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Microscopic Analysis of TiB_2 Formation Mechanism in Al-Ti-B Alloy

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The role of titanium (Ti) in aluminum alloys is very complex. For 1000 series alloys, presence of Ti in solution, even at parts per million (ppm) level is undesirable due to its significant impact on the electrical conductivity. It is reported that electrical resistivity of aluminum alloys decreased 24 times (2.88μΩ.cm to 0.12μΩ.cm) by removing 1% of Ti from solution into their stable borides (TiB or TiB_2) [1]. The significance of Ti and TiB_2 is also paramount during the grain refinement of almost all series of aluminum alloys. Theories on the nucleation of α-Al grains on the existing $TiAl_3$ and TiB_2 particles have been reported in literature [2]. In this paper, removal of the Ti from molten aluminum by the inoculation with AlB_2 based Aluminum Boron master alloy was investigated. Moreover, mechanism of TiB_2 formation in molten Al alloys is also briefly proposed.

For this study, high purity Al, Al-10% Ti and Al-5% B master alloys were used to prepare Al-1wt%Ti-0.45% B alloy. After the melting of Al and Al-10%Ti ingots, Al-5% B ingots were added, and samples were taken after regular intervals to investigate the reaction between Ti and B. Samples were polished and analyzed under scanning electron microscope (SEM) for possible evidence of reaction and product phases formed during melt holding time. Detail experimental procedure is given elsewhere [3]. Figure 1 shows the SEM-SI image of Al-1wt%Ti-0.45% B alloy samples taken after 5, 10, 15, 30, 45 and 60 minutes of reaction. There are three distinct structures in all images. Gray matrix is Al, black clusters inside ring is AlB_2 particles initially added as a source of B and ring is reaction product of B/AlB_2 and Ti. It was confirmed by point and selected area EDS spectrum that ring is composed of Al, Ti and B. It is not clear whether TiB_2 particles have Al in their structure from this study. Moreover, with melt holding time, AlB_2 particles are dissolving and thickening the boride ring, as shown in Figure 1(f). Figure 2(a) shows the EDS point analysis of boride ring that encapsulate the AlB_2 clusters. It is extremely difficult to reveal the presence of B during EDS analysis being light element. Figure 2(b) shows the rings of Ti formed during melt holding time.

It is proposed that the reaction between Ti and B was rapid as revealed by the formation of TiB_2 rings in the early stage of reaction. This phenomenon is similar to the reaction of V with B, as reported earlier [3]. Reaction product (TiB_2) ring partially obstruct the mass transfer of B outwards and Ti inwards to complete the reaction and achieve equilibrium. This has resulted in the slow kinetics of reaction as shown in by partially dissolved AlB_2 particles in the microstructures. It is commended to increase the mass transfer of both B and Ti to enhance the reaction kinetics that can be achieved by breaking the TiB_2 ring with the help of melt stirring. This will disperse the smaller TiB_2 particles in the melt that will facilitate the heterogeneous nucleation of α- Al. Ultimately finer grain size and better electrical conductivity will be achieved.

References

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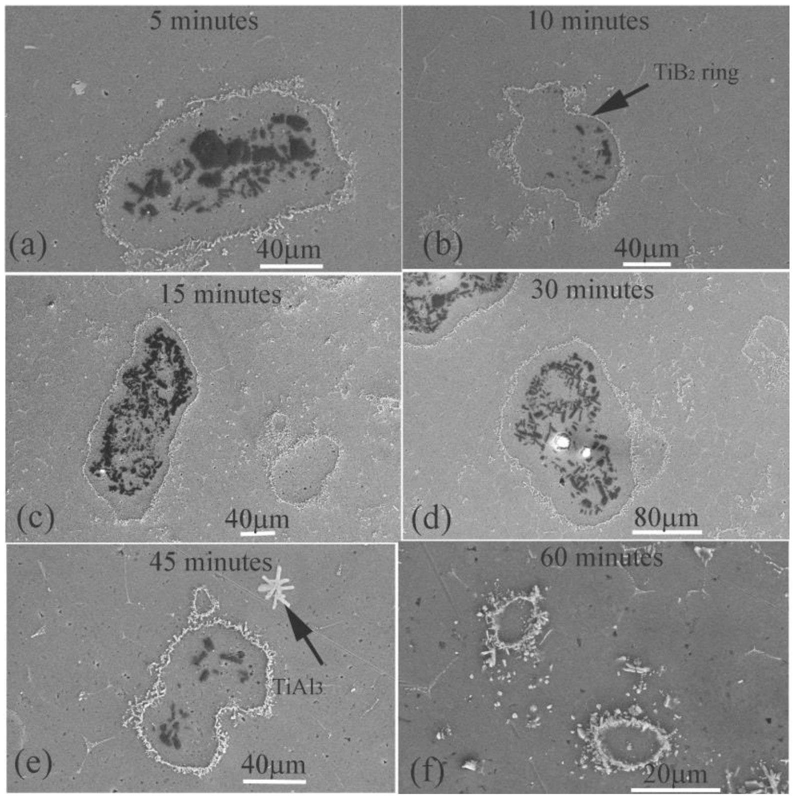
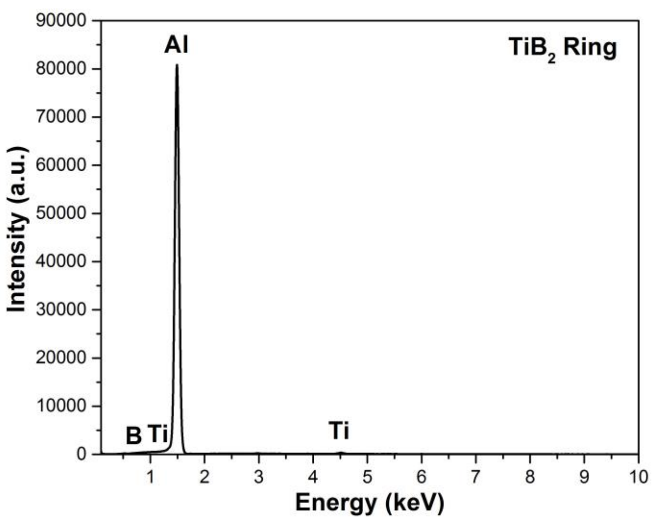
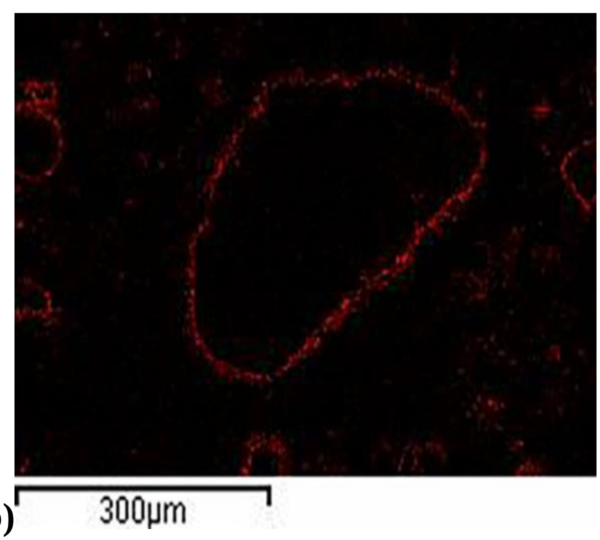


Figure 1. Scanning electron images (SI) of (a) Al-1wt%Ti-0.45wt%B alloys taken at 5, 10, 15, 30, 45 and 60 minutes of reaction at 750^{o}C.



(b)



(a)

Figure 2. (a) EDS analysis of borides ring (b) Ti maps obtained by EDS analysis.

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