

Introducing the in-situ carbides to induce the ductility of the L₂₁-based alloy: a Complex-Concentrated Alloy study

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Complex-concentrated alloys, based on a combination of 3d transitional elements and aluminium, can ensure a combination of favorable mechanical properties, low density and oxidation resistance at high temperatures by ensuring the right alloying, manufacturing and heat-treatment strategies [1],[2]. This fact makes them potential candidates for future aerospace and energy applications. Recently developed Fe₃₂Cu₁₂Ni₁₁Ti₁₆Al₂₉ alloy has shown competitive compressive strength in comparison to Ni-based superalloys and other high-temperature CCAs in the range up to 1000° C [3]. Based on microstructural data, it was found that it is comprised of the L₂₁ Heusler-phase Fe-rich matrix and body-centered cubic Cu-rich phase with minor addition of C14 Laves phase [4]. Despite its promising properties, it was found that prolonged heat-treatment results in the embrittlement of the alloy, inducing ductile-to-brittle transition temperature (DBTT) rise to above the 1000° C [5], which is similar to Ti-rich L₂₁-based iron aluminides [6].

In the current work, it was decided to overcome the ductility limitation using powder metallurgical production route. The elemental powders were mechanically alloyed in an n-Heptane environment and consolidated by spark plasma sintering (SPS). The alloying in carbon-rich atmosphere and fast sintering process resulted in sub-micron grain-sizes and in formation of the TiC particles on the grain boundaries. Those particles were found to suppress the formation of the C14 Laves phase due to the Ti-content tailoring as well as by population of the grain-boundary nuclear sites. Also, the subsequent heat treatment revealed that the grain sizes are stabilized by the particle pinning by the aforementioned carbides. Based on the grain refinement and Laves phase suppression, the DBTT temperature was reduced to 500° C.

References

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