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Submicron lamellar porous structure formed by selective dissolution of Ti-Al alloy

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ABSTRACT

We created high-aspect-ratio sub-micron-sized lamellar porous structure by simple anodic selective dissolution of lamellar Ti-Al alloy in NaCl aqueous solution. The geometries of lamellar structures, which determined those of lamellar porous structure, were controlled by hot forging and subsequent ageing treatment before dissolution process. Although the changes in microstructure affected the selective dissolution behaviors, γ-TiAl phase could be dissolved selectively. As a result, the average sizes of unidirectional units of lamellar pores could be controlled in the range from to 25 μm to 500 μm. The pitches of the lamellar pores were controlled in the wide range from below 100 nm to over 1 μm.

1. Introduction

Nano/sub-micron periodic structures of metallic materials that are widely utilized as photovoltaics [1–2], catalysts [3–4] have attracted considerable efforts due to their high surface area, good thermal and electric conductivity. Recently, electrochemical treatment has become a promoting approach for the fabrication of submicron or nanoscale architectures such as nanoholes/pores and nano-pillars/wires, which were generally achieved by dealloying or selective dissolution of alloys [5–17]. For instance, three dimensional submicron porous structure was formed by electrochemical selective dissolution of amorphous Zr-Ni-Cu-Al ribbons [5] and directionally solidified NiAl-Mo eutectic [6]. Nanowires/fibers were produced by selective dissolution of Ag-Cu alloy [7] and Ni-Al alloy [8]. The topographies of these nano/submicron architectures were affected by electrochemical potentials, temperatures and the periods of dissolution as well as the microstructures of materials.

On the other hand, lamellar Ti-Al alloys have been intensively studied as structural materials due to their good mechanical properties, good oxidation and corrosion resistances [18–21]. The lamellar structure consisting of α_2-Ti_3Al lamellae and γ-TiAl lamellae with a very flat interface parallel to (0001) basal plane of α_2 phase and {111} planes of γ phase, which is known as Blackburn's relationship [22] that can be described as: $(0001)_{\alpha2}$ // $\{111\}_\gamma$, $<11\bar{2}0>_{\alpha2}$ // $<1\bar{1}0>_\gamma$. The corrosion resistance of α_2-Ti_3Al phase is obviously higher than that of γ-TiAl phase mainly due to its high concentration of Ti. As a result, γ phase was selectively etched from lamellar Ti-Al alloys by chemical etching in a corrosive electrolyte [23]. Besides, γ phase was also selectively

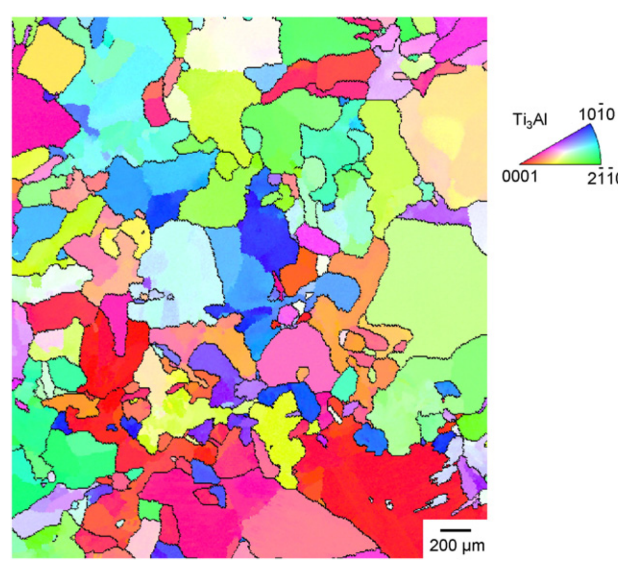

Fig. 1. SEM-EBSD inverse pole figure (IPF) map of Ti-40 at.% Al ingot.

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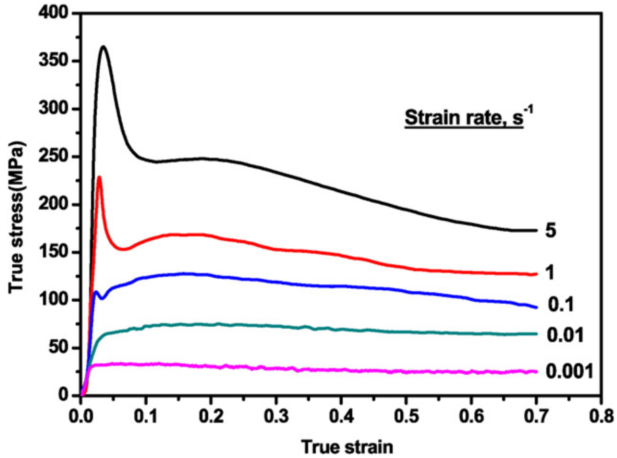

Fig. 2. True strain-stress curves of Ti-40 at.% Al alloy deformed at 1473 K with different strain rates.

dissolved by electrochemical etching conducted at a certain potential in non-corrosive NaCl aqueous solution [24–26] mainly owing to the difference in anodic polarization behavior of α_2 phase and γ phase [26,27]. In both cases, the α_2-Ti_3Al phase remained and various nano/submicron architectures were formed on the surface. For instance, nanofins with average thickness of <100 nm and ~1000 nm were produced by selective dissolution of γ lamellae from lamellar Ti-41 at.% Al single crystals by electrochemical method, and the dissolution behaviors were affected by the initial thicknesses and distributions of lamellae [26]. However, the architectures were relatively inhomogeneous. Thus, if the initial microstructures (the lamellae and colonies) can be homogenized, we may be able to produce functional nano/submicron architectures. Furthermore, since nano-pores or tubes with various dimensions and distributions can be formed by anodization of Ti-Al alloys [14,28], nano/submicron architectures with promising properties may be obtained by combination of selective dissolution and anodization of lamellar Ti-Al alloys with proper morphologies.

According to previous studies, the lamellar structures were usually formed by the precipitation of γ lamellae though ageing the Al-supersaturated α_2 matrix at $\alpha_2 + \gamma$ dual phase temperatures [22, 29–31]. The dimensions of lamellae can be adjusted from nanoscale to micron scale by appropriate combination of ageing temperature and period [30–31]. Moreover, the precipitation of γ lamellae can be accelerated and controlled by dislocations introduced by plastic deformation prior to ageing [32–35]. Thus, if dislocations were able to be introduced locally with appropriate density and distribution prior to ageing, the lamellar structure should be manipulated regularly.

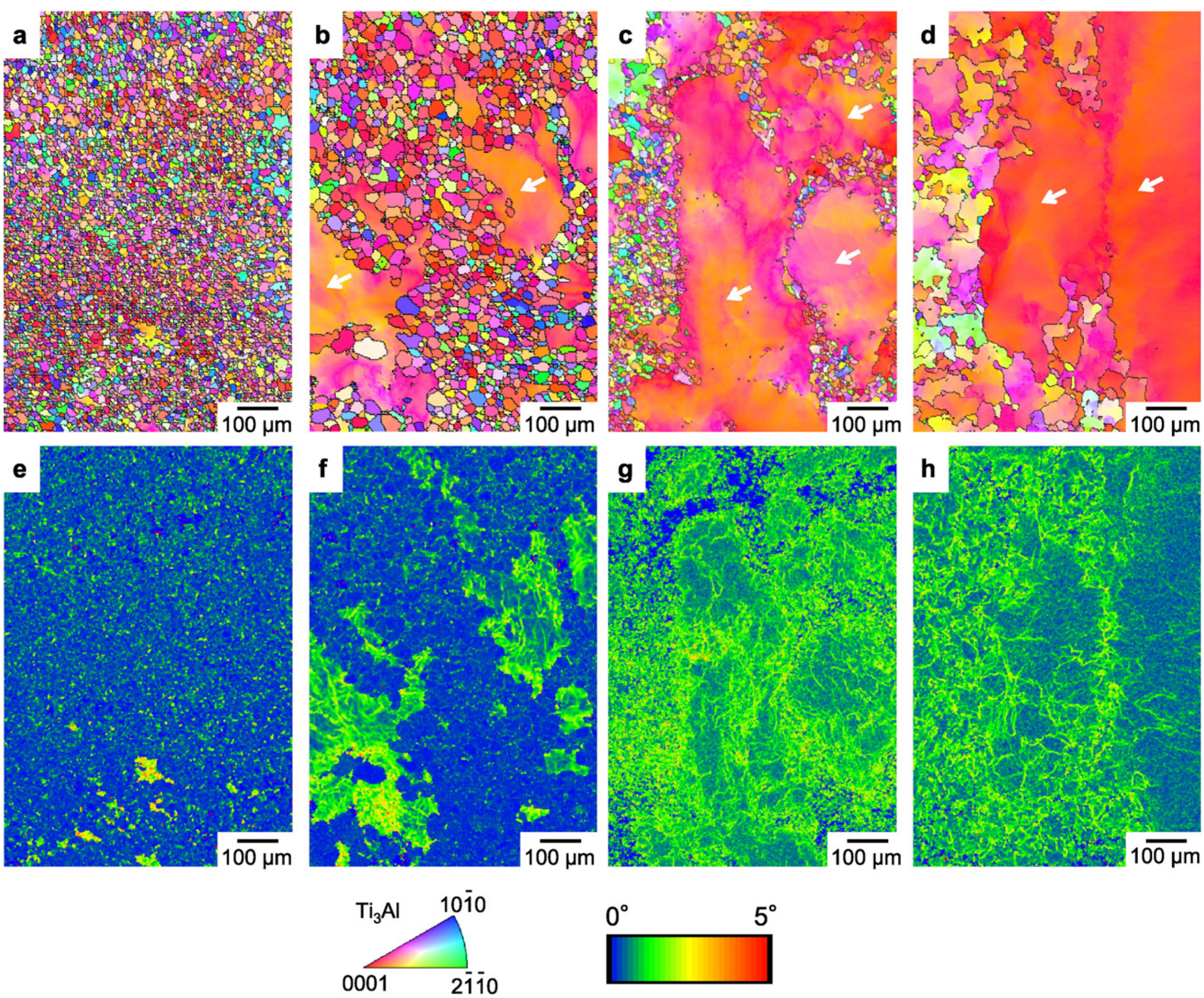

Fig. 3. (a-d) SEM-EBSD inverse pole figure (IPF) maps and (e-f) SEM-EBSD kernel average misorientation (KAM) maps of Ti-40 at.% alloy deformed at 1273 K with strain rates of: (a and e) 1 s^{-1}, (b and f) 0.1 s^{-1}, (c and g) 0.01 s^{-1}, (d and h) 0.001 s^{-1}.