JOURNAL OF MATERIALS SCIENCE LETTERS **19** (2000) 795–796

Influence of SiC particulates on grain structure development of an aluminum 7075 alloy during laser rapid solidification

K. ZHANG, G. N. CHEN
Materials Center, Institute of Mechanics, Chinese Academy of Sciences, People's Republic of China
E-mail: kzhang@cc5.imech.ac.cn

Microstructure development during laser rapid solidification of monolithic alloys has been extensively studied [1]. Thorough work on metal matrix composites, however, does not seem to be existing. Direct transportation of rules developed for microstructural control in the solidification of unreinforced metals may well be unreliable to reinforced metals. The key issue is that the reinforcements will modify matrix solidification response, as found during conventional solidification [2].

Grain structure is one of important features influencing material properties. Usually, epitaxial columnar grains can be observed in solidified laser melted alloy [1]. This might not be the case for a composite. It is known that, under the condition of conventional solidification, the presence of reinforcements may alter grain structure of the base alloy through changing nucleation process and/or growth process of primary phase [2]. Therefore, this study investigates the effect of inert particles on microstructure formation of alloys during laser rapid solidification, with an attempt to understand grain selection of composites.

For comparison, three different alloys are selected as starting materials. One is an aluminum 7075 alloy, the others are 7075 alloys containing 10 vol % SiC_p (10 μm in diameter) and 2 vol % SiC_p (4 μm in diameter), respectively. All three materials are supplied in the form of hot rolled plates and in T4 condition.

A continuous CO_2 laser is used for scanning surface re-melting experiments. The diameter of laser beam, set at 2 mm, the beam power, 600 W, and the scanning velocity, 30 mm/s, are major process parameters. A preliminary study has demonstrated that, under such a condition, particle melting and particle/matrix reactions can be avoided. Optical microscopic observations of longitudinal sections taken through the center of laser tracks are made; modified Keller etchant is used.

Subgrain structures of laser remelted zone are depicted in Fig. 1. Comparison of Fig. 1a and b reveals that the presence of particles yields a notable change in crystal growth of primary α-Al, i.e. the arrangement of α-Al changes from regular to random. A similar observation has been made in laser cladded SiC_p/Ti composites [3].

Distortion of subgrain structure may be responsible for random growth during directional solidification, according to Ref. [4, 5]. Since the particle acts as a barrier to solute and heat transfer, disturbed solute field and temperature field may thus give rise to unsteady

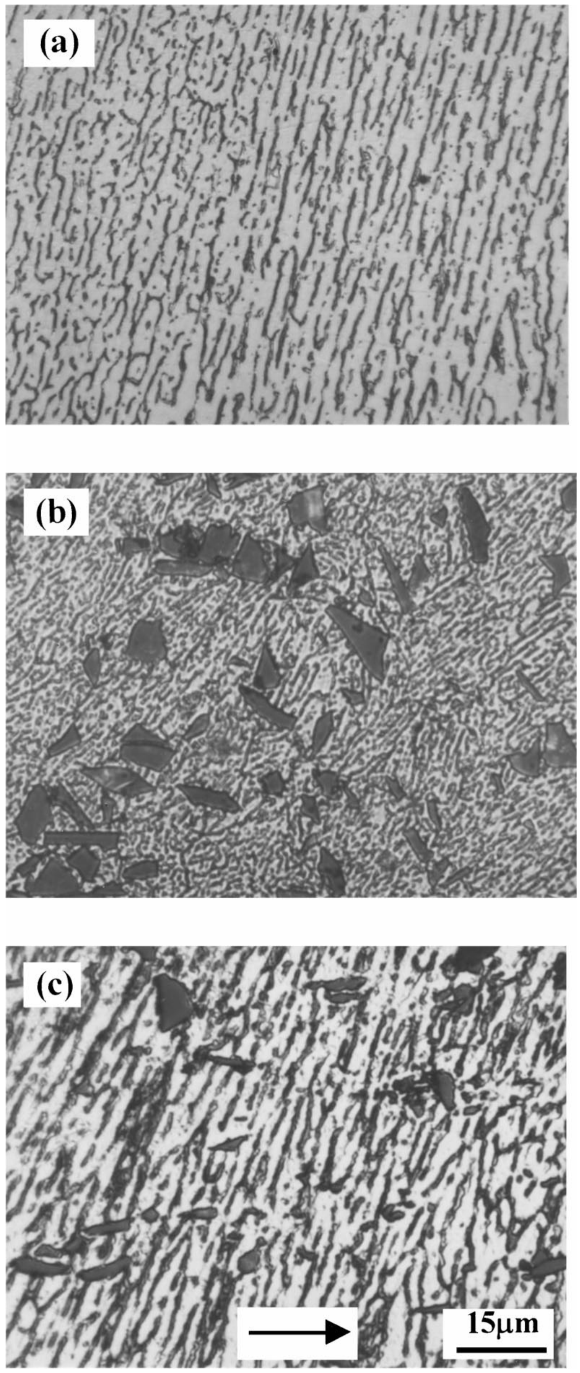

Figure 1 Typical subgrain structures of laser remelted (a) 7075 alloy, (b) 7075 alloy-10% SiC_p (10 μm) and (c) 7075 alloy-2% SiC_p (4 μm) under similar process conditions, showing chaotic growth of primary phase due to the presence of particles with a large size and a high content. The direction of beam travel is indicated as the arrow.

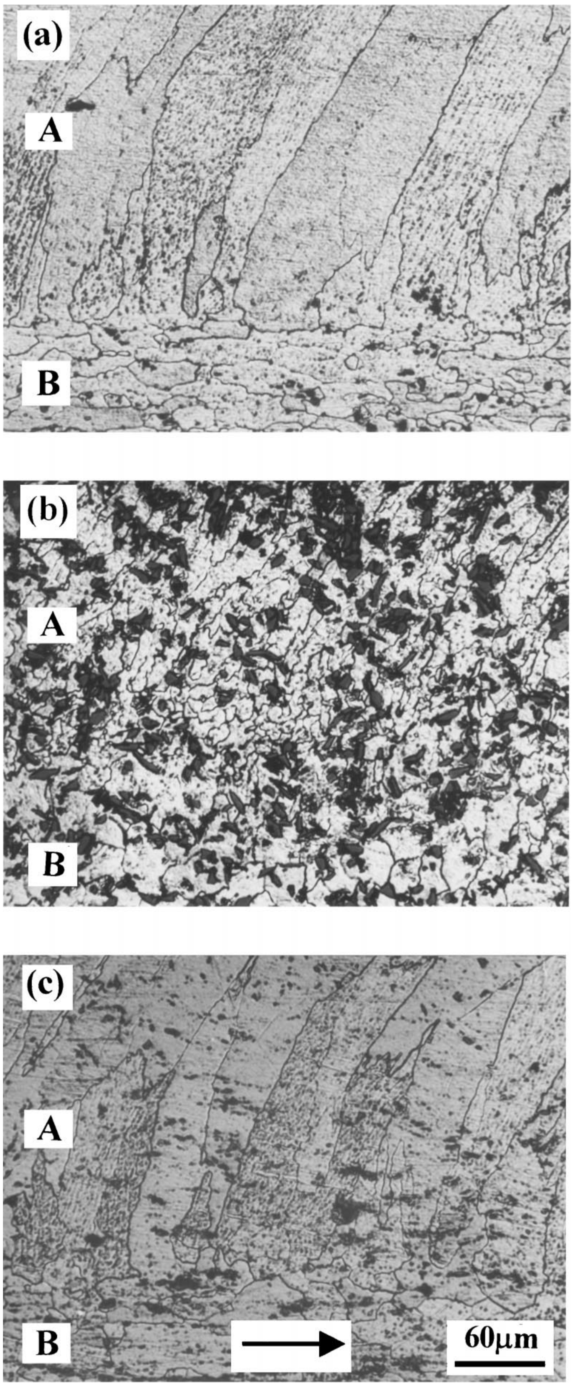

Figure 2 Typical grain structures of laser remelted (a) 7075 alloy, (b) 7075 alloy-10% SiC_p (10 μm) and (c) 7075 alloy-2% SiC_p (4 μm) under identical process conditions, showing non-epitaxial grain development in the case of a high volume fraction of large particles. The direction of beam travel is indicated as the arrow. The remelted zone and unmelted zone are labeled with A and B, respectively.

solidification. Once an unsteady branched dendritic structure is formed, irregular growth may occur in any given columnar grain. If so, disturbed solute field should be the major factor, due to the fact that crystal growth of alloy melts is primarily influenced by the solute diffusion rather than thermal conductivity. At lower volume fractions of smaller particles, disturbing effect will be negligible and thus, disruption of orderly columnar structure may not be expected (Fig. 1c). Close examination of Fig. 1c supports the validity of the argument that SiC does not catalyze heterogeneous nucleation of primary α-Al [2].

The contribution to random growth is identified to be mainly from non-epitaxial grain structure development (Fig. 2). In the reinforced metal, a non-epitaxial columnar structure characterized by the continual appearance of new anisotropic grains in laser scanning direction is obtained. Sometimes an equiaxed grain structure is also observed in the vicinity of the fusion boundary (Fig. 2b). This morphology differs significantly from an usual epitaxial grain structure obtained in the unreinforced metal, when processed under the same conditions (Fig. 2a). The loss of the epitaxial relationship with the unmelted substrate in the presence of particles is ascribed to the mechanism of particle restricted growth [2]; particles ahead of the solidification interface create diffusion barriers to crystal growth, and the restricted growth allows sufficient time for new grains to develop. The finding on Al-Cu-SiC_p by Dutta and Surappa [6], especially relevant to our work, is that equiaxed growth is promoted in particle-containing region and columnar growth in particle-depleted region during permanent mould casting. Note that the effect of particle restricted growth depends on particle size and volume fraction. When the particles are fine and the content of particles is low, this effect will be marginal so that grain structure remains unchanged compared to unreinforced alloy, as shown in Fig. 2c.

The mechanism for non-epitaxial grain structure formation is different from that in Ref. [7, 8], where a large interfacial undercooling and a number of efficient nucleants are expected to be present. Indeed, the nucleation rate is believed to be not high in this work. As a result, many of the new grains grow a considerable distance in the direction of heat source, and appear elongated in morphology, as seen in Fig. 2b.

In conclusion, the presence of SiC particles may restrict crystal growth of primary phase during laser rapid solidification of an aluminum 7075 alloy. Under the condition of higher volume fraction of larger particles, non-epitaxial grain development is favored in laser resolidified zone.

Acknowledgment
This project is supported by the Natural Science Foundation of People's Republic of China (59836220).

References
1. P. GILGIEN, A. ZRYD and W. KURZ, *ISIJ Int.* **35** (1995) 566.
2. R. ASTHANA, *J. Mater. Sci.* **33** (1998) 1679.
3. S. MRIDHA and T. N. BAKER, *J. Mater. Process. Technol.* **63** (1997) 432.
4. P. K. ROHATGI, K. PASCIAK, C. S. NARENDRANATH, S. RAY and A. SACHDEV, *J. Mater. Sci.* **29** (1994) 5357.
5. Y. H. LIU, Z. M. HE, S. F. LIU and Z. C. YANG, *J. Mater. Sci. Lett.* **12** (1993) 254.
6. B. DUTTA and M. K. SURAPPA, *Composites* **29A** (1998) 565.
7. M. GREMAUD, D. R. ALLEN, M. RAPPAZ and J. H. PEREPEZKO, *Acta. Metall. Mater.* **44** (1996) 2669.
8. C. RIEKER and D. G. MORRIS, *Mater. Sci. Engng.* **A133** (1991) 854.

*Received 31 August
and accepted 26 October 1999*