PD-02

Discovery of corrosion resistant materials for liquid Sn divertor
溶融錫中において優れた耐食性を示す材料探索に関する研究

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Liquid tin (Sn) is one of the candidate coolants for liquid divertor systems due to its excellent heat transfer characteristics and extremely low vapor pressure. Material compatibility of the liquid Sn with structural materials is important issue for the development of the liquid Sn cooled divertor system. The purpose of the present study is to explore corrosion resistant materials for the liquid Sn. The corrosion characteristics of various materials such as SiC, Al_2O_3, Cr_2O_3, W, Zr, steels with oxide layer etc. were investigated by means of static corrosion tests at 773K for 262 hours. The results indicated that the ceramic materials and the oxide layers exhibited excellent corrosion resistant in the liquid Sn.

1. Introduction

Liquid tin (Sn) is one of the candidate coolants for liquid divertor systems due to its excellent heat transfer characteristics and extremely low vapor pressure [1]. Material compatibility of the liquid Sn with structural materials is important issue for the development of the liquid Sn cooled divertor systems. In the previous study [2], the corrosion characteristics of the reduced activation ferritic martensitic (RAFM) steel JLF-1 in liquid Sn at 873K was investigated. It was found that the corrosion was caused by severe alloying reaction between the steel compositions and Sn. In the other study [3], the corrosion characteristics of AISI316L steel (Fe-17.3Cr-12.1Ni-2.31Mo) and their temperature dependence was investigated by means of short-term corrosion tests. However, the information on corrosion resistant materials for liquid Sn is quite limited. The purpose of the present study is to explore corrosion resistant materials for the liquid Sn.

2. Thermodynamic consideration on oxygen potential in liquid Sn

The possible oxides, which can form in the liquid Sn at oxygen saturation condition, are SnO and SnO_2. The formation of SnO and SnO_2 are expressed as;

$$Sn + 1/2O_2 \rightarrow SnO \quad (1)$$

$$Sn + O_2 \rightarrow SnO_2 \quad (2)$$

$$SnO + 1/2O_2 \rightarrow SnO_2 \quad (3)$$

Figure 1 shows the standard Gibbs free energy of formations (ΔG_f) of oxides. $\Delta G_{f,SnO2}$ is slightly smaller than $\Delta G_{f,SnO}$. The Gibbs reaction energy (ΔG_r) in eq. (3) is expressed as;

$$\Delta G_r = -RT\ln K \quad (4),$$

where R is the gas constant (=8.314J/mol), T is the temperature [K] and K is the equilibrium constant. The composition ratio of the oxides is expressed as;

$$K = \frac{[SnO_2]}{[SnO]} = e^{-\frac{\Delta G_r}{RT}} \quad (5).$$

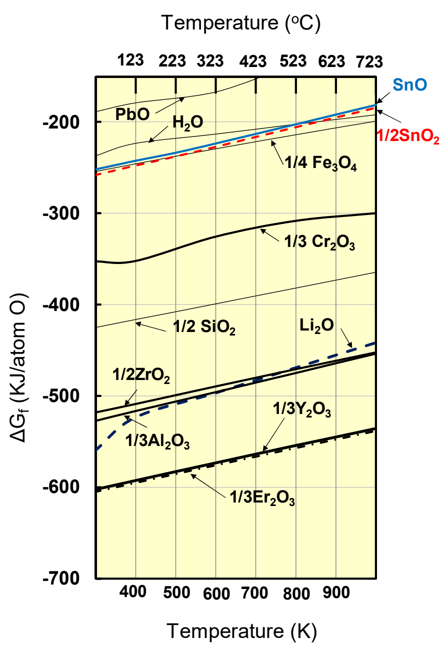

Fig. 1 Standard Gibbs free energy of oxides

The Gibbs reaction energy for eq. (3) is small as it is less than 10 kJ/mol. Then, both SnO and SnO_2 are stable in the oxygen saturated Sn. The composition ratios obtained by eq. (5) are shown in Fig .2.

These two oxides are rather chemically unstable than others as shown in Fig. 1. Therefore, oxide layers such as Fe_3O_4 and Cr_2O_3, which are formed on the steel surface, may be chemically stable and work as corrosion barriers [4]. Then, the compatibility depends on the stability of the layers. The Sn does not form any nitrides and carbides. Therefore, the effect of nitrogen potential [5] does not influence on the corrosion in the liquid Sn. The possible effect of the carbon potential on the corrosion is the carbon depletion from the steel due to the low carbon potential of the liquid Sn [6]. The coatings of oxides and nitrides on the steel surface may be effective to improve the compatibility.

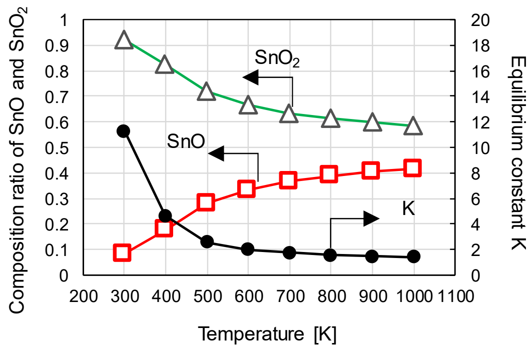

Fig.2 Compositional ratio of SnO and SnO_2 based on equilibrium constant K by eq. (4)

3. Corrosion tests with various kinds of materials

Corrosion tests were performed with various kinds of materials in a static Sn at 773K for 262 hours. The test materials are listed in Table 1. The detailed procedures of the static corrosion tests are reported in ref. [2]. The metal impurities initially dissolved in the liquid Sn are presented in Table 1. Pre-oxidation treatment was performed for some specimens to form the oxide layer before the exposure.

3. Corrosion resistant materials for liquid Sn

Figure 3 shows the some photos of the specimens tested in the liquid Sn. The experimental results indicated that the oxide bulks of Al_2O_3, Fe_2O_3 and Cr_2O_3 revealed a corrosion resistant in the liquid Sn. Other ceramic materials (SiC, SiN and AlN) also revealed a corrosion resistant. The adhered Sn on these materials were easily exfoliated from their surface. The surface colors of these materials were the same with those before the exposure.

Table 1 Test materials for corrosion tests in liquid Sn

	Specimen	Crucible		Specimen	Crucible
1	JLF-1	JLF-1	8	Al_2O_3	SUS316
2	NTK04L	SUS316	9	Fe_2O_3	SUS316
3	Ti	Ti	10	Cr_2O_3	SUS316
4	W	SUS316	11	SiC	SUS316
5	Y	SUS316	12	SiN	SUS316
6	Cr	SUS316	13	AlN	SUS16L
7	Zr	SUS316L	14		

14	JLF-1 (Preoxidation in air at 773K for 645 hours)	JLF-1
15	NTK04L (Preoxidation in air at 773K for 645 hours)	SUS316
16	Cr (Preoxidation in air at 773K for 264 hours)	SUS316
17	Zr (Preoxidation in air at 773K for 264 hours)	SUS316L

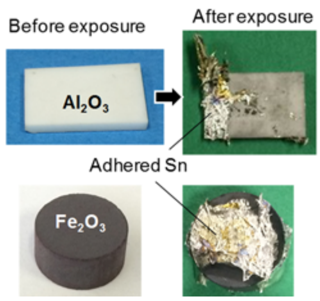

Fig.3 Photos of specimens before and after exposure

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Table 1 Initial metal impurities in liquid Sn (wppm)

	Purity	Bi	Cu	Fe	In	Pb	Sb
Sn grains (diameter 2-3 mm)	99.9%	10	50	10	ND	60	70