Performance of Solid Electrolyte Oxygen Sensor with Solid Fe/Fe_3O_4 Reference Electrode for Liquid Lead-bismuth Eutectic

*Pribadi Mumpuni Adhi[1], Masatoshi Kondo[2] and Minoru Takahashi[2]
[1]Dept. Nucl. Eng. Tokyo Tech, [2]RLNR, Tokyo Tech

Experimental study on the performance of solid electrolyte oxygen sensor with solid Fe/Fe_3O_4 powder reference electrode has been performed in air and lead-bismuth eutectic (LBE) environment. The effect of air in the reference cell on the sensor performance was made clear. The oxygen sensor worked well in both air and LBE environments under oxygen saturation condition in the temperature of 550°C - 600°C.

Keywords: Solid electrolyte oxygen sensor, Iron, Magnetite, Lead-bismuth Eutectic

1. Introduction Some solid electrolyte type oxygen sensors have been developed for oxygen control in a liquid Pb-Bi coolant of fast reactor [1]. The sensor with solid type reference electrode has the following advantages compared to that with the gas type reference electrode [2]: the reliable output can be obtained by the sensor with the solid type reference without the continuous supplying of air to the reference cell; the air ingress to the coolant from a broken sensor can be avoided. The equilibrium condition in the reference cell that influences sensor output must be made clear. The purpose of the present study is to investigate the equilibrium condition in the reference cell of the sensor.

2. Experimental condition Magnesia-stabilized zirconia (MSZ) sensors were used. The reference compartments of the sensor were filled with Fe/Fe_3O_4 powder as shown in Fig. 1. The Fe and Fe_3O_4 powders were mixed in 1:1 molar ratio. The volume ratio of air space in the reference cell was chosen as a parameter to investigate the effect of residual air in the reference cell on the sensor performance. The experimental conditions were summarized in Table 1. The sensor performance in air and LBE was investigated. The LBE was under oxygen saturated condition made by the immersion of PbO particles at the temperature of 450°C - 600°C.

Table 1 Experimental conditions

No.	Ambient	Sensor No.	V_{air} in sensor compartment (mL)	O_2 in sensor compartment (mol)
1	Air	1	0.06	2.58×10^{-6}
2		2	0.38	1.54×10^{-5}
3		3	0.90	3.70×10^{-5}
4	LBE	1	0.02	1.00×10^{-6}

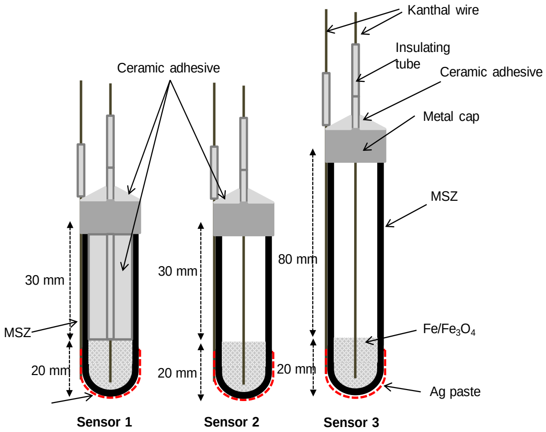

Fig. 1 Schematic figure of oxygen sensor

3. Results and Discussion Fig. 2 shows that the EMF output, or the oxygen potential in the reference cell, gradually changed from the potential of air to that of Fe_3O_4. After the reach to an equilibrium condition in the reference electrode, the EMF became constant, which agreed well with the theoretical one obtained by the Nernst equation. The test result indicated that the Fe powder in the reference cell was partially oxidized by air so that the oxygen partial pressure in the reference cell corresponded to Fe_3O_4 formation in the equilibrium condition of $3Fe+2O_2 \leftrightarrow Fe_3O_4$. Type 1 sensor showed faster initial EMF response than the other types of the sensor under the air environment, which means that the minimum space for the residual air in the reference cell contributed to earlier reach to the equilibrium condition than the other types of sensor. In the sensor test in LBE, the sensor showed the stable EMF output after the potential both in the reference electrode and working electrode reached the equilibrium condition. The oxygen potential in the Pb-Bi must be the potential for the formation of PbO. The sensor output agreed well with the theoretical one.

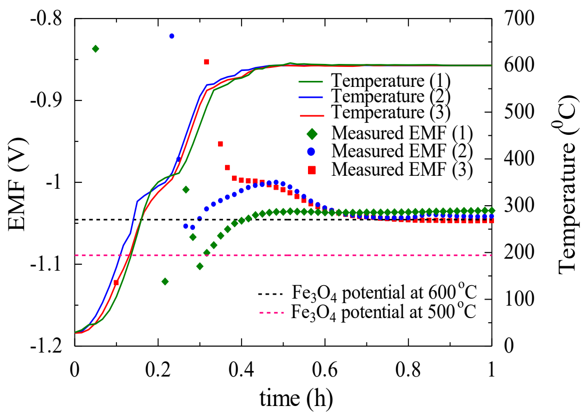

Fig. 2 Results of EMF in air

4.Conclusion The oxygen sensor with the solid type reference electrode performed well in the temperature of 550°C - 600°C and the residual air in the sensor compartment had an influence on the sensor performance. To have a reliable sensor the residual air in the sensor compartment should be minimalized.

References [1] C. Schroer, et al., J. Nucl. Mater. 415 (2011) 338–347.
[2] G. Manfredi, et al., Sensors Actuators B Chem. 214 (2015) 20–28.