Diffusion Mechanisms in Two-Phase Intermetallic Titanium Aluminide Alloys

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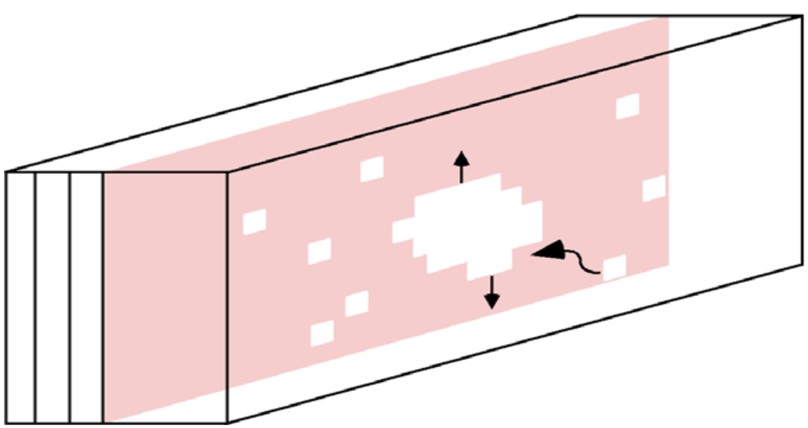
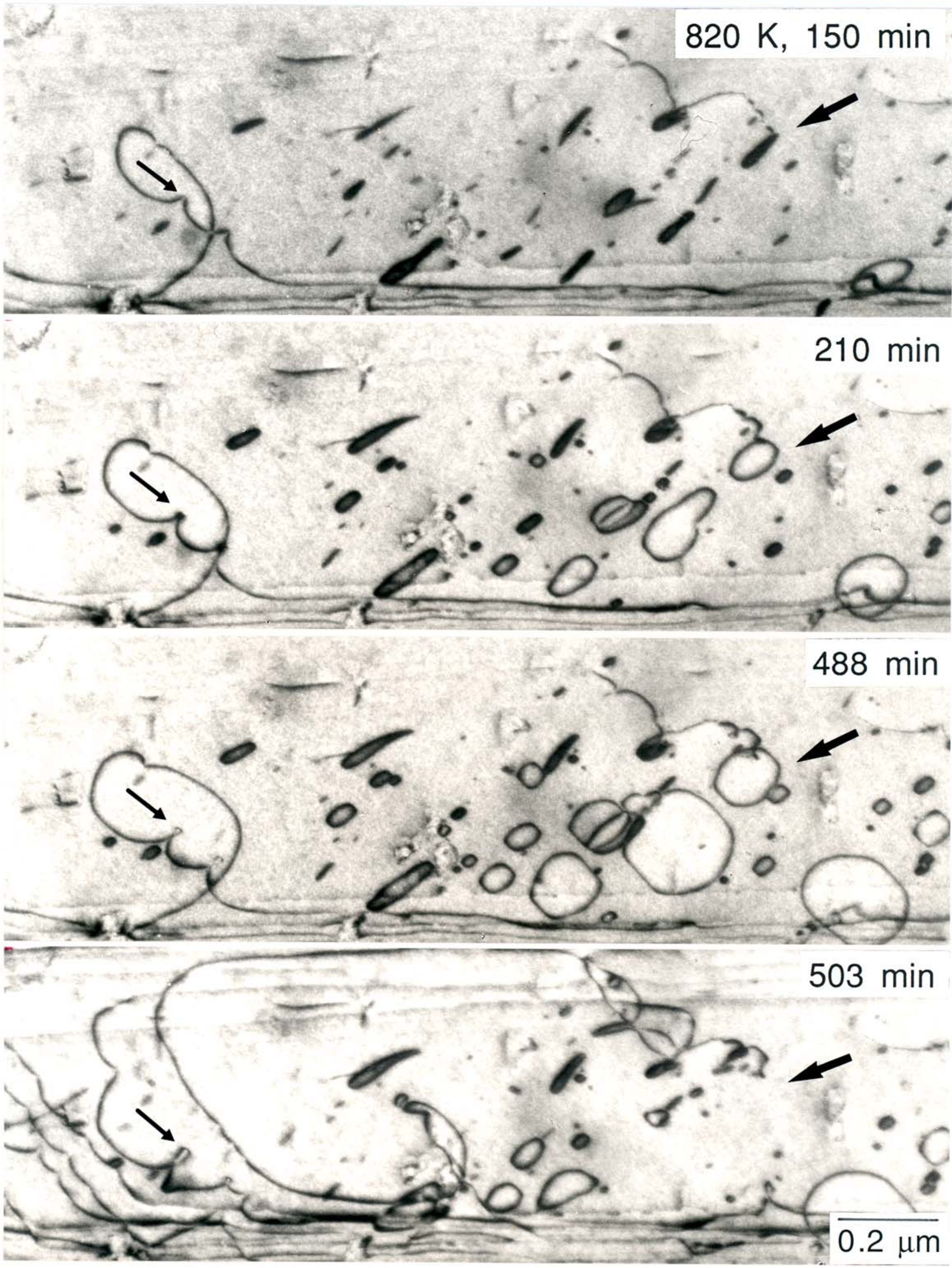
Dislocation Multiplication by Diffusion Assisted Bardeen-Herring Climb Sources

TEM in-situ heating

Ti-48Al-2Cr (at.%)





Titanium Aluminide Alloys

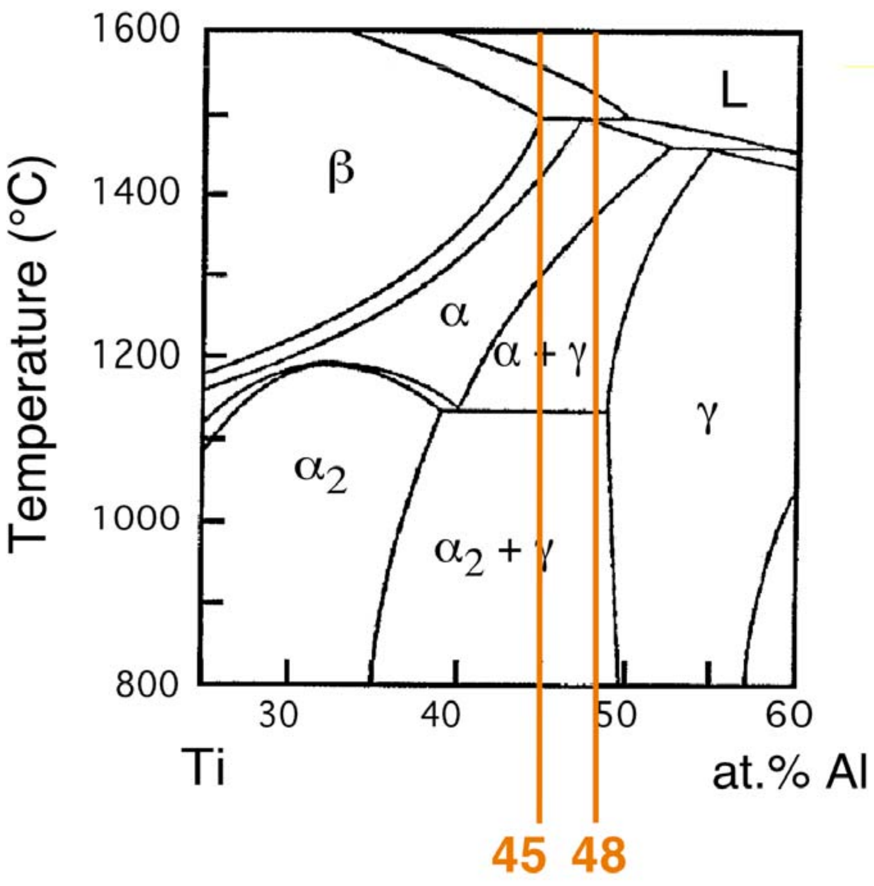
Intermetallic compounds
$\alpha_2(Ti_3Al)+\gamma(TiAl)$

▶Problems:

Insufficient structural stability

strain ageing phenomena

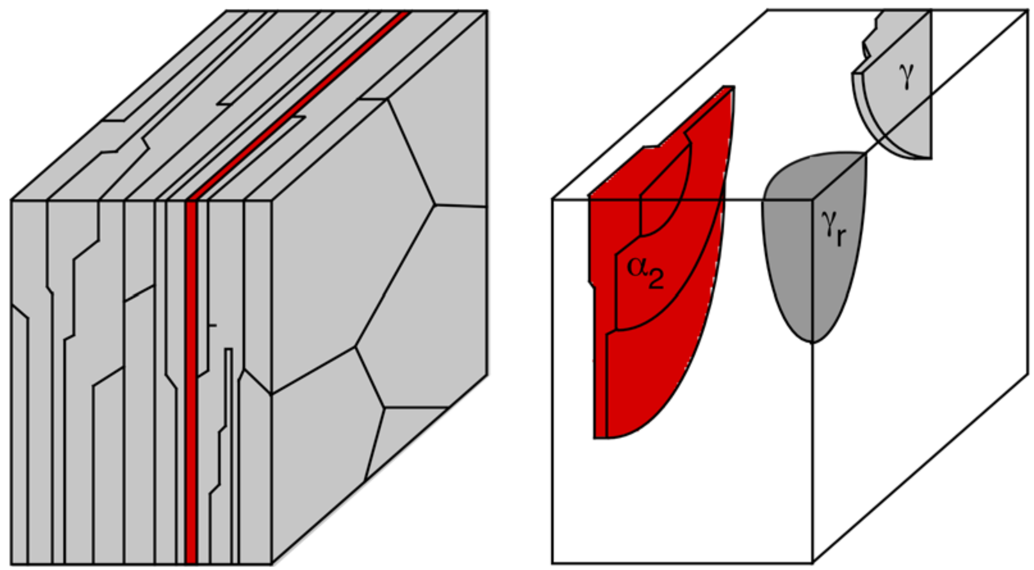
▶ *occur at (0.3 - 0.5)* T_m



Diffusion assisted phenomena associated with
non-equilibrium phase constitution and chemical disorder

Degradation of Lamellar Microstructures

- Reduction of interface energy
- Recrystallization
- Phase transformation

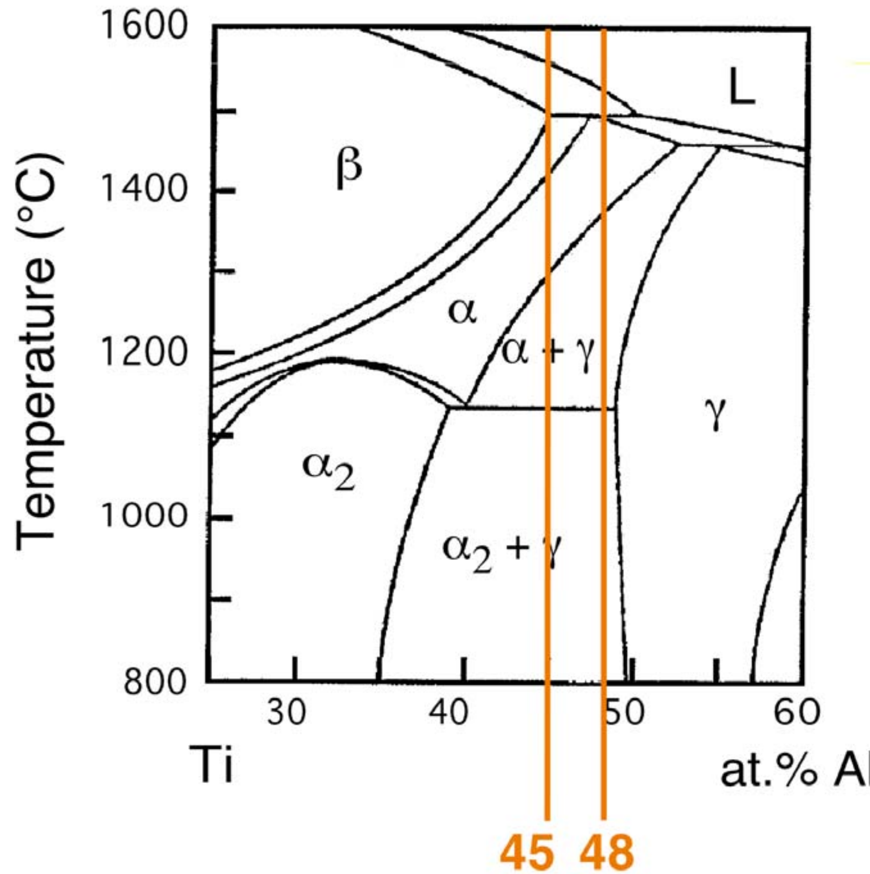


Solid State Transformations

▶ Transformation pathway depends on alloy composition

•••••• (at.%)• $\alpha \rightarrow \alpha+\gamma \rightarrow \alpha_2+\gamma$

$(0001)_{\alpha 2} \| \{111\}_{\gamma}, \quad <11\!-\!20>_{\alpha 2} \| <1\!-\!10>_{\gamma}$

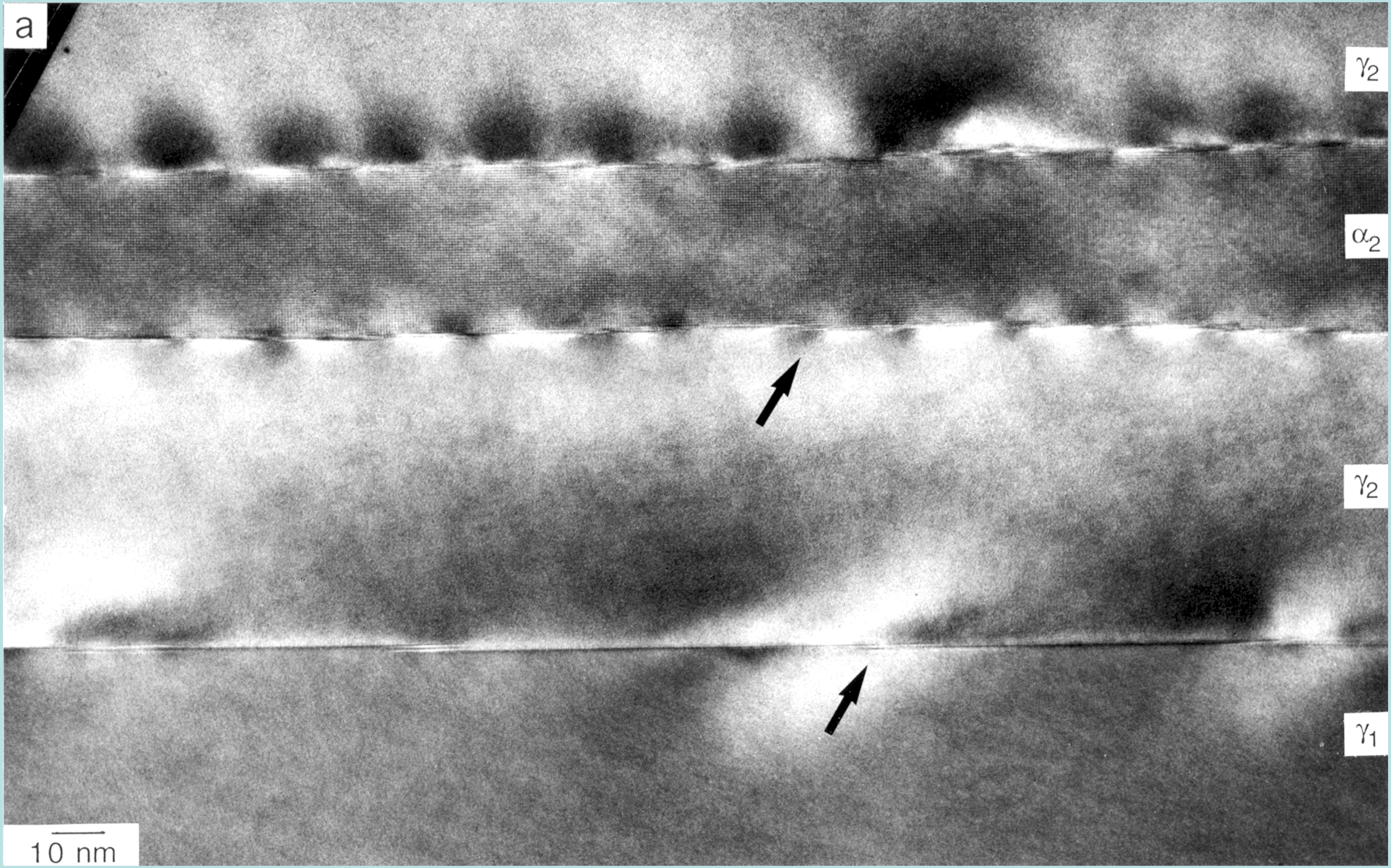


▶ $\alpha \rightarrow \alpha+\gamma$ transformation is sluggish

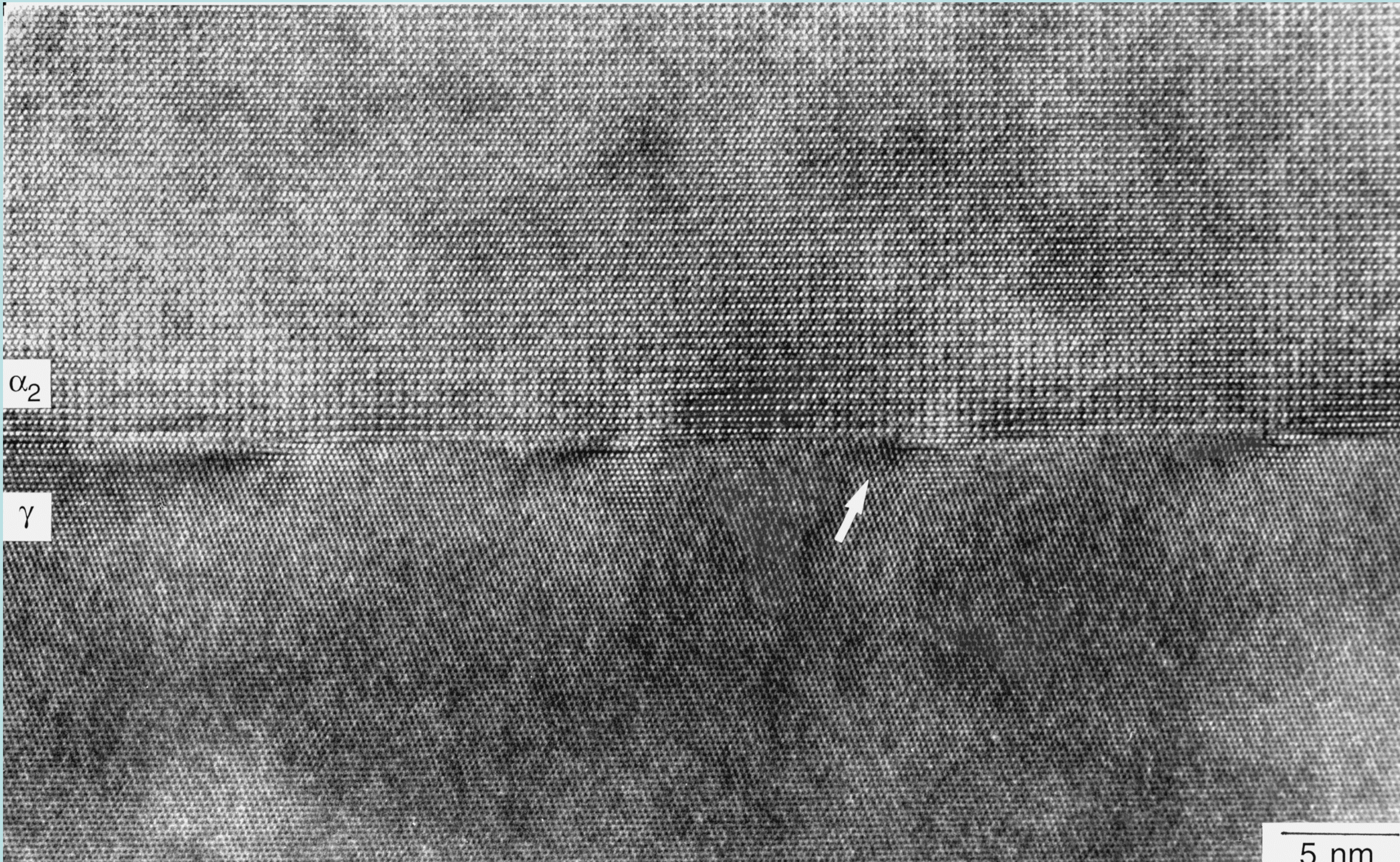
non-equilibrium phase composition with excess α_2 phase

provides driving force for phase transformation and dynamic recrystallization

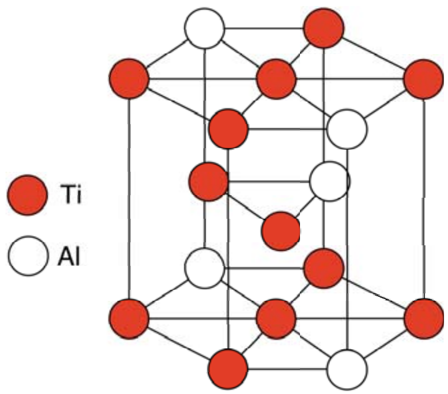
Phase Transformation During High-Temperature Creep



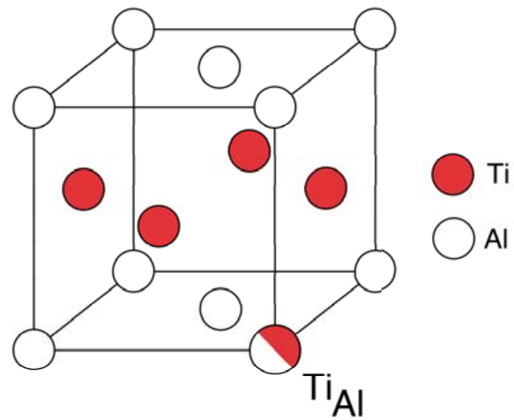
Phase Transformation During High-Temperature Creep



Diffusion Mechanism to Attain Phase Equilibria

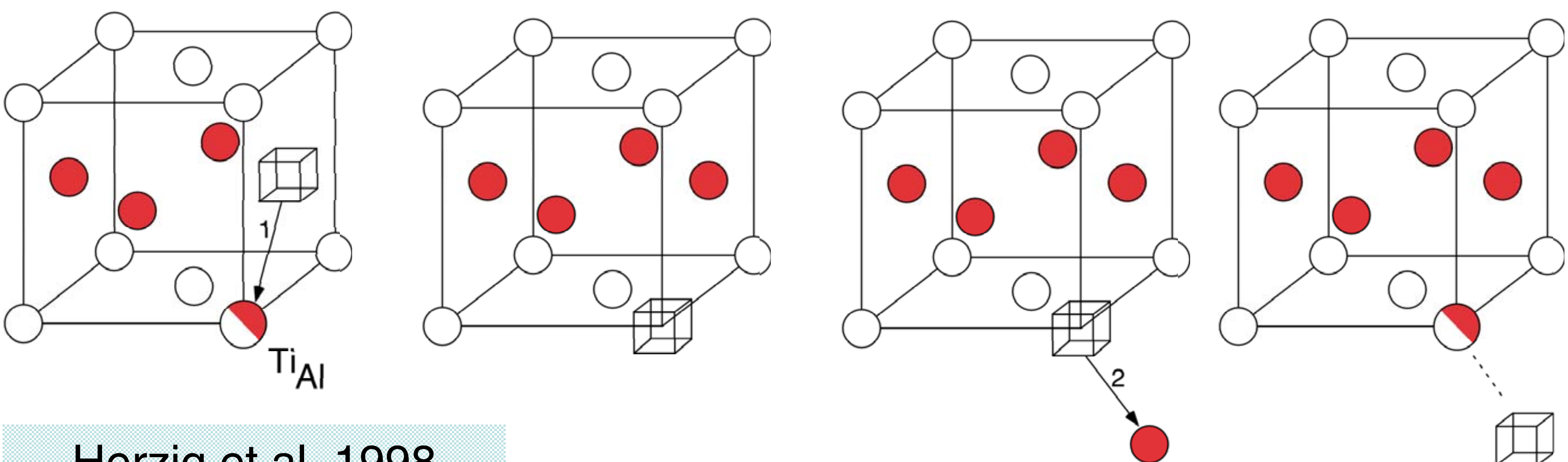


α_2 ⌫ γ



high density of Ti_{Al} antisite defects

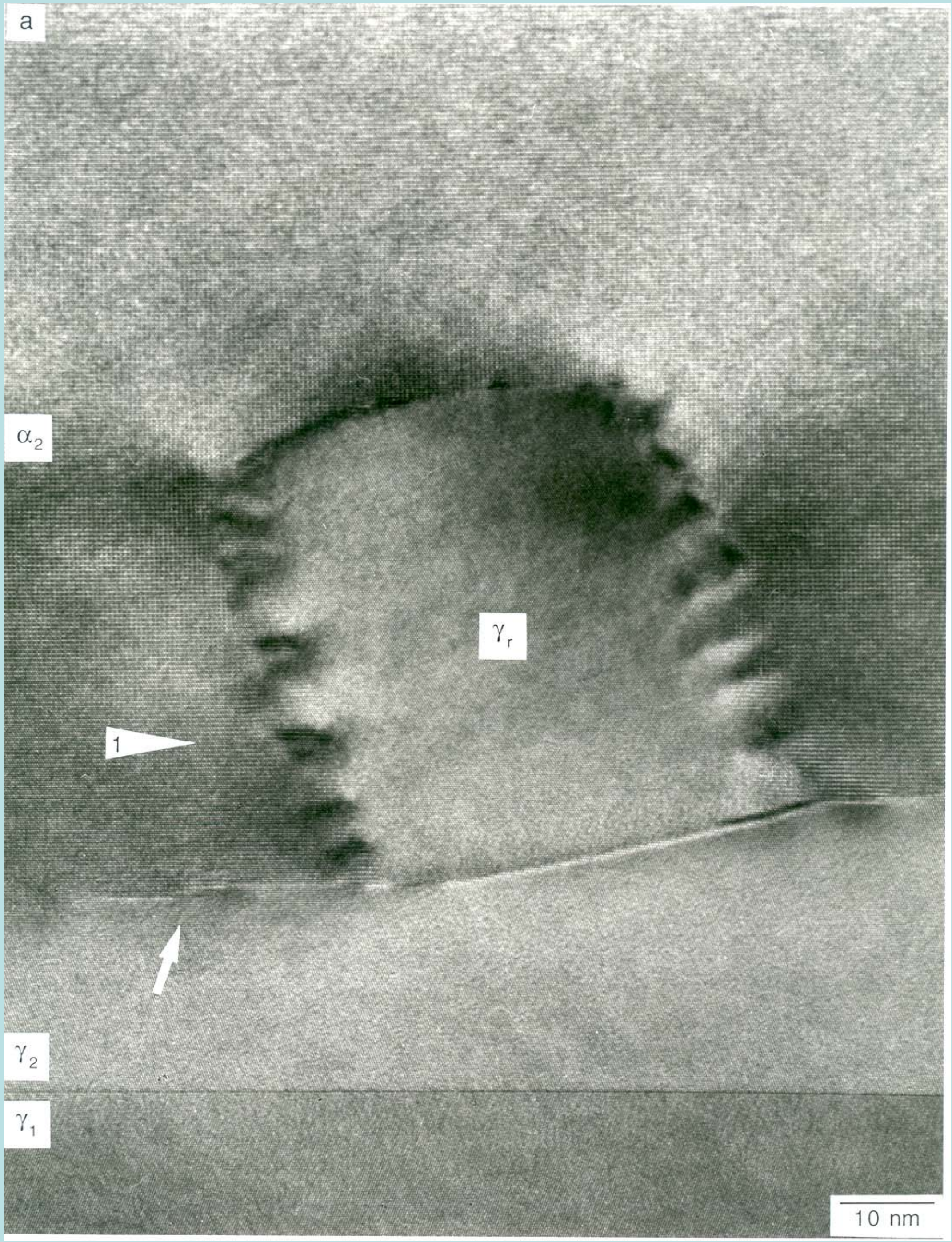
$V_{Ti}+Ti_{Al}$ —1 ⌫ V_{Al} — 2 ⌫ $V_{Ti}+Ti_{Al}$



Herzig et al .1998

Phase Transformation and Recrystallization during Long-Term Creep

Ti-48Al-2Cr (at. %)
T=700 °C,
σ=110MPa,
t=13400 h
ε=0.46 %



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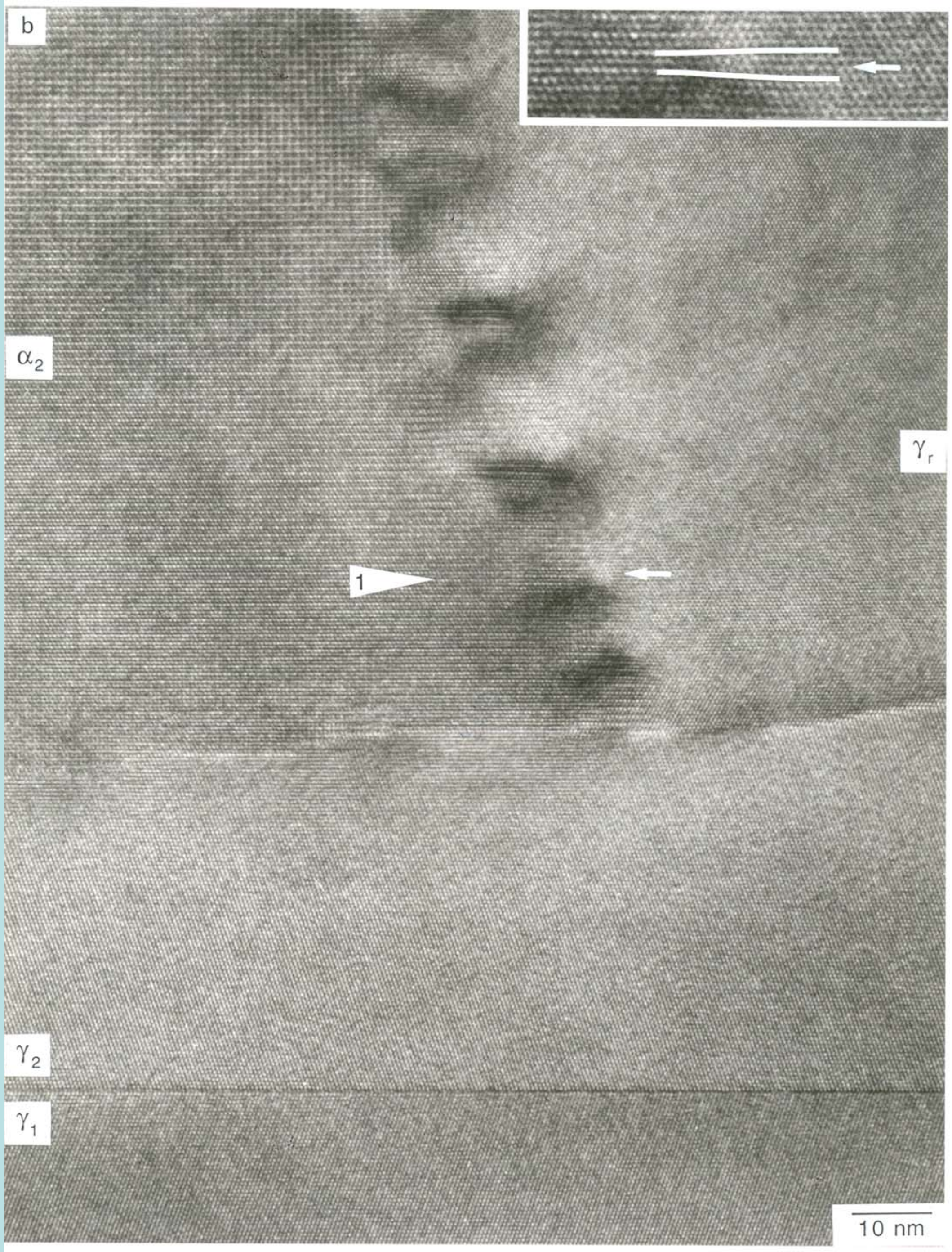
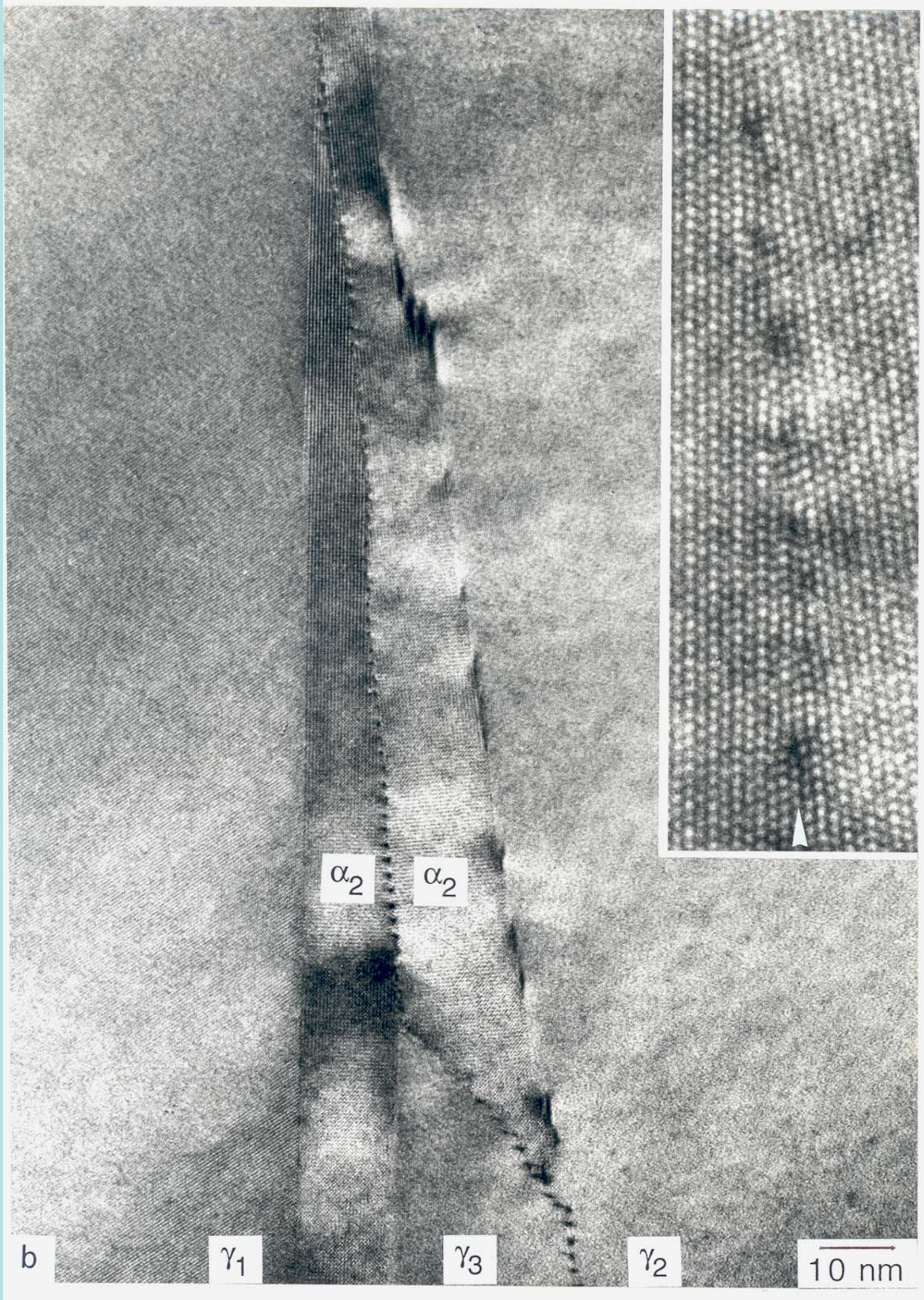


Structural features of lamellar interfaces in an engineering alloy

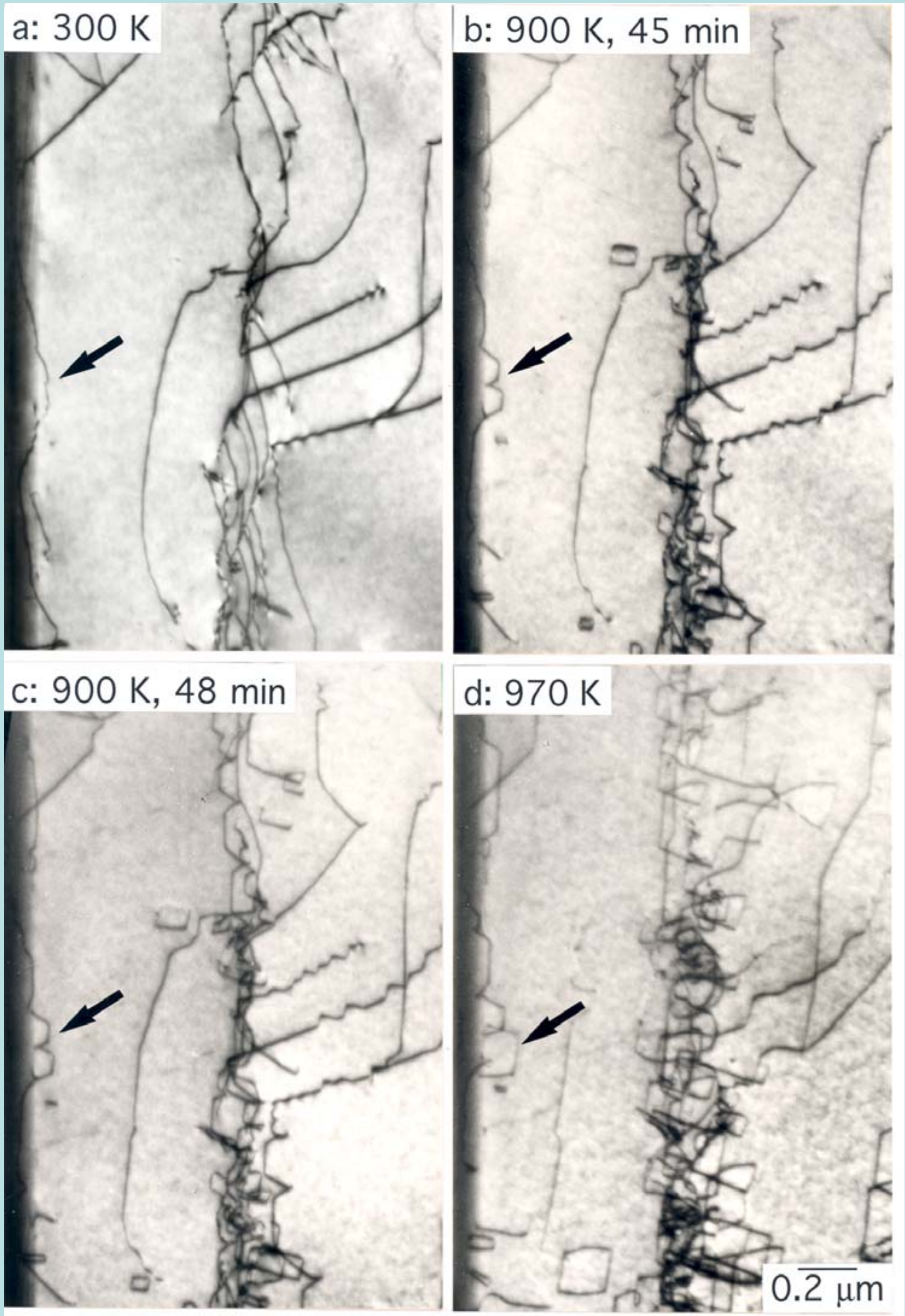
Ti-46.5Al-4(Cr, Nb, Ta, B):

Tilt boundary between α_2-lamellae



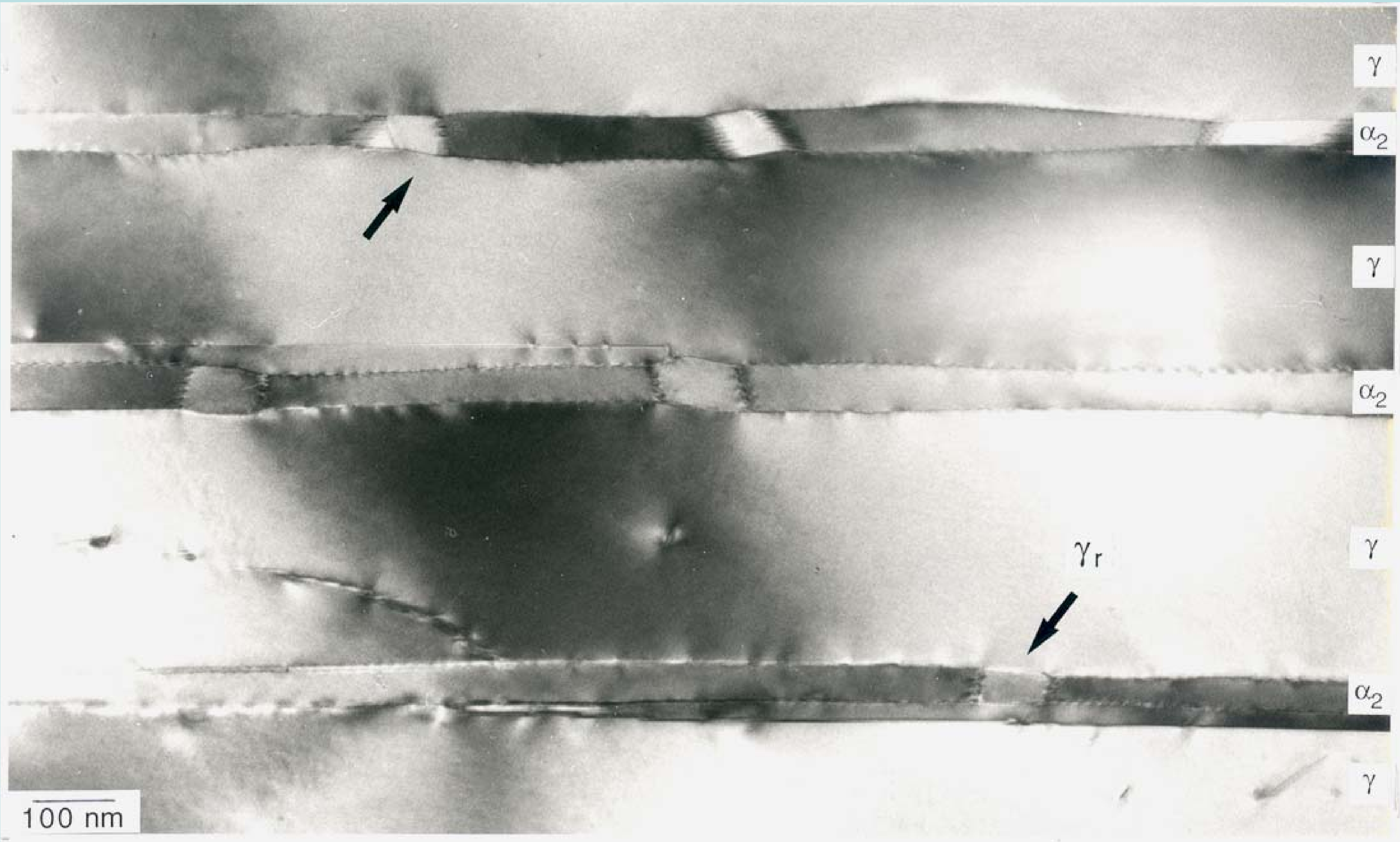
Climb of interfacial dislocations during in situ heating inside the TEM

Ti-48Al-2Cr (at. %)

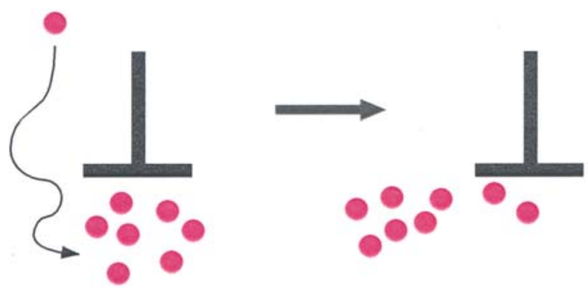


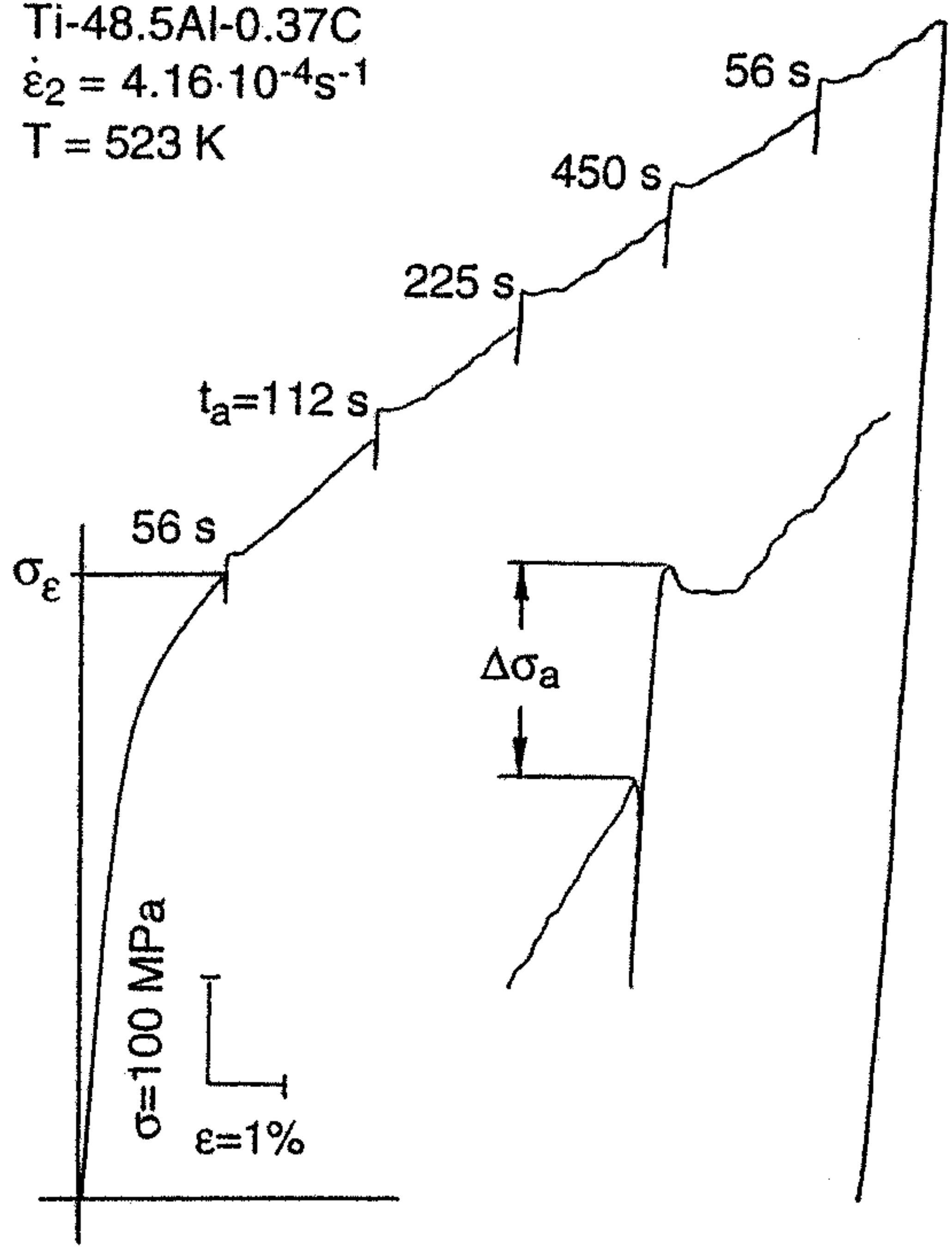
Phase Transformation during Long-Term Creep,

Ti-48Al-2Cr (at. %),T=700 °C, σ=110Mpa,t=13,400 h,ε=0.46 %



Static Strain Ageing



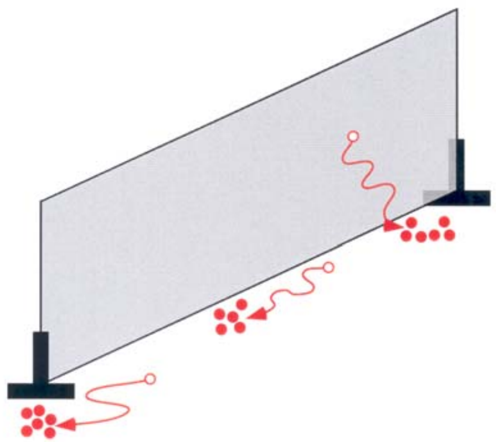


Classical yield point return technique

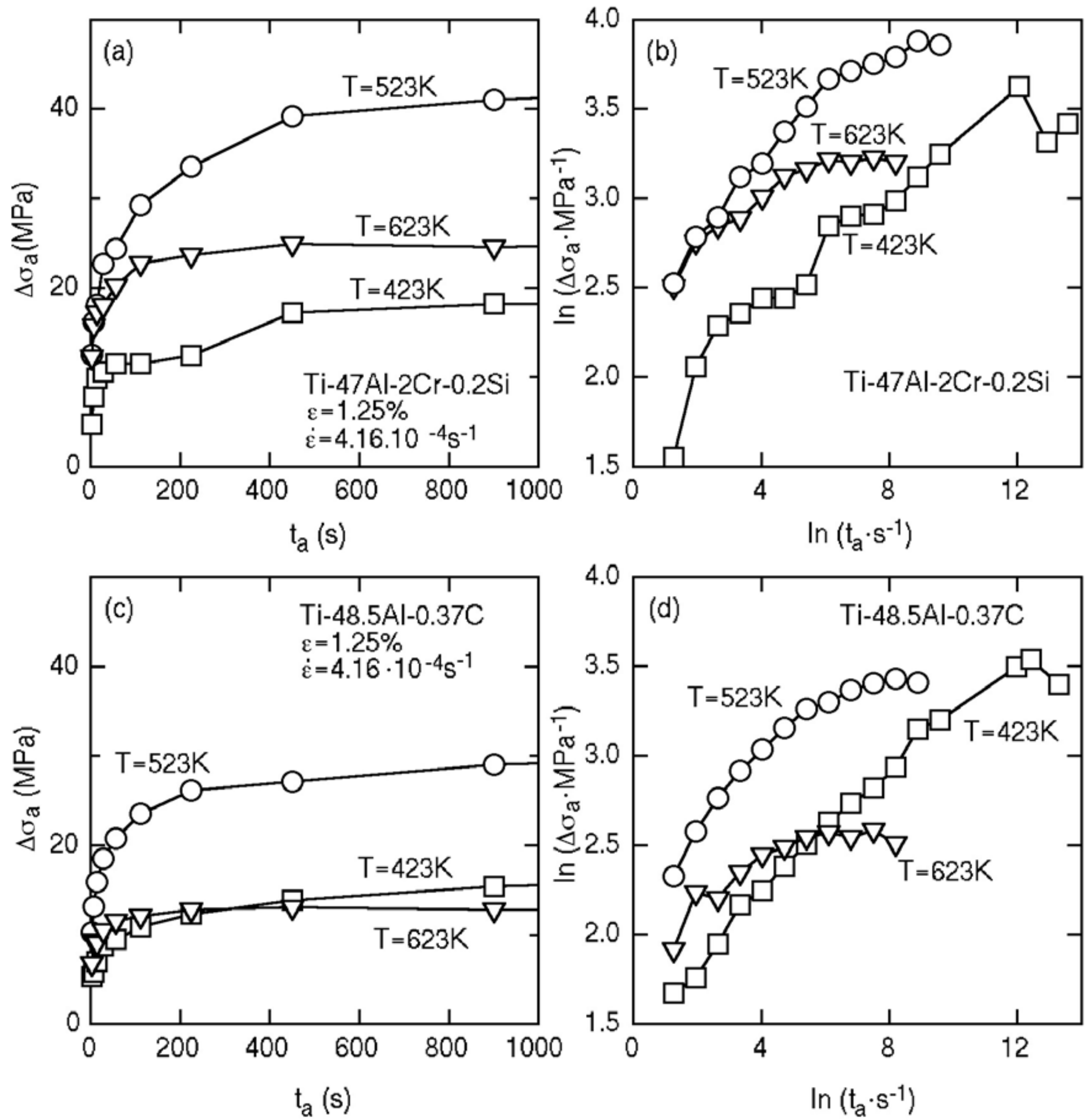
stress increments $\Delta\sigma_a$ upon reloading

associated with degree of dislocation locking

Static Strain Ageing



Kinetics:
Strain age yield point becomes saturated



Estimation of Activation Ernergy

Arrhenius plot:

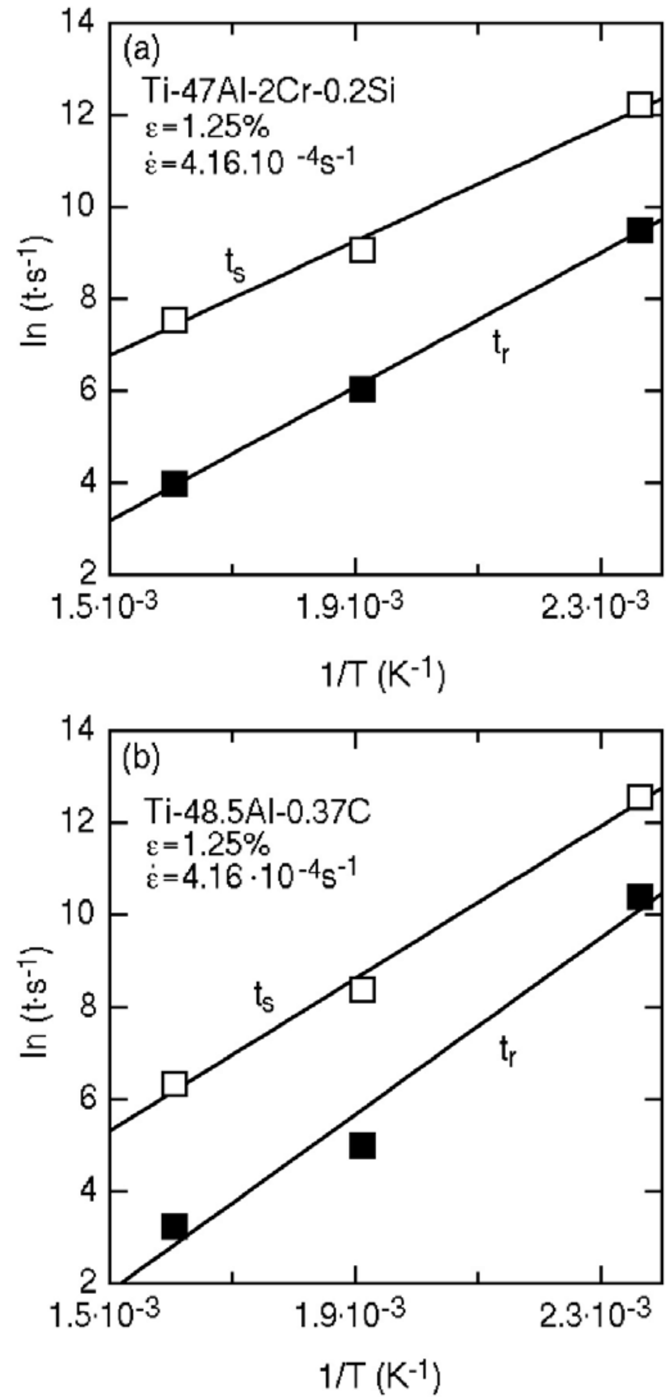
Time necessary to achieve a certain degree of completeness of dislocation pinning combined with related temperature.

Activation energy: $Q_a = 0.58 - 0.77$ *eV*

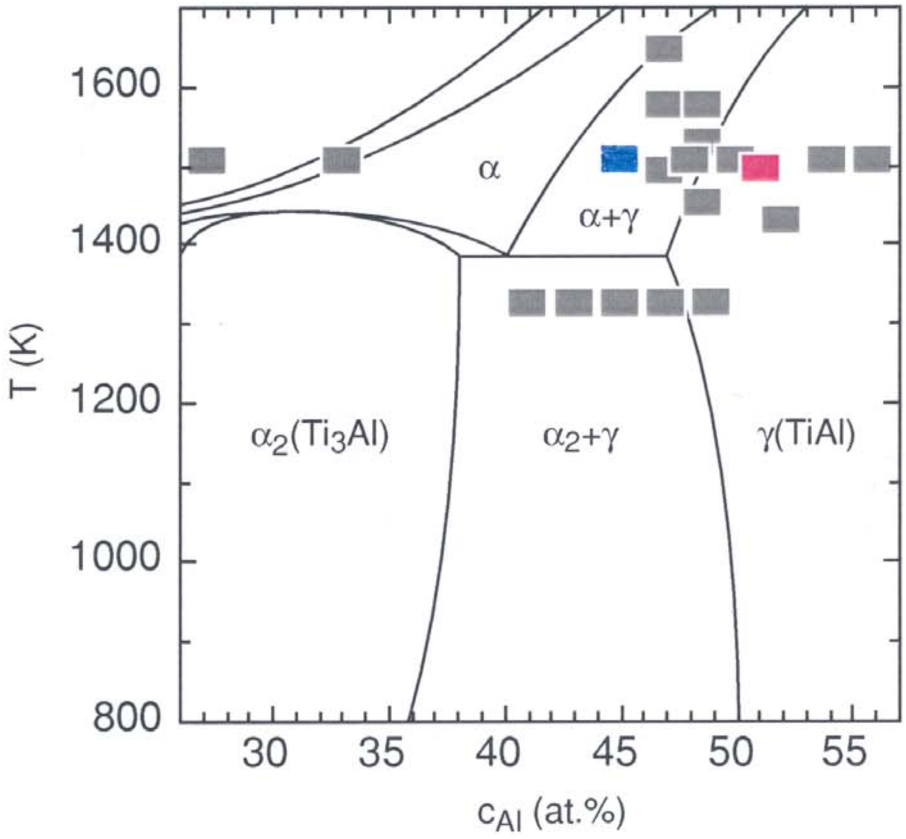
not consistent with classical diffusion mechanisms

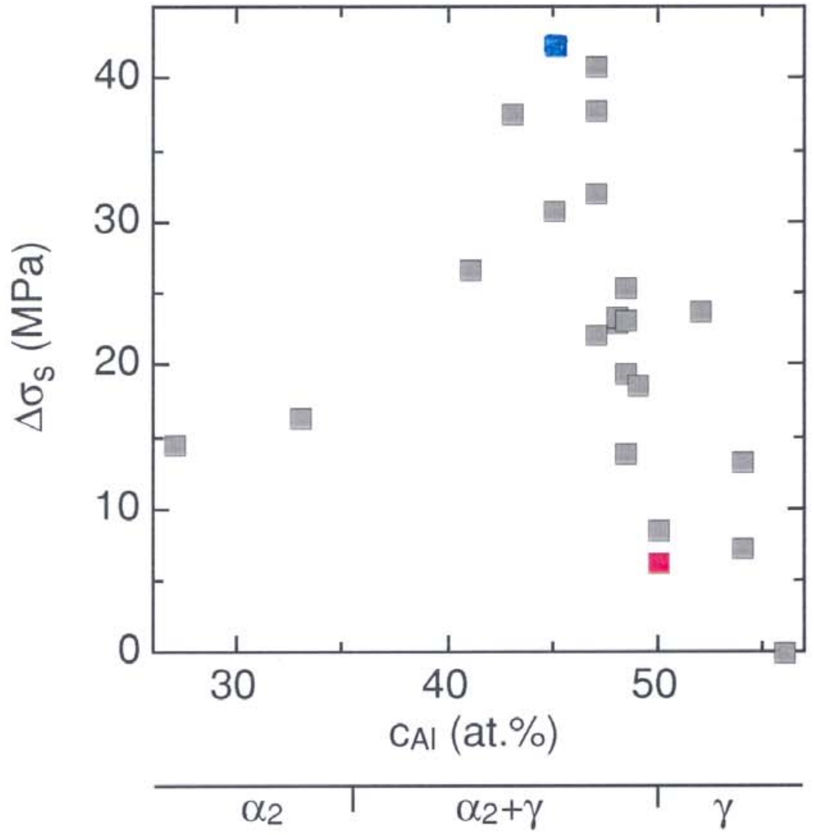
self diffusion energy $Q_{sd} = 2.6$ *eV*

pipe diffusion $Q_p = 0.5\, Q_{sd}$



Static Strain Ageing: Effect of Alloy Composition





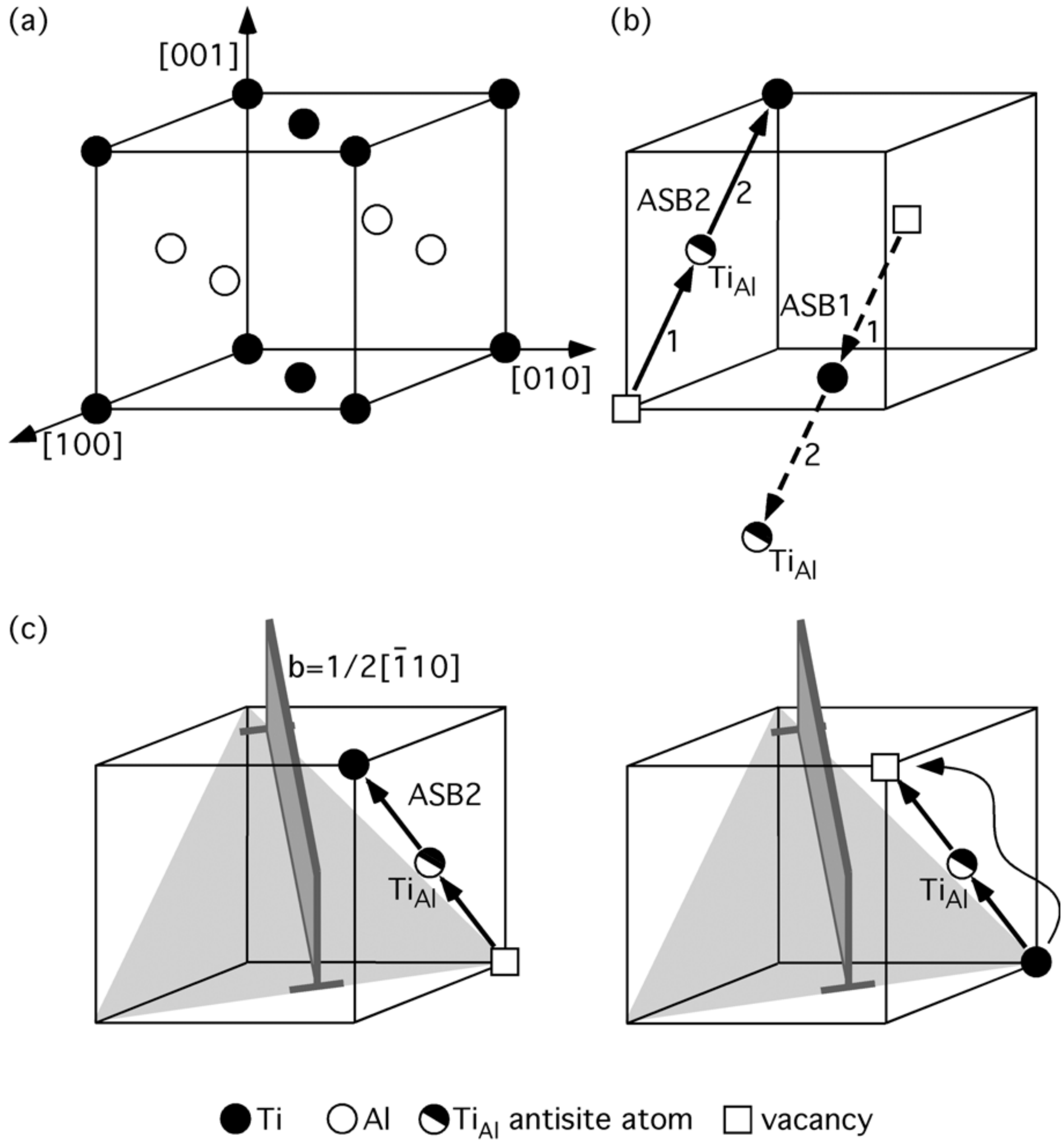
▶ Strain ageing phenomena most pronounced in Ti-rich Alloys

Locking Mechanism

Ti_{Al}-vacancy complex produce asymmetric distortion

various crystallographically equivalent orientations

reorientation in the dislocation stress field leads to locking



Diffusion Asisted by Antisite Defects

Vacancies propagate by two nearest-neighbour jumps, without disturbing the long-range order

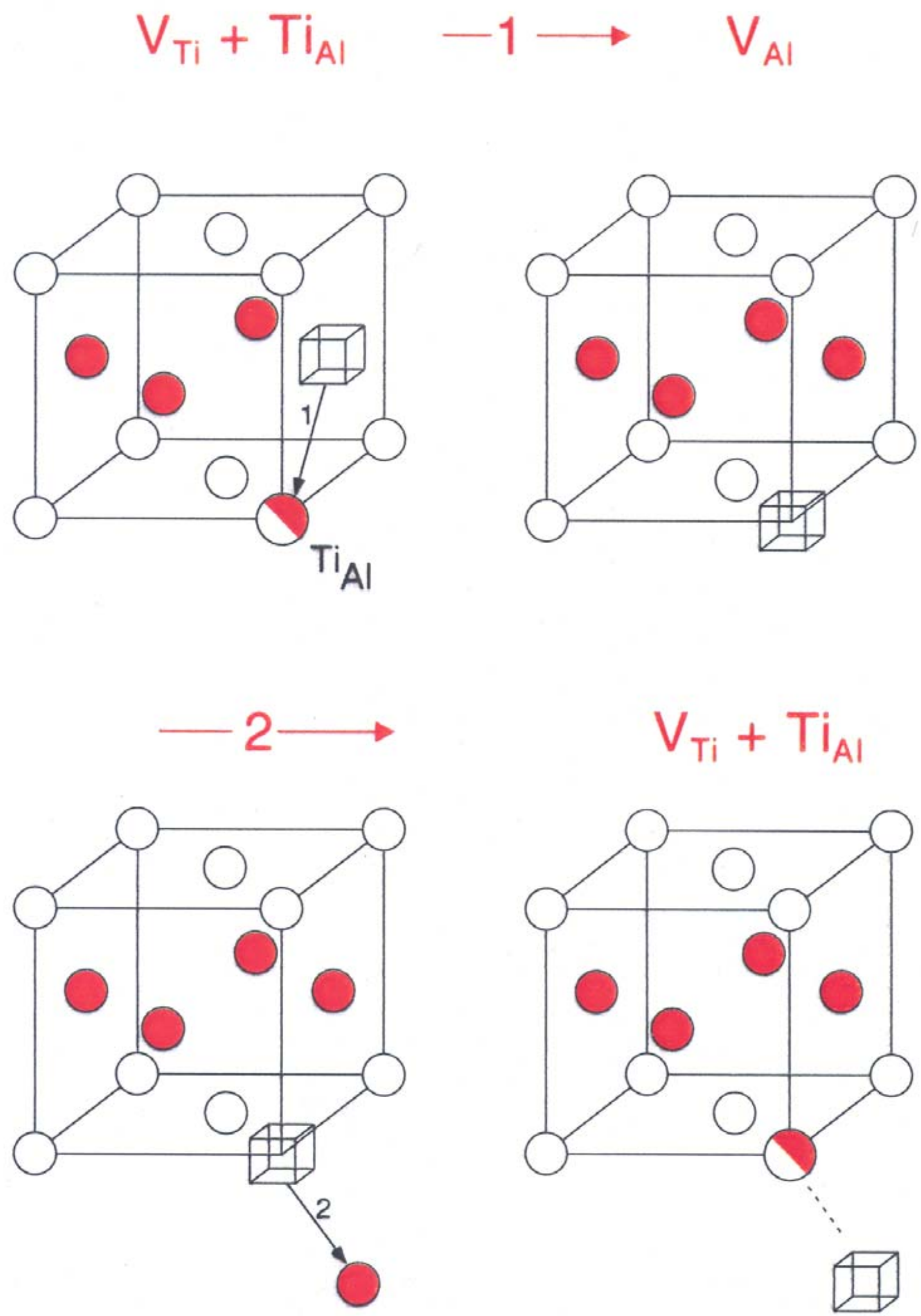
Energetics:

(Herzig and Mishin, 2000)

- $Q_{ASB}(Ti_{Al}) = 0.712\ eV$
  $Q_{ASB}(Al_{Ti}) = 1.323 eV$

Strain ageing:

$Q_a = 0.58\text{-}0.77\ eV$



Conclusions

- Diffusion plays a major and complex role in the mechanical behaviour of intermetallic titanium aluminide alloys.
- Off-stochiometric deviations are compensated by the formation of antisite defects on the respective sub-lattice.
- This chemical disorder effectively supports diffusion at moderately high temperatures of $(0.3\text{-}0.5)T_m$.
- The operation of this mechanism leads to significant structural changes upon long-term service and to dislocation locking by the formation of ordered defect atmospheres.