

THE EFFECT OF BORON ON THE GRAIN SIZE OF THE ALUMINIDES MATRIX IN HOT PRESSED WC COMPOSITES

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Abstract

The effect of boron on the grain size of the intermetallic matrix in WC composites was investigated. Doped FeAl and Ni₃Al binders, with boron levels ranging from 0 to 0.01 wt.%, were prepared using controlled atmosphere ring grinding and then blended with submicron (0.7 μm) WC powder. WC-40 vol.% (FeAl-B) and WC-40 vol.% (Ni₃Al-B) composites were processed at 1500°C by uniaxial hot pressing. X-Ray and electron diffraction results showed that with increasing the amount of boron up to 0.01%, the grain size of the FeAl as well as Ni₃Al matrix decreases, and no new phases developed during sintering, neither the WC-FeAl-B nor WC-Ni₃Al-B composites.

Keywords: *intermetallic matrix composites, aluminides, boron, grain size*

INTRODUCTION

Over the last few decades, significant research has been done to identify alternative binders for conventional cermets in order to improve their mechanical properties and also to overcome some shortcomings, like poor corrosion resistance, high cost and environmental toxicity [1]. Iron, cobalt and nickel-based alloys were found to be suitable binders for WC-based cermets by various investigators due to their excellent wetting of the carbide phases and, also the solubility of the carbide phases in the molten binder [2-4]. However, they are expensive, but also toxic if there are fine particulates [2]. Intermetallic compounds, particularly Nickel and iron aluminides, are a relatively new class of materials that provide the advantages of good mechanical properties, high melting point, low density, inexpensive raw materials, high wear resistance, good corrosion resistance and high specific strength at elevated temperatures [5-6]. Such properties could overcome certain shortcomings of the cobalt binder in the WC-Co composites [7]. However, the main limitation of the iron and nickel aluminides is their poor ductility and tendency toward intergranular fractures at ambient temperatures [8]. It has been established that microalloying of FeAl and Ni₃Al alloys with boron leads to significant improvements of ductility and toughness [9,10].

Since FeAl-B and Ni₃Al-B alloys exhibit superior properties compared to Co, they could be considered as potential alternative binders to Co in WC based hardmetals. Previous studies showed it found that boron addition improves wear resistance, hardness and fracture toughness of WC composites based on FeAl-B and Ni₃Al-B binders [11, 12]. The present study reports the effect of boron on the grain size of boron doped FeAl and Ni₃Al binders in WC-FeAl-B and WC-Ni₃Al-B composites.

EXPERIMENTAL

Intermetallic matrix composites based on iron and nickel aluminide binders, WC-40 vol.% (FeAl-B) and WC-40 vol.% (Ni_3Al -B), with an average grain size of carbide 0.69 μm have been investigated. The starting materials used for processing the composites were WC powder (0.65 μm , Chemical Pure, Inc.), Fe chips (99.98%, Aldrich Chemical Company), Ni balls (99.9%, Aldrich Chemical Company), and B pieces (99.9%, Aldrich Chemical Company). Fe-40 at.% Al and Ni_3Al with boron levels ranging from 0 to 0.01 wt.% were produced using a vacuum arc melting furnace. Milling was performed in a stainless steel ring-grinding vessel under high-pressured helium to achieve ultra fine powders. Mixing of Fe and Ni aluminide powders (<45 μm) with WC powder was performed in a controlled atmosphere cylindrical mixer for 72 hours. Sintered WC composites were produced from blended powders by uniaxial hot pressing under vacuum in a 6.5 mm diameter graphite die at a pressure of 20 MPa. The processing was carried out in a furnace maintained under vacuum and low Ar pressure of about 10^{-2} Pa at a temperature of 1500°C for 4 minutes. The hot press chamber was flushed a few times with high purity argon before sintering. After cooling, specimens were cut, mounted and polished with an automatic Struers Rotopol-1 lapping machine to a mirror finish with a 3 μm diamond paste. Polished specimens were used for X-ray diffractometry and as initial specimens for transmission electron microscopy. X-ray and electron diffractometry techniques were used to investigate the effect of boron on the grain size of the aluminides in the intermetallic matrix composites.

RESULTS AND DISCUSSION

The X-ray diffraction patterns obtained from hot pressed WC-40 vol.% (FeAl-B) and WC-40 vol.% (Ni_3Al -B) composites at 1500°C with different amounts of boron ranging from 0 to 1000 ppm are shown in Figs.1a and b. XRD analysis reveals that, firstly, the composites have only two phases, the original FeAl or Ni_3Al phase and WC phase in which no evidence of new phases formed during sintering, neither WC-FeAl-B nor WC- Ni_3Al -B composites, up to 0.01wt.% B and within the limits of XRD. This is most likely that the present amounts of boron levels in the binders are below the limit of its solubility in the aluminides. Secondly, increasing the amount of boron up to 0.1 wt.% resulted in a broadening of the peaks of FeAl and Ni_3Al phases could be associated with a refining of the aluminide grains. It can be seen that the FeAl and Ni_3Al peaks are quite small and broad at 1000 ppm B.

Selected area electron diffraction (SAED) was also used to identify phase compositions and aluminide matrix grains in WC-FeAl-B and WC- Ni_3Al -B composites. A field limiting aperture of 70 μm was selected in order to obtain spotty ring patterns from large areas containing a large number of grains, so that interplanar spacings of phase present in composites could be checked against those observed using XRD. Figures 2 and 3 show the selected area electron diffraction patterns generated from the fine polycrystalline structure of the WC-FeAl-B and WC- Ni_3Al -B composites.

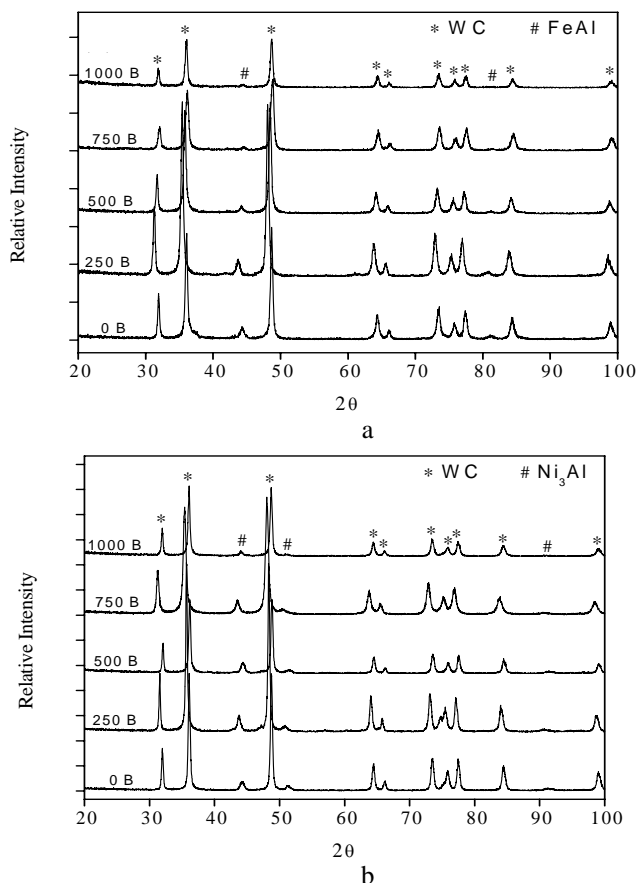


Fig.1. X-ray diffraction patterns of a) WC-FeAl-B and b) WC-Ni₃Al-B with different amounts of boron (ppm).

Examination of several SAED patterns obtained from both the boron containing composites heat treated at 1500°C revealed no evidence of phases additional to those detected using XRD, and specifically no evidence of new grain boundary phases. Figures 2 and 3 show examples of fully indexed spotty ring patterns obtained from WC-40 vol.% (FeAl-0.1 wt.% B) and WC-40 vol.% (Ni₃Al-0.1 wt.% B) composites, with the expected phases present and no evidence of new phases. It can be seen that there are very fine speckled patterns generated from fine and coarse polycrystalline structures. It can be seen that with increasing the amount of boron, the spotty rings of FeAl (e.g. FeAl (110)) and Ni₃Al (e.g. Ni₃Al (111)) become more continuous, perhaps due to the finer grain size.

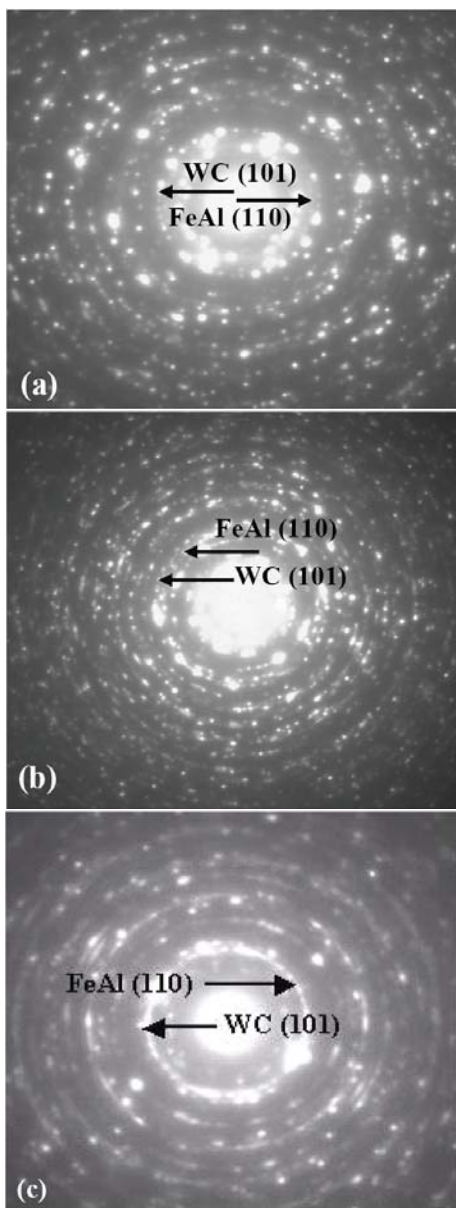


Fig.2. Selected area electron diffraction pattern of WC-FeAl with a) 0 ppm B, b) 500 ppm B and c) 1000 ppm B.

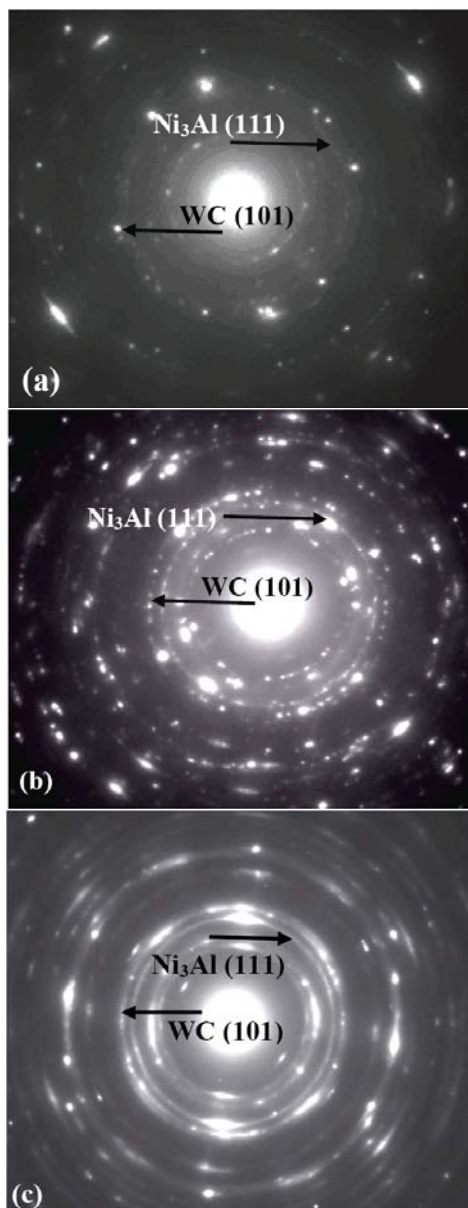


Fig.3. Selected area electron diffraction pattern of WC-Ni₃Al with a) 0 ppm B, b) 500 ppm B and c) 1000 ppm B.

The TEM electron diffraction results are consistent with the obtained XRD results presented in the previous section. It is important to mention that grain size refinement is the most attractive way of improving both the ductility and the strength of aluminides at same time [13,14]. Hence it seems that a boron addition up to 0.1 wt.% in FeAl and Ni₃Al binders in the hot pressed WC composites at 1500°C did not reveal new phase, and also

resulted in decreasing the aluminide grain size of binders. This could result from improvement of the ductility, strength and fracture toughness of the matrix, and also that of the composites.

CONCLUSIONS

X-ray and TEM electron diffraction results showed that a boron addition up to 0.01 wt.% does not lead to the formation of new phase in both WC-FeAl-B and WC-Ni₃Al-B composites. The aluminide grain sizes also decreased in both WC-FeAl-B and WC-Ni₃Al-B composites with increasing the amount of boron in the binders. It is believed that one reason for the increase in the fracture toughness of the intermetallic matrix composites, with increasing the boron content, is related to the decreasing of the aluminide matrix grains.

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