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Uniform Dispersion of Solute Clusters in Liquid Metal by Ultrasound

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1. Introduction

The better properties of the alloys have been demanded up to the present and the diverse method to promote the mechanical properties have been proposed. The final quality of castings is broadly dependent upon many factors which will have an effect on the solidification of the metal. Any structural defect occurring in the castings may be transferred to the final product. Thus, any process which would reduce defects and improve the metal structure of the castings could clearly be of benefit to the foundry industry. One of the processes is a grain refinement of castings. Castings with large grains have poor mechanical properties compared to castings with fine equiaxed grain structure. Currently grain refinement in casting alloys is mainly accomplished by the special composition's master alloy as a chemical reagent. However, the addition of the chemical reagent would increase the cost for production of castings, and results in the contamination of the alloy melts, because of the byproduct of the reaction. It has been shown that high intensity ultrasound can change the microstructure, refine the grain size, and improve the uniformity of minor phases and the casting's homogeneity. However, the mechanism of some effects on grain refinement is not well understood. The proposed mechanism on the grain refinement by the injection into metal melts of ultrasound can be classified as occurring before or during solidification [1]. The main objective of this investigation is to study the mechanism of the effect on the grain refinement of ultrasonic vibration before solidification of a model Al-Si and Sn-Zn alloys. Most previous studies were done with the treatment in solid-liquid co-existence temperature range. Our experiments were focused on the investigation the effects of uniform dispersion of solute clusters in liquid metal on microstructure.

2. Experimental procedure

Table I shows the experimental conditions for ultrasound injection in metal melt. The ultrasonic frequency of the apparatus is 20 kHz and the maximum power output is 1,200W.

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Table I. Experimental conditions

Alloy composition (mass%)	Al-7Si, Al-17Si Sn-3Zn, Sn-14Zn
Melting temperature (°C)	Al alloys: 650-700 Sn alloys: 250-290
Ultrasonic frequency (kHz)	20
Ultrasonic power (W)	840
Ultrasonic injection time (min)	0 or 10

About 500 g of Al-Si or Sn-Zn alloy ingots were melted in graphite crucible, when the temperature of the melt reached experimental condition, then the preheated injection horn was dipped about 20 mm in the alloy melt. After ultrasonic injection, the melt was cast in a steel permanent mold.

3. Results and discussions

The optical micrographs of the samples from castings made with and without high intensity ultrasound injection into alloys melts are shown in **Fig. 1 and 2**, Al alloys and Sn alloys, respectively.

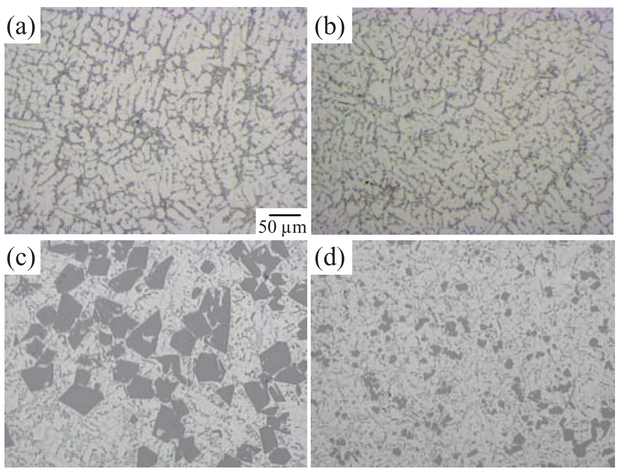

Fig. 1. Microstructure of Al-Si alloys with and without ultrasound injection in melt:
(a), (b): Al-7Si and (c), (d): Al-17Si alloy
(a), (c) without and (b), (d) with ultrasound.

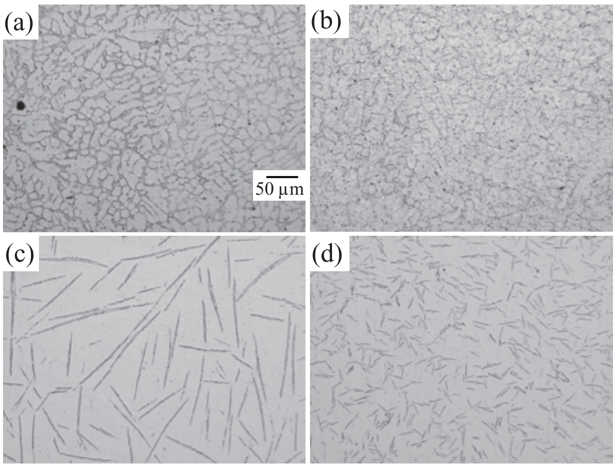

Fig. 2. Microstructure of Sn-Zn alloys with and without ultrasound injection in melt:
(a), (b): Sn-3Zn and (c), (d): Sn-14Zn alloy
(a), (c) without and (b), (d) with ultrasound.

The microstructure refinement, especially primary alpha phase, could not be achieved in Al-7Si alloy with ultrasound injection into alloy melt as shown in Fig. 1 (a) and (b). However, primary silicon of Al-17Si alloy with ultrasound injection into melts was very small and dispersed uniformly in alloy matrix as shown in Fig. 1 (c) and (d). The results in this study show the effect of melt homogeneities, especially solute homogeneity in melt, on microstructure refinement by ultrasound injection into melt, and based on experimental results, solute cluster theory could be suggested. The solute cluster theory proposed in this paper was based on the non-uniformity of alloying element (solute) in the melt. Until now, it has been supposed that the melt is very uniform and the alloying element is dispersed uniformly as an atom scale size. However, the structure of the silicon solute in Al-Si melt was investigated that Si existed in the melt as a cluster by using a high temperature X-ray diffractometer [2].

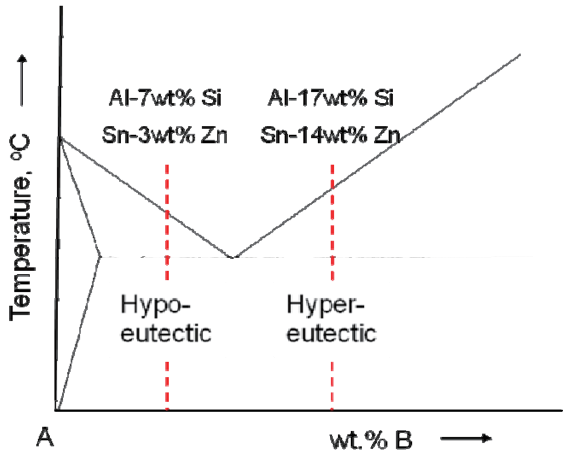

Fig. 3. Equilibrium binary eutectic phase diagram

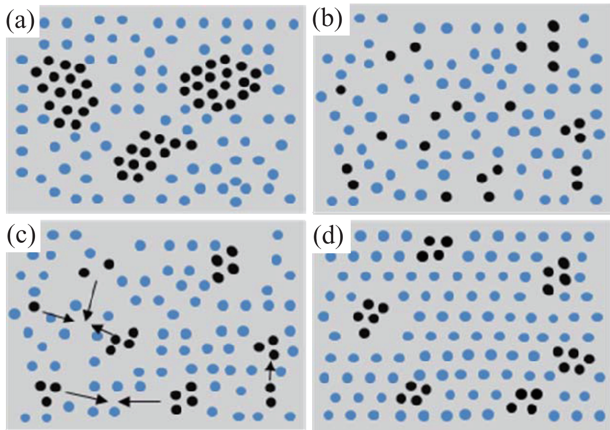

Fig. 4. Illustration of the refinement mechanism by dispersion of solute clusters with ultrasound injection and solidification course: (a) After melting, (b) ultrasound injection, (c) during solidification, (d) refined microstructure.

The Si clusters exist in Al-Si melt and the bonds of cluster are loose with the increasing melt temperature. We carried out the similar experiments on Sn-Zn alloy, which is a eutectic solidification alloy as Al-Si alloy. Figure 2 shows the photographs of Sn-Zn alloys microstructure with and without ultrasound injection into Sn-Zn melt. As shown in these figures, we got the same experimental results as like Al-Si alloy. This indicates that the microstructure changing as variation of chemical composition, hypo- or hyper eutectic composition as shown in **Fig. 3**, with ultrasound injection into the melt is not a typical phenomenon only in Al-Si alloy. The size of clusters affects the solidification process in hyper-eutectic alloy which is crystallized as primary phase, solute itself. The reason that there is a difference of the refinement of primary phase between hypo- and hyper-eutectic alloys at same experimental conditions could be explained by solute cluster theory.

4. Conclusion

The present investigation attempts to explain the mechanism of ultrasound vibration on the microstructure of hypo- and hyper-eutectic alloys. This is because that the difference of the solidification procedure between the hypo- and hyper-eutectic alloy after ultrasound injection. The microstructure refinement can be achieved by uniformity of solute cluster in melt as a chemical composition.

References

1. G. I. Eskin: *Ultrasonic Treatment of Light Alloy Melts* (Gordon and Breach, Amsterdam, 1998)
2. X. Bian and W. Wang: Mater. Lett. 44 (2000) 54.