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Developing A Sensing System for the Measurement of Oxygen Concentration in Liquid Pb-Bi Eutectic: Quarterly Progress Report (July 1 – Sept. 30, 2004)

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Quarterly Progress Report
(July. 01 – Sept. 30, 2004)

Task 13:
Developing A Sensing System for the Measurement of Oxygen
Concentration in Liquid Pb-Bi Eutectic

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Developing A Sensing System for the Measurement of Oxygen Concentration in Liquid Pb-Bi Eutectic

Introduction

Dr. Jiang Ma and Mr. Xiaolong Wu worked in LANL between July 1 and Sept. 15 to conduct the experiment. Test of the corrosion of different materials in LBE was performed. The influence of the process of gas introduction to the LBE was studied. Data analysis work was performed based on accumulated data. In the same time, progress has been made in the simulation for transport in oxygen mixing, and one paper was presented in a conference. Another paper was composed and submitted to IEEE International Symposium of Circuits and Systems for the track Chemical Sensors. Preparation of a paper regarding to the RGA analysis for the calibration of oxygen sensor is on the way.

Personnel

Principal Investigators:

- Dr. Yingtao Jiang (Electrical and Computer Engineering)
- Dr. Bingmei Fu (Mechanical Engineering)

Professional

- Dr. Jian Ma, Professional, (Mechanical Engineering)

Students:

- Mr. Xiaolong Wu (Electrical and Computer Engineering)
- Mr. Shahidur Rahman (Mechanical Engineering)

Management Progress

Expenditures incurred during this quarter are within the target amount allocated.

Management Problems

In July, the director of LANL, Mr. Nanos, addressed the suspension of LANL due to the safety and security purpose. All work in LANL has to be suspended until the security risk (SR) level 3 will be satisfied. Our experimental work will be able to start after SR level 3 is passed on October 26.

Technical Progress

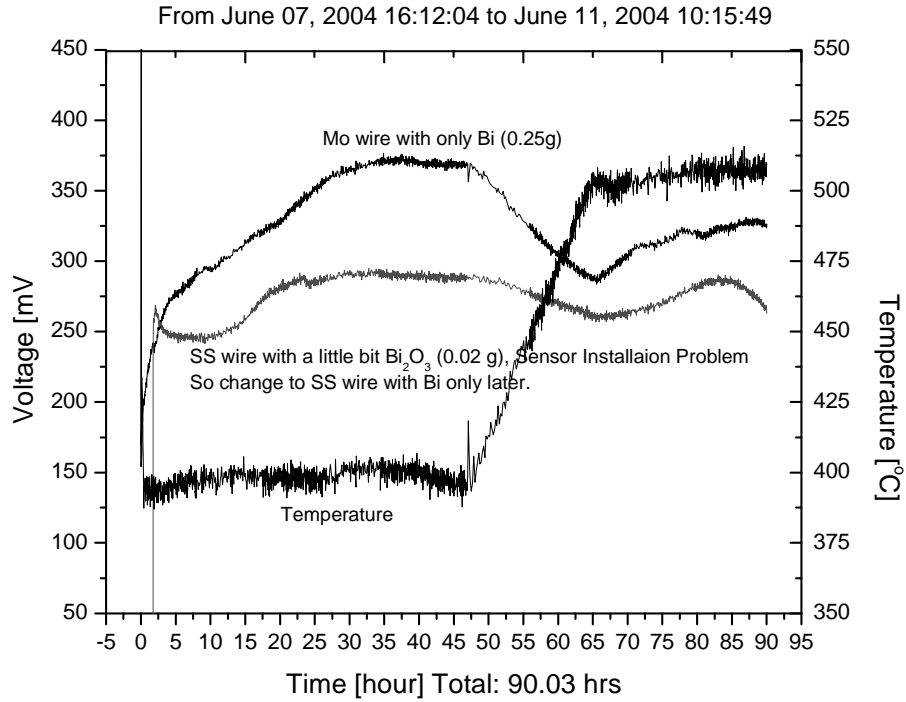
A. Carried out the data analysis for the previous experiments

1. The comparison of different electrode (**Molybdenum** and **stainless steel**)
2. The comparison of different quantitative of signal reference

Conclusion:

1. The corrosion for different materials is same at lower temperature (< 400 °C)

2. Less quantitative will lead to sensor signal values decrease.



B. Residual Gas Analysis (RGA) data analysis

The mass detection of the cover gas in the LBE container is obtained by RGA system. According to the ratio of partial pressure of H_2O and H_2 in the cover gas, the oxygen concentration in LBE can be obtained. Furthermore, the sensor signal can also be obtained theoretically.

According to J.S. Zhang's paper:

The electrochemical potential $E(v)$ is:

$$E(v) = \frac{1}{2F} \left(\frac{1}{3} \Delta F_{\text{Bi}_2\text{O}_3}^0 - \Delta F_{\text{PbO}}^0 - RT \ln a_{\text{PbO}} + RT \ln a_{\text{Pb}} \right) \quad (1)$$

The reference is Bi_2O_3 . Sensor is soaked in LBE. If the sensor is soaked in pure Lead, activity a_{Pb} is unity.

$$\ln a_{\text{PbO}} = \frac{1}{2} \left(\ln P_{\text{O}_2} - \frac{2}{RT} \Delta F_{\text{PbO}}^0 + 2 \ln a_{\text{Pb}} \right) \quad (2)$$

If using $\text{H}_2\text{O}/\text{H}_2$ system to generate extremely low partial pressure O_2 ,

$$\ln P_{\text{O}_2} = 2 \ln \frac{P_{\text{H}_2\text{O}}}{P_{\text{H}_2}} + \frac{2}{RT} \Delta F_{\text{H}_2\text{O}}^0 \quad (3)$$

Apply (2) and (3) into (1),

We obtain,

$$E(v) = \frac{1}{2F} \left(\frac{1}{3} \Delta F_{Bi_2O_3}^0 - RT \ln \frac{P_{H_2O}}{P_{H_2}} - \Delta F_{H_2O} \right)$$

where,

F is Faraday constant, 96484.6 C/mol

R is universal gas constant, 8.3144 J/mol/K

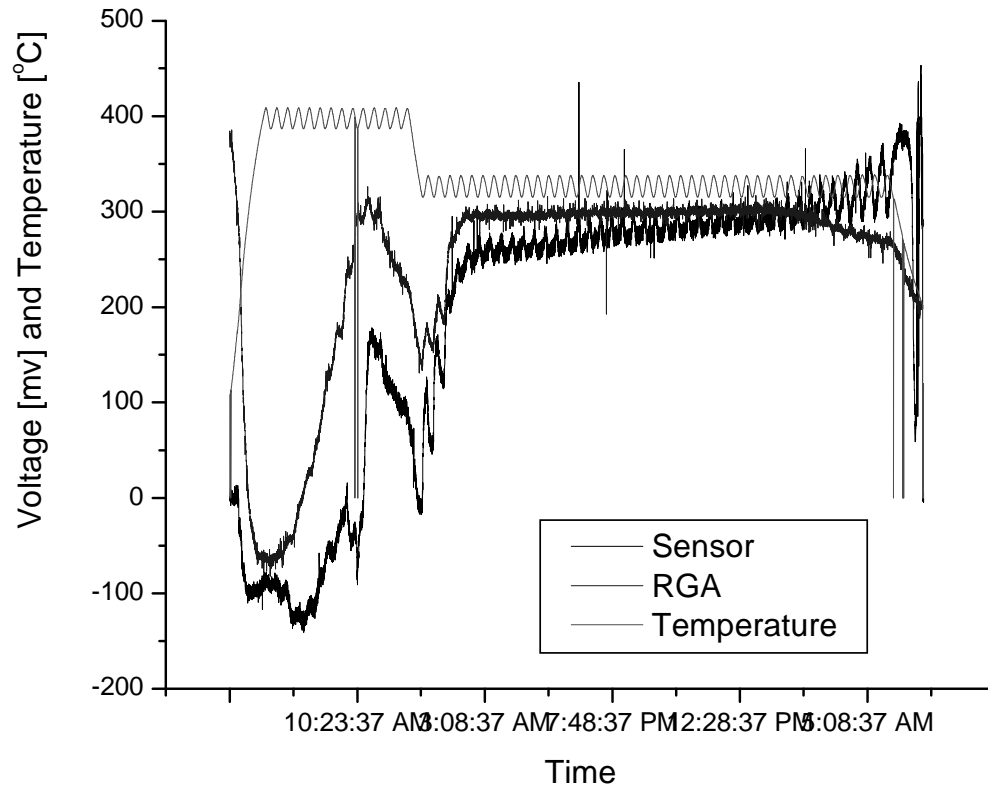
$$\Delta F_{Bi_2O_3}^0 = -582070 + 282T \text{ J/mol}$$

$$\Delta F_{H_2O}^0 = -245570 + 54.45T \text{ J/mol}$$

T is temperature in K.

Finally, we obtain,

$$E(v) = 0.2671 + 0.0002T - 0.000043 \ln \left(\frac{P_{H_2O}}{P_{H_2}} \right) T \quad (4)$$



Conclusion:

The comparison of RGA data and sensor data shows good agreement. However, there still some parameters need to be verified and the measurement error of RGA need to be compensated.

Technical Difficulties

The experimental setup from LANL experienced a few serious corrosion problems. Design of a new system is needed and is under its way.

Plans for the Next Quarter

- We shall restart the experiment in LANL on Nov. 1, 2004.
- A new apparatus will be constructed by Dr. Wei Hang with the assistance of Mr. Xiaolong Wu. We plan to build a similar system in UNLV.
- Dr. Jian Ma will work on the design of new apparatus in UNLV.
- Based on the above results, the paper regarding to the RGA analysis for the calibration of oxygen sensor is being prepared.