Oxygen Sensor Development for LBE system

Seung Ho Jeong, Chi Bum Bahn, Seung Hee Chang, Sang Yeon Choi and Il Soon Hwang
Nuclear Transmutation Energy Research Center of Korea (NUTRECK), Building 31-1, Seoul National University, San 56-1 Shinlim-dong, Gwanak-ku, Seoul 151-742, Republic of Korea, skyseven@peacer.org

1. Introduction

Material corrosion problem has been studied worldwide. [1] The key element from surroundings affecting LBE corrosion is oxygen because the passive oxide formation on the metal surface is the decisive factor. Too low oxygen contents cause mass dissolution of metal substrate into LBE, but too much oxygen contents will be resulted in the coolant channel blockage by oxidation of Pb or Bi, and the porous oxide formation, which is not dense enough to protect the base metal [2-5]

Thus oxygen contents in LBE as well as oxygen partial pressure in cover gas must be monitored and controlled within appropriate value, typically about 10-6wt%. [2-5]

Generally YSZ (Yttria Stabilized Zirconia) tube or membrane is used to measure the oxygen activity, which acts as a good oxygen ion conductor. Theoretically YSZ membrane can measure the oxygen partial pressure down to 10-30 atm or less. But current oxygen sensors have several problems such as temperature hysteresis while operation, short lifetime, and leakage of ambient air into sensor.

We developed an oxygen sensor to improve the leakage characteristics by applying new joining technology between YSZ ceramic and stainless steel metal structure. Various metal/oxide references were also tested.

2. Sensor Design and Calibration Method

2.1 Sensor Design

Sealing between metal block and YSZ ceramic was enhanced by applying new technique to joint the YSZ ceramic into Inconel tubing body structure. This decreased the leakage compared to current metal/sealant/ceramic brazing method.

Bi/Bi2O3 or Fe/Fe3O4 reference was used within a compact 3/8" diameter tube body. Thus it is easily installed into commercial tube fitting parts. Ta or Mo wire was inserted into metal/oxide reference to transmit the emf signal generated by oxygen activity on the inner surface of YSZ tube. Guide tube having many holes and windows for free flowing of LBE onto sensor outside surface was devised to protect the YSZ tube.

All the parts of the sensor were assembled and welded by electron beam so that we can maximize the sealing performance.

2.2 Calibration Strategy

Oxygen contents signal should be calibrated in proper way. Oxygen gas titration and DCPD (Direct Current Potential Drop) was applied to our system. With oxygen control system, we can gradually increase the oxygen contents in LBE from very low activity. While the oxygen increases, oxygen partial pressure and oxygen activity in LBE will also increase gradually. Thus, if the oxygen partial pressure in cover gas reaches certain potential of metal/oxide equilibrium, we can expect a plateau type signal curve will appear. If the metal wire or plate corresponding to this equilibrium oxygen potential submerged in LBE, the potential between the metal specimens will increase under constant current condition. By this combination, we can calibrate the oxygen sensor signal to exact oxygen activity at this equilibrium line.

3. Experimental

Simulation Experiments are conducted in two types of facility – static cell apparatus and flowing loop system. A Pb-Bi loop facility named HELIOS (Heavy Eutectic liquid metal Loop for Investigation of Operability and Safety) was developed as a scaled down model from the prototype, PEACER 300. [6] We will develop a calibration strategy by combining the oxygen titration method and DCPD measurement of metal specimen.

4. Summary and Discussion

A new oxygen sensor was developed to enhance the sealing performance between sensor and ambient air. Calibration test will be conducted with combining the oxygen titration and DCPD method under oxygen controlled condition. But the signal hysteresis and lifetime issue are still unsolved.

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REFERENCES

[1] E.P. Lowen, A. T. Tokuhiro, "Status of Research and Development of the Lead-Alloy-Cooled Fast Reactor", Journal of Nuclear Science and Technology, Vol. 40, No. 8, (2003 August), 614-627

[2] Ning Li, “Active Control of Oxygen in Molten Lead-Bismuth Eutectic System”, Journal of Nuclear Materials 300 (2002) 73-81
[3] G. Muller et al., "Result of Steel Corrosion Tests in Flowing Liquid Pb/Bi", Journal of Nuclear Materials 301 (2002) 40-46
[4] H. Glasbrenner et al., “Corrosion Investigations of Steels”, Journal of Nuclear Materials 296 (2001) 237-242
[5] Y. Kurata et al., “Corrosion Studies in Liquid Pb-Bi Alloy at JAERI”, Journal of Nuclear Materials 301 (2002) 28-34
[6] S.H. Jeong, et al, “Overview and Status of HELIOS,” Proceedings of International Congress on Advances in Nuclear Power Plants (ICAPP) ’05, Seoul, Korea , May 15-19, 2005.