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Performance Tests of a Permeation Sensor for Test Blanket Modules Using Liquid Metal

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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 (solubility) and high hydrogen diffusivity coefficient. However, EU's response time is still too long time about tens of minutes to measure the tritium concentration in the online system [7-8].

We have been performing the preliminary tests with designed and fabricated sensors to solve the late response of sensor. However, we could not continue the tests because of the membrane's oxidation (pure Fe) and the difficulty of welding nonferrous metals.

In present study, a permeation sensor made of vacuum flanges with a porous plate inside is proposed not only to eliminate the difficulty of the fabrication but to optimize the performance of sensor

2. Results of the previous works

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 between 0.1 and 0.5 mm. And more, the various hydrogen permeable materials such as pure iron (Fe), Niobium (Nb) and Tantalum (Ta) 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. 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 [9].

The sensors made of pure Fe were confirmed that there were no leakage problem and then, we performed the permeation test. 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 [9].

Table.1 The results of fabricated sensors according to the materials, thickness and shapes

Material	Thickness (mm)	Geometry	H_2 pressure 10000 Pa
pure Fe	0.2T	Cylindrical type	oxidation of the membrane
		Annular type with filter	
		Plate type with filter	
	0.3T	Cylindrical type	
		Annular type with filter	equivalent time (64H)
		Plate type with filter	oxidation of the membrane
	0.5T	Cylindrical type	
		Annular type with filter	
		Plate type with filter	
	0.18T (surface treatment)	Plate type with filter	
Nb	0.1T	Plate type with filter	difficulty of welding
Ta	0.1T	Plate type with filter	

3. Design of the Flange Type Permeation Sensor

A permeation sensor made of vacuum flanges with a porous plate inside is proposed 1) to reduce the thickness of membrane, 2) to increase surface area of sensor per unit volume, 3) to endure high pressure operational condition, and 4) to eliminate the manufacturing difficulties which are mentioned above (Fig. 1).

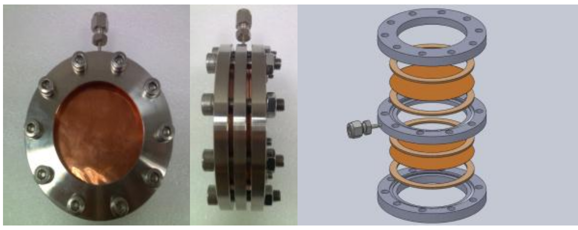

Fig. 1 Photographs and an assembly drawing of the proposed hydrogen permeation sensor made of modified CF flanges with hydrogen permeable membranes

4. Performance Tests of 0.3t Flange Type Nb membrane sensor

A pure niobium plate (0.3mm thick; The Nilaco Corporation, Japan), was used as a hydrogen permeation membrane. Later two membranes were assembled in CF flanges on both sides. Operating conditions for hydrogen permeation measurements are presented in Table 2. Pure hydrogen was feed on both sides of membranes in test chamber. The feed-side pressure was controlled between 10 kPa and 20 kPa, but the inner pressure in sensor was fixed to vacuum condition at the primary stage.

Table 2. Operating condition for hydrogen permeation test

Membrane material		Niobium
Effective membrane	Thickness	0.3 mm
	Area	0.00912 m^2
Feeding gas		Pure hydrogen (99.9999%)
Pressure	Feed side	10, 15 and 20 kPa
	Permeation side	Vaccum condition
Temperature		278 - 283 K

Before starting the main performance tests, the soundness of the test facility and the sensor with CF flanges was verified on the leakage test by nitrogen. As shown in fig 2, it shows that it would take long time to reach the pressure equivalent at 300K below. (The time leg related with hydrogen diffusion coefficient is not out of consideration at the results of tests.)

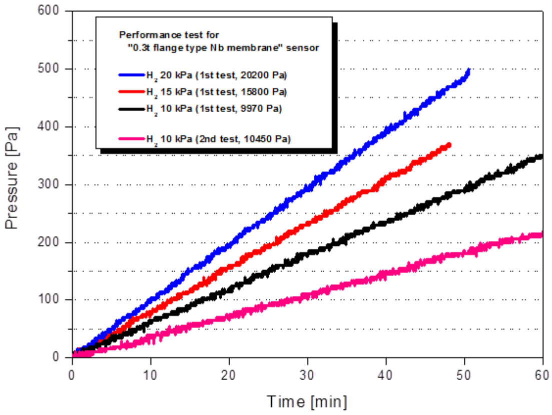

Fig. 2 Measured pressures for 0.3t flange type Nb membrane sensor at different permeation side pressures.

5. Conclusion and future works

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 various shapes and materials. We found that the previous sensors have limitation; the oxidation problems (pure Fe) and the difficulty in welding (nonferrous metals).

Therefore we proposed a permeation sensor with the vacuum flanges filled with porous disks to eliminate the problems. By using the CF flanges, the problem caused by welding is removed. But the permeable response time of sensors took a long time to reach the pressure equivalent.

References

[1] D.W. Lee, et al., "Current status and R&D plan on ITER TBMs of Korea" Journal of Korean Physical Society 49 (2006) S340-S344.

[2] D.W. Lee, et al., "Preliminary design of a helium cooled molten lithium test blanket module for the ITER test in Korea," Fusion Eng. Des. 82 (2007) 381-388.

[3] D.W. Lee, et al., "Helium cooled molten lithium TBM for the ITER in Korea," Fusion Sci. Tech. 52 (2007) 844-848

[4] D.W. Lee, et al., "Design and preliminary safety analysis of a helium cooled molten lithium test blanket module for the ITER in Korea," Fusion Eng. Des., Vol. 83 (2008) 1217-1221.

[5] D. W. Lee, et al., "Current status on the Korean test blanket module development for testing in the ITER," Proc. of the KNS Spring Meeting, Yong-pyoung, Korea, May 2010.

[6] E.H. Lee, et al., Development of hydrogen permeation sensor in the liquid Pb-15.7Li alloy, "The fifteenth International conference on fusion reactor material" (2011) 2002764

[7] A. Aiello, et al., "TRIEX hydrogen sensor qualification" ENEA division FPN FIS ING (2007), 1-23.

[8] A. Ciampichetti, I. Ricapito, G. Benamati, M. Zucchetti, A. Aiello, "Performance of a hydrogen in Pb-17Li," Journal of Nuclear Materials (2007) 367-370.

[9] B.G. Choi, et al., "Development of a hydrogen permeation sensor for liquid breeder type TBMs" Korean Nuclear Society Autumn Meeting (2012)