Effect of Y Addition on the Microstructure and Mechanical Properties of Sn-Zn Eutectic Alloy

Jung-Ho Moon, Tae Kwon Ha

Abstract**—**The effect of Yttrium addition on the microstructure and mechanical properties of Sn-Zn eutectic alloy, which has been attracting intensive focus as a Pb-free solder material, was investigated in this study. Phase equilibrium has been calculated by using FactSage® to evaluate the composition and fraction of equilibrium intermetallic compounds and construct a phase diagram. In the case of Sn-8.8Zn eutectic alloy, the as-cast microstructure was typical lamellar. With addition of 0.25wt.%Y, a large amount of pro-eutectic α phase have been observed and various YZn_x intermetallic compounds were expected to successively form during cooling. Hardness of Sn-8.8Zn alloy was not affected by Y-addition and both alloys could be rolled by 90% at room temperature.

Keywords**—**Sn-Zn eutectic alloy, Yttrium, FactSage®, microstructure, mechanical properties.

I. Introduction

EUTECTIC Sn-Zn system has been recognized as a possible replacement for Sn-Pb because Sn-9Zn eutectic alloy has a melting temperature (198^{o}C) close to that of Sn-Pb eutectic alloy (183^{o}C), and offers better mechanical properties. However, poor wettability between Sn-9Zn and Cu substrate must be overcome for this solder to be used. The poor wettability of Sn-9Zn on Cu [1], [2] are generally attributed to the higher surface tension and oxidation sensitivity of Zn in it, and the latter may cause other problems during application, such as producing too much dross when used in wave soldering and shortening the shelf-life of solder pastes when used in reflow soldering [3], [4]. In the development of Sn-Zn solders, almost all attention has been focused on eutectic Sn-9Zn since it has lowest melting point [5], which conforms to the requirement of low process temperature in electronic industry.

Recently, rare earth (RE) elements have been observed to possess many merits as doping elements in solders. In the previous work, RE elements, primarily, Ce and La were added to Sn-0.7Cu and Sn-9Zn lead-free eutectic alloys to study the effects on the microstructure [6]. It was found that the addition of RE elements could generally improve the microstructure by providing finer grain size so that the yield strength was improved. As the preceding aspects have suggested, Sn-Zn-RE system has good potential as a lead-free solder alloy. Wetting property of Sn-Zn-RE alloys was also studied ant it was revealed that the addition of 0.05wt.%RE elements reduced wetting angle and increased wetting force because of the decrease of the interfacial tension between the solder alloy and Cu substrate by interaction of RE and Cu [7]. Finer microstructure was also obtained with RE addition and there was no change to the liquidus temperature.

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In the present study, the effect of Y addition on the phase equilibrium and physical properties of Sn-Zn eutectic alloy were investigated. Precipitation behavior of Sn-8.8Zn-0.25Y alloy have been studied by thermodynamic simulation using FactSage® and experimental works, such as microstructure observation, cold rolling, equal channel angular pressing (ECAP) and hardness tests.

II. Experimental Procedures

The material used in this study was Sn-8.8Zn-0.25Y alloy fabricated by vacuum induction melting. Cold rolling was performed on the ingot to obtain a 1mm thick plates at the roll speed of 30m/min. Equal channel angular pressing was also carried out at room temperature using specimens of 4mm thickness, 20mm width, and 100mm length. Schematic illustration of ECAP process employed in this study is given in Fig. 1 together with the sample geometry. The values of the channel angle Φ and the angle of arc of curvature Ψ were 120^o and 30^o respectively.

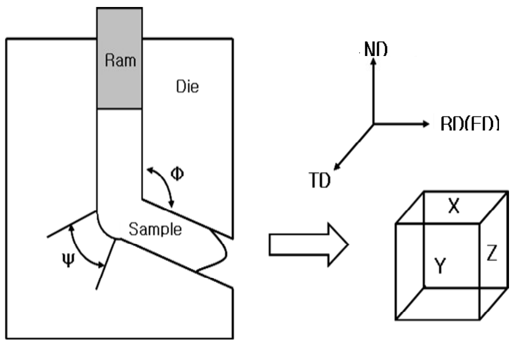

Fig. 1 Schematic illustration of ECAP process and sample geometry employed in this study

To predict the equilibrium phases, their compositions and weight fraction, and the forming temperatures, FactSage®, commercial thermodynamic simulation software was used in this study. Microstructure of cold rolled and ECAPed specimen was also observed by optical microscopy and hardness was measured by micro-Vickers test.

III. Results and Discussion

Fig. 2 shows as-cast microstructures of Sn-8.8Zn and Sn-8.8Zn-0.25Y alloys. While fully lamellar structure can be observed in Sn-8.8Zn alloy, some modification appeared to occur in Sn-8.8Zn-0.25Y alloy.

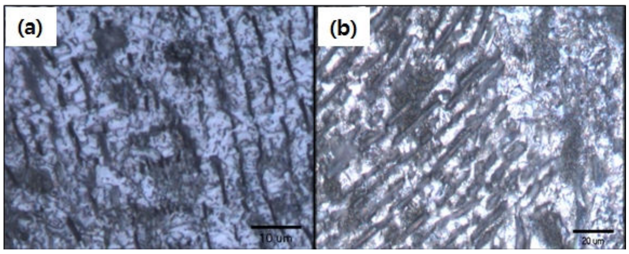

Fig. 2 As-cast microstructures of (a) Sn-8.8Zn and (b) Sn-8.8Zn-0.25Y alloys produced in this study

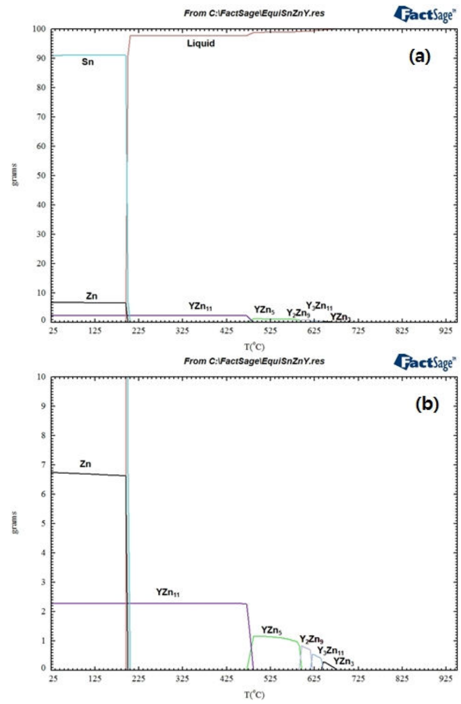

Fig. 3 Calculated phase equilibrium of Sn-8.8Z-0.25Y alloy (a) and distributions of intermetallic compounds (b) used in this study

Calculated phase equilibrium of Sn-8.8Zn-0.25Yalloy and phase fractions of intermetallic compounds were given in Fig. 3, in which equilibrium phases, their equilibrium weight fraction and the forming temperatures are indicated. As shown in the Fig. 3 (b), on cooling, Y_xZn_y intermetallics were expected to form at temperature from 700^{o}C. YZn_2, YZn_3, Y_3Z_{11}, Y_2Zn_9, YZn_5, and YZn_{11} phases are successively formed.

Fig. 4 shows microstructures of Sn-8.8Zn-0.25Y alloy processed by ECAP after various passes. It is apparent that finer microstructure was obtained as ECAP process was repeated. Interestingly, in the alloy without Y addition, this effect was not observed as shown in Fig. 5.

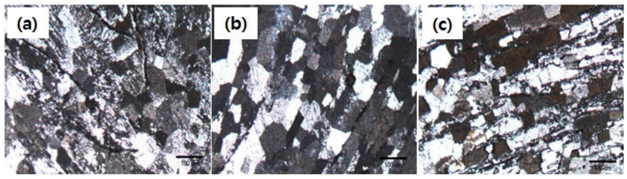

Fig. 4 Microstructure of Sn-8.8Zn-0.25Y alloy after ECAP processing of 1 pass (a), 2 passes (b), and 4 passes (c), respectively

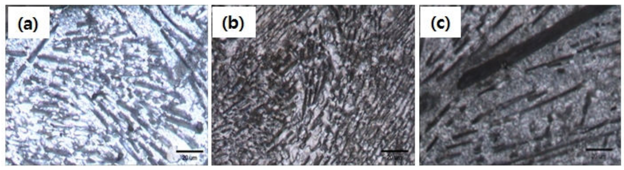

Fig. 5 Microstructure of Sn-8.8Zn alloy after ECAP processing of 1 pass (a), 2 passes (b), and 4 passes (c), respectively

Cold rolling experiment was successfully conducted on Sn-8.8Zn-0.25Y alloy at room temperature as shown in Fig. 6, although some side cracks were observed. Cold rolling and ECAP process had not meaningful effect on the hardness of Sn-8.8Zn-0.25Y alloy.

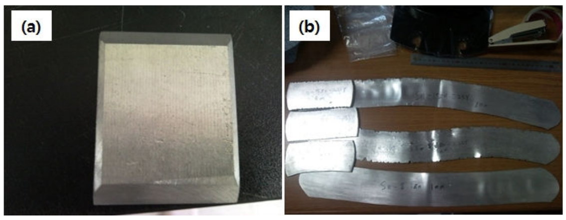

Fig. 6 Appearances of Sn-8.8Zn-0.25Y alloy before (a) and after (b) cold rolling conducted at room temperature

IV. Conclusions

On cooling Sn-8.8Zn-0.25Y alloy, Y_xZn_y intermetallics were expected to form at temperature from 730^{o}C, and YZn_2, YZn_3, Y_3Z_{11}, Y_2Zn_9, YZn_5, and YZn_{11} phases are successively formed. Finer microstructure was obtained as ECAP process was repeated. Cold rolling experiment was successfully conducted on Sn-8.8Zn-0.25Y alloy at room temperature. Cold rolling and ECAP process had not meaningful effect on the hardness of Sn-8.8Zn-0.25Y alloy.

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