Proceedings of the 12th International Conference on
Aluminium Alloys, September 5-9, 2010, Yokohama, Japan

pp. 835-839

Effect of Powder Blending Ratio on the Microstructure of AlN Matrix Composite Fabricated by Reactive Infiltration

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Reactive infiltration is a low-cost and energy saving manufacturing process of metal matrix composites. In this study, we intended to fabricate AlN-TiB_2-BN composite by reactive infiltration process of molten aluminum into powder preform consisting of BN and Ti. We also investigated the effect of the powder blending ratio (BN/Ti) on the microstructure of the composite. The starting materials for the composites were BN powder , Ti powder and pure aluminum ingot. The BN-to-Ti molar blending ratio was set to 2.0, 3.0 and 4.0. The powder mixtures were compressed at 200 MPa to make a preform. The aluminum ingot was placed on the (BN+Ti) powder preform, and heated in nitrogen atmosphere at 1473K or 1673K for 1h by using a high-frequency induction furnace. The possibility of infiltration of molten aluminum into the powder preform was judged by the vertical cross-section. In every condition, molten aluminum infiltrated into the powder preform spontaneously. This is due to good wettability between molten aluminum and BN powder, which was assisted by exothermic reaction between aluminum and titanium. When BN/Ti powder blending ratio was 2.0, the microstructure showed TiB_2 particle dispersion (average 2~3μm) in AlN matrix. By increasing BN/Ti powder blending ratio to 3.0 or 4.0, dispersion of BN particle was observed together with TiB_2 in AlN matrix.

Keywords: *ceramics matrix composite, reactive infiltration, aluminum nitride, boron nitride, wettability*

1. Introduction

Aluminum nitride (AlN) possesses good properties like low density, high thermal conductivity and low electrical conductivity. But traditional sintering method requires high heating temperature (around 2173K) and long holding time (for about 8 hours), so it is a high cost process to fabricate AlN [1]. Furthermore, AlN has a drawback in toughness and impact resistance. So we tried to fabricate AlN matrix composite which has high toughness and good engineering property by dispersing boron nitride (BN) in AlN [2].The schematic illustration of reactive infiltration process used in this research is shown in Fig. 1. As reactive infiltration method, we set aluminum ingot on the powder blended preform of titanium and BN, and heat them. Then molten aluminum infiltrates into preform, AlN and titanium diboride (TiB_2) were produced by the reaction.

Powder blending ratio of BN and titanium is changed in order to disperse surplus BN particle. At the BN/Ti powder blending ratio of 2.0, infiltrated aluminum changes to AlN by receiving nitrogen from BN, and titanium particles change to TiB_2 by receiving boron from BN. On the other hand, at the BN/Ti powder blending ratio of 3.0 or 4.0, infiltrated aluminum changes to AlN and titanium particles change to TiB_2 in the same way, but all BN particles are not decomposed because powder mixture contains an excessive amount of BN particles.

The aim of this study is to search the effect of the processing parameter on the microstructure of AlN matrix composites fabricated by reactive infiltration. In the presentation, the effect of powder blending ratio, powder compacting pressure and heating condition on the microstructure will be discussed.

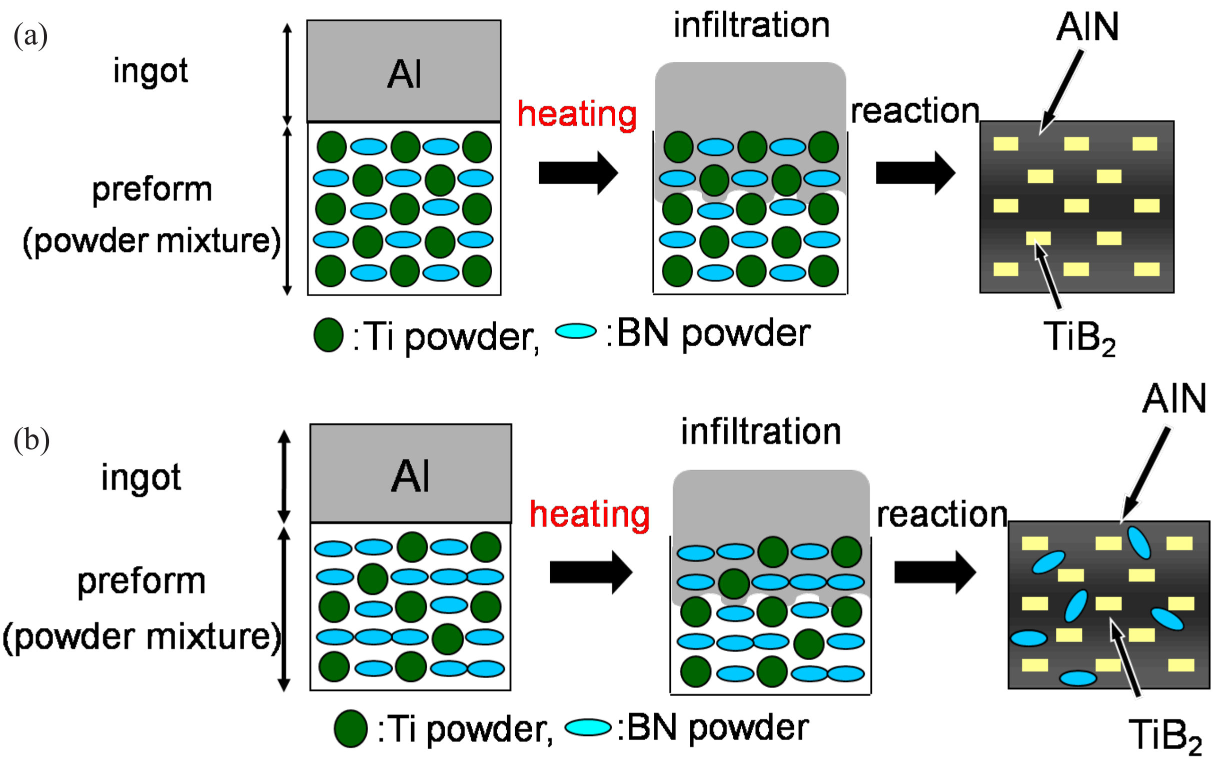

Fig. 1 The schematic illustration of reactive infiltration process
(a)BN/Ti molar ratio =2.0 (b)BN/Ti molar ratio ＞2.0

2. Experimental procedure

BN powder (grain size: 10μm) and titanium powder (grain size: ＜45μm) were used as starting materials. We chose BN powder for the source of nitrogen for AlN. This is because BN has good wettability between aluminum and has good properties like high toughness, high thermal conductivity and low electrical conductivity [3,4]. In this paper, the blended powder of BN and titanium is expressed as '(BN+Ti) blended powder'. Then, there are two filling procedures of the (BN+Ti) blended powder. One was to use the (BN+Ti) blended powder naturally in the crucible (non-compacted). Another was to use the compacted (BN+Ti) blended powder. When the compacted (BN+Ti) blended powder was prepared, compacting pressure to make a preform was 200MPa, the shape of preform was columnar and its diameter and height were 10mm and 5mm, respectively. The blended powder was placed at a bottom part of an alumina (Al_2O_3) crucible, and a pure aluminum ingot was located on the blended powder preform. The specimen was then heated up to 1473K or 1673K and held at these processing temperatures for 60 minutes by a high-frequency induction furnace in N_2 gas atmosphere. After the heating process, the specimen was cooled down to a room temperature and taken out of the crucible. The specimen was cut by the vertical cross section and polished for microstructure observation. Then, the vertical cross section was observed. In order to confirm whether an infiltration trial was succeeded or not, microstructures of the composites were examined by scanning electron microscope (SEM).

3. Results and discussion

In reactive infiltration process, we confirmed that molten aluminum infiltrated into powder mixture preform at 1073K. Spontaneous infiltration of molten aluminum into the (BN+Ti) blended powders occurred at all conditions. This result shows the wettability between molten aluminum and (BN+Ti) blended powders was extremely good.

Figure 2 shows microstructure of the infiltrated part of the specimen (non-compacted, processing temperature: 1473K). As shown in Fig. 2 (a), when the BN/Ti powder blending ratio was 2.0, TiB_2 particles were dispersed in AlN matrix and BN particles were not observed. As shown in Fig. 2 (b), when the BN/Ti powder blending ratio was 3.0, BN particles were dispersed in AlN matrix, and TiB_2 particles were dispersed around the BN particles. This shows that TiB_2 particles received boron from BN particles. Fig. 3 illustrates the XRD patterns of the specimen (non-compacted, processing temperature: 1473K, BN/Ti=2.0). The porosity of the non-compacted (BN+Ti) blended powder was so high that excessive amount of molten aluminum infiltrated in the blended powder. Consequently, a sharp diffraction peak of Al was detected as shown in Fig. 3.

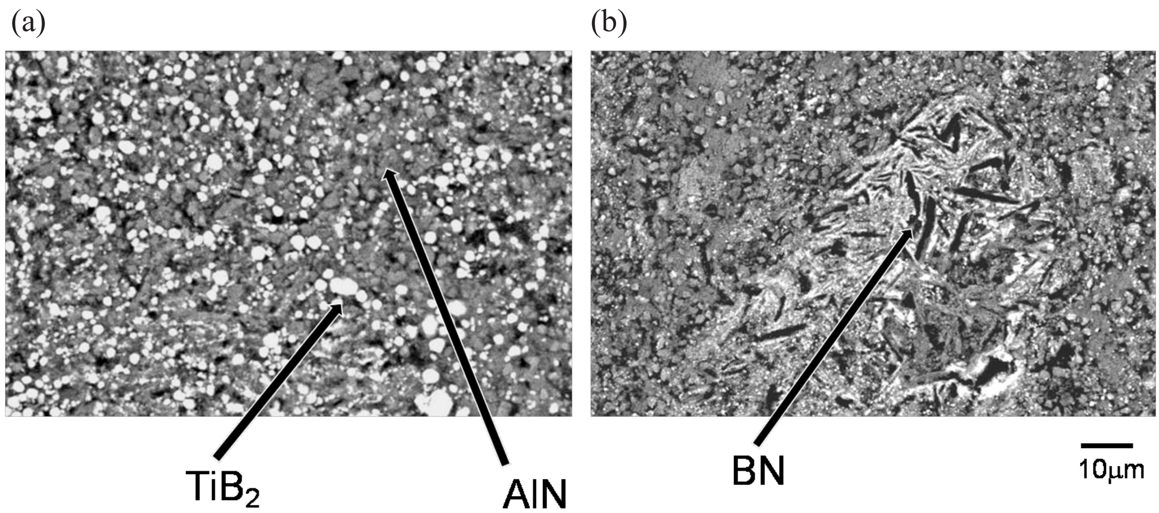

Fig. 2 Microstructure of the infiltrated part of the specimen
(non-compacted, processing temperature: 1473K)
(a)BN/Ti=2.0, (b)BN/Ti=3.0

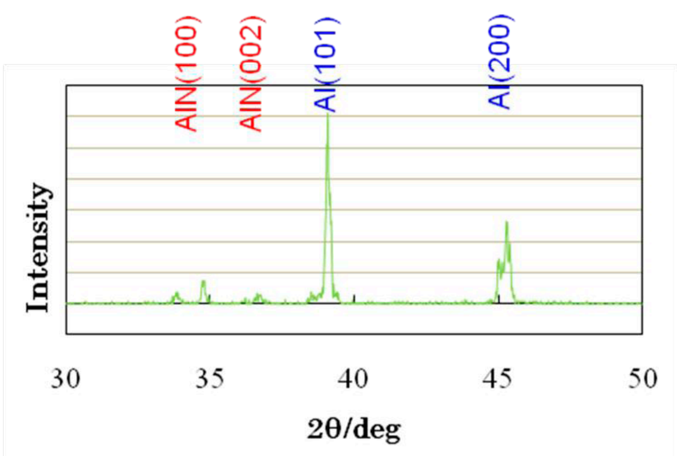

Fig. 3 The XRD patterns of the specimen
(non-compacted, processing temperature: 1473K, BN/Ti=2.0)

Figure 4 shows microstructure of the infiltrated part of the specimen (compacted, processing temperature: 1473K). As shown in Fig. 4 (a), by using compacted preform, BN particles were not decomposed completely even when the BN/Ti powder blending ratio was 2.0.This is because the porosity of the compacted preform was so low that aluminum required for the following reaction could not be supplied completely.

$$2Al+2BN+Ti \rightarrow 2AlN+TiB_2 \quad (1)$$

However, these unreacted BN particles in the compacted preform (BN/Ti=2.0) disappeared by raising holding temperature from 1473K to 1673K as shown in Fig. 5.

(a) (b)

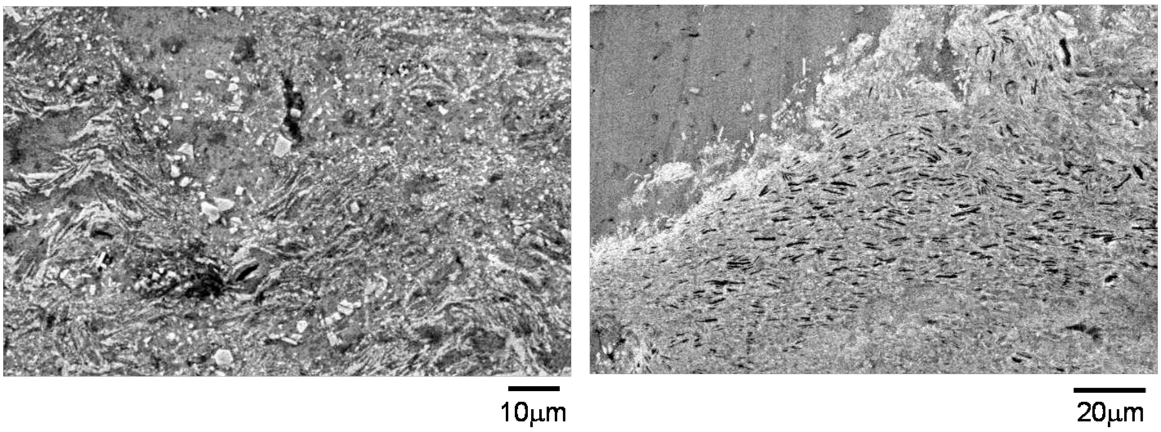

Fig. 4 Microstructure of the infiltrated part of the specimen
(compacted, processing temperature: 1473K)
(a)BN/Ti=2.0, (b)BN/Ti=3.0

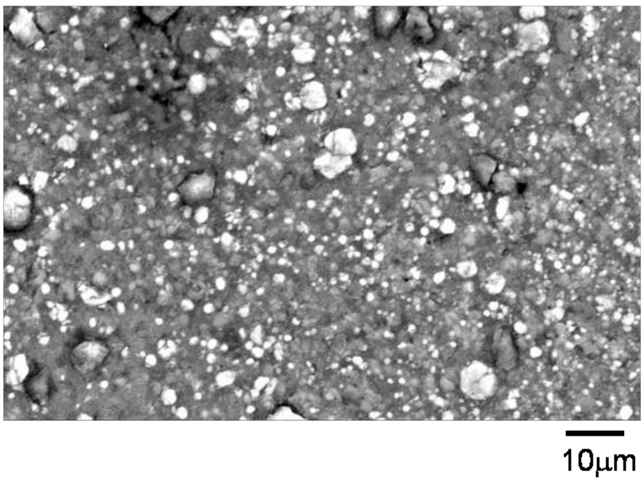

Fig. 5 Microstructure of the infiltrated part of the specimen
(compacted, processing temperature: 1673K)

4. Conclusion

AlN matrix composites with dispersion of BN and TiB_2 particles were fabricated by reactive infiltration of molten aluminum in (BN+Ti) blended powder, and the following results were obtained.

1. Molten aluminum infiltrated into the (BN+Ti) blended powder preform at temperatures above 1073K.
2. The porosity of the non-compacted (BN+Ti) blended powder was so high that excessive amount of molten aluminum infiltrated in the blended powder. Consequently, the AlN/Al ratio of matrix was low.
3. The porosity of the compacted (BN+Ti) blended powder was so low that BN particles were not decomposed completely even when the BN/Ti powder blending ratio was 2.0.
4. The unreacted BN particles in the compacted preform (BN/Ti=2.0, processing temperature: 1473K) were completely reacted by raising holding temperature to 1673K.

References

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