Temperature dependence of densities of Sb and Bi melts

GENG HaoRan†, SUN ChunJing2, WANG Rui3, QI XiaoGang2 & ZHANG Ning1

1 School of Material Science and Engineering, Jinan University, Jinan 250022, China; 2 Key Laboratory of Liquid Structure and Heredity of Materials, Ministry of Education, Shandong University, Jinan 250061, China; 3 Mechanical Engineering Department, Luoding Vocational Technology College, Guangzhou 527200, China

The densities of Sb and Bi melts were investigated by an improved Archimedean method. The results show that the density of the Sb melt decreases linearly with increasing temperature, but the density of the Bi melt firstly increases and then decreases as the temperature increases. There is a maximum density value of 10.002 g/cm³ at 310 °C, about 39 °C above the melting point. The temperature dependence of the Sb melt is well fitted with the expression \( \rho = 6.8590 - 5.8105 \times 10^{-4} T \), and that of the Bi melt is fitted with \( \rho = 10.3312 - 1.18 \times 10^{-3} T \). The results were discussed from a microstructure viewpoint.

density, Sb melt, Bi melt, liquid structure

Compared with solid and gas, liquid has special microstructures, properties and law of behavior. As the origin of crystals and amorphous solid materials, it is of significant importance to investigate the structure and property of metal melts[1].

Density is one of the basic physical parameters of metal melts, reflecting the condensation degree of materials. From a microstructure viewpoint, density presents the mean spatial volume of atoms[2]. It is demonstrated that the density changes of the metal melts influence directly the convection and component dispersion. It is one of indispensable parameters depicting the property of the melts as well as radial distribution function. So far, much attention has been paid to the density of liquid including the metal melts[3–5]. Because of the limit of experiment conditions, such as sample oxidation at an elevated temperature and experimental apparatus, however, it is very difficult to obtain precise and systematic density data of the melts.

Elements Sb and Bi are important engineering materials and additives. As a semimetal, Sb possesses physical and chemical properties of the metal and semiconductor. Bi has a special property of hot shrinkage and cold expansion. Nevertheless, it is ambiguous in which temperature zone the abnormal phenomenon occurs and what relationships between the density and temperature for Sb and Bi melts are. In this paper, the temperature dependence of the densities for Sb and Bi melts was investigated by an improved Archimedean method, and some discussions were made.

1 Experimental procedure and principle

The experiments were carried out using the improved HGWX-B instrument for the measurement of physical properties of high-temperature melts. With the Archimedean method, the density of a liquid was calculated from the buoyancy force exerted by the liquid sample on a sinker or bob immersed in the liquid, which was suspended by a wire attached to the arm of a balance. However, this technique is prone to large errors arising from the convection flow of the liquid at high temperature and influence of the surface tension on the wire.

Received February 12, 2007; accepted March 13, 2007
doi: 10.1007/s11434-007-0309-7
†Corresponding author (email: mse_genghr@ujn.edu.cn)
Supported by the National Natural Science Foundation of China (Grant No. 50371047) and Natural Science Foundation of Shandong Province (Y2006F55)
suspending the sinker. To get rid of the effect of surface tension, the double-sphere method has been used [6]. Figure 1 is the double-sphere schematic drawing. The sinker is made of graphite which cannot react with the Sb and Bi melts. To immerse the sinker in the melts, a molybdenum rod was attached to the suspending sinker.

![Figure 1: Double-sphere schematic drawing.](image)

The samples of Sb and Bi (≥99.9 wt.%) were put into the graphite crucible. The samples were heated up to 200°C above the melting point in a resistance furnace, and held for one hour. The melts were made homogeneous by stirring and then cast into the crucible for the density measurement. To avoid the convection flow, the temperature of the top part of the crucible was let to be higher than that of the bottom part. The experimental procedure was performed in an argon atmosphere. The sample was heated to a certain temperature above the melting point and held for two hours, and then the density measurement was carried out. The temperature intervals were 10 and 30°C. Three measurements were performed at a temperature point and the average value was calculated.

2 Results and discussion

The famous empiric expression of the melt density is as follows:

\[ \rho = \rho_m + \lambda (T - T_m), \]

where \( \rho_m \) is the density at the melting point \( T_m \) and \( \lambda \) is a constant related to the melt and temperature. It is obvious that the density of the melt exhibits a linear correlation to the temperature.

Figure 2 shows the temperature dependence of the density for the Sb melt. It can be seen that the density of the Sb melt increases from 6.203 g/cm³ at 640°C to 6.262 g/cm³ at 920°C. The relationship between the density and the temperature is linear and can be well fitted with the expression:

\[ \rho = 6.79244 - 5.75487 \times 10^{-4} T. \]

The correlation \( R \) is 0.9993. In terms of eq. (1), eq. (2) can be transformed into the following expression:

\[ \rho = 6.48 - 8.3 \times 10^{-4} (T - 903.5), \]

where the \( \lambda \) value in eq. (3) is well consistent with that of ref. [7]. The density of the Sb melt calculated from eq. (3) is 6.48 g/cm³ at the melting point, close to 6.4925 g/cm³ in ref. [7] with an error of 0.19%. A comparison of the density for the Sb melt between the present paper and other literatures is shown in Figure 3. It is obvious that all density values decrease with increasing temp-

![Figure 2: Temperature dependence of the density for the Sb melt.](image)

![Figure 3: Comparison between the experimental results of the Sb melt in the present paper and those in literatures.](image)