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Phase Equilibria in the Sn-Rich Corner of the Ni-Sb-Sn System

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Phase equilibria in the ternary Ni-Sb-Sn system are of interest for high-temperature soldering, both considering ternary alloys as solder materials themselves or as the basis for understanding the reactions between Sb-Sn-based solders and Ni-based substrates. Therefore, the Sn-rich corner of the ternary Ni-Sb-Sn phase diagram with Sn content of more than 75 at.% was investigated by a combination of powder x-ray diffraction (XRD), differential thermal analysis (DTA), and electron probe microanalysis (EPMA). Ternary phase equilibria and phase compositions of the respective equilibrium phases were determined within the isothermal section at 200°C, and two isopleths were constructed for constant Sn contents of 80 at.% and 85 at.%. The experiments were supported by CALPHAD-type calculations of this ternary system to yield a consistent reaction scheme which shows four invariant ternary transition reactions in this composition range. A liquidus projection is presented, accompanied by the corresponding Scheil diagram.

Key words: Lead-free solder, high-temperature solder, Ni-Sb-Sn system, phase equilibria, phase diagram calculation

INTRODUCTION

High-temperature solders are solder materials with melting temperatures in the range between about 250°C and 300°C. Despite serious efforts to minimize or completely remove Pb-containing materials from electronics for more than two decades, the majority of high-temperature solders used in industry still contain up to 95 mass% Pb. This situation was the background for initiating COST Action MP0602 on "Advanced Solder Materials for High Temperature Application."[1]

One group of potential candidate high-temperature lead-free solder materials are Sb-Sn-based alloys, whose melting temperatures can be modified by adding a third element, for example, Ag, Cu or Ni. On the other hand, the two elements Cu and Ni are also very common contact materials in electronics. Thus, the two ternary systems Cu-Sb-Sn and Ni-Sb-Sn are also of importance to understand the chemical reactions behind the soldering procedure when binary Sb-Sn solders are used in combination with the corresponding metallization. Whereas the ternary Cu-Sb-Sn system has been investigated repeatedly, with respect to both thermochemical properties and phase equilibria (see the critical evaluation by Ghosh[2] as well as more recent work by Romanowska,[3] Lapsa et al.,[4] Jendrzejczyk-Handzlik et al.,[5] and Lee et al.[6]), much less is known about the ternary Ni-Sb-Sn system. Therefore, a study of this ternary alloy system was initiated in the authors' laboratory, including thermochemical studies,[7,8] phase diagram studies, and preparation of tin-rich Ni-Sb-Sn nanosolders.[9]

Due to large differences in the melting points of the component elements, the ternary Ni-Sb-Sn phase diagram is expected to have three distinct regions with varying melting temperatures, such as the high-melting Ni-rich corner, the intermediate-melting Sb-rich corner, and the low-melting Sn-rich corner. Especially tin-rich alloys will be of potential practical application in soldering, therefore this part was also the starting point for our phase diagram studies.

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