§6. Sc Doped $CaZrO_3$ Hydrogen Sensor for Liquid Blanket

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The control of tritium is essential for the performance of liquid blankets of fusion reactors. On-line hydrogen (isotopes) measurement is a key technology. The on-line hydrogen sensor made of proton conduction ceramics, $CaZr_{0.95}O_{3-a}Sc_{0.05}$, was designed to be used in reducible condition such as liquid blanket system (Fig.1).

The $CaZrO_3$ doped with Sc_2O_3 has higher chemical stability than those with the other dopant oxides such as In_2O_3 or Ga_2O_3 due to high thermodynamic stability. 5mol% Sc_2O_3 was doped in the $CaZrO_3$, and this made oxygen vacancy in the oxides as

$$CaZrO_3 \xrightarrow{Sc_{0.05}} CaZr_{0.95}Sc_{0.05}O_{3-\alpha} \quad \cdots\cdots(1).$$

The evaluation of the expected performance of the sensor in molten salt $LiF\text{-}BeF_2$ (Flibe), liquid metal lithium (Li) and lead-17lithium (Pb-17Li) was carried out by means of the performance test in gas atmosphere at 700°C with hydrogen partial pressures equivalent to those for the melts. The partial pressure of tritium in Flibe, Pb-Li and Li were estimated as 1×10^{-2} atm, 2.8×10^{-4} atm and 3.4×10^{-14} atm, respectively. The sensor performance in liquid metal with low oxygen potential was investigated by means of the test in molten Al. Fig.2 shows experimental apparatus for sensor performance test in molten Al.

Then, the system of the sensor is expressed as

$P_{H(1)}$ ($\underline{H}$ in melt) / $CaZr_{0.95}Sc_{0.05}O_{3-a}$ / $P_{H(2)}$ (Ar-x%H_2)··(2).

In this system, an electromotive force (EMF) with the unit of V is given by the Nernst equation as

$$E = \frac{RT}{2F} \ln \frac{P_{H(1)}}{P_{H(2)}} \quad \cdots\cdots(3).$$

Figure 3 shows the sensor output before and after the change of reference gas of sensor with keeping the immersion in molten Al at 700ºC. The sensor EMF transited and reached constant shortly after the change of hydrogen partial pressure in reference gas from 1% hydrogen to 10% hydrogen. The transition of the EMF was measured as 90mV, and this is lower than that theoretically estimated as 96.5mV. This is possibly because the sensor temperature problem. The temperature of the reference gas was 660 ºC, and the system was placed in air at 30ºC. These temperature profiles made the temperature of the sensing part lower than the Al temperature of 700ºC. This influenced the output of sensor. If the sensing part was at 640ºC, the transition was estimated as 90mV and this agreed with that of experimental data. After the reference gas was changed from 10% hydrogen to 1% hydrogen, the EMF transited to the value which was obtained before the change of hydrogen partial pressure in reference gas. The transition was completed within several minutes.

The sensor exhibited stable output and fast response when the hydrogen concentration in molten aluminum was changed

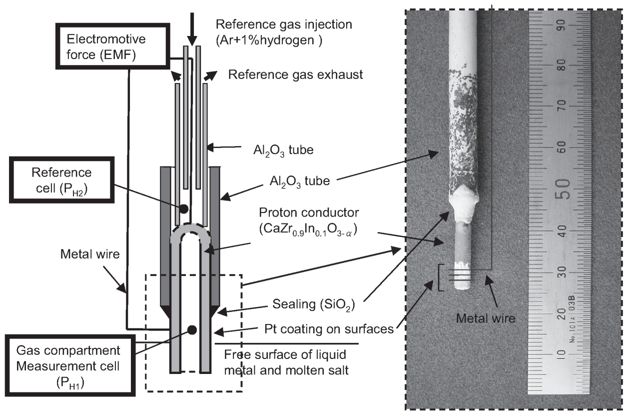

Fig. 1 Cap type sensor for liquid blanket system

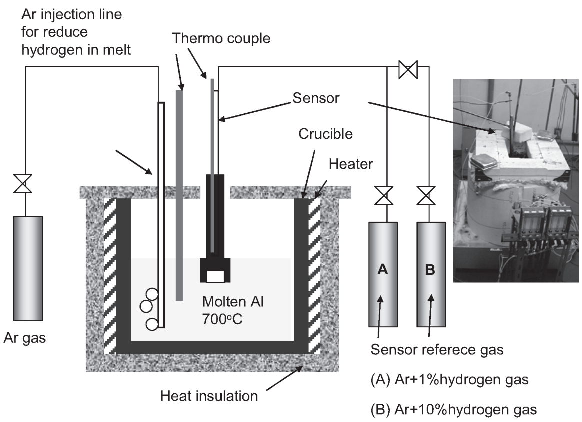

Fig. 2 Experimental apparatus for sensor performance test in molten Al

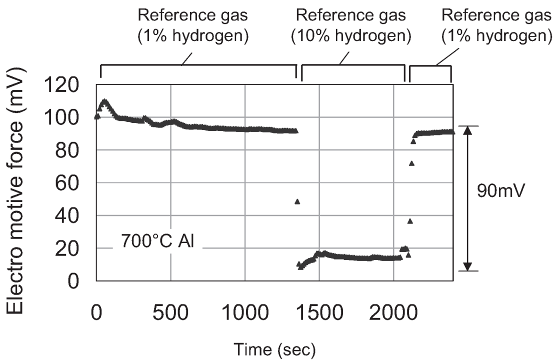

Fig. 3 Sensor output in molten Al at 700°C by change of reference gas from 1% hydrogen to 10% hydrogen