Embrittlement of TiAl after high temperature exposure

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This poster presents work performed to confirm the development of a near-surface tensile residual stress after exposure. In Ref. [1], this was proposed to be responsible for embrittlement after high temperature exposure.

Background

Titanium aluminide alloys have recently been introduced into jet engine applications by General Electric, Pratt & Whitney, MTU and Snecma but still suffer from environmental embritttlement [2]:

- After high temperature exposure, plastic elongation is reduced by 50% for low strength alloys and by 100% for high strength alloys.
- Ductility is restored by removing a few microns of material from the exposed surface.
- The reason for the embrittlement is unknown, but it has been proposed [1] that tensile stresses develop in outer surface layer and lead to premature fracture.

[1] X. Wu, A. Huang, D. Hu and M.H. Loretto; Intermetallics 17 (2009) 540-552
[2] F. Appel, J.D.H. Paul and M. Oehring; Gamma Titanium Aluminide Alloys - Science and Technology Wiley-VCH, Weinheim, (2011).

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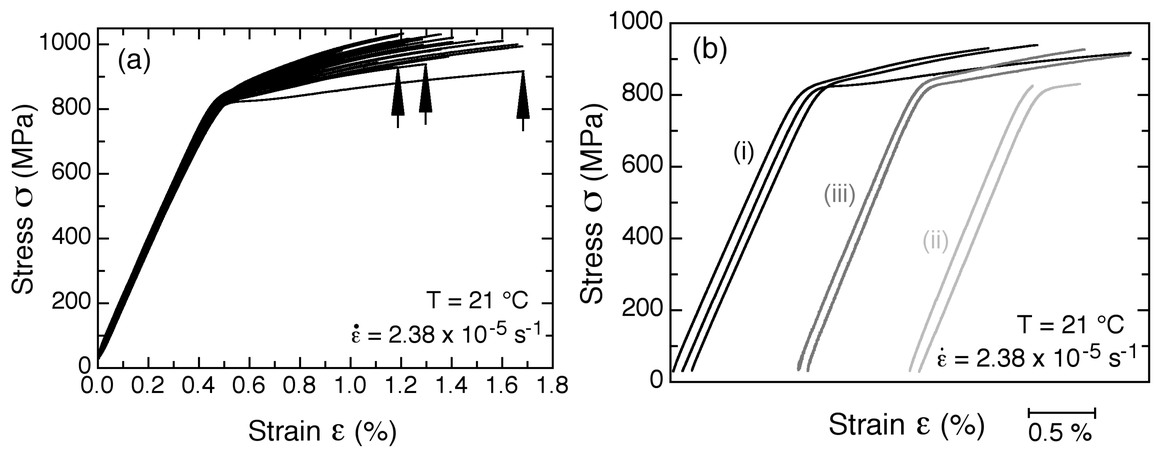


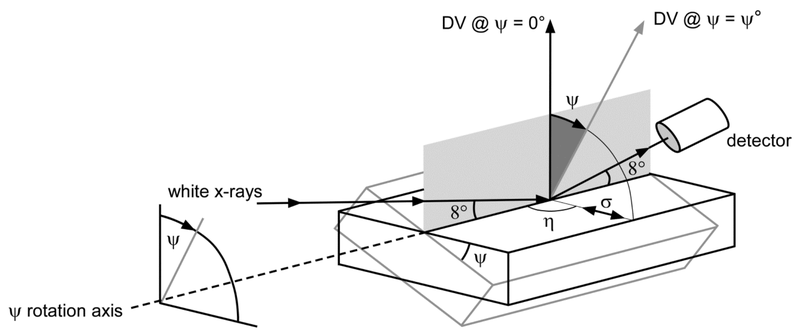
Room temperature tensile test curves: (a) for Ti-45Al-8Nb-0.2C showing that heat treatment of tensile test blanks at 800 °C for 1504 hours in air (the three arrowed curves) does not significantaly change the plastic elongation to failure compared to un-exposed specimens. The three tensile test curves in (b) labelled (i) are the same curves as arrowed in (a). Those marked (ii) were test specimens that had been exposed at 700 °C for 24 hours in air, and show significant embrittlement. Ductility is restored after removal of around 100 μm from the oxidised tensile specimens by grinding, the curves labelled (iii).

Experimental/Results

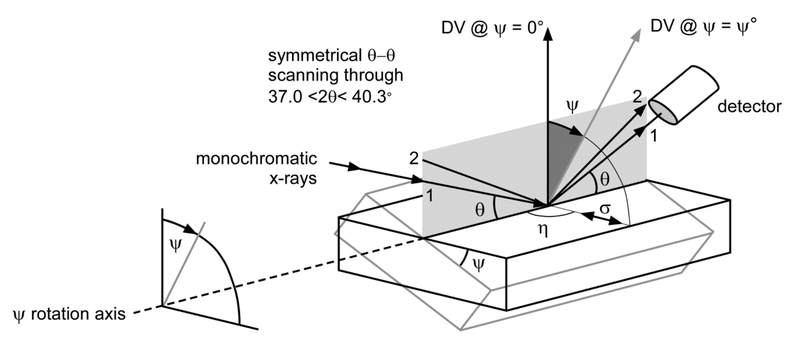
Ti-49Al, HIPed (1200°C/4 h/ 200 MPa) pre-alloyed powder, 1.2% a_2, texture-free.

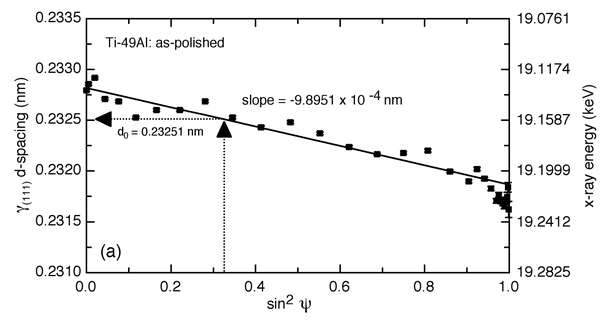
Ti-45Al-5Nb-0.2B-0.2C (extruded ingot), slight texture.
Conditions investigated: mechanically polished (unexposed) and after 700 °C/1 h (exposed).

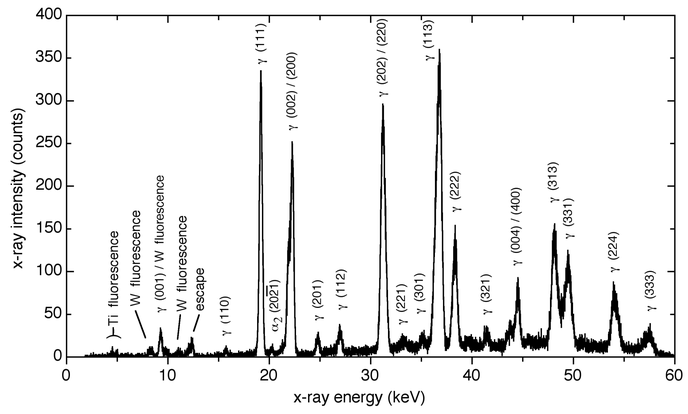
Wavelength dispersive diffraction

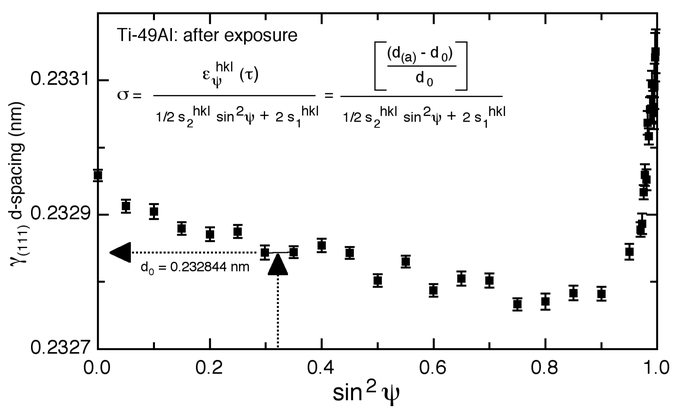


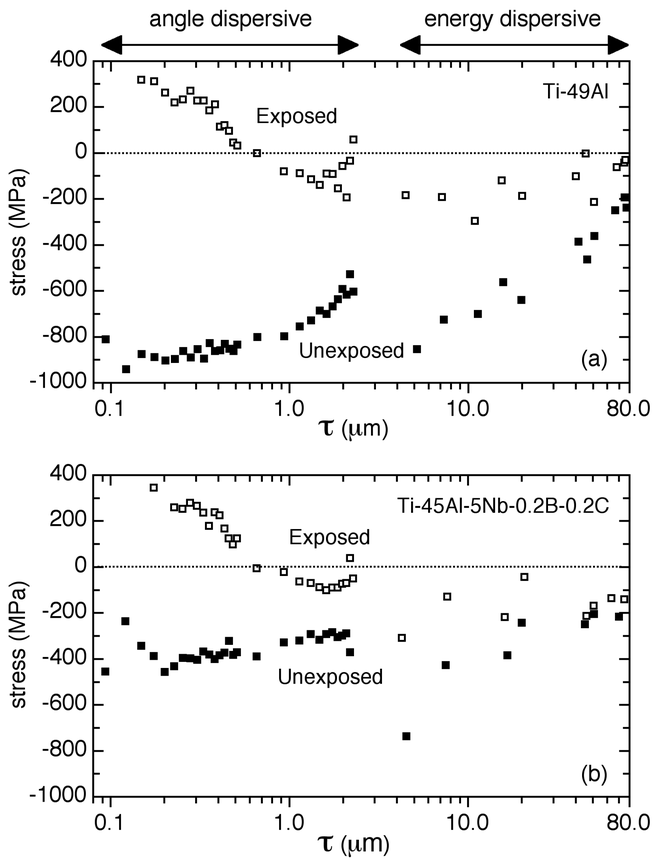
Angle dispersive diffraction











Summary

1. Unexposed specimens have compressive near surface residual stress probably as a result of mechanical grinding/polishing.

2. A tensile residual stress within the outer 0.6 μm of the surface seems to develop after high temperature exposure in air at 700 °C for 1 h. The deeper compressive residual stresses are reduced after exposure.

3. It is speculated that the development of surface tensile stress and the reduction of compressive residual stress deeper within the material may be responsible for the embrittlement after high temperature exposure.

Future work

Investigation of near-surface chemistry changes after exposure treatment an artificial air composed of 80% ($^{15}N_2$), 20% ($^{18}O_2$) and heavy water vapour (D_2O equivalent to ≈ 80% relative humidity at room temperature).

=> Proposal to be submitted for a joint SIMS investigation at KIT

X-ray diffraction measurements and stress profile calculations performed by HZB

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