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Thermodynamic Study of Sn-Bi-Nd, Tb Ternary Systems

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Abstract. The aim of this study was to investigate the effect of the addition of rare earth elements on Sn-Bi-based alloy, and to study the phase equilibrium of Sn-Bi-Nd,Tb ternary systems by means of establishing the thermodynamic database. Combined with the thermodynamic parameters of relevant binary systems, the thermodynamic database of the Sn-Bi-Nd, Tb ternary systems has been developed to present the significant information for the design of low-temperature lead-free solder alloys.

1. Introduction

With the development of modern technology, low-temperature lead-free solders are used more and more wildly in the field of low-temperature assembly. Phase equilibrium plays an important role in the process of optimizing the composition of low-temperature lead-free solder. Owing to the low melting point and good wettability, the Sn-Bi alloy is treated as one important and representative choice of the low-temperature Pb-free solders [1-3]. The addition of rare earth (RE) elements can control and eliminate the negative effect of impurity elements, which improve the spreading property of Bi-based solder[4, 5]. Therefore, it is essential to understand the phase equilibria in the Sn-Bi-RE system.

In the present work, combined with the assessed relevant binary systems, the thermodynamic database of the Sn-Bi-RE (RE=Nd,Tb) ternary systems have been developed and provides important information about phase equilibria and thermodynamic properties, such as stable and metastable phase equilibrium, phase fraction, mixing enthalpy, activity, Gibbs energy of formation, etc. which is very helpful to design new types of low-temperature lead-free solders.

2. The Sn-Bi-Nd system

In the Sn-Bi-Nd ternary system, the phase equilibria of the Sn-Bi, Bi-Nd and Sn-Nd binary systems have been assessed by Lee et al. [6], Wang et al. [7] and Wang et al. [8] respectively. Combined with the thermodynamic parameters of Ref. [6-8], the phase equilibrium of the Sn-Bi-Nd ternary system has been calculated. The isothermal sections at 150 ℃ and 200 ℃ are predicated and shown in figures 1-2. Figure 3 shows the calculated longitudinal section of the Sn-Bi-Nd ternary system.

The melting temperature of low-temperature lead-free solder is 220 ℃ to 230 ℃ or lower, which is equal or lower than the melting point of the eutectic solder [9]. As is shown in figure 3, with the addition of the rare earth Nd element, the temperature of solidus is 139 ℃, and the temperature of liquidus up to 1 at.% Nd is under 230 ℃. In this range, the phase equilibrium can provide theoretical guidance for optimizing the composition of low-temperature lead-free solder. Above 1 at.% Nd, the temperature of liquidus exceed 230 ℃ because of the formation of intermetallic compounds, which is not suitable for low temperature lead-free packaging materials. In addition, the isothermal sections and longitudinal section can provide theoretical guidance for the experimental study of the Sn-Bi-Nd ternary equilibrium.

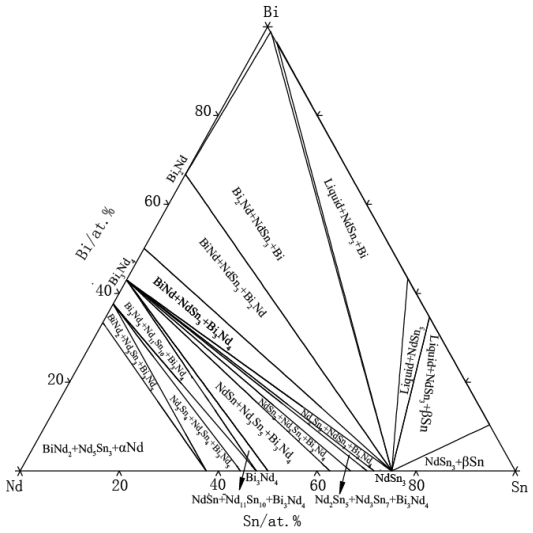

Figure 1. The calculated isothermal-section of the Sn-Bi-Nd ternary system at 150 ℃.

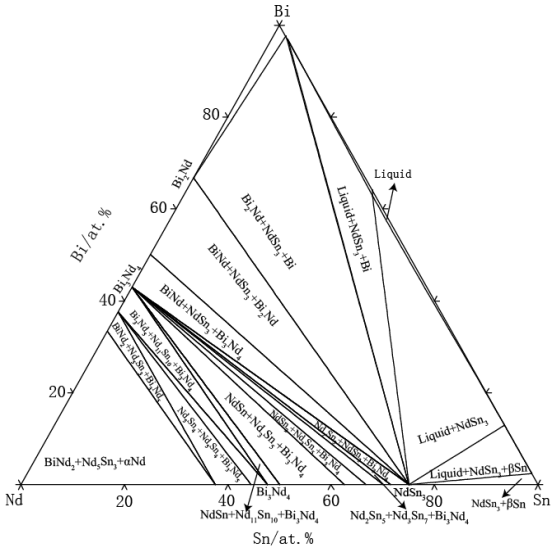

Figure 2. The calculated isothermal-section of the Sn-Bi-Nd ternary system at 200 ℃.

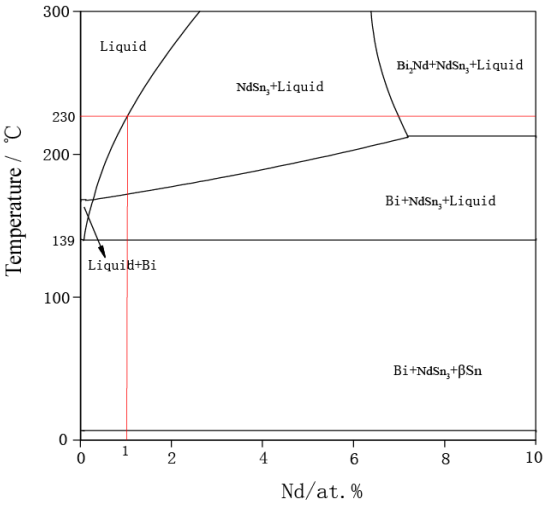

Figure 3. The calculated longitudinal-section of the Sn-Bi-Nd ternary system.

3. The Sn-Bi-Tb system

In the Sn-Bi-Tb ternary system, the thermodynamic assessments of the Sn-Bi, Bi-Tb and Sn-Tb binary systems were carried out by Lee et al. [6], Wang et al. [8] and Wang et al. [10] respectively. On the basis of the assessed thermodynamic parameters of relevant binary systems [6,8,10], the phase equilibrium of the Sn-Bi-Tb ternary system has been calculated. Figures 4-6 show the calculated isothermal section at 150 ℃ and 200 ℃ and longitudinal section.

As is shown in figure 6, with the addition of the rare earth Tb element, the temperature of solidus is 127℃, and the temperature of liquidus up to 8.3 at.% Tb is under 230℃. In this range, the phase equilibrium can provide theoretical guidance for optimize the composition of low-temperature lead-free solder. Above 8.3 at.% Tb, the temperature of liquidus exceed 230℃ also because of the formation of intermetallic compounds, which is not suitable for low temperature lead-free packaging materials. What's more, the isothermal sections and longitudinal section can provide theoretical guidance for the experimental study of the Sn-Bi-Tb ternary equilibrium.

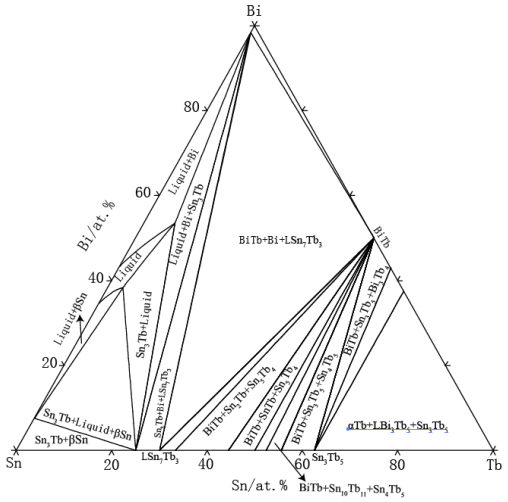

Figure 4. The calculated isothermal-section of the Sn-Bi-Tb ternary system at 150 ℃.

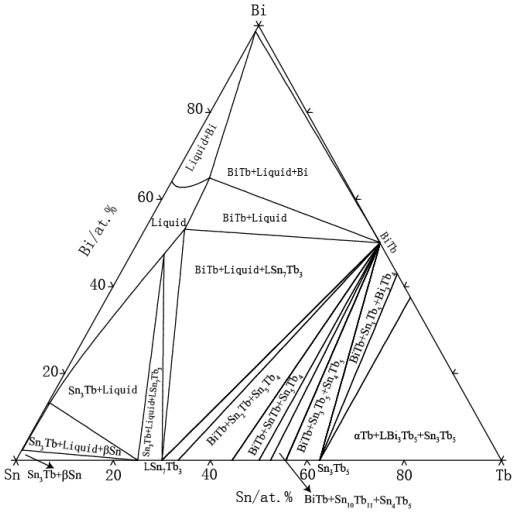

Figure 5. The calculated isothermal-section of the Sn-Bi-Tb ternary system at 200 ℃.

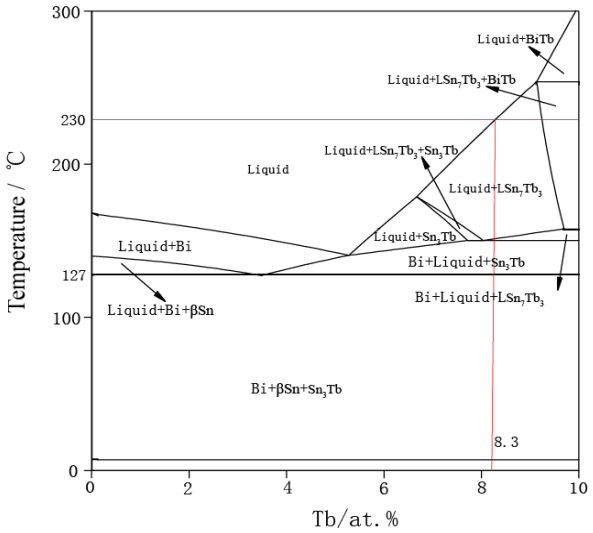

Figure 6. The calculated longitudinal-section of the Sn-Bi-Tb ternary system.

4. Summary

The phase equilibrium of the Sn-Bi-Nd and the Sn-Bi-Tb ternary systems has been calculated on the basis of the thermodynamic parameters of relevant assessed binary systems. And the effect of addition of RE (Nd,Tb) element is theoretical analyzed on the Sn-Bi-based lead-free solder.

5. References

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