§7. Development of Proton Conducting Ceramic Sensor for Hydrogen Measurement in Liquid Blanket System

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The chemical control of impurity in coolants is one of the critical issues for the development of self-cooled liquid breeder blankets for fusion reactors. Especially, hydrogen (isotopes) level is the key parameter for corrosion and mechanical properties of the in-reactor components. In addition, the control of tritium is essential for the tritium breeding performance of the fusion reactors. Therefore, on-line hydrogen sensing is a key technology for these systems. In the present study, the conceptual design for the on-line hydrogen sensor to be used in molten salt $LiF\text{-}BeF_2$ (Flibe) and liquid metal lithium (Li), lead-lithium (Pb-17Li) was performed. The evaluations of expected performance of the sensor and experimental validation at hydrogen pressures equivalent to those for the Flibe, Li and Pb-17Li were carried out.

Figure 1 shows the hydrogen sensor developed for the present work[1] based on the design of the sensor for the use in liquid aluminum[2]. This is cap type sensor which has gas compartment. The sensor cell is made of In doped $CaZrO_3$ ceramics, which is solid electrolyte and well-known as proton conducting ceramics. In this concept, the cell is immersed into the melt which is containing the hydrogen at the concentration of S (wt%). Hydrogen comes to the compartment from the melt. After equilibration, the hydrogen concentration is derived by the partial pressure of the hydrogen at P_{H1} (atm) in the compartment according to the Sievelt's law

$$S = k\sqrt{P_{H1}} \quad \cdots\cdots (1).$$

Then, the reference cell is filled with Ar-H_2 mixture gas at regulated hydrogen partial pressure of P_{H2} (atm). The electromotive force (EMF) is obtained by the proton conduction in the electro chemical system expressed as P_{H1} (melt) | solid electrolyte | P_{H2} (reference gas). The Nernst equation is used for the evaluation of the hydrogen partial pressure from the obtained EMF as

$$E = \frac{RT}{2F}\ln\frac{P_{H1}}{P_{H2}} \quad \cdots\cdots (2).$$

The performance tests for the In-doped $CaZrO_3$ sensor in the gas atmosphere at 600ºC were carried out. Fig.2 shows the test apparatus in TYK cooperation. In the test, the hydrogen partial pressure in the gas varied from 2.2×10^{-14} atm to 1 atm, to simulate those in the liquid Flibe (1atm), Pb-17Li (1×10^{-4}atm) and Li (1×10^{-10}atm). It was found that the sensor exhibited good response, and reproducibility at the hydrogen pressures equivalent to those for Li, Pb-17Li and Flibe (Figs.3 and 4).

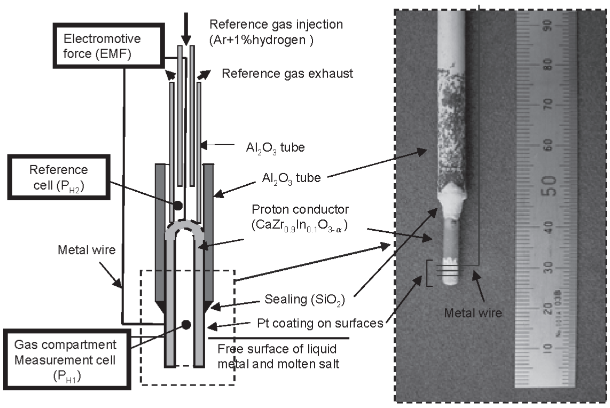

Fig. 1 Cap type sensor for liquid blanket system

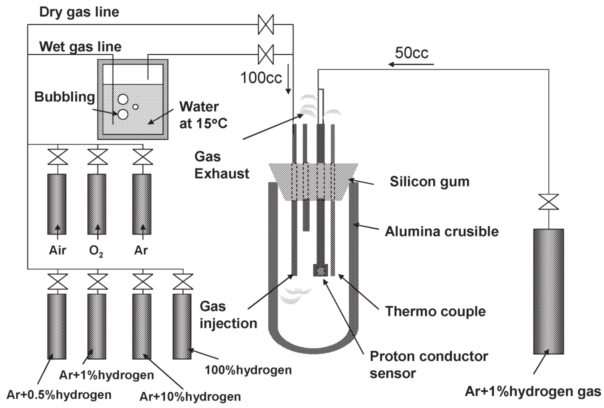

Fig. 2 Test apparatus for sensor performance test in gas atmosphere

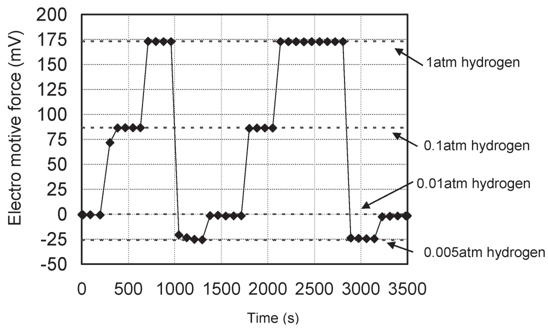

Fig. 3 Sensor performance in high hydrogen partial pressure gas atmosphere

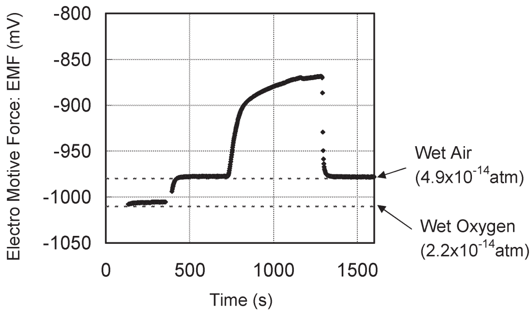

Fig. 4 Sensor performance in low hydrogen partial pressure gas atmosphere

Reference

1) Kondo, M., et al., Proc. of 15th International conference of nuclear engineering, (2007) ICONE15-10588
2) Yajima, T., et al., Solid State Ionics., **79** (1995) 333