§2. Feasebility Study of Chemistry Control in LiPb Dual Coolant Concepts

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High temperature blanket for efficient and attractive energy conversion is one of the most important subjects in fusion technology. Concepts with Lithium-Lead eutectic is expected as a liquid blanket material for future fusion reactors that is possible to test as a Test Blanket Module in ITER, and also eventually expected to be an advanced blanket to be operated at high temperature encompassing 900 degree C. However, despite the characteristics of LiPb as a breeder or heat transfer medium has relatively well studied, its chemical purity that strongly affects its behavior remains as a feasibility issue. This study has a purpose to develop a feasible technique to monitor and control the chemical purity of LiPb, particularly with hydrogen and oxygen. The authors have suggested that oxygen and proton ionic conductors can be used as sensors for liquid metal systems that continuously monitor the oxygen or hydrogen contents without sampling. Its continuous nature and expected wide operating concentration range are also advantages.

This year, we report the basic behavior of the sensors and early results with LiPb on oxygen and hydrogen measurement with them.

2. Theory

Ionic conductor membrane with two electrodes on the both sides can detect the difference of the ion activity as the electromotive force (emf) between them. In the case of oxygen ion in oxide conductor, The $a^{\mathrm{II}}_{O_2}$ is calculated from $P^{\mathrm{I}}_{O_2}$ and emf as given by Nernst equation:

$$E = \frac{RT}{4F}\ln\frac{P^{\mathrm{I}}_{O_2}}{a^{\mathrm{II}}_{O_2}}$$

$$\ln a^{\mathrm{II}}_{O_2} = \ln P^{\mathrm{I}}_{O_2} - \frac{4FE}{RT}$$

When one side of the oxide is exposed to the known oxygen activity, for instance, with air, the emf measured by the cell is converted into oxygen activity in the metal with this equation.

On the other hand, the partial pressure of the equilibrium oxygen in the metal can be calculated from Gibbs free energy equation. The equilibrium of the reaction of Li and oxygen is shown as the following with the standard generation free energy $\Delta G^0(Li_2O)$ of its oxide.

$$4Li + O_2 \Leftrightarrow 2Li_2O$$

$$\Delta G^0(Li_2O) = -RT\ln\frac{[Li_2O]^2}{[Li]^4[O_2]}$$

With the oxygen activity,

$$\ln a_{O_2} = \frac{\Delta G^0(Li_2O)}{RT}$$

In the alloy, activity of oxygen and metal has been changed, and its influence has to be considered in above equation. The consideration in that case, by Peter Hubberstey[1].

$$4Li(LiPb) + O_2(LiPb) \Leftrightarrow 2Li_2O(LiPb)$$

$$\Delta G^0(Li_2O) = -RT\ln\frac{{a_{Li_2O}}^2}{{a_{Li}}^4 a_{O_2}}$$

And the oxygen potential is expressed,

$$\ln a_{O_2} = \frac{\Delta G^0(Li_2O)}{RT} - 4RT\ln a_{Li} \quad .$$

3. Results and Consideration

Typical result of oxygen measurement with yttria stabilized zirconia cell between 400 and 500 degree is shown in the figure 1. The oxygen potential was in the order of 10-30 atm range, that well agreed with the theoretical value.

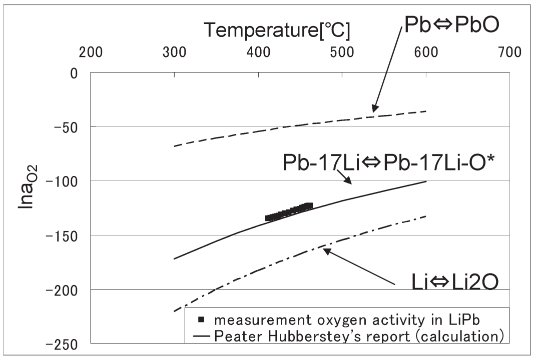

Fig. 1. Oxygen potential in liquid LiPb.

This result suggest that the YSZ cell can measure the oxygen potential as expected, and with this known relationship, the emf also suggest the LiPb alloy composition.

Further study with proton conductor is expected to show the hydrogen potential that is important for tritium recovery from blankets.

Reference

1) P. Hubberstey, *J. Nucl. Mater*. ***247***, *1*, 208-214 (1997).