SYNTHESIS, MICROSTRUCTURE AND MECHANICAL PROPERTIES OF NB-BASED COMPOSITES CONTAINING CARBIDE AND BORIDE CERAMIC PHASES

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Keywords: Nb-based composites; Microstructure; Mechanical property; Intermetallics

1. Introduction

Nb-based composites have received considerable attention in recent years as the potential candidates of next generation high temperature structural materials to replace the current Ni-based superalloys [1,2]. For the practical applications of these composites, the balance of several important properties, including toughness, strength, creep resistance and oxidation resistance, is required at room and/or high temperatures [3,4]. Currently, the intermetallic compounds such as silicides (Nb5Si3 and/or Nb4Si) and/or Cr2Nb Laves phases have been introduced to strengthen Nb-based composites [4,5]. Carbide and boride of niobium possess some excellent properties such as high melting point, high strength, high thermal and electrical conductivity, and chemical stability [6]. In this work, the objective was to synthesize Nb-based composites containing carbide and boride ceramic phases, and then evaluate their hardening and strengthening effect at room and/or high temperatures, so as to examine the potential of this new Nb-based composites for high-temperature applications.

2. Experimental

Raw materials used in this work were pure Nb (99.99 %), pure Ti (99.99 %), pure C (99.85 %) and pure B4C (99.9 %). The samples with compositions of Nb20Ti4C4B and Nb20Ti4C4B10Mo (at. %) were synthetized using the arc-melting method. Phase constitutions and microstructure of the composites were identified by X-ray diffraction (XRD) analysis and scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy (EDS). Vickers hardness (HV) was measured under an applied load of 9.8 N. Room-temperature compression properties were assessed at an initial strain rate of 2.78 ×10⁻⁴ s⁻¹, and the size of the specimens was 3 mm × 3 mm × 6 mm. The 1273 K and 1473 K compression properties were assessed at a strain rate of 0.85 × 10⁻³ s⁻¹ under vacuum, and the the size of the specimens was 5 mm × 5 mm × 10 mm.

3. Results and Discussion

3.1 Phase identification

XRD patterns of as-cast samples are shown in Fig. 1. It shows that the composites contains Nb solid solution (Nbss), NbB boride and (Nb,Ti)C carbide phases, and Mo addition does not induce any new phase and not cause any change in the crystal structure types of constituent phases. According to EDS results, in the case of Nb20Ti4C4B sample, Ti presents in the Nbss, (Nb,Ti)C and NbB. When Mo is added, Mo is found in the Nbss and NbB, but not detected in (Nb,Ti)C.

3.2 Microstructure

Fig. 2 shows SEM backscattered electron (BSE) micrographs of the composites. It can be found that , in each case, the hybrid boride and carbide are formed in the interdendritic eutectic network around the primary Nbss dendrites. Moreover, Mo addition refines the primary Nbss dendrites.

3.3 Mechanical properties

Table 1 lists the mechanical properties of the composites at room and high temperatures, including Vickers hardness (HV), 0.2% yield strength (σ0.2). The σ0.2 (73MPa) of Nb20Ti4C4B composites are hither than the reported Nb35Ti6Al5Cr8V10C alloy (51MPa) at 1473 K [7]. Moreover, the composites with 10at.% Mo addition exhibits the higher hardness and strength, which could be contributed by the solid solution strengthening and the refined primary Nbss after Mo addition. These results indicate that the introduction boride and carbide ceramic phases is a effective strengthening method in the Nb-based composites.
4. Conclusion

Nb-based composites containing carbide and boride ceramic phases were synthesized using the arc-melting method. The hybrid boride and carbide are formed in the interdendritic eutectic network around the primary Nbss dendrites, and Mo addition refines the eutectic network and primary Nbss dendrites. The introduction of boride and carbide improved the harden and strength of Nb-based composites.

Fig. 1 XRD patterns of Nb-based composites containing Nbss, (Nb,Ti)C and NbB phases.

Fig. 2 SEM-BSE micrographs of Nb20Ti4C4B (a) and Nb20Ti4C4B10Mo (b) composites. The insets show the high magnification images of the eutectic.

Table 1 Mechanical properties of Nb-based composites at room and high temperatures.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Hardness (HV)</th>
<th>293K $\sigma_{0.2}$ (MPa)</th>
<th>1373 K $\sigma_{0.2}$ (MPa)</th>
<th>1473 K $\sigma_{0.2}$ (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nb20Ti4C</td>
<td>4B</td>
<td>304</td>
<td>700</td>
<td>271</td>
</tr>
<tr>
<td>Nb20Ti4C</td>
<td>4B10Mo</td>
<td>409</td>
<td>940</td>
<td>368</td>
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</tbody>
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References