Measurement of Impedance of Oxide Layers on Ferritic-Martensitic Steels in Sodium Environment

Sang Hun Shin, Jeong Hyun Lee, Jeong Gi Lee,Ji Hyun Kim*
Interdisciplinary School of Green Energy, Ulsan National Institute of Science and Technology (UNIST)
100 Banyeon-ri, Eonyang-eup, Ulju-gun, Ulsan 689-798, Republic of Korea
**Corresponding author: kimjh@unist.ac.kr*

1. Introduction

HT9 and Gr.92 (Ferritic/martensitic steels) are considered as candidates cladding materials of Sodium-cooled Fast Reactor (SFR). Their compatibility with sodium is one of issues especially dissolution, chemical reaction with impurities, and mechanical properties.

HT-9 and Gr.92 are known as compatible in sodium environment because the usual refueling time of SFRs is designed about 54 months. It is very important to investigate the corrosion-related behavior such as surface corrosion rate, carburization, decarburization and mechanical properties for its operation time.

To monitor the corrosion behavior of these candidate materials in sodium environment, Electrochemical Impedance Spectroscopy (EIS) method is first introduced and investigated in this study. Alumina covered HT-9 and Gr.92 work as working electrode (WE) and two molybdenum rods will work as counter electrode (CE).

For the development of reference electrode (RE), solid electrolyte (gadolinia doped ceria used) based oxygen sensors are developed.

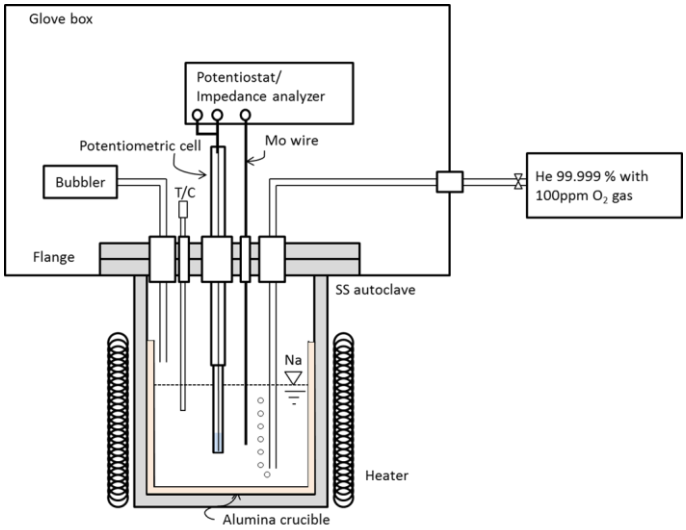
The compatibility of cladding materials with sodium has to be carefully investigated, as sodium could promote corrosion of cladding and structural materials in two ways. One is produced by the dissolution of alloy constituents into the sodium, and the other is produced through a chemical reaction with impurities (especially oxygen and carbon) in the sodium environment [1]. With the latter consideration, the concentration of dissolved oxygen in sodium has to be monitored and controlled during the operation of reactor. The need to monitor oxygen levels in the liquid sodium in fast reactor coolant circuits is well established [2-5].

2. Experiments

Since electrochemical oxygen sensors provide a sensitive means to measure the oxygen concentration in liquid sodium, and are capable of achieving the highly sensitive detection that is required in the operation of reactor system, it can be used as reference electrode in electrochemical method.

For the oxygen sensor signal calibration, electromotive force (emf) signal measurements of GDC based oxygen sensor was performed by using open circuit potential technique with Solatron potentiostat 273A in oxygen saturated sodium at 180-210℃. Galvanic cell used in this study can be represented as below:

$$Mo, Na, Na_2O \,|\, GDC \,|\, In, In_2O_3, Mo$$



(a)

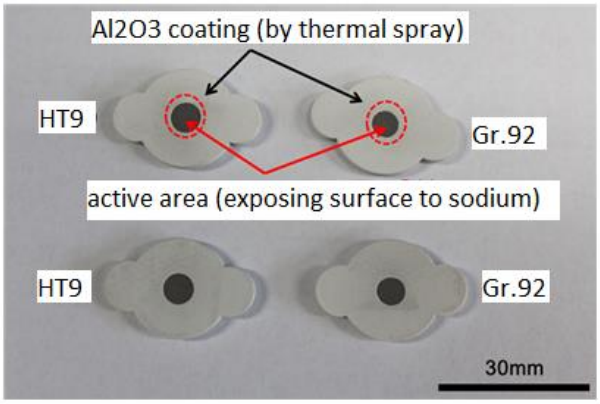
(b)

Fig. 1 Schematic of experimental system which consists of oxygen sensor, thermo couple and molybdenum lead wire respectively (a) and appearance of the oxygen sensors used in this study (b).

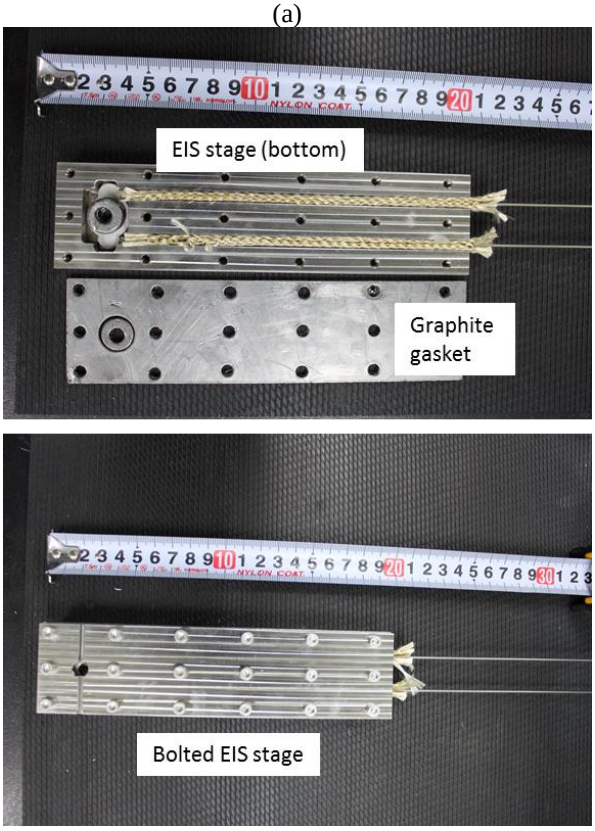
Working electrode was coated by thermal spray method to control active area when it exposed to liquid sodium and EIS sample stage was manufactured in this study.

3. RESULTS

Fig. 3 shows the emf signal of GDC based oxygen sensor in oxygen saturated sodium at 180-210 ℃. The results show the temperature dependence on emf signal.



(a)



(b)

Fig. 2 Electrochemical Impedance Spectroscopy (EIS) test preparation with (a) coated working electrode (HT9 and Gr.92) and (b) EIS stage

This measurement is conducted in oxygen saturated sodium, emf signal may imply the oxygen saturation condition. The correlation of oxygen solubility in sodium as a function of temperature derived from the measured emf data in this study is given by the following expression:

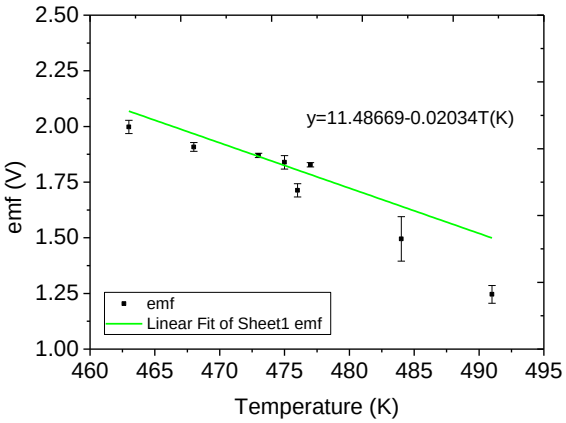


Fig. 3. Emf signal of GDC-10 based oxygen sensor as function of temperature.

$$\log c_{O,S}\,(ppm) = 209.23 - \frac{112333}{T}(460 - 491K) \qquad (1)$$

It shows higher oxygen solubility limit compared to other literature data [6]. The additional study on reference electrode is needed.

At the sodium flowing loop described in author's previous study [7], EIS test with reference electrode (oxygen sensor), counter electrode (Mo) and working electrode (HT9 and Gr.92) will be set with controlled oxygen concentration in liquid sodium.

ACKNOWLEDGEMENT

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