate of 0.5 K/s.

After gas loading, the deuterium retention in MAAHMS is comparable to reduced activation ferritic-martensitic steel EK-181 at the same conditions (Fig. 1.a). After plasma irradiation, MAAHMS steel samples retains 20 times more deuterium than samples of EK-181 under the same conditions (Fig. 1.b). The results can be explained by the slower transport of hydrogen to MAAHMS.

The permeability of MAACHIS at interaction with deuterium gas was investigated in the membrane temperature range of 250-350 °C. The membrane under study separated two high–vacuum chambers, the first of which was filled with deuterium up to a pressure of 10 - 500 mbar. The deuterium flux permeating through the membrane was registered in the second chamber using a quadrupole mass spectrometer. According to the estimates, the deuterium diffusion coefficient in MAAHMS steel is 20 times lower than in nickel austenitic steels and 3.5 orders of magnitude lower than in EK-181 steel.

a) b)

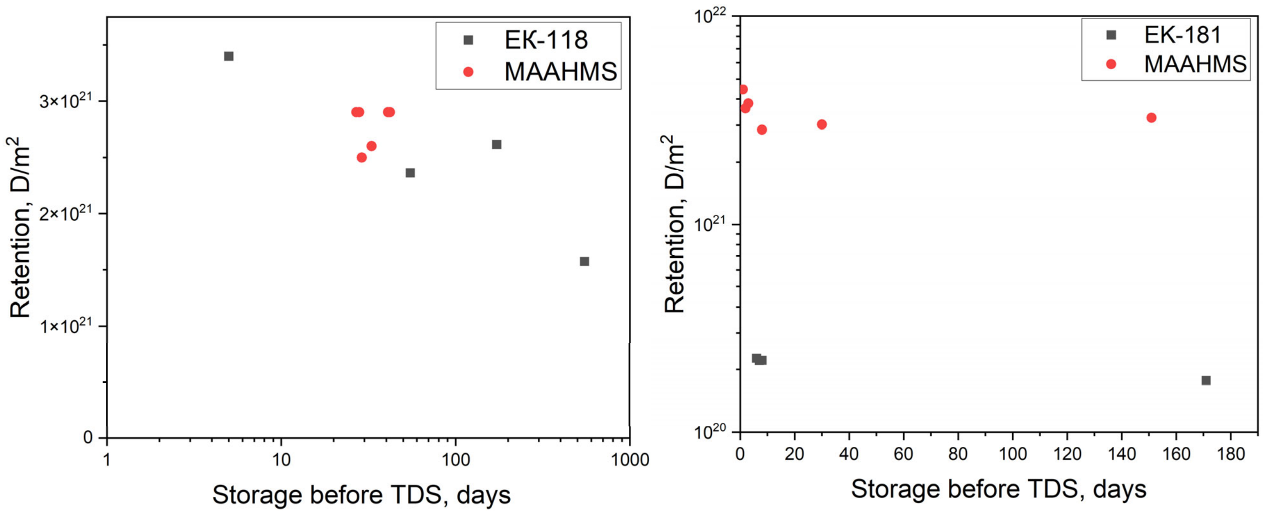

Fig. 1. The deuterium retention in MAAHMS as compared with EK-181: a) after exposure in D_2 at 5 bar and 200 °C; b) after 100 eV D-plasma irradiation at 200 °C.

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References

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