

§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-BeF₂ (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 work¹⁾ based on the design of the sensor for the use in liquid aluminum²⁾. This is cap type sensor which has gas compartment. The sensor cell is made of In doped CaZrO₃ 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

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

Then, the reference cell is filled with Ar-H₂ 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

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

The performance tests for the In-doped CaZrO₃ sensor in the gas atmosphere at 600°C were carried out. Fig.2 shows the test apparatus in TYK cooperation. In the test, the hydrogen partial pressure in the gas varied from 2.2x10⁻¹⁴ atm to 1 atm, to simulate those in the liquid Flibe (1atm), Pb-17Li (1x10⁻⁴atm) and Li (1x10⁻¹⁰atm). 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).

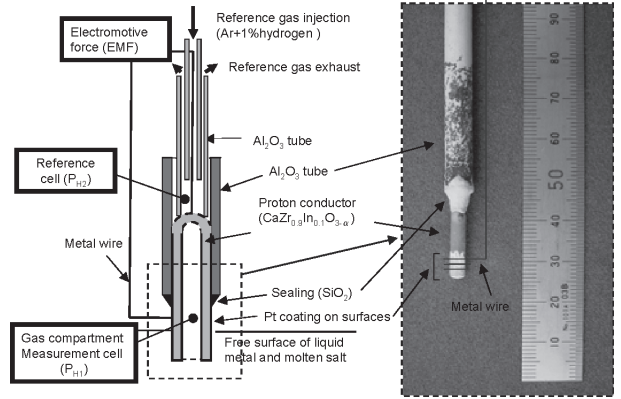


Fig. 1 Cap type sensor for liquid blanket system

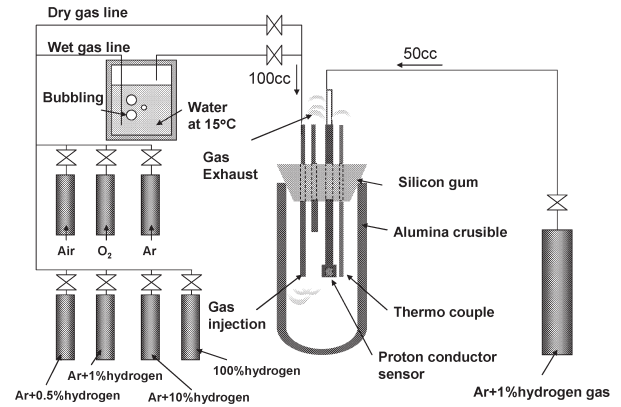


Fig. 2 Test apparatus for sensor performance test in gas atmosphere

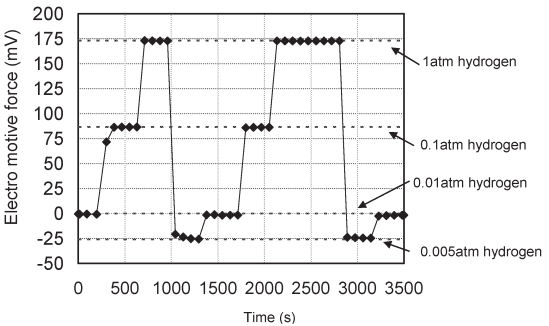


Fig. 3 Sensor performance in high hydrogen partial pressure gas atmosphere

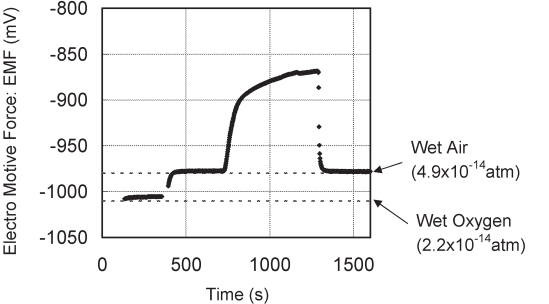


Fig. 4 Sensor performance in low hydrogen partial pressure gas atmosphere

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