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Effect of Al Addition on Microstructure and Properties of NbTiZrCrAl Refractory High Entropy Alloys

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Abstract : Refractory high entropy alloys are alternative materials expected to be employed at high temperatures. The comprehensive changes of microstructure and properties of NbTiZrCrAl refractory high entropy alloys are systematically studied by adjusting Al content. Five kinds of button alloy ingots with different contents of Al in NbTiZrCrAlX (X=0, 0.2, 0.5, 0.75, 1.0) were prepared by vacuum non-consumable arc melting technology. The microstructure analysis results show that the five alloys are composed of BCC solid solution phase rich in Nb and Ti and Laves phase rich in Cr, Zr, and Al. The addition of Al changes the structure from hypoeutectic to hypereutectic, increases the proportion of Laves phase, and changes the structure from cubic C15 to hexagonal C14. The hardness and fracture toughness of the five alloys were tested at room temperature, and the compressive mechanical properties were tested at 1000℃. The results showed that the addition of Al increased the proportion of Laves phase and decreased the proportion of the BCC phase, thus increasing the hardness and decreasing the fracture toughness at room temperature. However, at 1000℃, the strength of 0.5Al and 0.75Al alloys whose composition is close to the eutectic point is the best, which indicates that the eutectic structure is of great significance for the improvement of high temperature strength of NbTiZrCrAl refractory high entropy alloys. The five alloys were oxidized for 1 h and 20 h in static air at 1000℃. The results show that only the oxide film of 0Al alloy falls off after oxidizing for 1 h at 1000℃. After 20h, the oxide film of all the alloys fell off, but the oxide film of alloys containing Al was more dense and complete. By producing protective oxide Al_2O_3, inhibiting the preferential oxidation of Zr, promoting the preferential oxidation of Ti, and combination of Cr_2O_3 and Nb_2O_5 to form $CrNbO_4$, Al significantly improves the high temperature oxidation resistance of NbTiZrCrAl refractory high entropy alloys.

Keywords : NbTiZrCrAl, refractory high entropy alloy, al content, microstructural evolution, room temperature mechanical properties, high temperature compressive strength, oxidation resistance
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