Microsc. Microanal. 21 (Suppl 3), 2015
doi:10.1017/S1431927615006649 Paper No. 0585

The Atomic Interfacial Structure between α_2 and γ Phases within a TiAl Alloy in Lamellar Form

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Due to the attractive properties such as high strength-to-weight ratio and excellent high temperature creep and oxidation resistance, TiAl-based alloys with fully lamellar microstructure have been widely applied in producing aerospace and car engines [1-3]. The distribution of α_2 and γ phases, strongly affected by their interface, plays an important role in determining their mechanical properties at high temperature [4-6]. Although many researchers have investigated it by transmission electron microscopy [4, 7], the atomic interfacial arrangement and the chemical bonding nature have not been fully clarified. Therefore, we aim on analysing of the detailed interfacial structure in TiAl alloys.

We studied TiAl-based alloys synthesized by arc melting (at China Iron and Steel Research Institute Group). The lamellar structure was achieved by the heat treatment including 1340 ℃ for 0.5 h, 1 h and 2 h followed by air cooling. The microstructure morphology was studied by the optical microscopy and scanning electron microscopy. The samples were mechanically polished and etched by the aqueous reagent of 2% hydrofluoric acid and 10% hydrogen nitrate prior to the optical characterization. The TEM samples were prepared by the twin-jet electro-polishing technique with an electrolyte of 4% perchloric acid. The detailed atomic structure was investigated using a JEOL ARM200F Scanning Transmission Electron Microscopy (STEM) with a probe corrector.

The lamellar structure, consisting of α_2 (Ti_3Al, DO_{19}) and γ (TiAl, $L1_0$) phases, was successfully synthesized through the above approaches. The lamellar spacing increases with increasing annealing time. A well-defined orientation relationship of $\{111\}_\gamma//(0001)_{\alpha2}$ & $<1\text{-}10>_\gamma//<11\text{-}20>_{\alpha2}$ was additionally confirmed using the selected area diffraction (SAD) technique (see Figure 1). There are always three sets of diffraction patterns co-existing within the same regions. The diffraction labeled by the yellow rectangle in figure 1 is from α_2 phase. The other two diffraction patterns, indicated by the red and green rectangles, belong to $<011]_\gamma$ and $<1\text{-}10]_\gamma$, respectively. The atomic arrangement of γ phase viewed along $<011]_\gamma$ and $<1\text{-}10]_\gamma$ is different (see the STEM-high-angle annular dark-field (HAADF) images in figure 2 (b) and (c)) due to the ordered $L1_0$ structure with a slightly larger c axis. Although the c axis is not equivalent to the other two axes in γ structure, the c/a ratio is only in the range of 1.01-1.03 depending on the Al content. As shown in the STEM-HAADF images in figure 2, α_2 phase has brighter Z-contrast compared to the γ phase. Viewed from $<11\text{-}20>_{\alpha2}$, the Ti column has slight brighter contrast compared to the Ti-Al column. The interface between α_2 and γ phase is atomic sharp, as shown in figure 2 (d) and (e). In addition, we always detected the twining (figure 2 (e)) and pseudo-twining (figure 2(f)) of γ phase viewed along $<011]_\gamma$. The pseudo-twinning refers as the mirror structure of γ phase forming at sides of α_2 phase with a dimension of ~2 nm.

The detailed atomic arrangement of the α_2/γ interface is currently under investigated by atomic resolution STEM and electron energy-loss spectroscopy techniques (EELS). Different atomic models can be built to study their interface energy by applied first principles computation.

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[8] Thanks for the supplying samples from China Iron and Steel Research Institute Group. We also thank Prof. Ji Zhang for helping and benefit discussions.

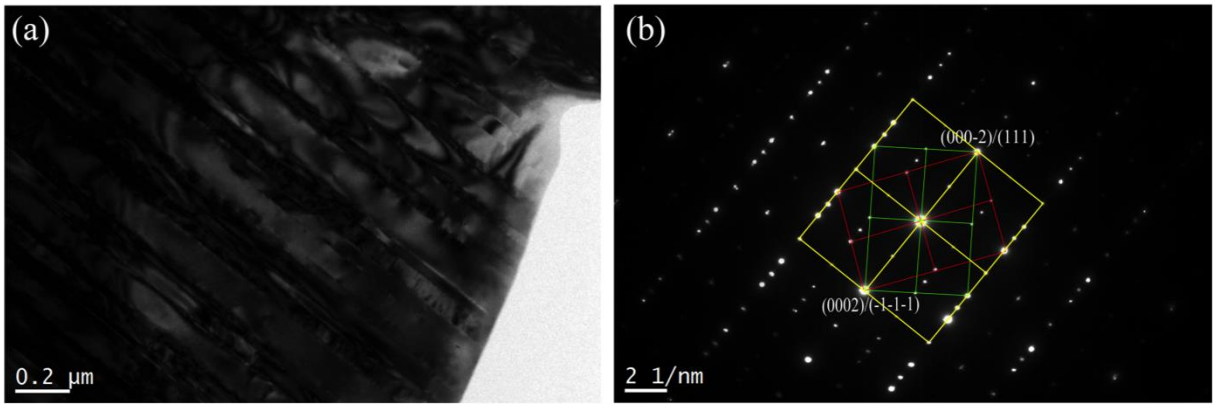

Figure 1. The lamellar structure. (a) the bright field image (b) the corresponding diffraction pattern.

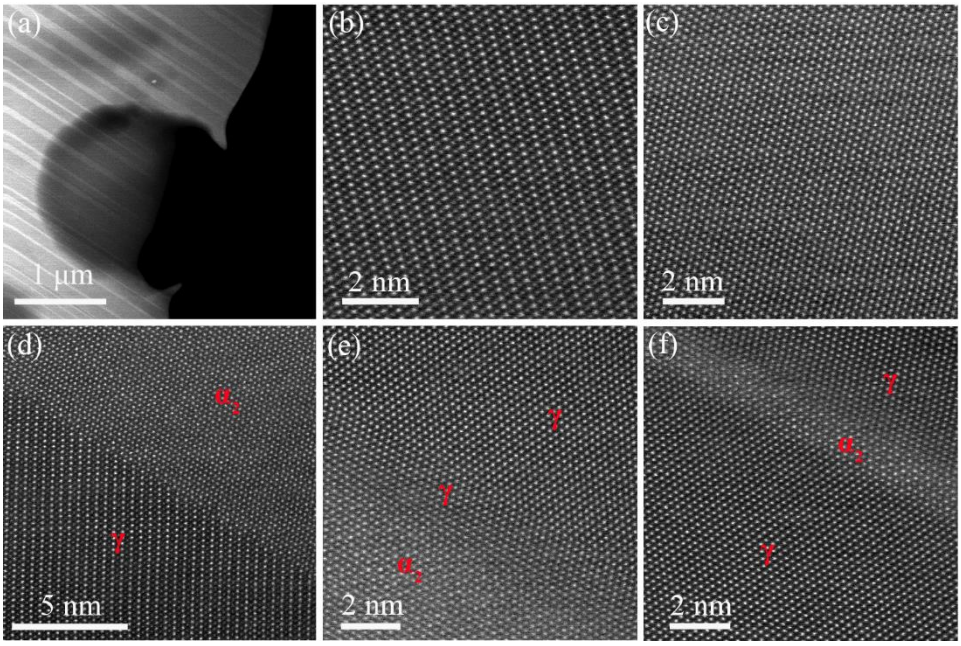

Figure 2. The atomic structure of lamellar microstructure. (a) the low magnification HAADF image (b)-(c) shows the atomic structure of γ phase when the beam is parallel to $<1\text{-}10]_{\gamma}$ and $<011]_{\gamma}$, respectively (d) the interface of γ and α_2 (e)-(f) the twining and pseudo-twining, respectively.