# JASMAC



### **OR1-3**

## 蛍光 X 線分析を用いた液体 Sn 中における Bi の 不純物拡散係数測定

## Measurement of Impurity Diffusion Coefficient of Bi in Liquid Sn through X-ray Fluorescence Analysis

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#### 1. Introduction

Diffusion coefficients in liquid metals are required for the elucidation of mass transport in liquid and the simulation of the solidification process. The accuracy of the diffusion measurement through the X-ray fluorescence analysis (XRF) depends on the validity of the linearity between the intensity and the concentration under the measurement<sup>1</sup>). The objective of this study is to investigate the concentration dependence of the systematic error in the diffusion measurement through the XRF by measuring the impurity diffusion coefficient of Bi in liquid Sn under the different concentration conditions. This alloy system was chosen because the concentration dependence of the diffusion coefficient is negligible in the low Bi concentration of liquid Sn<sup>2</sup>).

#### 2. Experimental Procedure

The experimental device for the diffusion measurement was the same as that in the reference<sup>1</sup>. A Sn-Bi rod and a pure Sn rod were set in the container as to provide stable density layering<sup>3</sup>, as shown in **Fig.1**. The initial Bi concentrations  $c_0$  in the Sn-Bi rods were set as 5 and 10 at.%. A Cu-filter (25.4 µm thickness) was set onto the tip of the X-ray source<sup>4</sup>.



Figure 1 Schematic of the experimental device for the diffusion measurement through the XRF.

In the diffusion measurements, the sample in the container was heated to 573 K and its temperature was maintained for approximately 30000 s after heating in a vacuum. The X-ray source was positioned 10 mm above the bottom of the rods and emitted X-rays constantly. The X-ray fluorescence was repeatedly detected with an integration time of 60 s. The intensities of L $\alpha$  and L $\beta$  emission lines of Bi (Bi L $\alpha$  and Bi L $\beta$ ) were obtained by summing the detected intensity and subtracting the background in each peak.

#### 3. Results

The Bi L $\alpha$  and Bi L $\beta$  intensities were obtained in each experiment. Assuming the linearity between the intensity and the concentration, the intensity *I* was expressed by

$$I(x,t) = \frac{I_0}{2} \left\{ \operatorname{erf}\left(\frac{L+x}{\sqrt{4D_{app}t}}\right) + \operatorname{erf}\left(\frac{L-x}{\sqrt{4D_{app}t}}\right) \right\},\tag{1}$$

where  $I_0$  is the detected intensity from the initial Sn-Bi rod (Bi concentration of  $c_0$  at.%), L is the initial height of the Sn-Bi rod,  $D_{app}$  is the apparent diffusion coefficient, and t is the time after the Sn rod melted. The unknown values of  $I_0$  and  $D_{app}$  were calculated by fitting Eq.(1) to the temporal distribution of each intensity in each experiment. **Figure 2** shows the fitting results from each intensity in each experiment. **Figure 2(b)** also shows the obtained value in  $\mu$ g condition ( $\mu$ g data)<sup>5</sup>). The error bar in **Fig. 2(b)** shows the 95% confidence interval of the fitting value. The  $I_0$  values at the  $c_0$  were fitted to the linear functions with the determination values  $\geq 0.999$ .



Figure 2 Fitting results in the experiments for each  $c_0$ : (a)  $I_0$  values and (b)  $D_{app}$  values. The error bar shows the 95% confidence interval of the fitting value.

#### 4. Discussion

**Figure 2(a)** proved the linearity between the intensity and the concentration in these experiments. According to **Fig. 2(b)**, the  $D_{app}$  values obtained from the Bi L $\alpha$  and Bi L $\beta$  intensities in different  $c_0$  conditions agreed with one another in the error range and were also close to the µg data. Thus, no significant difference in the apparent diffusion coefficients was confirmed in the present diffusion measurements between the different concentration conditions.

#### 5. Conclusion

In this study, no concentration dependence of the systematic error was observed in the diffusion measurement.

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