Supporting Information

Growth behavior of columnar grains in TiAl alloy during directional induction heat treatment

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The equipment of DHT is mainly composed of a heating system, a cooling system, a motion system and a vacuum system, as shown in Fig. S1. The induction coils were supplied by AC with frequency of 50 kHz. The effective heat treatment area in sample can be heated rapidly by adjusting the loaded power. Due to strong cooling effect from liquid Ga-In alloy, an average temperature gradient about 20 K/mm is generated between effective heat treatment area and bottom of sample during DHT. It is the existence of temperature gradient that causes heat flow along the axial direction of sample during DHT. Meanwhile, grains in effective heat treatment area will grow up against the direction of heat flow. The temperature of effective heat treatment area is measured by WRe5 - WRe26 thermocouple. The thermocouple is inclined close to the sample to ensure full contact between them. When the temperature of effective heat treatment area reaches the set value (1750 K), sample is conducted to heat preservation for 20 min before turning on the motion system. After setting pulling rate (4.17 μm/s) of the motion system, sample will be pulled downwards at a uniform speed with pulling bar and a continuous dynamic heat treatment experiment is carried out. The whole process of experiment was conducted under high vacuum Ar gas protection. Firstly, the chamber was evacuated to a pressure of 5 Pa. Then Ar gas was backfilled into the chamber until pressure of the chamber reached 300 Pa. After 3 - 5 times of cleaning the chamber, DHT experiment was conducted under Ar protection of 300 Pa.

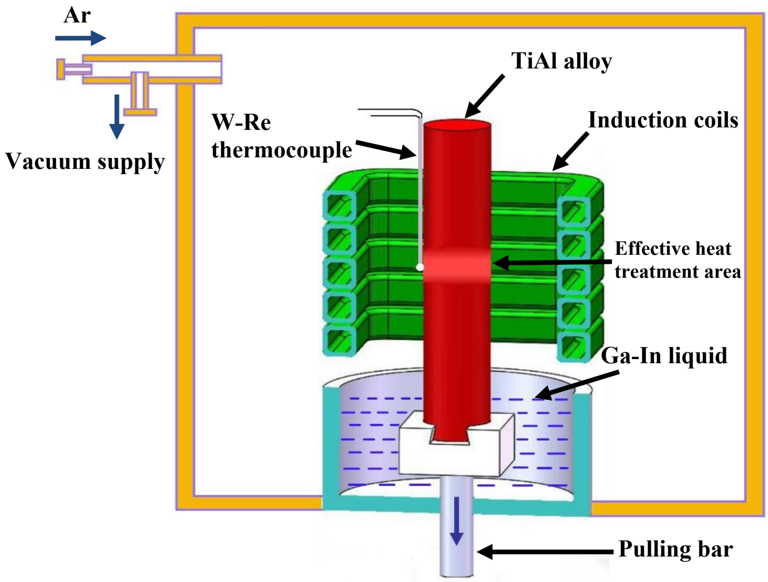

Fig. S1. Device schematic of DHT.

Assuming the pressure difference to be ΔP between both sides, the equilibrium condition is,

$$2l\sigma \cdot \sin(d\theta/2) = \Delta Plrd\theta \quad (1)$$

Where, *l is depth of grain boundary; σ is interface; dθ* is angle for curve grain boundary; r is radius of grain.

When $d\theta$ is little enough，sin($d\theta/2$)→$d\theta/2$，thus the equation (1) could be simplified as equation (2).

$$\Delta P = \sigma/r \quad (2)$$

Therefore, when the interface tension (σ) keeps a constant value, the greater interface curvature is (namely the less r), the greater ΔP is. It is easy for atoms to diffuse from concave side towards convex side.

Atoms diffusion is dominated by vacancy mechanism and the self-diffusion coefficient could be simply expressed as,

$$D = D_0 \exp\left[\frac{-E_j}{K_B T}\right] \quad (3)$$

where D is diffusion constant; E_j is activation energy for atoms jumping to an adjacent vacancy; K_B represents the Boltzmann`s constant and T is the temperature.

D_0 is given by

$$D_0 = fa^2 vX_v \tag{4}$$

where f, a ,v and Xv are the correlation factor, the nearest-neighbor jump distance, the jump frequency and the site fraction of vacancies on the appropriate sublattice, respectively. Ti44Al alloy was heat treated at 1750K. Therefore, the self-diffusion coefficient for atoms is high. It is beneficial to migration of grain boundary.

The migration of grain boundary can be calculated as follow,

$$S_1 = V_1 \cdot t \tag{5}$$

$$S_2 = \left(V_1 + V_0\right) \cdot t \tag{6}$$

Where S_1 is the expansion distance of grain boundary along radial direction (mm), S_2 is the expansion distance of grain boundary along axial direction (mm). t is migration time for grain boundary (s). V_1 is the spontaneous migration rate for grain boundary (μm/s). V_0 is the movement speed of pulling bar (4.17 μm/s).