

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 °C 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 (Ti₃Al, DO₁₉) and γ (TiAl, L1₀) phases, was successfully synthesized through the above approaches. The lamellar spacing increases with increasing annealing time. A well-defined orientation relationship of $\{111\}_\gamma // (0001)_{\alpha_2}$ & $\langle 1-10 \rangle_\gamma // \langle 11-20 \rangle_{\alpha_2}$ 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 $\langle 011 \rangle_\gamma$ and $\langle 1-10 \rangle_\gamma$, respectively. The atomic arrangement of γ phase viewed along $\langle 011 \rangle_\gamma$ and $\langle 1-10 \rangle_\gamma$ is different (see the STEM-high-angle annular dark-field (HAADF) images in figure 2 (b) and (c)) due to the ordered L1₀ 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 $\langle 11-20 \rangle_{\alpha_2}$, 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 twinning (figure 2 (e)) and pseudo-twinning (figure 2(f)) of γ phase viewed along $\langle 011 \rangle_\gamma$. 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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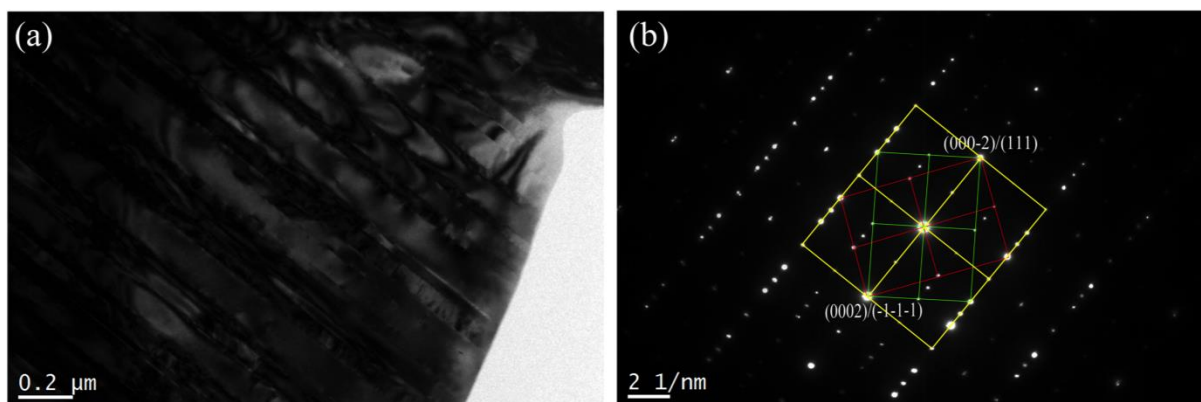


Figure 1. The lamellar structure. (a) the bright field image (b) the corresponding diffraction pattern.

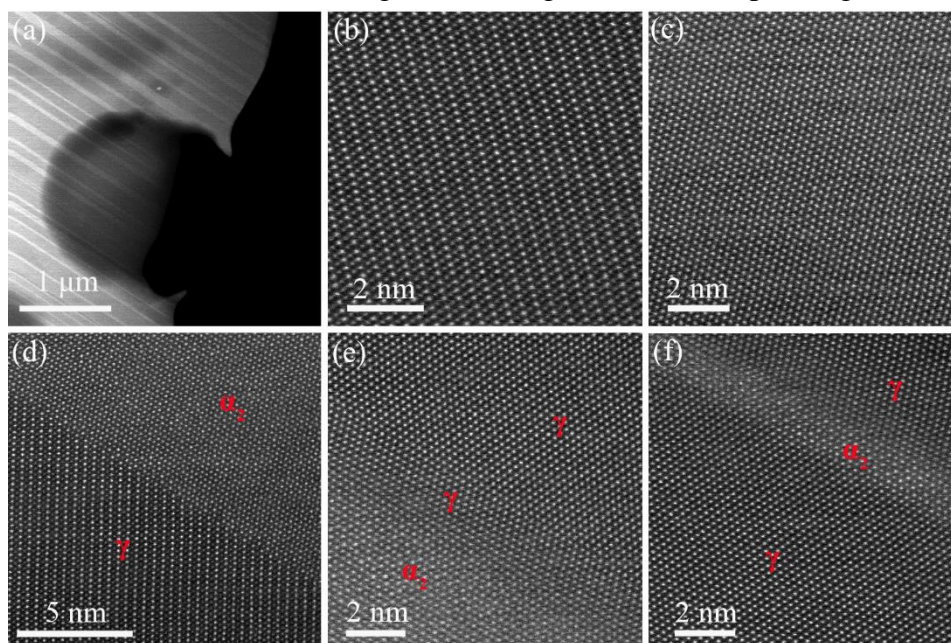


Figure 2. The atomic structure of lamellar microstructure. (a) the low magnification HAADF image (b)-(c) shows the atomic structure of γ phase when the beam is parallel to $\langle 1-10 \rangle_{\gamma}$ and $\langle 011 \rangle_{\gamma}$, respectively (d) the interface of γ and α_2 (e)-(f) the twinning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