Thermophysical properties of germanium and its alloys in liquid states related to the modeling of diffusion phenomena

by
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Abstract: Thermophysical properties of liquid metals, such as the density, the viscosity and the compressibility, are necessary for the modeling of diffusion phenomena in liquid germanium alloys. These properties were investigated by several kinds of experimental method and have been accumulated as the database of thermophysical properties.

1. Introduction

Thermophysical properties give us important clues and essential information for the modeling of diffusion in liquid metals. Especially, the density, viscosity and compressibility are necessary to consider the relation between diffusion phenomena and liquid structures. In this project, these properties have been investigated in experimental studies by ourselves and obtained data have been distributed to the part of theoretical analysis of diffusion phenomena in our project. In this section, the latest data of these properties are shown briefly. The details of each measurement technique can be referred to the previous report of our research project [1].

2. Thermophysical properties of liquid germanium alloys

2.1 Density

Density is one of the most fundamental properties of matter. However, in the case of high temperature melts, it is difficult to measure the density with high accuracy because of the high chemical reactivity of high temperature melts to crucible materials and the limitation of observation ways. A gamma ray attenuation technique is one of the best ways for the measurement of density of metallic melts if the good crucible materials can be selected. The fused silica has been used for a crucible material of gamma ray attenuation techniques at the temperature less than 1500K. The glassy carbon was applied as a crucible material to several kinds of experiments and it is a good candidate of crucible material for the gamma ray attenuation method. In this project, the understanding of diffusion coefficient in the wide temperature range is a most important subject. Therefore, JAXA collaborated on the measurements of the density of liquid germanium alloys at the temperature higher than 1500K with Prof. Tsuchiya (Niigata University) who is the specialist of density measurements with the use of gamma ray attenuation method. Up to now, the new furnace for the high temperature experiments has been constructed and test run is in progress. Prior to the experiment at the temperature higher than 1500K, densities of Ge-Sn and Ge-Si alloys at the temperature lower than 1500K have been measured with the use of fused silica crucible. The results are shown in figure 1 and figure 2. The data reflect to the theoretical analysis and computer simulations those are described in previously.

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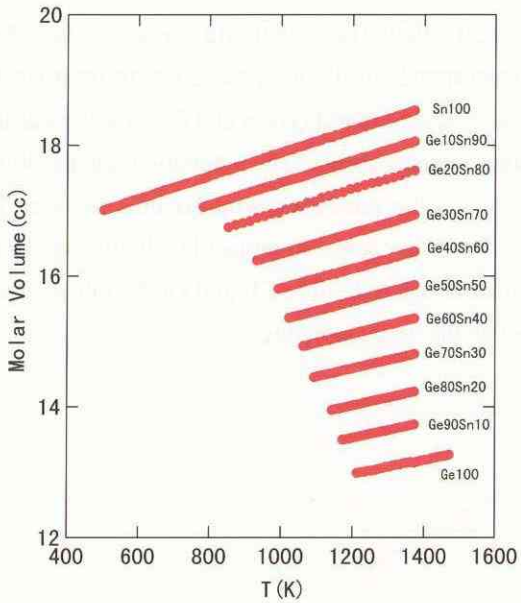

Figure 1 Molar volume of liquid Ge-Sn alloy

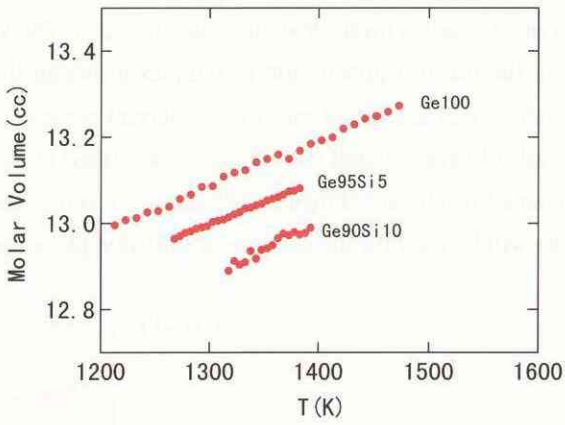

Figure 2 Molar volume of liquid Ge-Si alloy

2.2 Viscosity

Viscosity of liquid matter is derived from the momentum transport of atoms. It is well known that the viscosity coefficient can be related to the diffusion coefficient through the Stokes-Einstein equation. In this project, the viscosity coefficient of liquid germanium and its alloys were measured with the use of oscillating cup method. The details of this method have been described already in previous reports of our research project [1]. Therefore, the current results are shown in this report. Figure 3 shows the viscosity coefficient of Ge-3 atomic%Si and Ge-3 atomic%Sn. On the addition of Sn or Ge, the viscosity coefficients are increased compared to the case of the pure germanium.

Currently, the concentration dependence of viscosity coefficients of liquid Ge-Sn and liquid Ge-Si has been tried to be measured. In the near future, the detailed analysis will be performed about the relation between the viscosity coefficients and diffusion coefficients.

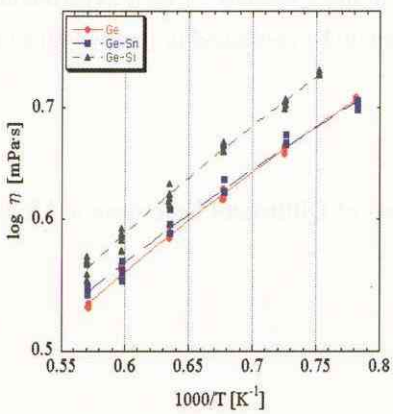

Figure 3 Viscosity of molten Ge and Ge alloys

2.3 Compressibility

The isothermal compressibility is important for theoretical calculations of liquid properties based on the liquid structure because the isothermal compressibility corresponds to the long wave length limit (or the thermodynamics limit) of static structure factor. The velocities of sound in liquid Ge-Sn and Ge-Si was measured with the use of transmission techniques to obtain the adiabatic compressibility. The adiabatic compressibility obtained was converted into the isothermal compressibility by using the standard thermodynamic relation. The details of experimental facilities were described in previous reports of our research project [1]. In this report, the obtained results are shown briefly. Figure 4 shows the isothermal compressibility of liquid Ge-Sn alloys. These data will be used for the analysis of diffusion phenomena based on the liquid structures.

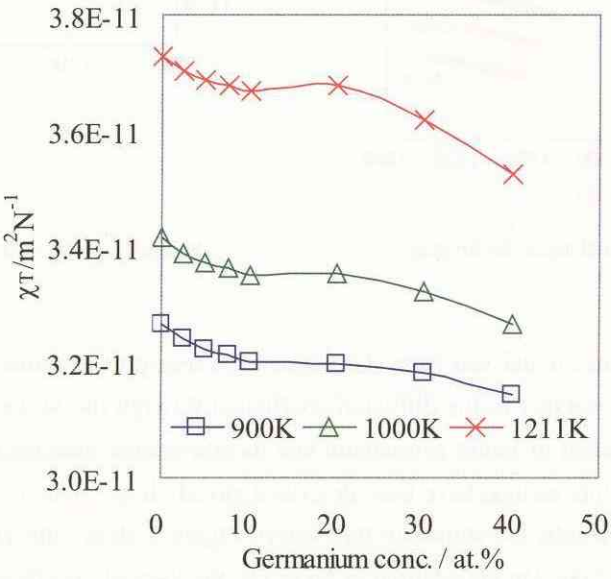

Figure 4 Isothermal compressibility of liquid Ge-Sn alloys

3. Summary

The thermophysical properties of liquid metals with high accuracy are important for the theoretical researches. However, it is hard to obtain these because of their experimental difficulty. In this project, efforts for the measurements of these properties are to be continued in future with a close relation to the theoretical research of diffusion phenomena.

Reference

[1] "Modeling and Precise Experiments of Diffusion Phenomena in Melts under Microgravity" Annual Reports 2002, NASDA-TMR-030005E.