High Mechanical Properties TiAl Composite Materials by Introducing In-Situ Nano-Borides Under Ultrasound

Lingyan Zhou, Xiaokang Yang, Hongze Fang, Ruirun Chen
National Key Laboratory for Precision Hot Processing of Metals, Harbin Institute of Technology, Harbin, Heilongjiang 150001, China
*Corresponding address: Heilongjiang Province, Harbin City, Nangang District, 92 West Dazhi Street
*Corresponding e-mail: ruirunchen@hit.edu.cn

Abstract: To form in-situ nano borides in the solid-liquid two-phase region, Ti46Al8Nb2.6C0.8TaxB alloys were prepared under ultrasound to improve the microstructure and mechanical properties. The morphology and distribution of borides, and characteristics of lamellar colonies were observed through SEM, TEM, and XRD, revealing the influence of borides on microstructure evolution and the improving mechanisms of strength and plasticity. Results indicate that the morphology of borides is elongated and spherical. As the content of B increases, borides gradually spheroidized, and nanoscale borides precipitate on the lamellar phase. There are a large number of dislocations around the borides to form the SFs and dislocation wall. The size of the lamellar colony has decreased from 26.9 to 19.3 μm. The increasing nucleation site of borides with increasing content of B and primary borides being broken by ultrasound are the reasons for forming B27-type borides. And the increase of nucleation particles refines the lamellar colony. The compressive strength increased from 2026 to 2224 MPa, and the strain increased from 26.3 to 29.6% when the addition of boron increased from 0 to 1.2%. Uniformly distributed nano borides hinder the movement of dislocations to form SFs and dislocation walls and the lamellar colonies are refined are the main reasons for the significant improvement of mechanical properties.

Keywords: TiAl, Nano borides, Compressive property, Dislocation.

1 Introduction

High Nb-TiAl alloy has received widespread attention as the most high-temperature-resistant lightweight material to prepare aerospace turbine blades [1-2]. However, the insufficient high-temperature strength and unreasonable matching of strength and plasticity of TiAl alloy severely limit its development. The formation of in-situ self-generated particles is expected to enhance the high-temperature usability of alloys, providing prospects for TiAl alloys to meet more stringent service conditions [3].
This work focuses on improving the unbalanced strength plasticity and the microstructure containing multiple reinforcing phases of TiAl alloy. Under UT conditions, boron is introduced into TiAl alloy to form borides, refining the microstructure and improving the strength of TiAl alloy.

2 Experimental procedure

The designed compositions are Ti46Al8Nb2.6C0.8Ta-*x*B (*x* = 0, 0.4, 0.8, 1.2, 1.6, 2.0 at. %). In the following research, it will be named TANCT-*x*B. The button ingot is completed through arc melting and UT. The five remelting treatments performed during melting are to ensure that the alloy material is completely melted. Then perform UT for 100s under the same ultrasound process.

3 Result and discussion

3.1 Microstructure characteristics

As the boron content increases, most boride particles appear in small spherical shapes between the layers, while a small amount of boride particles appear in a white curved shape in the matrix. When the content of boron increases from 0 to 1.2 at.%, the size of the lamellar colonies decreases from 26.9 to 19.3 μm.

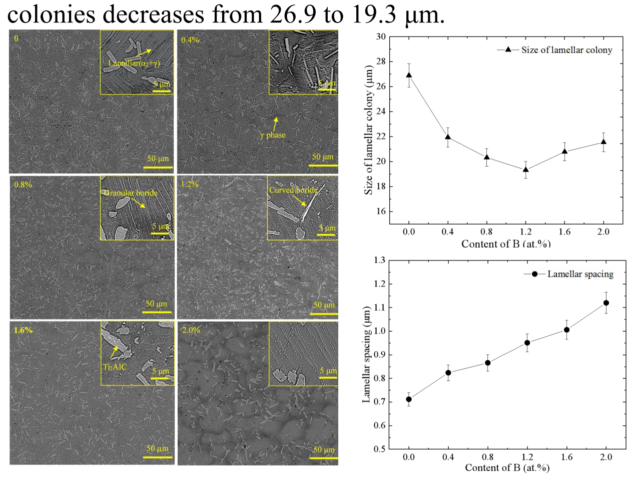

Fig. 1 SEM of the Ti46Al8Nb2.6C0.8Ta-xB(at.%) alloys and schematic diagram of statistical results

3.2 Element distribution and phase composition

In Ti46Al8Nb2.6C0.8Ta-*x*B alloy, the main phase of the alloy is γ， α_2. Ti_2AlC and (Ti, Nb, Ta) B phases. Among them, (Ti, Nb, Ta) B phase is a TiB phase that solidly dissolves some Nb and Ta. man).

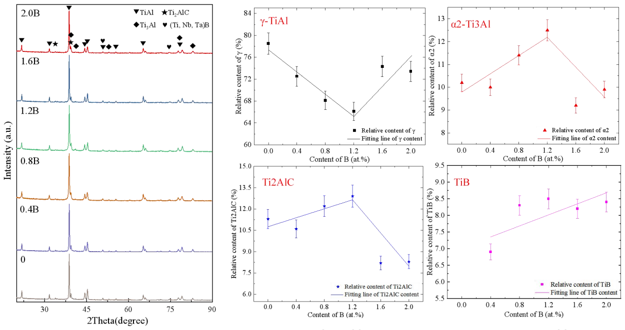

Fig. 2 XRD pattern and cntents of different phases with different B content

3.3 Dislocation characteristics around precipitates

Micron and nanoscale Ti_2AlC precipitated in the matrix, a large number of dislocations with interlaced and entangled distributions can be observed around the Ti_2AlC phase.

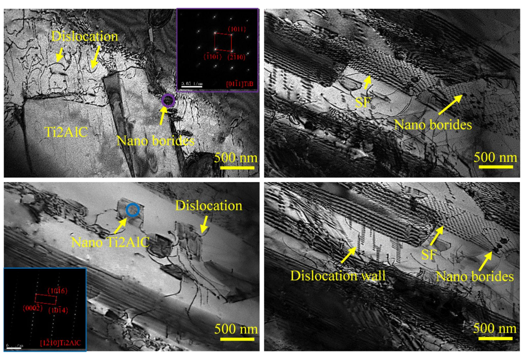

Fig. 3 TEM image of Ti46Al8Nb2.6C0.8Ta1.2B

In addition to the nano borides attached to the Ti_2AlC phase, many nano TiB particles are also precipitated between the γ/α_2 lamellar. The stacking faults (SFs) caused by these nano borides are obvious, the dislocation wall formed around the boride due to dislocation entanglement. The intricate and intertwined dislocations around the precipitates are one of the main reasons that significantly affect the mechanical properties of the alloy.

3.4 Mechanical properties

When the boron content increased from 0 to 1.2 at.%, the compressive strength increased from 2026 to 2224 MPa, the compressive strain increased from 26.3 to 29.6%. The improvement of compression performance is mainly influenced by grain refinement strengthening, dislocation strengthening, and boride precipitation strengthening.

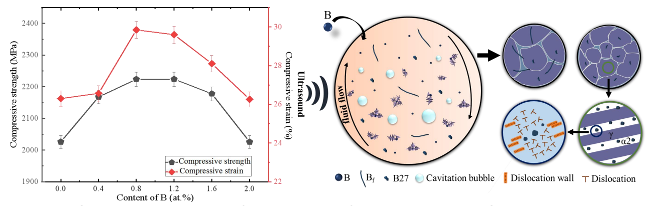

Fig. 4 Compression performance of Ti46Al8Nb2.6C0.8Ta-xB and the schematic diagram on microstructure evolution

4 Conclusion

By forming in-situ generated nano borides, a large number of dislocations are generated, leading to the formation of SFs and dislocation walls. The mechanical properties of the high-Nb Ti_2AlC/TiB TiAl alloy alloy have been improved, with a maximum strength of 2224 MPa and a maximum strain of 29.6%.

5 Acknowledgments

The authors are grateful to the financial support by National Natural Science Foundation of China (Grant No. U21A2042), the National Nature Fund Youth Fund Project of China (No. 52101038), and Young Elite Scientists Sponsorship Program by CAST (2021QNRC001).

References

[1] Salvador C A F, Maia E L, Costa F H, et al. A compilation of experimental data on the mechanical properties and microstructural features of Ti-alloys[J]. Scientific Data, 2022, 9: 188.

[2] Huang L, Liu B, Wang Z, et al. Effect of carbon nanotube content on the microstructure and mechanical properties of CNTs/TiAl alloys[J]. Ceramics International, 2023, 49: 8196-8203.

[3] Edwards T E J, Di Gioacchino F, Goodfellow A J, et al. Transverse deformation of a lamellar TiAl alloy at high temperature by in situ microcompression[J]. Acta Materialia, 2019, 166: 85-99.