15th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2011, Prague, Czech Republic, 12-18 September 2011

THERMAL ANALYSIS OF Ag-Cu-In-Sn SYSTEM

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ABSTRACT
In this paper, the results of DSC analysis in Ag-Cu-In-Sn system are presented. Ten samples from the section with constant molar ratio (In:Ag:Cu=7:2:1) were investigated in order to obtain characteristic temperatures of each alloy. The results confirmed the influence of indium on thermal behaviour of these alloys.
Keywords: Ag-Cu-In-Sn, DSC analysis

1. INTRODUCTION
Lead has been widely used in modern society, particularly in microelectronics and presents the base of majority solders up to now. But, this metal is highly toxic and therefore, it should be removed from different materials, especially electonic, according to WEEE [1], so development of lead-free solder materials has received seriously attention in recent years [1-6].
The solder chosen for a particular use should have a low enough melting temperature that the melted solder does not damage any temperature-sensitive components that are to be joined. However, the melting temperature should also be high enough that the joint formed will not be affected by the operating temperature of the device or by subsequent soldering operations. In modern electronic applications, the temperature sensitivity of microelectronic components requires the use of solders at relatively low temperatures. In comparison, solders for joining and sealing pipes in plumbing operations are generally applied at much higher working temperatures because the components are not as temperature sensitive.
Solders with small pasty ranges are also important in certain "step-soldering" operations where components are added to a device sequentially. These operations are also dependent upon solders with specific melting temperatures. In step soldering, the first components are joined using a relatively high melting temperature solder. When later components are joined, a lower melting temperature solder is used so that the earlier-soldered joints are not affected by the soldering operation. Further components may then be added using solder with an even lower melting temperature. The availability of solders with different melting points is critical to such step-soldering processes. It is also important, if several soldering steps are to be performed, for the melting ranges of the solders to be small.
However, the most promising lead-free solder alloys, such as Sn-Ag or Sn-Ag-Cu have higher melting temperatures than conventional tin-lead solder. Because of that, in practice the temperature during

electronic assembling must be raised by 30-40°C which reduces reliability and functionality of electronic components. Low processing temperature is desirable for preventing damage of electronic devices during soldering.
An attractive solution for melting temperature decreasement is addition of indium [7], so the indium based multicomponent solder alloys might have appropriate characteristics.
Considering these facts, Ag-Cu-In-Sn alloys might be potentional candidates for replacement standard lead solder alloys, and in this paper the results of DSC analysis are presented.

2. EXPERIMENTAL

From large concentration area of the system Ag-Cu-In-Sn, one section was chosen, with constant molar ratio In:Ag:Cu= 7:2:1. From this section ten alloys were investigated using DSC analysis in order to determine characteristic temperatures for each alloy.
All samples were prepared from Ag, Cu, In and Sn of 99,99% purity. The samples were melted under argon atmosphere, homogenized at 200 ^{o}C for 2 h and slowly cooled down to the room temperature at a rate less than 5 K/min. The mass loss of samples was less than 1%.
The DSC measurements were performed on a SDT Q600 (TA instruments) in order to established transition temperatures. Alumina crucibles were used and measurements were performed under flowing argon atmosphere. Samples weighing about 50 mg were measured at heating rate 10 K/min.

3. RESULTS AND DISCUSSION

Ten samples from investigated section in the Ag-Cu-In-Sn system were investigated using DSC analysis, and characteristic temperatures for all samples are given in Table1.

Table 1. Characteristic temperatures of Ag-Cu-In-Sn investigated alloys

Alloy, at%	Characteristic temperatures, K
Ag10Cu5In35Sn50	386, 435
Ag9Cu4,5In31,5Sn55	386, 441
Ag8Cu4In28Sn60	387, 449
Ag7Cu3,5In24,5Sn65	454
Ag6Cu3In21Sn70	470
Ag5Cu2,5In17,5Sn75	473
Ag4Cu2In14Sn80	476
Ag3Cu1,5In10,5Sn85	504
Ag2Cu1In7Sn90	504
Ag1Cu0,5In3,5Sn95	508

For all investigated Ag-Cu-In-Sn alloys, melting temperatures are in range 435 - 508K. The melting point is marked as peak maximum, and for all alloys the endotermic peak was observed at DSC curve. The melting temperature is decreased with increasement of indium content in Ag-Cu-In-Sn alloy.
DSC curves for Ag10Cu5 In35Sn50 and Ag4Cu2In14Sn80 alloys are presented at Figures 1 and 2.

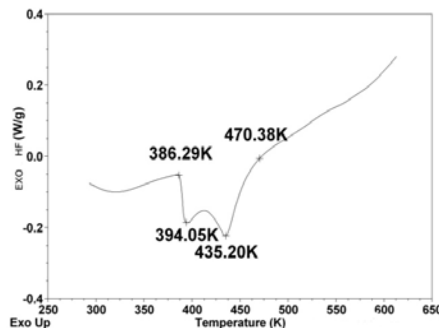

Figure 1. DSC curve for Ag10Cu5 In35Sn50 alloy

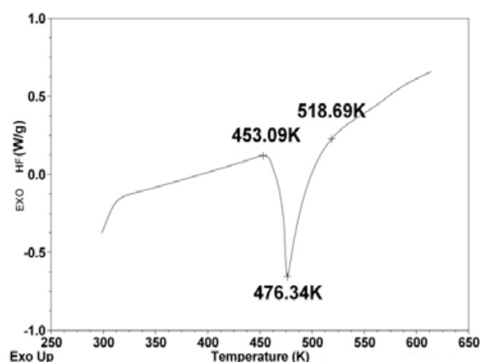

Figure 2. DSC curve for Ag4Cu2In14Sn80 alloy

The influence of indium on the thermal behaviour of these alloys is presented at Figure 1 and Figure 2. It is obvious that alloys with lower indium content (<20% In) have a sharp endothermic peak (Figure 2), unlike alloys with higher content of indium (Figure 1). The same was observed in ternary Ag-In-Sn and Cu-In-Sn systems, where this was a consequence of low melting In-Sn area, with the presence of In-Sn compounds in the structure [8].
Indium enters the Sn-matrix lattice sites to construct a substitutional solid solution. With higher indium addition, there is In_3Sn compound in tin matrix, which is undesirable because of partial melting of solder alloy. Moreover, Ag-Cu-In-Sn alloys with indium composition less than 20% have narrow pasty range which is suitable for replacement SnPb alloy in surface mount applications.

4. CONCLUSION

Lead-free soldering for electronic industry is a segment of global trend toward lead-free environment. In that way, Sn-based alloys with silver and copper are already used in some electronic processes, and the addition of indium is quite promising because of its low melting point and range of suitable properties.
In this paper the results of DSC analysis for the In:Ag:Cu=7:2:1 section in Ag-Cu-In-Sn system are presented. The characteristic temperatures for each investigated alloy were obtained, and confirmed the influence of indium content in alloy on thermal behavior of these solder alloys.

5. ACKNOWLEDGEMENT

Authors are grateful to the Ministry of Science and Technological Development of the Republik of Serbia (Project No.TR 34005) for financial support.

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