Microstructural Control of Binary Ti-41Al and Ti-45Al Alloys by Heat Treatment

Kouichi Niinobe[1] and Hiroyuki Kitagawa[2,3]

[1] *National Institute of Technology, Matsue College, Matsue 690-8518, Japan*
[2] *Interdisciplinary Faculty of Science and Engineering, Shimane University, Matsue 690-8504, Japan*
[3] *Next generation Tatara Co-Creation Centre (NEXTA), Matsue 690-8504, Japan*

A microstructural control for high Ti-rich TiAl was carried out using with Ti-41Al and Ti-45Al binary alloys. By heating at temperatures ranging from 1173 to 1523K, these alloys showed discontinuous coarsening reactions, forming second lamellar microstructures. However, the formation temperature and morphology of the second lamellar microstructures differed depending on the Al composition.

Keywords: *titanium aluminide, discontinuous coarsening reaction, lamellar microstructure, intermetallic compound*

1. Introduction

Titanium aluminide (TiAl) alloys show high strength and moderate oxidation resistance at high temperatures. It is also well known that the TiAl alloys exhibit a phase transformation during cooling from an α-Ti phase at high temperature, forming various microstructures [1)]. With an increase of the cooling rate from the α-Ti phase, the microstructure changes from the lamellar, through the Widmannstatten-lamellar and the feathery to the massive microstructures. However, the phase transformation occurs in the alloys with Al composition approximately of 46at%Al to 49at%Al.

On the other hand, high Ti-rich TiAl alloys with Al composition less than 46at%Al shows a discontinuous coarsening reaction, forming a second lamellar microstructure [2)]. In addition, ternary Ti-rich alloys containing V, Cr and Mo etc. have other phase transformations involving β-Ti phase [3,4)]. In this study, Ti-41at%Al and Ti-45at%Al binary alloys were prepared, and a microstructural control of these alloys was performed only by a heat treatment.

2. Experiment

Ti-41at%Al (Ti-41Al) and Ti-45at%Al (Ti-45Al) alloys were formed by an arc-melting in an argon atmosphere, obtaining bottom ingots with a weight of 100g. Specimens for the heat treatment were obtained from the ingots by an electric discharging machine. After the specimens were wrapped with a tantalum foil, the specimens were set into a quartz tube back-filled with a pure argon gas. The specimens were heated at temperatures ranging from 1323 to 1523K for 86.4ks(1day), followed by air cooling. An additional experiment was performed in a heating condition at 1173K for 604.8ks(1week). A microstructure observation was conducted by an optical and a scanning electron microscope and a mechanical test was carried out by a Vickers hardness test machine.

3. Results and Discussion

Figure 1 shows microstructures of the as-cast alloys obtained by the optical microscopy. As seen in Fig.1(a), Ti-41Al is composed of large grains with a size of more than one millimeter and small grains with a size of several hundred micrometers. Since the lamellar microstructure with thin plates are not observed in Fig.1(a), the as-cast alloy of Ti-41Al is mainly composed of α_2-Ti_3Al phase. In contrast, as seen in Fig.1(b), the lamellar microstructure is formed in all regions, indicating that the as-cast alloy of Ti-45Al is composed of α_2-Ti_3Al and γ-TiAl phases.

Figure 2 shows microstructures of the Ti-41Al after the heat treatment. As seen in Fig.2(a,b), second lamellar microstructures are limitedly formed at the grain boundaries and the volume fractions are extremely low. As seen in Fig.2(c), large equiaxed grains are observed in Ti-41Al heated 1473K. This means that Ti-41Al consists of α-Ti single phase during heating at 1473K.

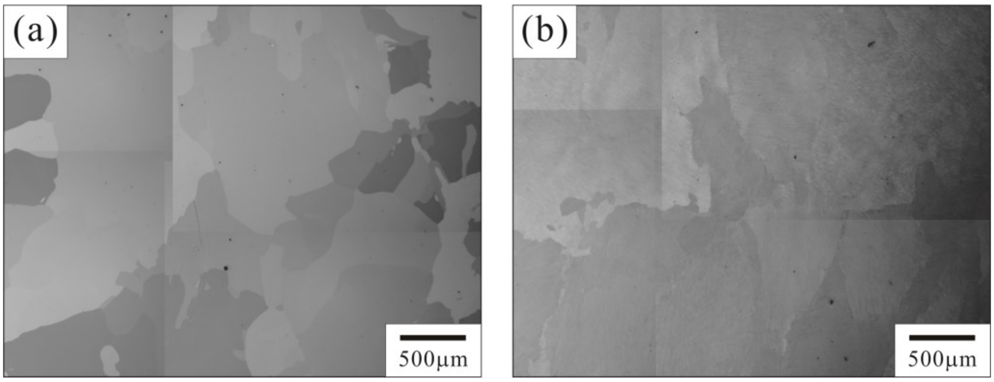

Figure 1 Optical microphotographs of the as-cast specimens for (a) Ti-41Al and (b) Ti-45Al alloys.

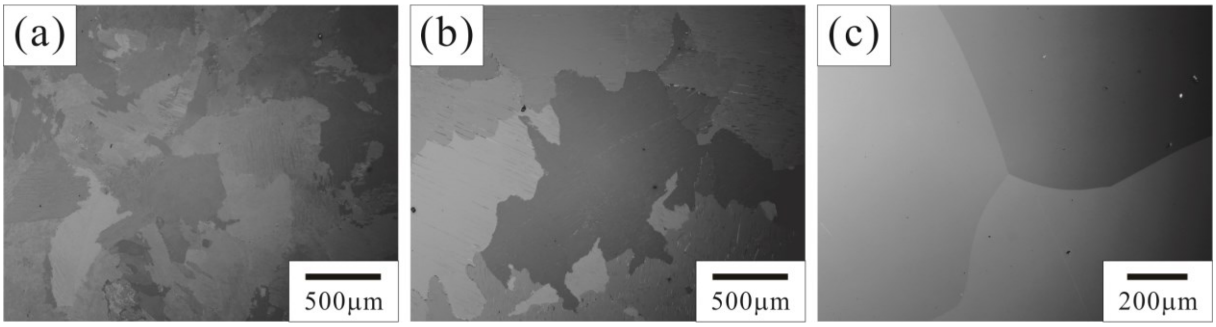

Figure 2 Optical microphotographs of the specimens in the Ti-41Al alloy heated at (a) 1373K, (b) 1423K and (c) 1473K for 86.4ks.

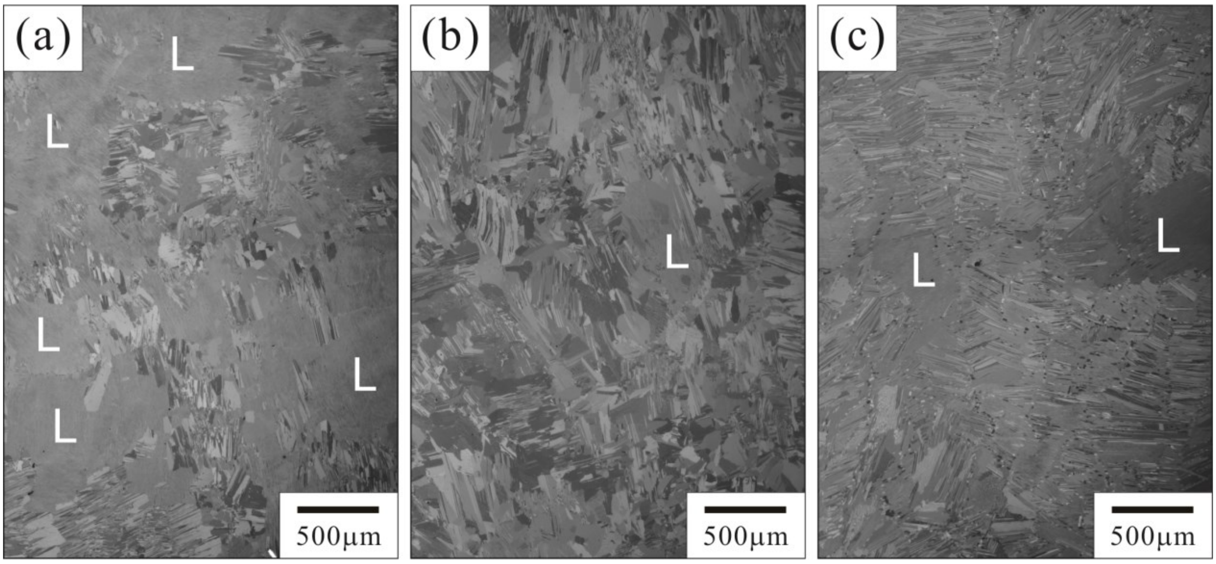

Figure 3 Optical microphotographs of the specimens in the Ti-45Al alloy heated at (a) 1373K, (b) 1423K and (c) 1523K for 86.4ks.

Figure 3 shows microstructures of Ti-45Al after the heat treatment. The second lamellar microstructures with thick plates are formed in Ti-45Al heated at 1373, 1423 and 1523K. However, the volume fraction of the second lamellar microstructure depends on the heating temperature. The second lamellar microstructure in Ti-45Al heated at 1373K is limitedly formed at grain boundaries and the lamellar microstructure as marked with a symbol of L are retained with a volume fraction more than 50%. On the other hand, Ti-45Al heated at 1423K consists almost of the second lamellar microstructure.

As shown in Fig.2, the formation of the second lamellar microstructure is limited in Ti-41Al. However, the reaction behavior shows different trend in the specimens heated at 1173K for 604.8ks. Although the second lamellar microstructure is hardly formed in Ti-45Al, it is formed in Ti-41Al with a volume fraction of more than 50%. The second lamellar microstructure formed in Ti-41Al consists of thinner lamellar plates than that in Ti-45Al. The second lamellar microstructure in Ti-41Al shows high hardness, which is slightly higher than that of as-cast Ti-41Al as shown in Fig.1(a) and α_2-Ti_3Al phase as shown in Fig.2(c). On the other hand, the second lamellar microstructures formed in Ti-45Al show clearly low hardness compared with the lamellar microstructure in the as-cast specimen shown in Fig.1(b).

4. Conclusion

Ti-41Al and Ti-45Al alloys show discontinuous coarsening reactions. The formation temperature and morphology of the second lamellar microstructures differed depending on the Al composition.

Acknowledgment

This work was partially supported by the Next Generation Tatara Co-Creation Centre (NEXTA), Shimane University. Here, NEXTA is established with Grant-in-aid for the Promotion of Regional Industries and Universities from Cabinet Office, Japan.

References

1) M. Takeyama and M.Kikuchi: Meteria Japan. 35 (1996) 1058-1064.
2) S.Mitao and L.A.Bendersky: Acta Mater. 45 (1997) 4475-4489.
3) M.Takeyama: Materia Japan. 60 (2021) 281-288.
4) M.Takeyama and S.Kobayashi: Intermetallics. 13 (2005) 993-999.