

Carbon in Nb-rich γ -TiAl based alloys

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Intermetallic γ -TiAl based alloys are light-weight high-temperature structural materials of great technological interest. They have the potential to partly replace the heavier Ni based super alloys for applications as compressor and turbine blades in gas turbines and aero engines [1]. TiAl alloys are two-phase alloys consisting of tetragonal γ -TiAl and small amounts of hexagonal α_2 -Ti₃Al. In order to extend their service range to higher temperatures research activities have been focused on high Nb bearing TiAl alloys. These so-called third generation or TNB alloys exhibit a significant increase in strength combined with improved creep properties and oxidation resistance [2].

Microalloying with carbon leads to additional improvements in both, strength and creep resistance. This can be due to either solid-solution hardening or age-hardening by carbide precipitates, depending on the carbon content and processing conditions. In conventional binary TiAl alloys precipitation hardening treatments using carbon additions result in the formation of either cubic perovskite-type Ti₃AlC (P-phase) or hexagonal Ti₂AlC (H-phase) precipitates [3]. A special heat treatment with subsequent ageing of the binary Ti-48.5Al (at.%) alloys with carbon additions leads to the formation of P-phase precipitates [4]. The addition of 0.4 at.% C improves the strength by almost 50 % [4].

Recently, attempts were made to apply the same hardening effect by carbon additions to modern TNB alloys. The mechanical properties of Ti-45Al-5Nb alloys were clearly improved by the addition of 0.5 at.% C [5,6], but the increase in strength of about 20 % [5] is low compared to conventional TiAl alloys. However, investigations of the microstructure by transmission electron microscopy (TEM), X-ray diffraction (XRD) and small angle neutron scattering (SANS), did not give any evidence for the presence of C-containing precipitates [6]. Additionally, three-dimensional atom probe tomography (3DAP) studies of these alloys indicate that Nb might increase the solubility of carbon in the γ -TiAl phase [7]. Thus it can be speculated that the carbon content in TNB alloys must be increased, to form carbide precipitates.

In order to study systematically the solubility of carbon and the formation of carbides in Nb-rich γ -TiAl alloys a series of 4 TNB alloys with a basic composition of Ti-45Al-5Nb-xC and carbon contents of 0, 0.5, 0.75 and 1 at.% was produced from alloy powders through hot-isostatically pressing. These powder compacts show a fine grained microstructure and are chemically homogenous.

High-energy X-ray diffraction (HEXRD) experiments were performed at the side station (EH1) of the HZG beamline HEMS at DESY. Samples with a diameter of 4 mm were measured in transmission geometry with a photon energy of 87 keV ($\lambda = 0.1425 \text{ \AA}$) and a beam size of 0.5·0.5 mm². The resulting diffraction rings were recorded on a Mar345 image plate detector with an exposure time of 4 seconds.

Figures 1a,b present the diffraction pattern of the 4 alloys. All alloys show γ -TiAl and α_2 -Ti₃Al reflections. However, in the alloy with 1 at.% C additional reflections can be observed. They can be indexed unambiguously as Ti₂AlC H-phase reflections. Additionally, a significant influence of carbon on the lattice parameters of γ -TiAl and α_2 -Ti₃Al can be noticed in figure 1b. Between 0 and 0.75 at.% C the lattice parameters of γ and α_2 expand about 0.5 % with increasing carbon content. According to this, the peaks of γ and α_2 reflections move to smaller scattering vectors q (Fig. 1b). Between 0.75 and 1 at.% this expansion stops or even slightly decreases. This indicates

that the solubility of carbon in Ti-45Al-5Nb is reached at about 0.75 at.% C and further carbon additions result in the formation of carbides.

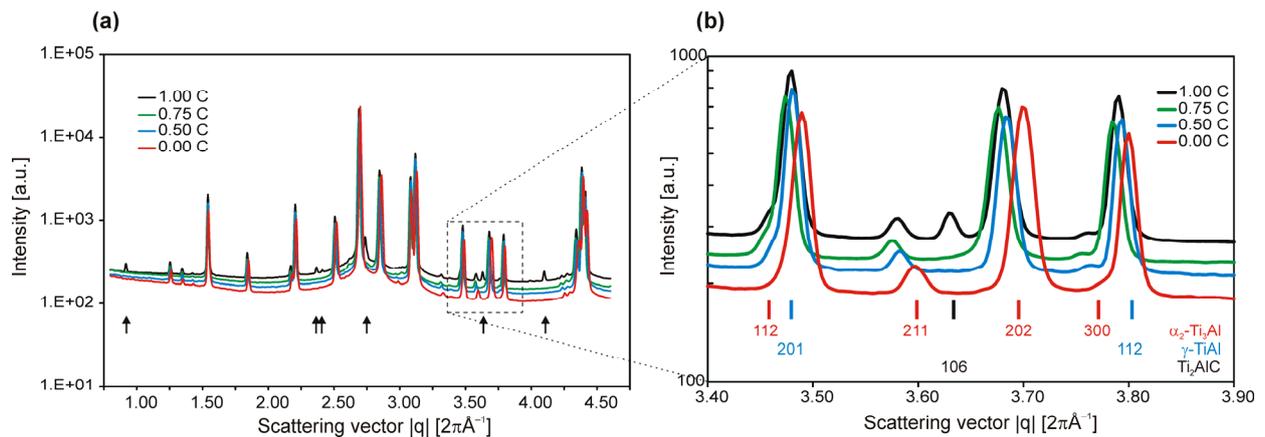


Figure 1: Diffraction pattern of Ti-45Al-5Nb-xC alloys ($x = 0$ to 1 at.%). $|\mathbf{q}| = 2\pi/d = 2\pi \cdot (2\sin\theta/\lambda)$. (a) The additional reflections of Ti_2AlC H-phase are marked by arrows. (b) Section of the diffraction pattern indicating the peak shift due to the lattice expansion with increasing carbon contents.

Further experiments with various heating cycles are planned to study the thermal stability and possible phase transformations of the carbides. Additionally, the precipitation kinetics during aging after solution heat treatment will be studied.

References

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