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Development of a hydrogen permeation sensor for liquid breeder type TBMs

B. G. Choi[1*], D. W. Lee[2], E. H. Lee[2], J. S. Yoon[2], S. G. Kim[2], K. I. Shin[2], and H. G. Lee[3]
[1]*Univercity of Science & Technology, Daejeon, Republic of Korea*
[2]*Korea Atomic Energy Research Institute, Daejeon, Republic of Korea*
[3]*National Fusion Research Institute, Daejeon, Republic of Korea*
[*]*Corresponding author: cbg@ust.ac.kr, bgchoi9958@kaeri.re.kr*

1. Introduction

Korea has developed Test Blanket Modules (TBMs) for ITER and DEMO fusion reactor. The tritium extraction from a breeder is one of the key technologies and its methods have been investigated [1-6]. For developing the tritium extraction methods and evaluating the amount of tritium in the system, a reliable and correct sensor is required to measure the hydrogen concentration in liquid metal breeder.

There are several researches for developing the sensors in the ITER participants and especially, EU has developed the permeation sensors trying to selecting materials with low Sievert's constant and high hydrogen diffusivity coefficient. When it comes to geometry, cylindrical- and annulus- shape of permeable sensors were invented to measure the hydrogen concentration in the liquid metal breeder. The annulus type was finally chosen to reduce the time necessary to measure the concentration. However, this response time is still too long time about tens of minutes to measure the tritium concentration in the online system [7-8].

To solve this problem, we designed and fabricated the several sensors, with various materials and shapes, the results are introduced in the present study.

2. Design and Fabrication of sensors

Three kinds with different shapes of sensors were fabricated; cylindrical, annular, and plate types. And the membrane thickness in sensing part was designed to be 0.1, 0.3 and 0.5 mm. And more, the various hydrogen permeable materials such as pure iron (Fe), Niobium (Nb), Tantalum (Ta), and Palladium (Pd) were used as the candidate ones because these materials have high hydrogen diffusivity in spite of high Sievert's constant. The fabricated sensors are summarized in Table I. The cylindrical type sensor made of Fe was a referred one which was based on the EU concept. Annular and plate type with filter were proposed for faster response time by optimizing the ratio of surface area per unit volume. These sensors were filled with porous disks (filter) and sealed by laser welding to endure with hydraulic pressure in liquid metal. Figures 1 and 2 show the schematic and photographs of the fabricated sensors.

Table I Fabricated sensors according to the thickness, materials, and shapes

Thickness (mm)	Geometry	material
0.1mm	Cylinderical type	pure Fe
	Annular type with filter	pure Fe
	Plate type with filter	pure Fe
0.1mm	Plate type with filter	Niobium
		Niobium
		Tantalum
		Tantalum
0.3mm	Cylinderical type	pure Fe
	Annular type with filter	pure Fe
	Plate type with filter	pure Fe
0.5mm	Cylinderical type	pure Fe
	Annular type with filter	pure Fe
	Plate type with filter	pure Fe

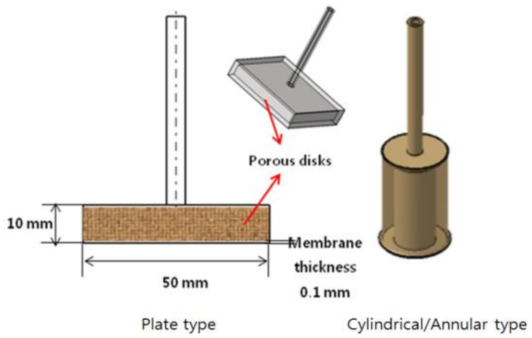

Fig. 1 The schematic of the fabricated sensors

Fig. 2 The photographs of the fabricated sensors

3. Performance tests of the sensors

Test chamber was prepared for the performance test of the fabricated sensors, as shown in Fig. 3: the shape is cylindrical and it is made from stainless steel 304. For leak and performance tests of the sensors, there is a supply system to inject the nitrogen (N_2) and hydrogen (H_2) gases, which is connected to the lower part of the chamber. The upper part of the chamber is connected with a vacuum pump to make vacuum inside of the chamber. A cap is located on the center of the top can be separated from a chamber to install the sensors.

Two pressure transmitters (Rosemount 3051S) are installed on the top of the chamber to measure pressure in the chamber and the permeation sensor, respectively. 1/4 inch tubes are used to connection.

A fabricated sensor was installed in the chamber, and N_2 gas was injected up to 5 kPa to check the leakage in joining parts of the sensors. The sensors made of pure Fe were confirmed that there were no leakage problem and then, we performed the permeation test. As shown in Fig. 4, it shows that it took about 60 hours to reach the pressure equivalent. However, we could not find any hydrogen permeation into the same sensors with same conditions after only a few days. It seems to be caused by the formation of the oxide layer at the surface of the sensors.

With the sensors made of nonferrous metals, the leakage test was performed to check soundness of the sensor. However, the pressure in sensors increased with the injection of 5 kPa pressure of N_2 into the test chamber (Fig. 5). It means that the sensor has a defect and we concluded that it is caused by difficulty of welding with very thin non-ferrous metals.

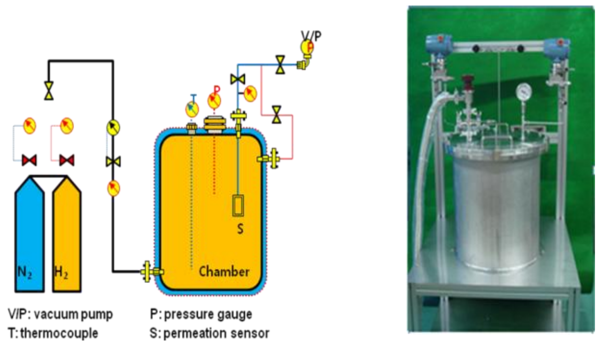

Fig. 3 The schematic of the chamber including gas supply system and its photograph

4. Conclusion

The permeation sensor to measure the hydrogen isotopes in liquid metal breeder has been proposed and evaluated to overcome the limitation of a long response time for the various shapes (cylindrical, annular and plate types), the various materials (pure Fe, Nb, Ta, and Pd), and the various thickness of membranes (0.1, 0.3, and 0.5 mm). In present study, We found that 1) the pure Fe sensors have limitation because of the oxidation problems, and 2) a sensor made of nonferrous metal is hard to fabricate by welding due to difficulty of welding.

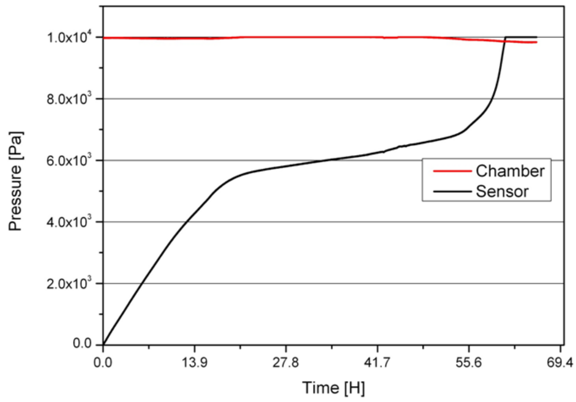

Fig. 4 Measured pressures for pure Fe sensor in performance test

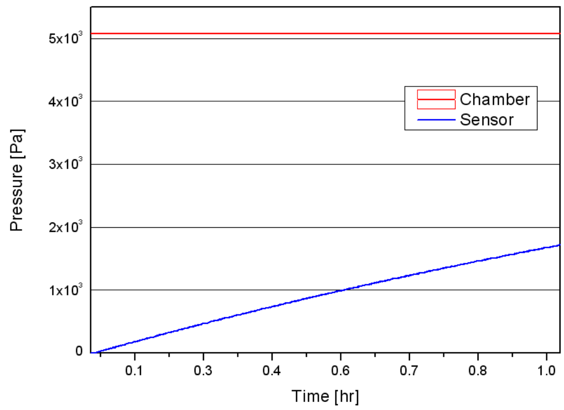

Fig. 5 Measured pressures for Ta sensor in the leakage test

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