Processing of titanium & aluminium alloys

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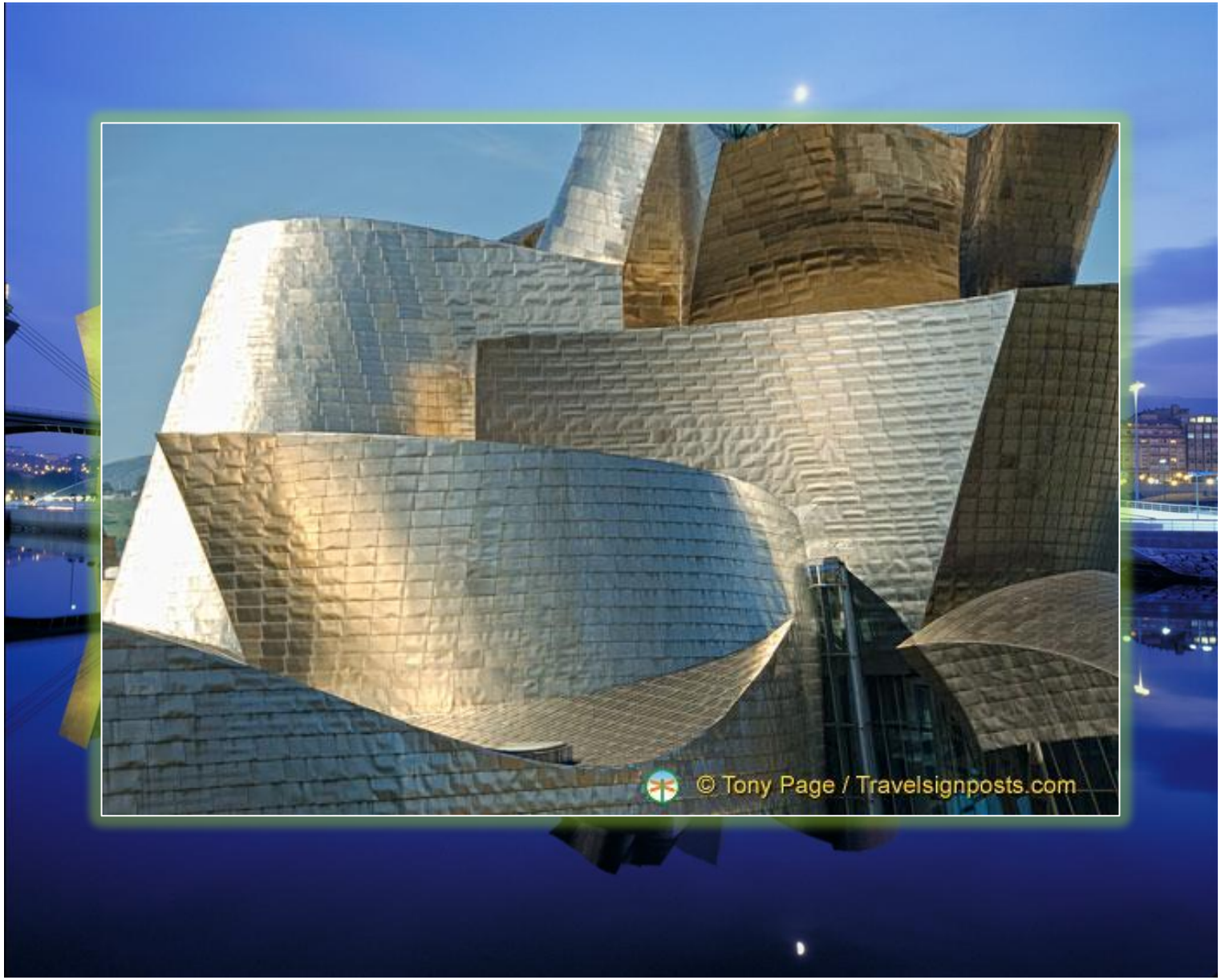
Overview

1. General introduction to titanium and aluminium wrought alloys
2. Processing of Titanium alloys
3. Processing of Aluminium alloys
4. Challenges

Titanium and aluminium wrought alloys

Rolls-Royce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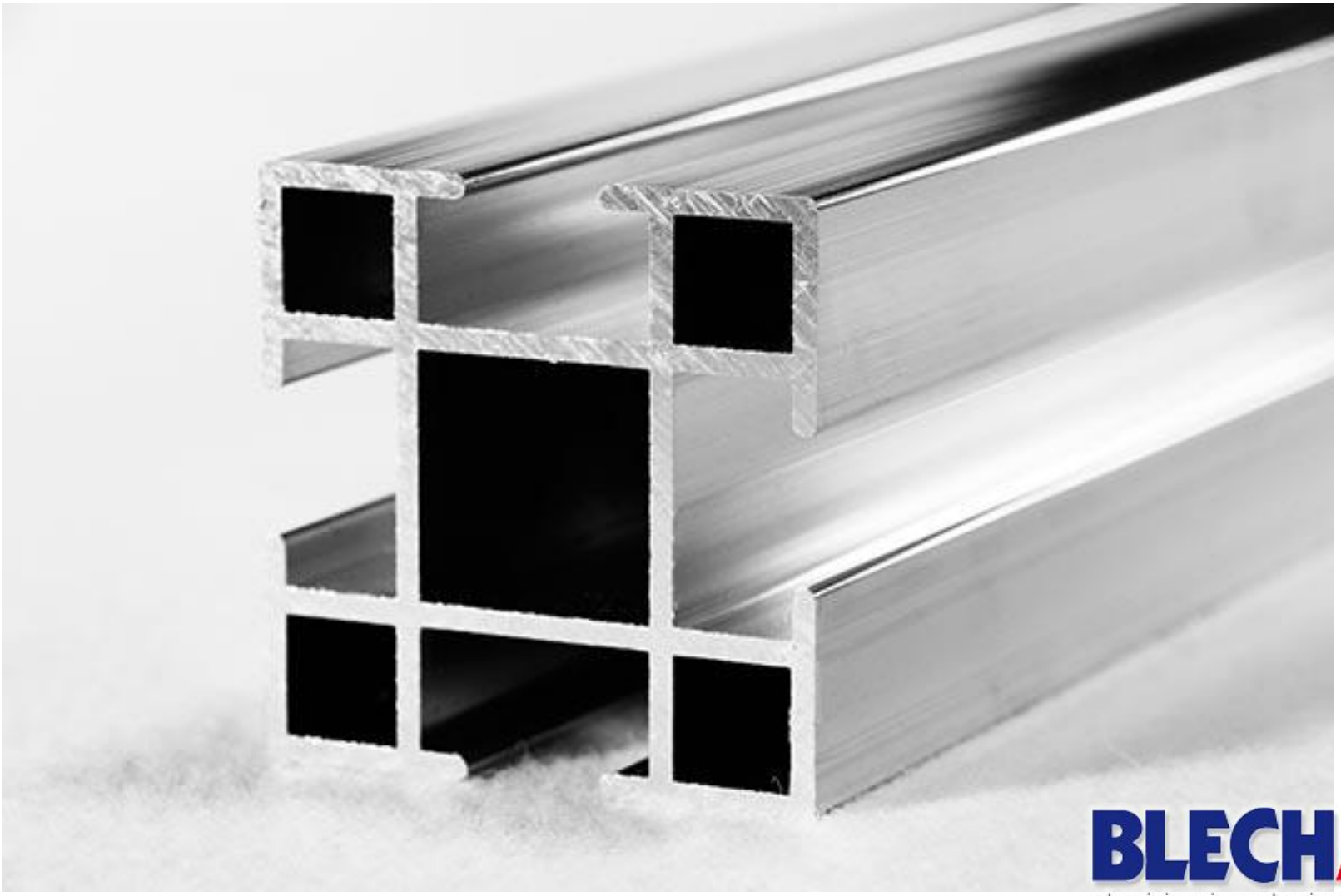
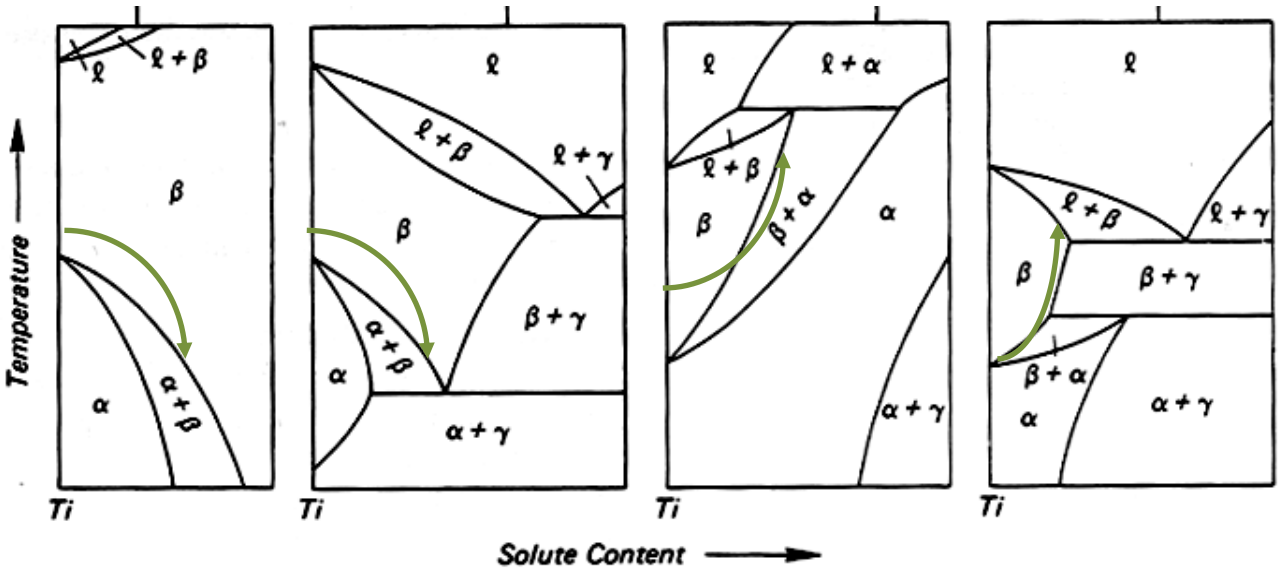

BLECHA
aluminium is our business
innovation our destination

Dipl. oec.troph. (FH) Verena Kampen

Titanium

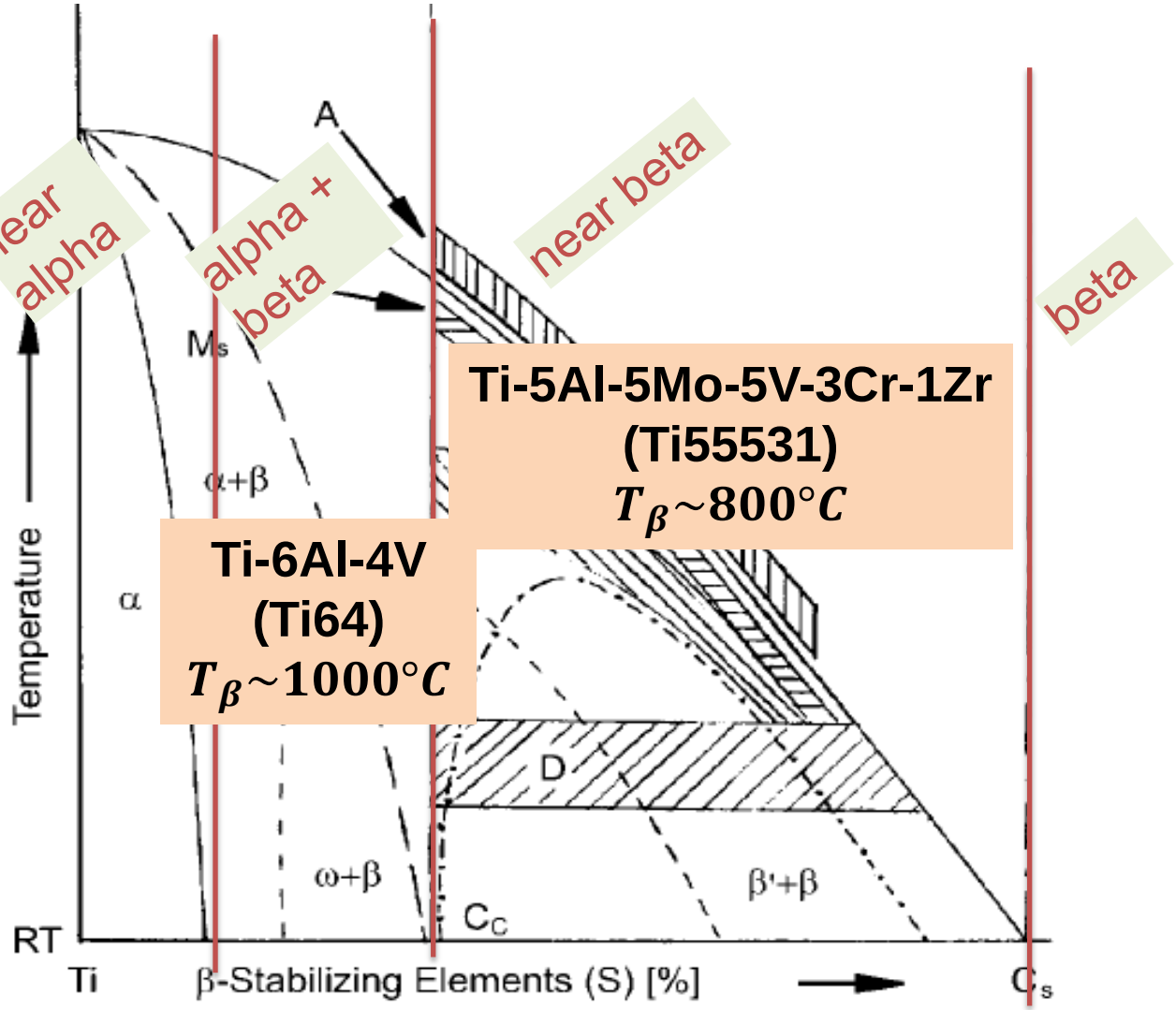
Pure titanium: $\alpha\ (hcp) \rightarrow^{882°C} \beta(bbc)$

Titanium alloys → α and β coexisting in a T range



β stabilizing α stabilizing

Titanium alloys: classification

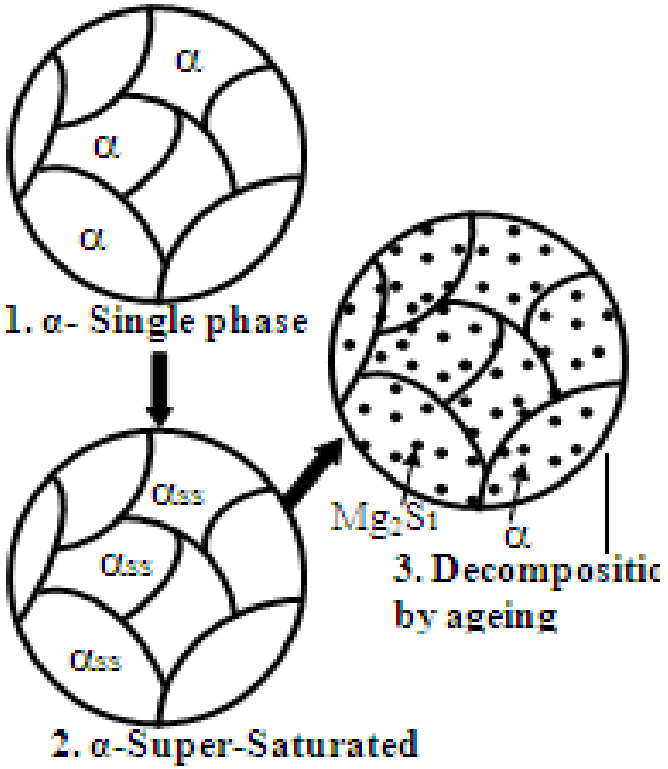


Aluminium alloys

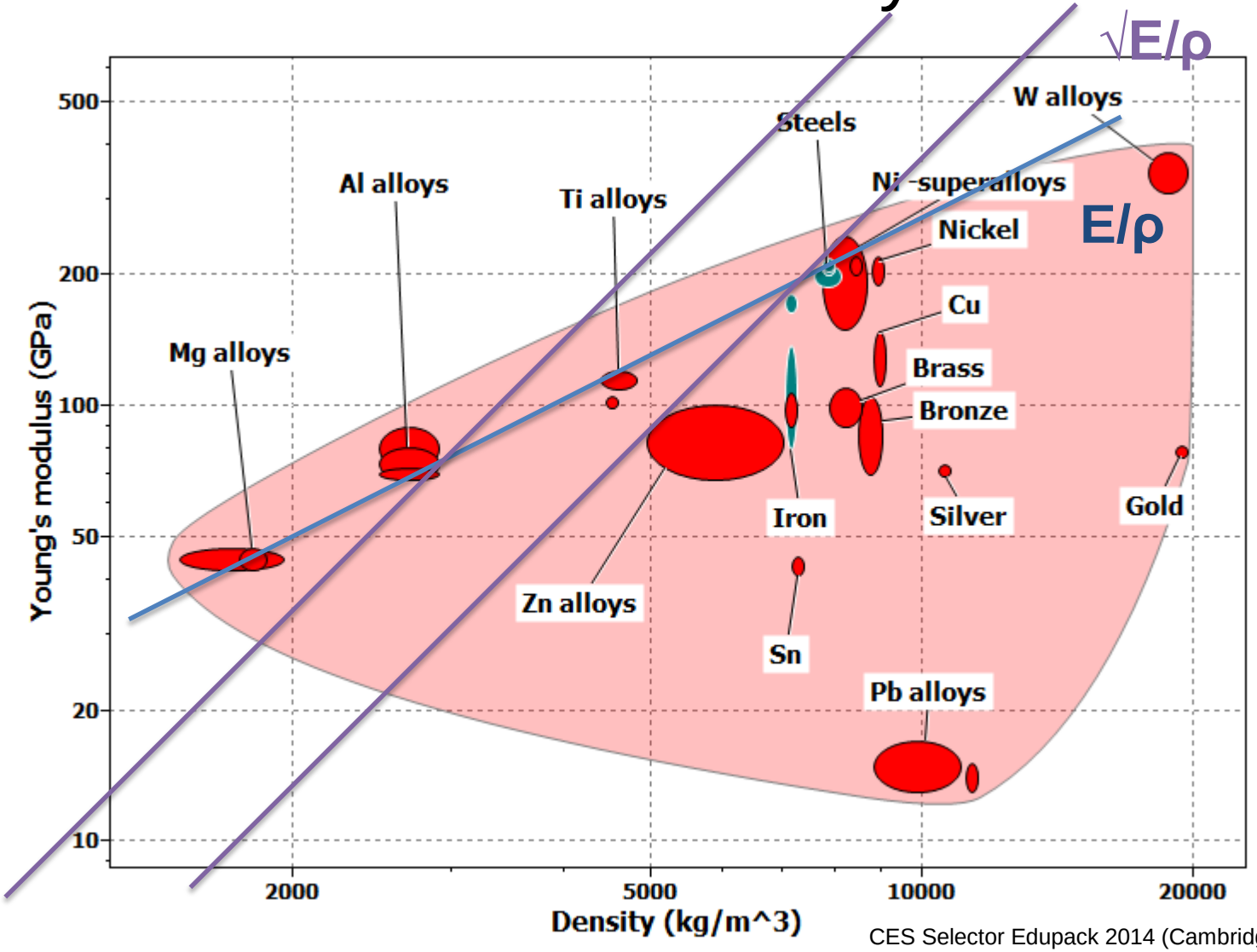
Pure aluminium → fcc

Al- wrought alloys:

- non age hardenable
- age hardenable

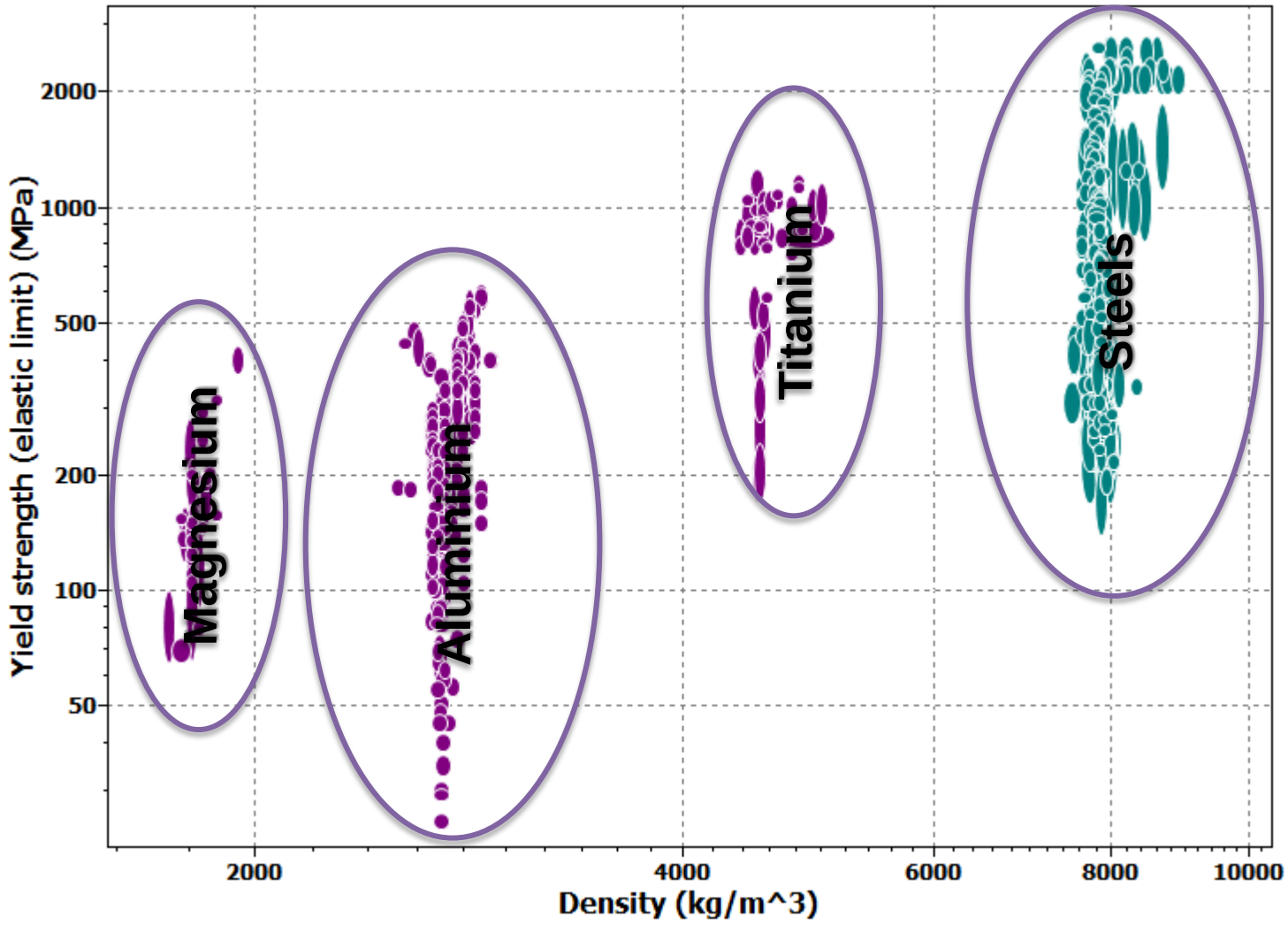


Titanium and aluminium alloys: stiffness



CES Selector Edupack 2014 (Cambridge Software)

Titanium and aluminium: strength



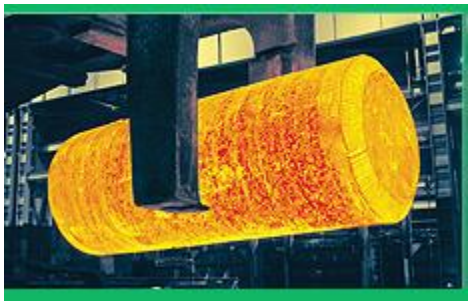
Objectives of thermomechanical processing

Requirement	Mechanism	Microstructure
Strength RT	Grain refinement	Fine grained
	Strain hardening	High dislocation density
	Precipitation hardening	Fine precipitates within grains
	Martensitic hardening	Martensitic structure
Creep resistance	Avoid GBS	Large grains
	Avoid GBS	Pinned grains (precipitates)
Fatigue resistance	Crack propagation reduction	Intrincated microstructure
High electrical conductivity	Defects reduction	Low dislocation density

Ice and olivine?

Processing of titanium alloys

Processing of titanium alloys



Ingot

Billet

Bar

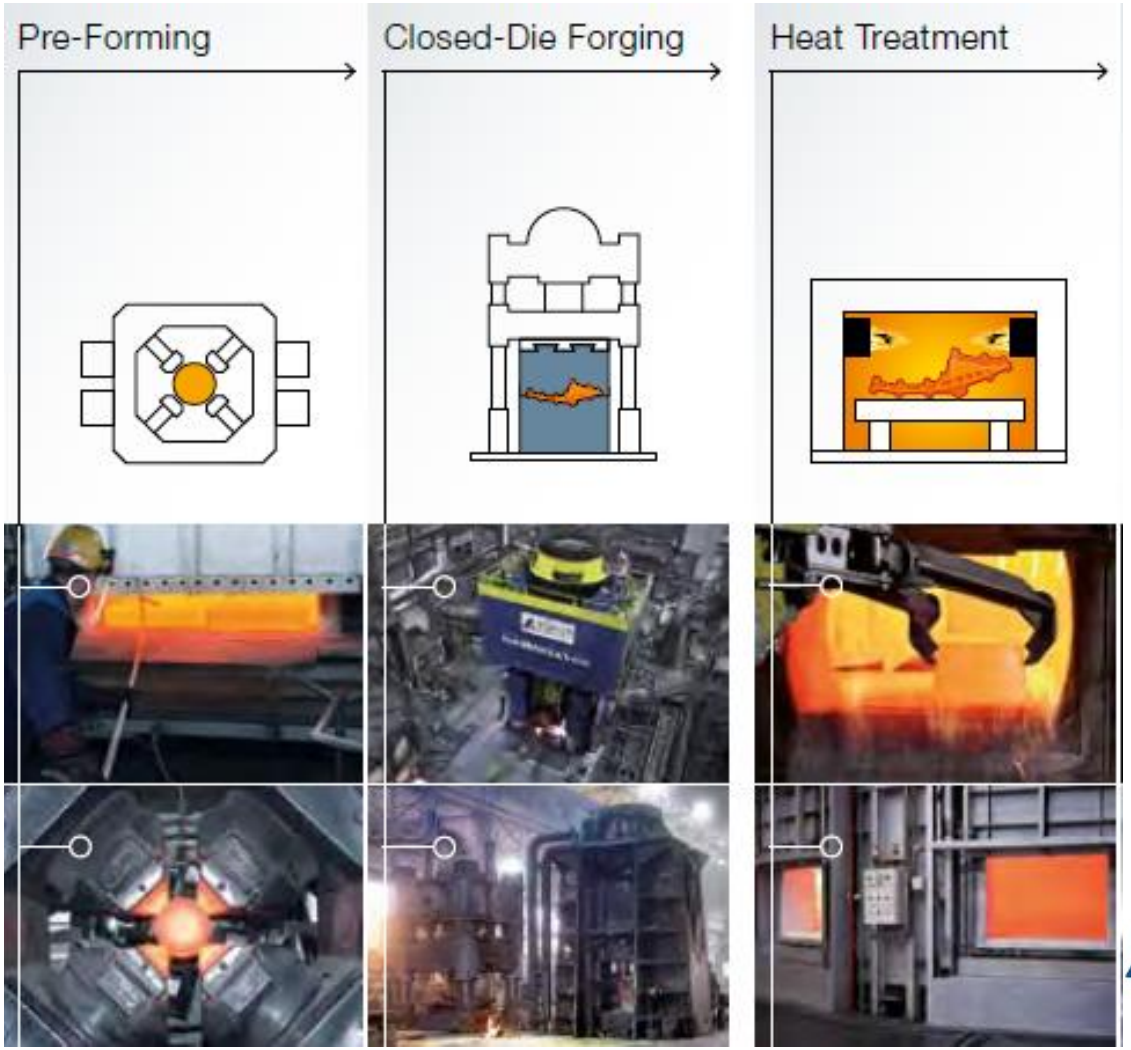
Sponge

Slab

Sheet

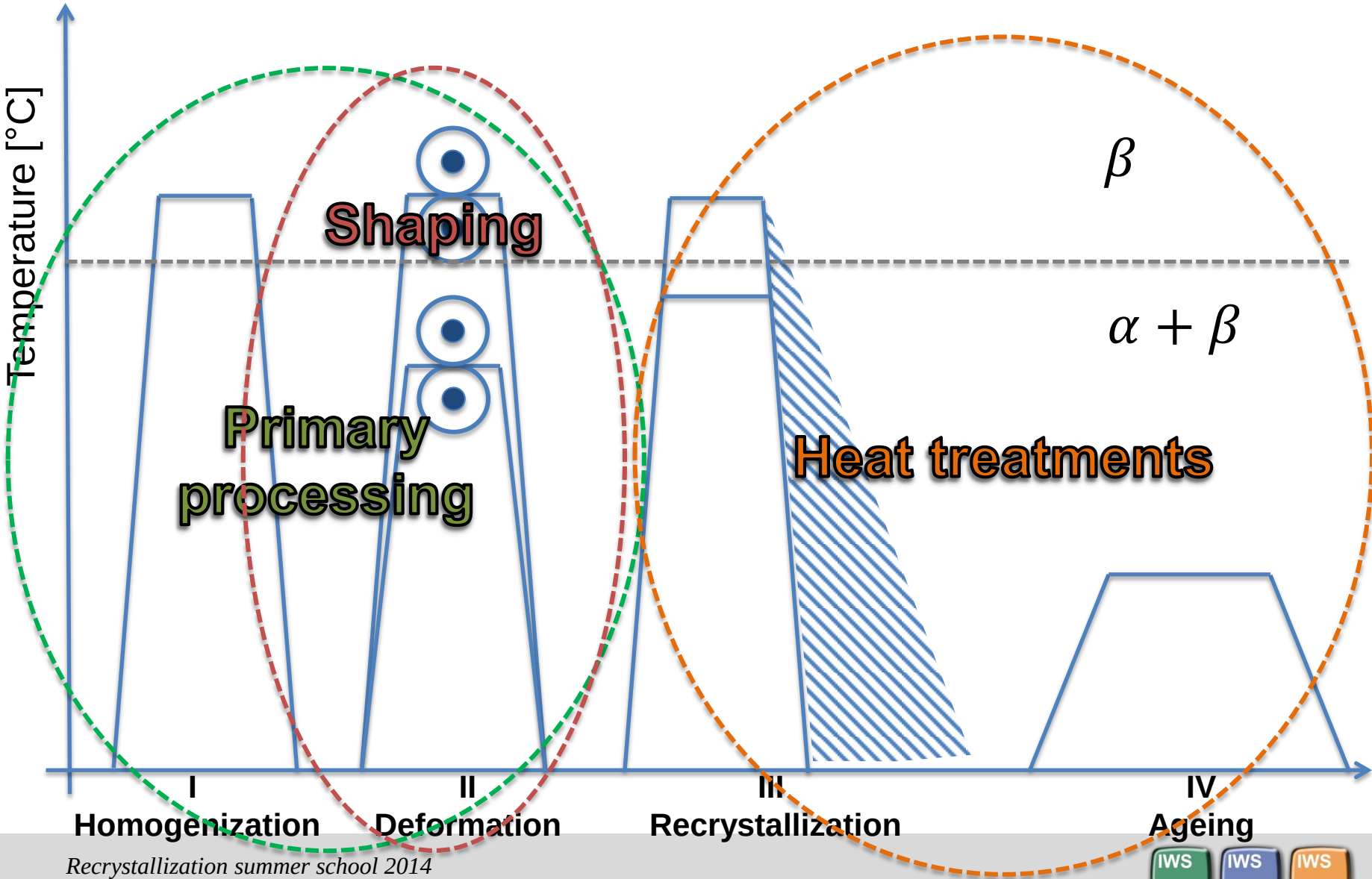
Cold strip

Processing from an ingot



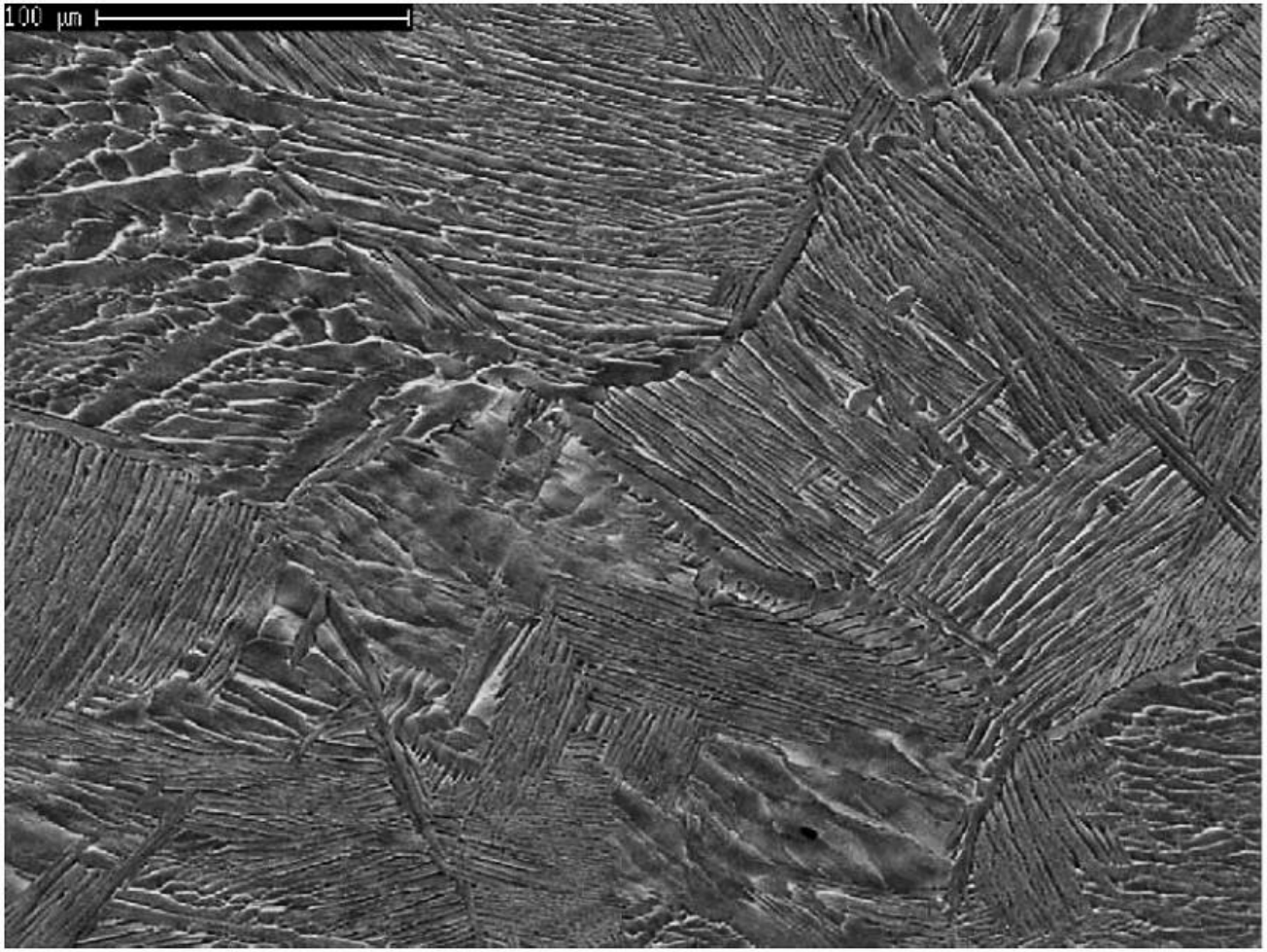
BÖHLER SCHMIEDETECHNIK

Processing of titanium alloys: general



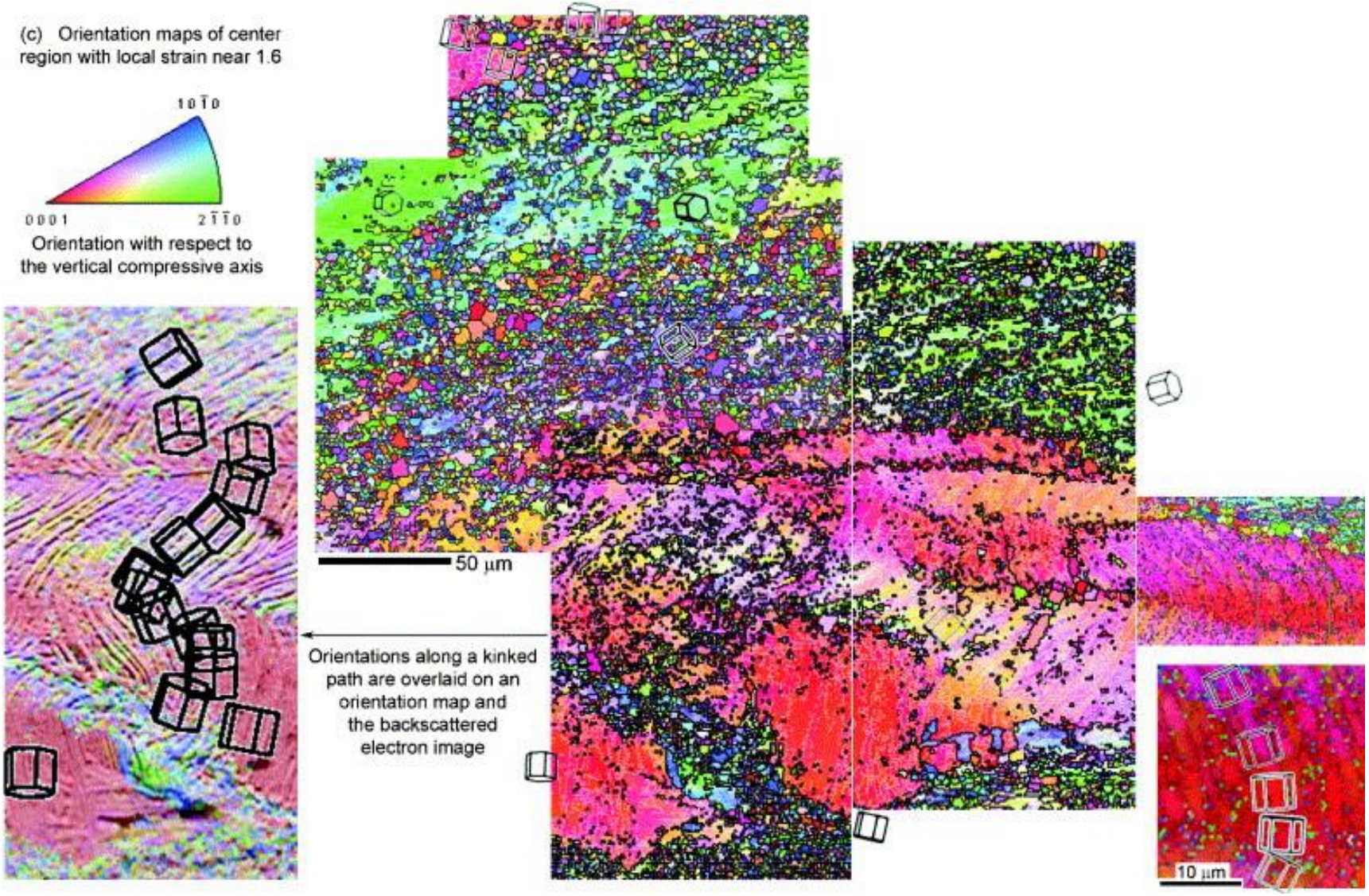
Primary processing: open die forging

Lamellar microstructure



Thomas R. Bieler, S.L. Semiatin. International Journal of Plasticity 18 (2002) 1165–1189

Break down of the lamellar microsctructure



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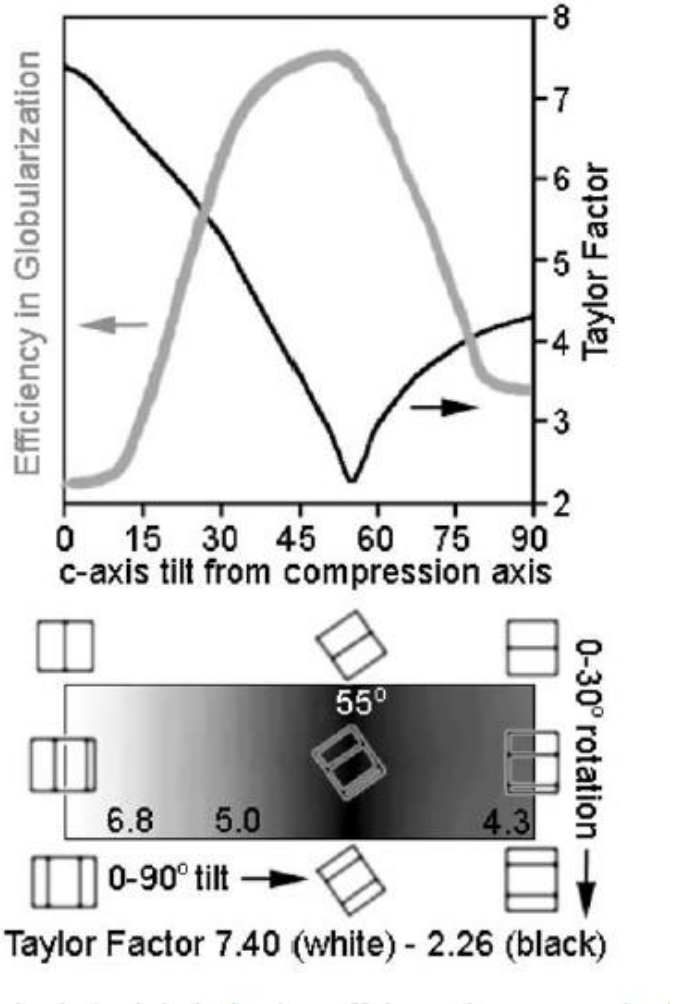
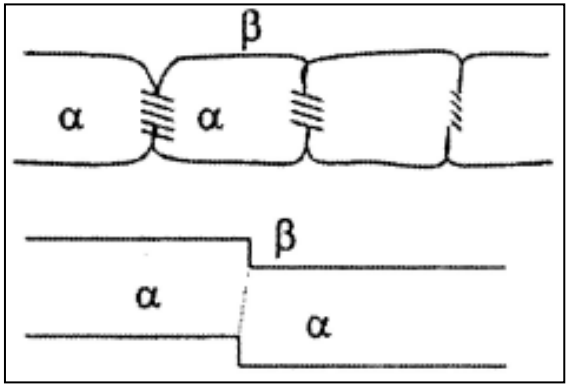
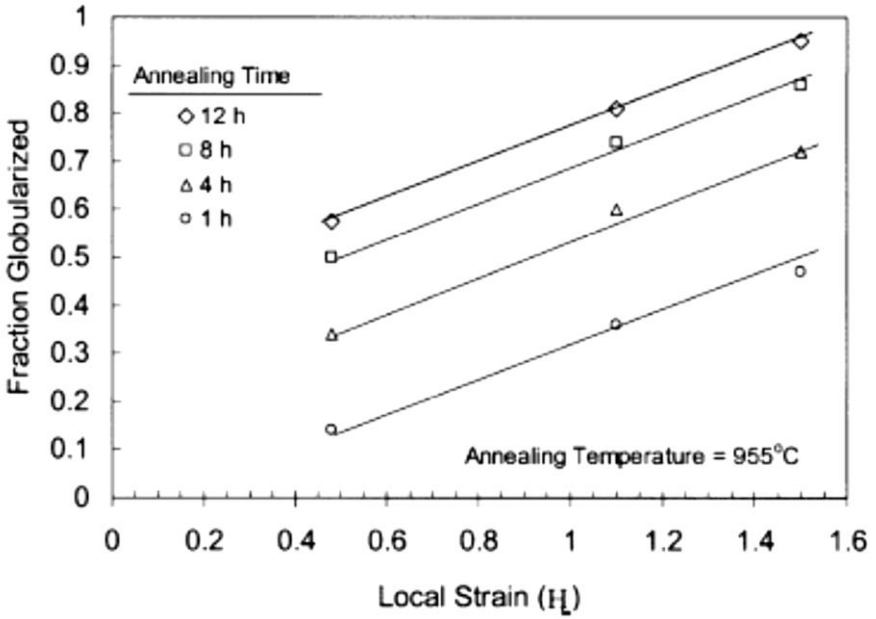


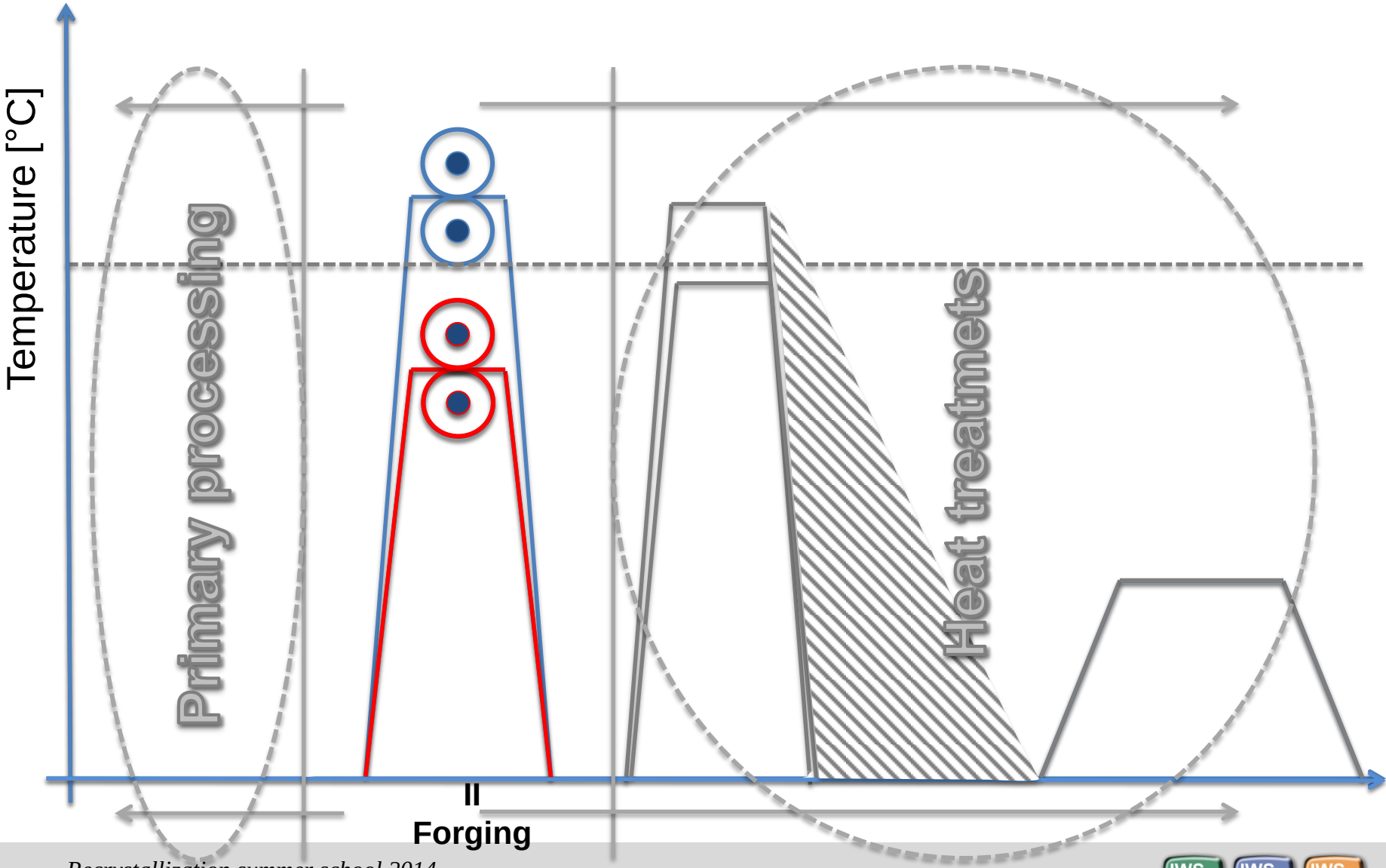
Thomas R. Bieler, S.L. Semiatin. International Journal of Plasticity 18 (2002) 1165–1189



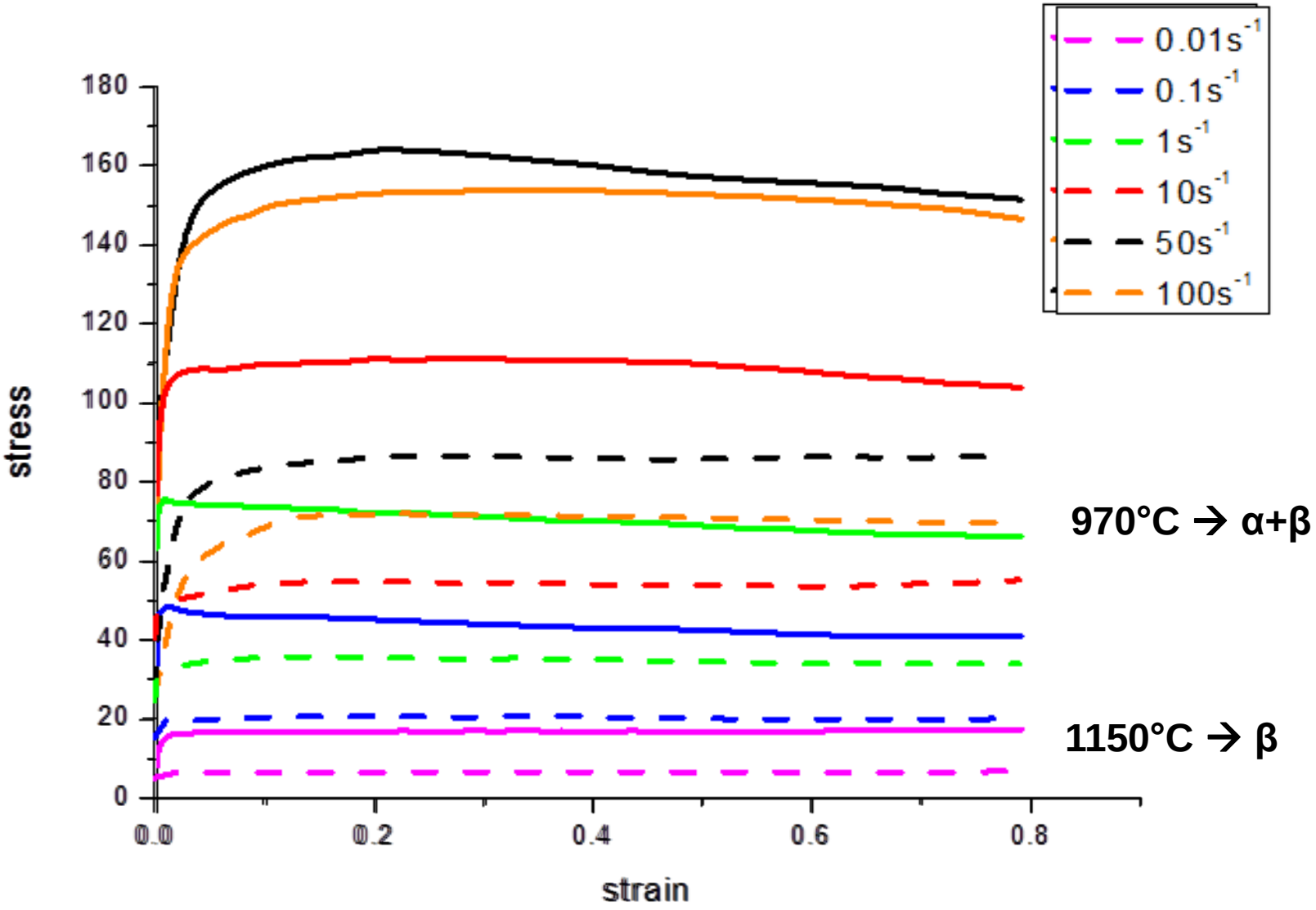


Stefansson N., Semiatin S.L. Metallurgical and materials transactions 34A (2003) 691-698

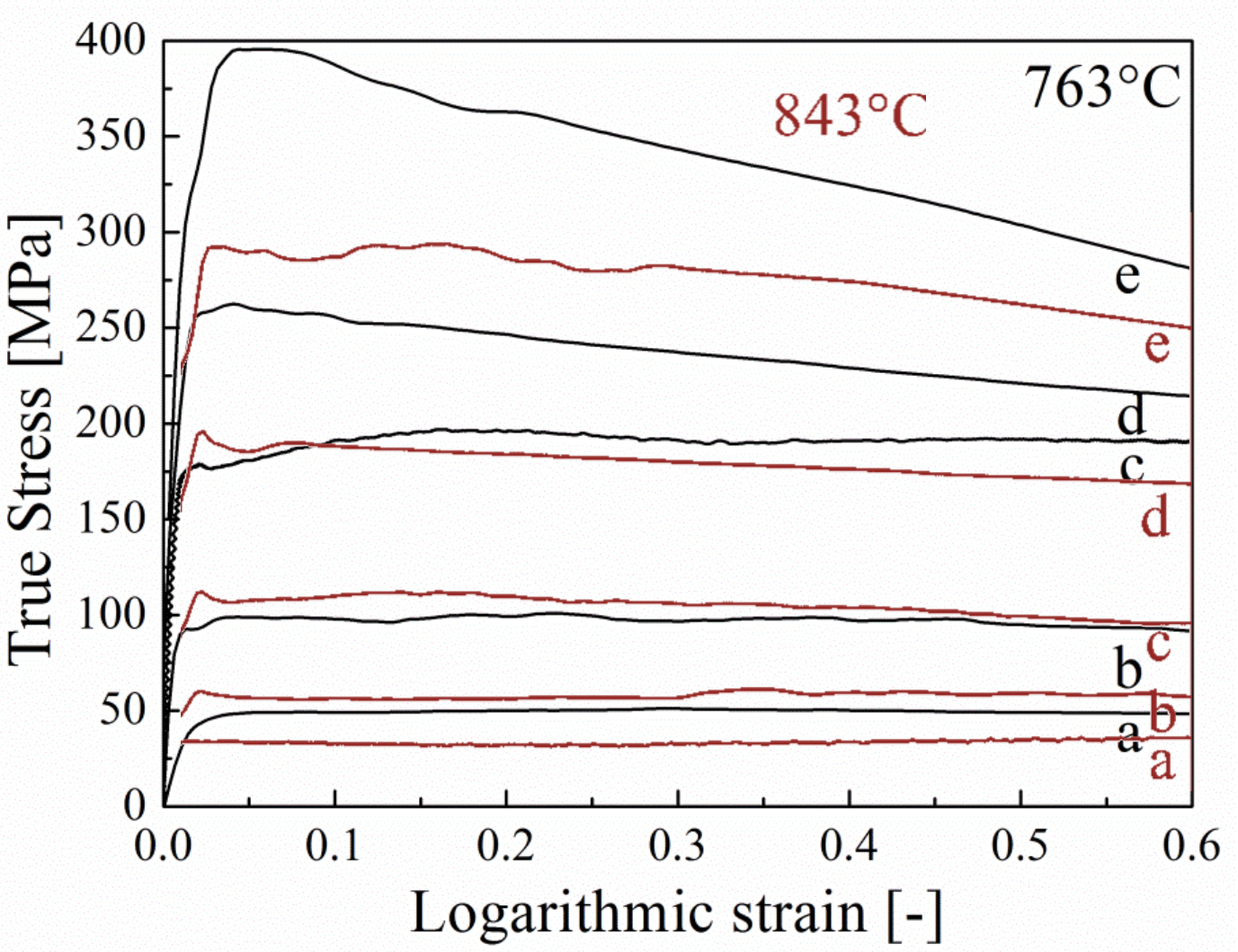
Forging: one or two phases field?



Flow curves Ti64

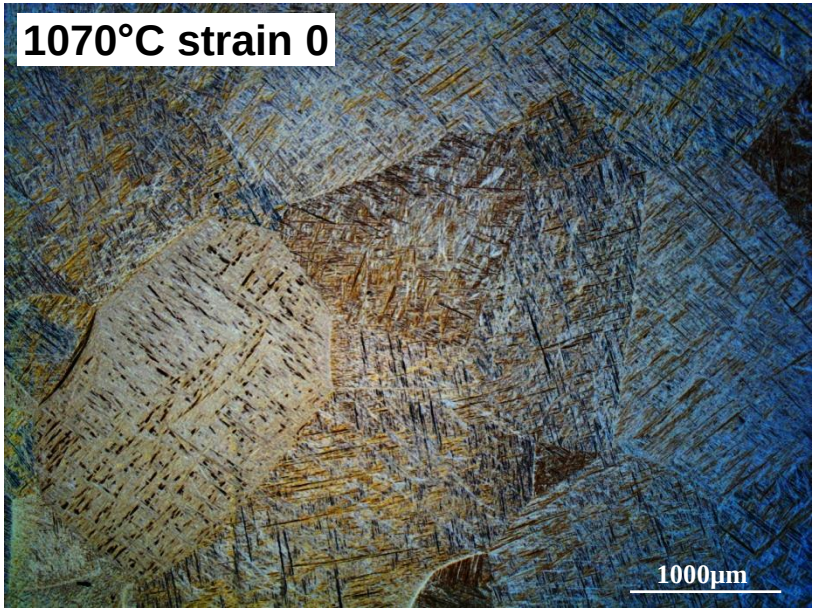


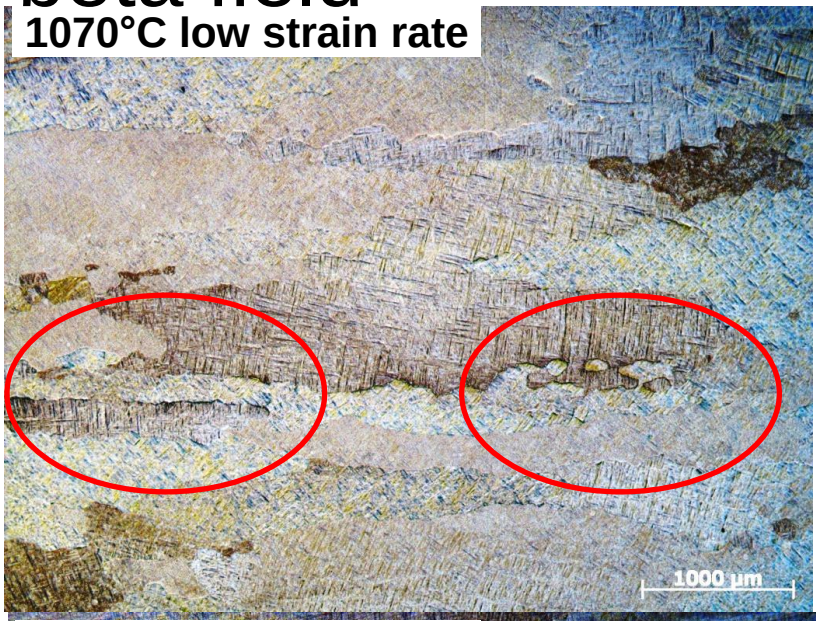
Flow curves Ti55531

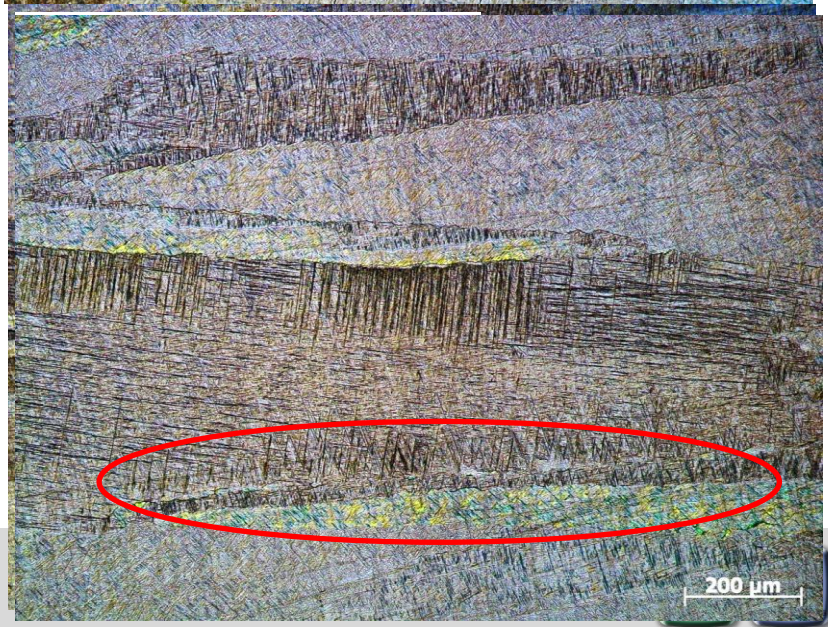


Strain rate decreases

Deformation of Ti64 in beta field







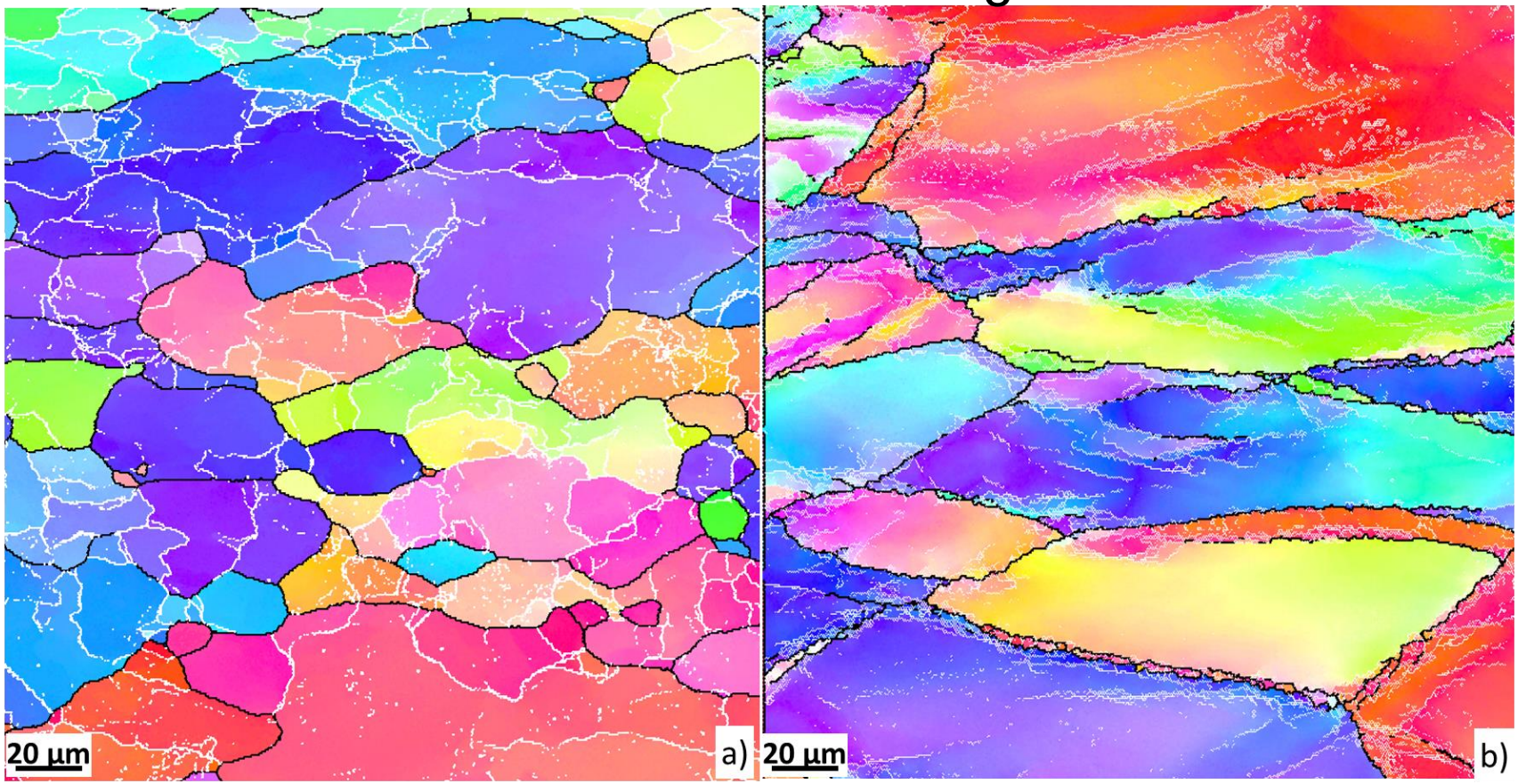
Compression tests +
water quenching

Warchomicka, F.; Poletti, M. C.; Stockinger, M.; Degischer, H. P.:Materials science forum 706-709 (2012) 252 - 257

Deformation of Ti55531 in beta field

Low strain rate

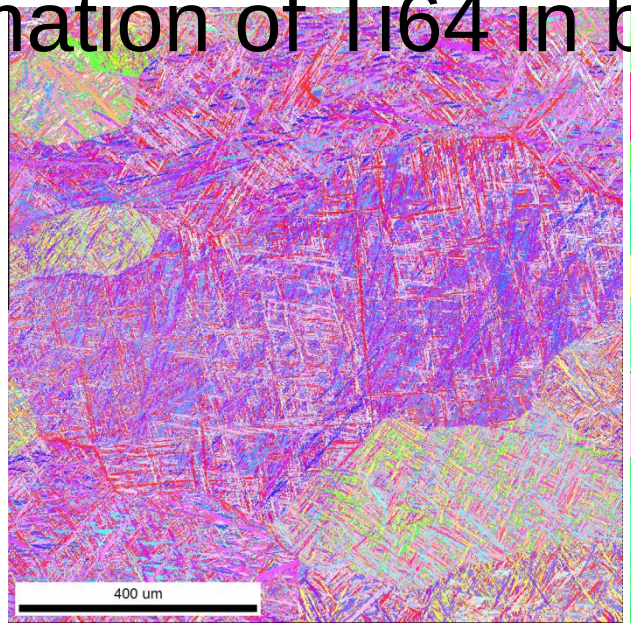
High strain rate

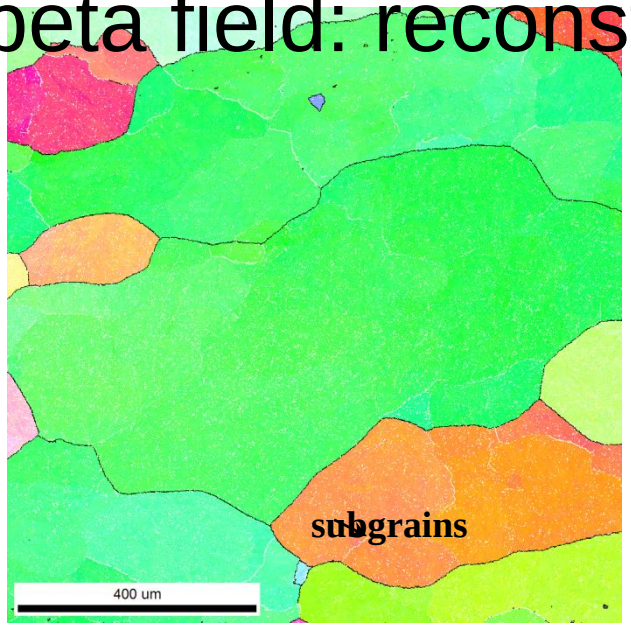


Dikovits, M.; Poletti, M. C.; Warchomicka, F. G. Metallurgical and materials transactions / A 45 (2014) 1586 - 1596

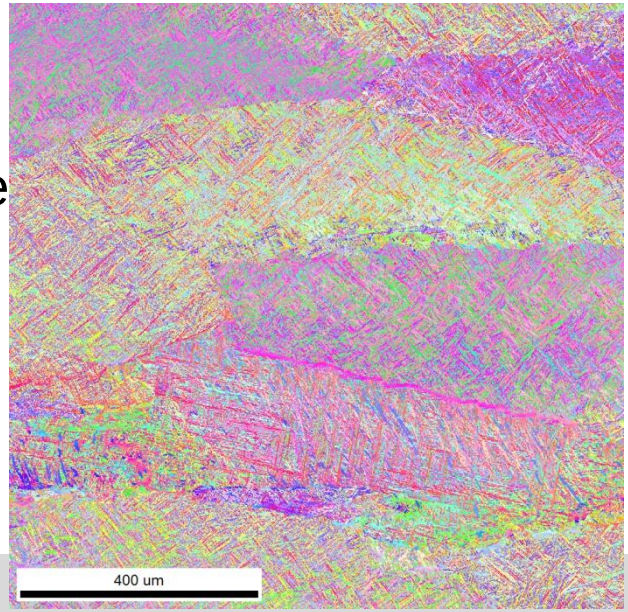
Deformation of Ti64 in beta field: reconstruction

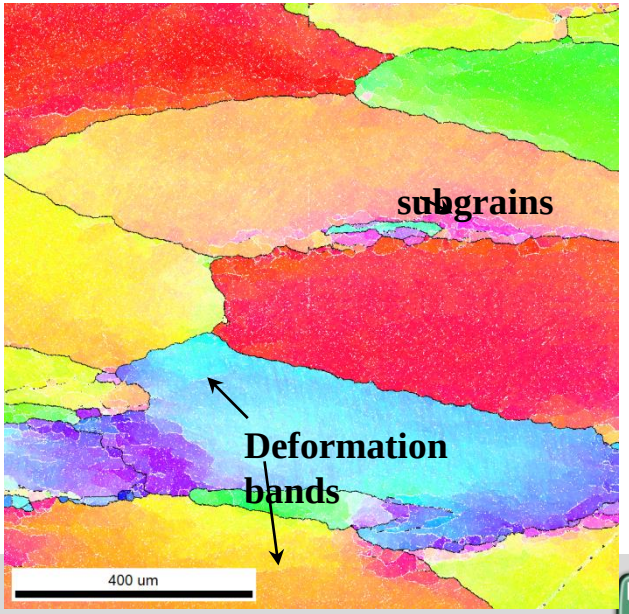
Low strain rate





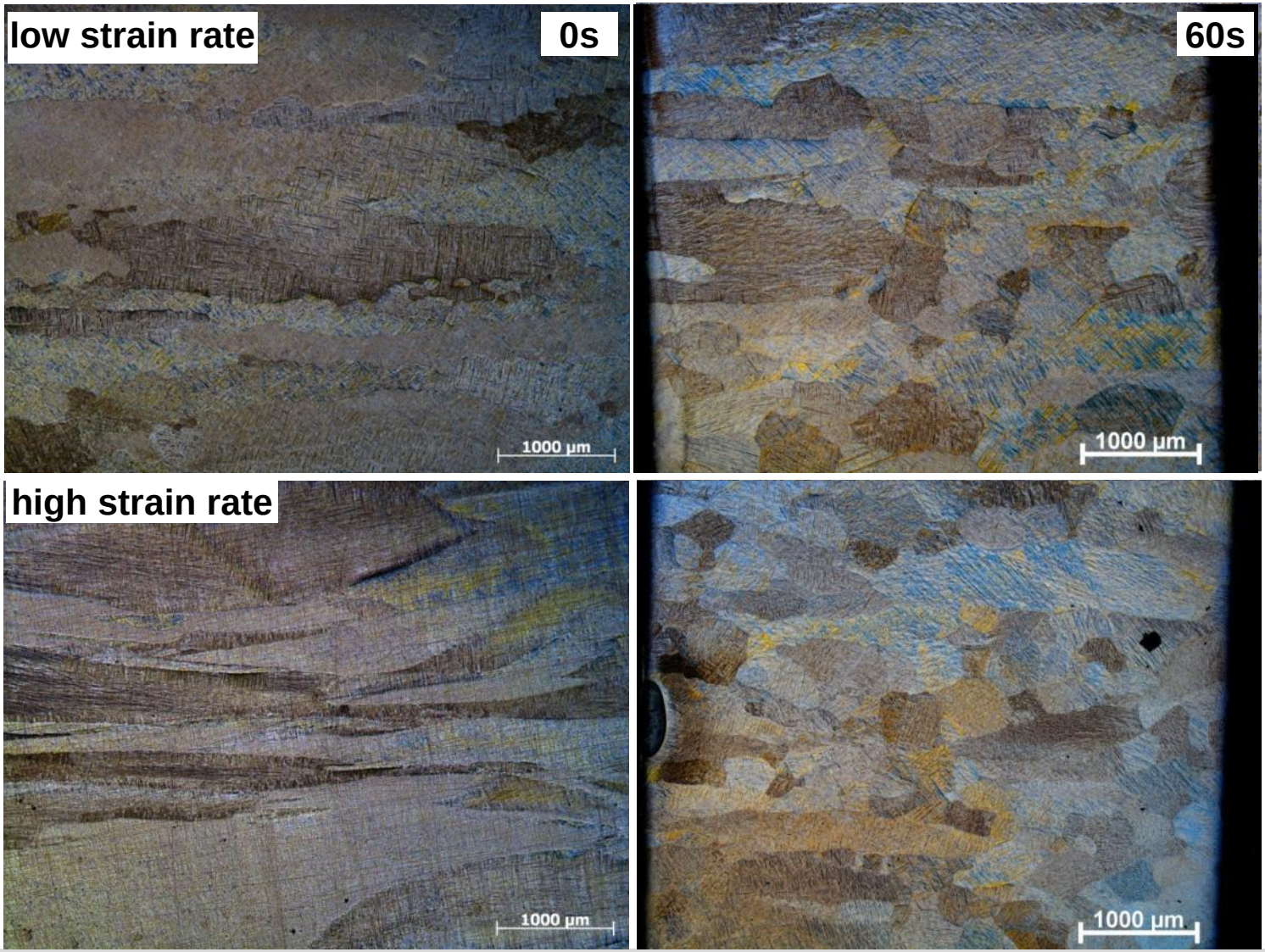
High strain rate



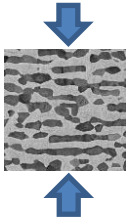


Cecilia Poletti, Lionel Germain, Fernando Warchomicka, Martina Dikovits and Stefan Mitsche. 2014 Unpublisched work

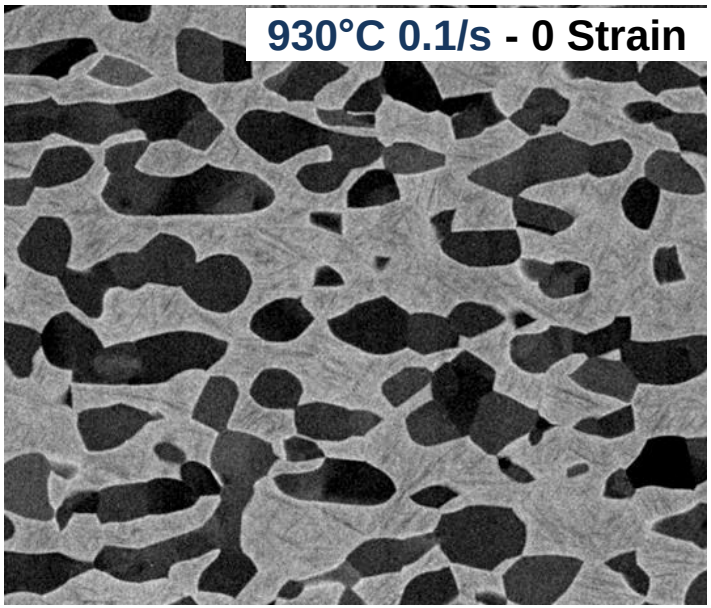
How are beta grains refined?

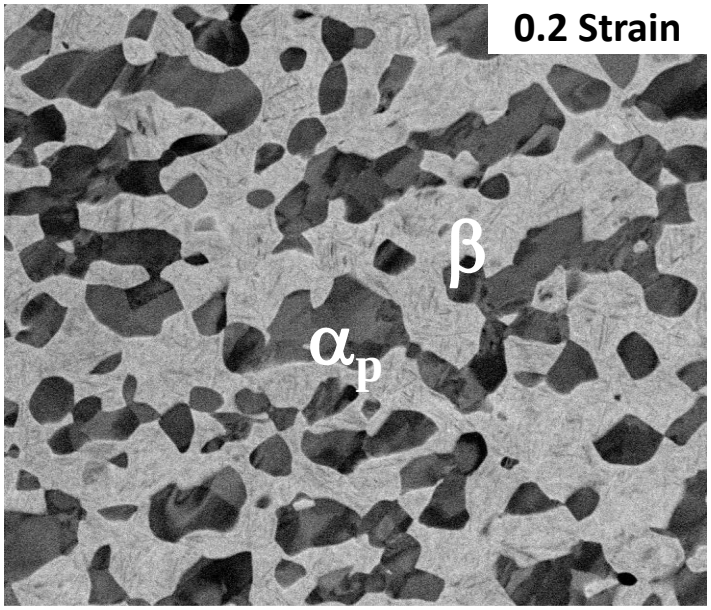


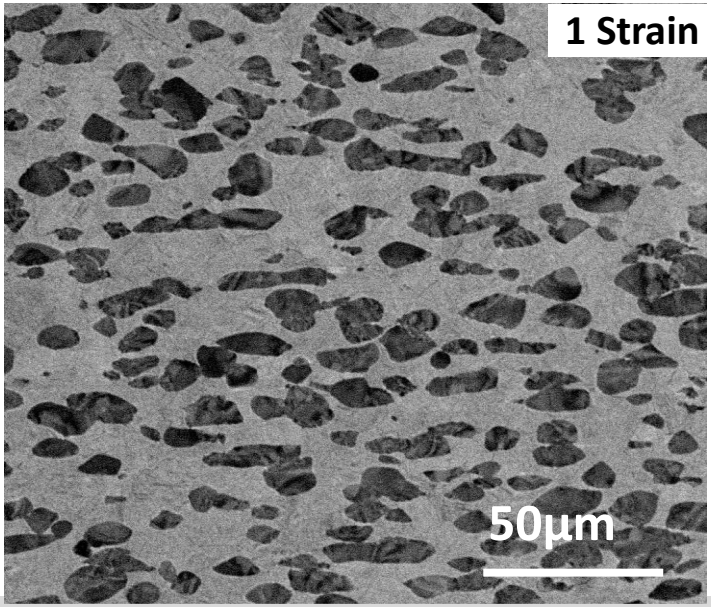
Deformation in alpha+beta: Ti64



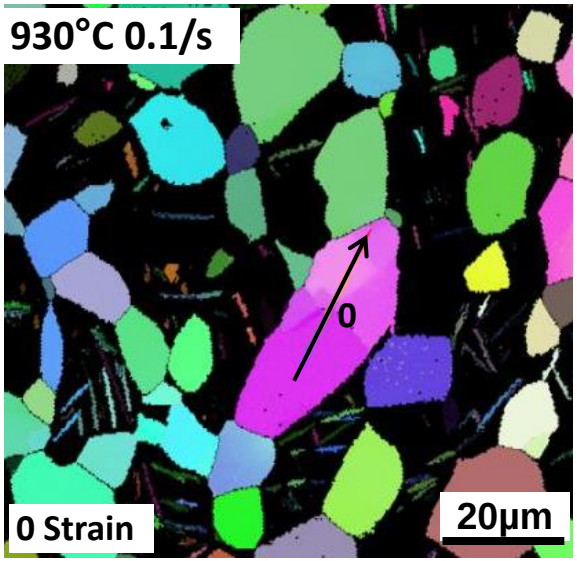
α_p~ 35%

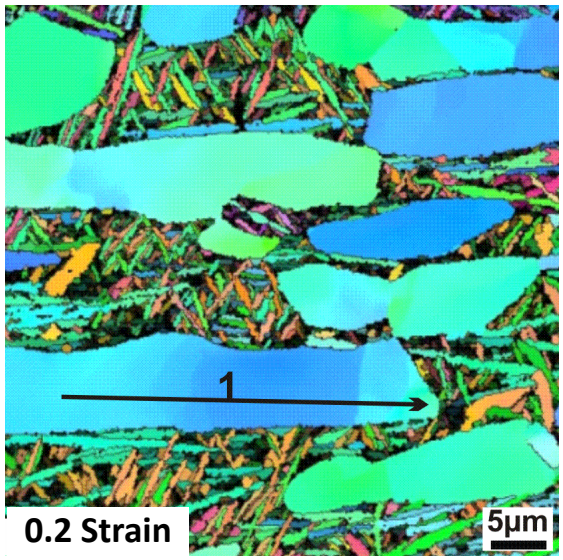


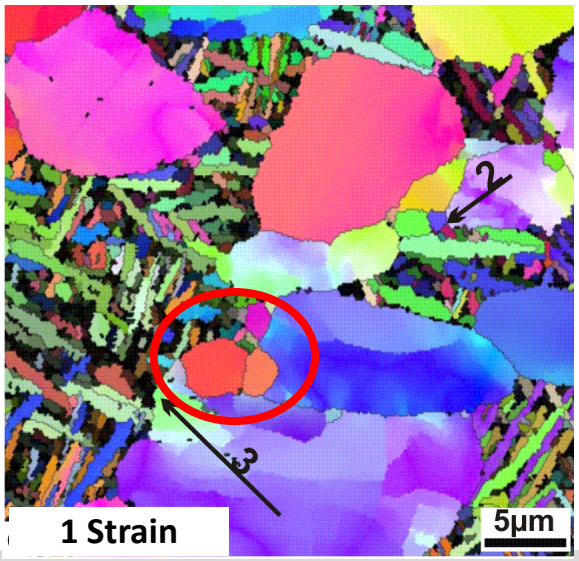


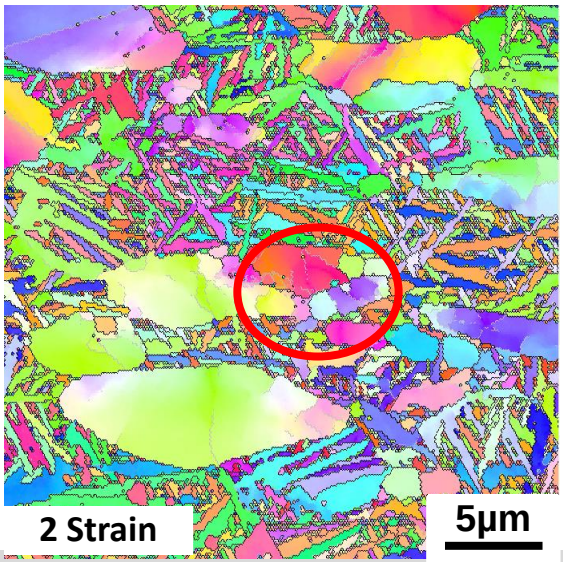


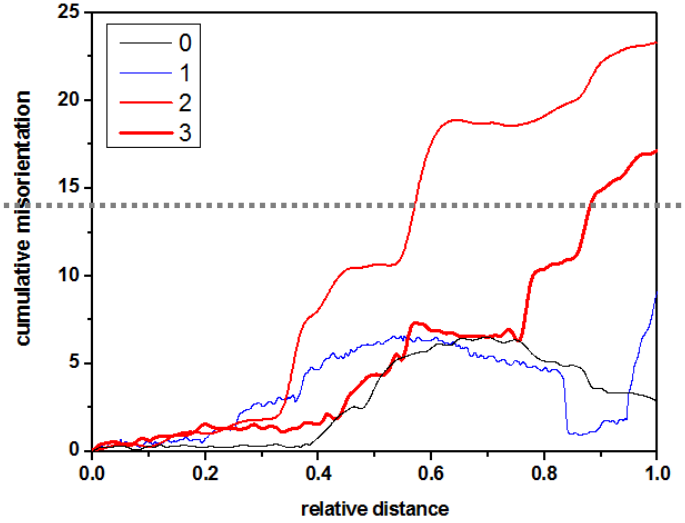
Deformation in alpha+beta:Ti64



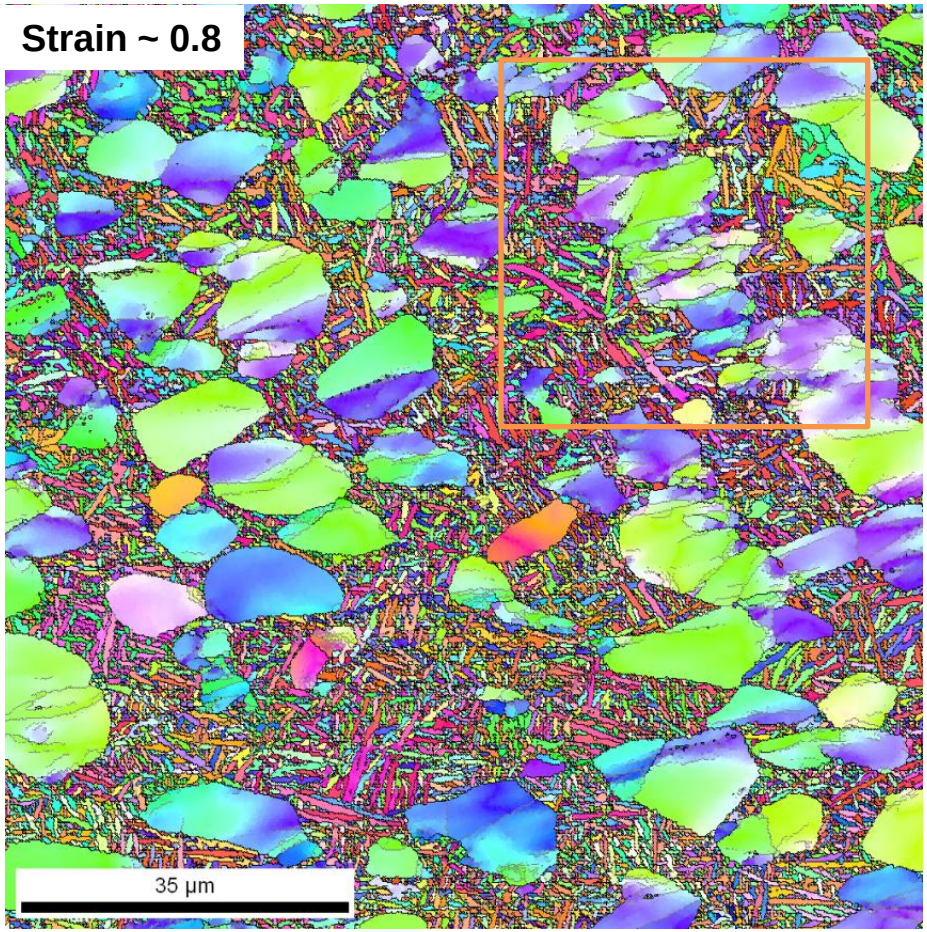


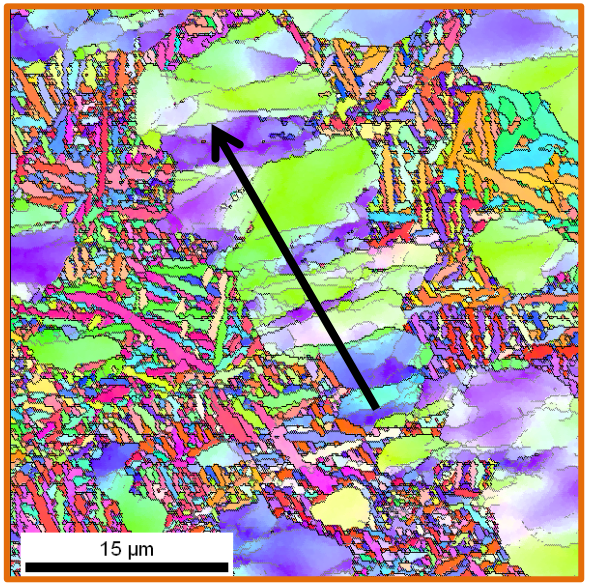


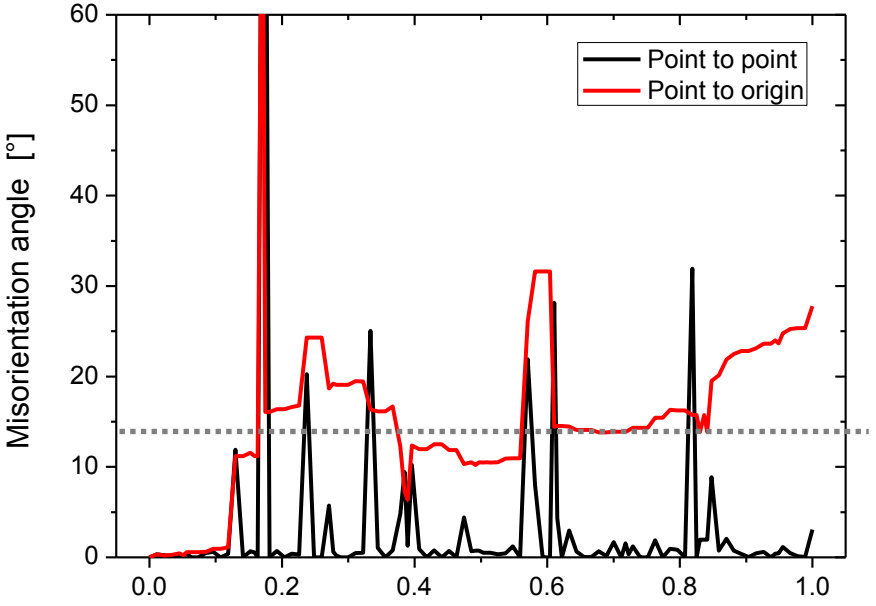




Deformation in alpha+beta: Ti64

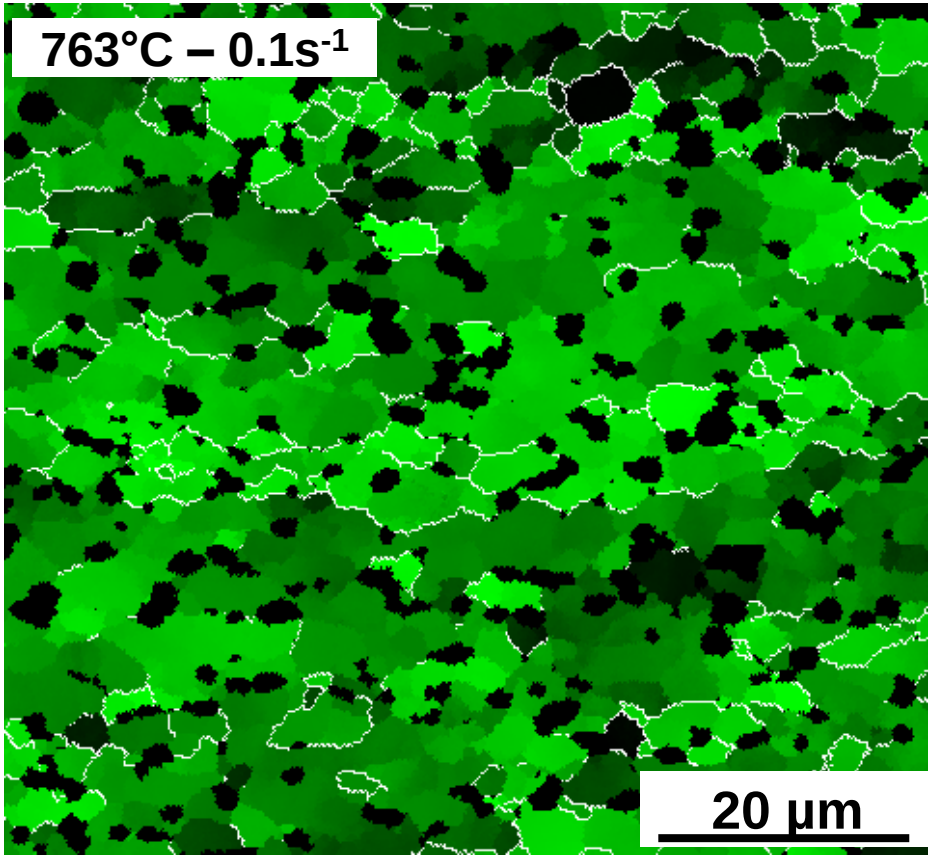


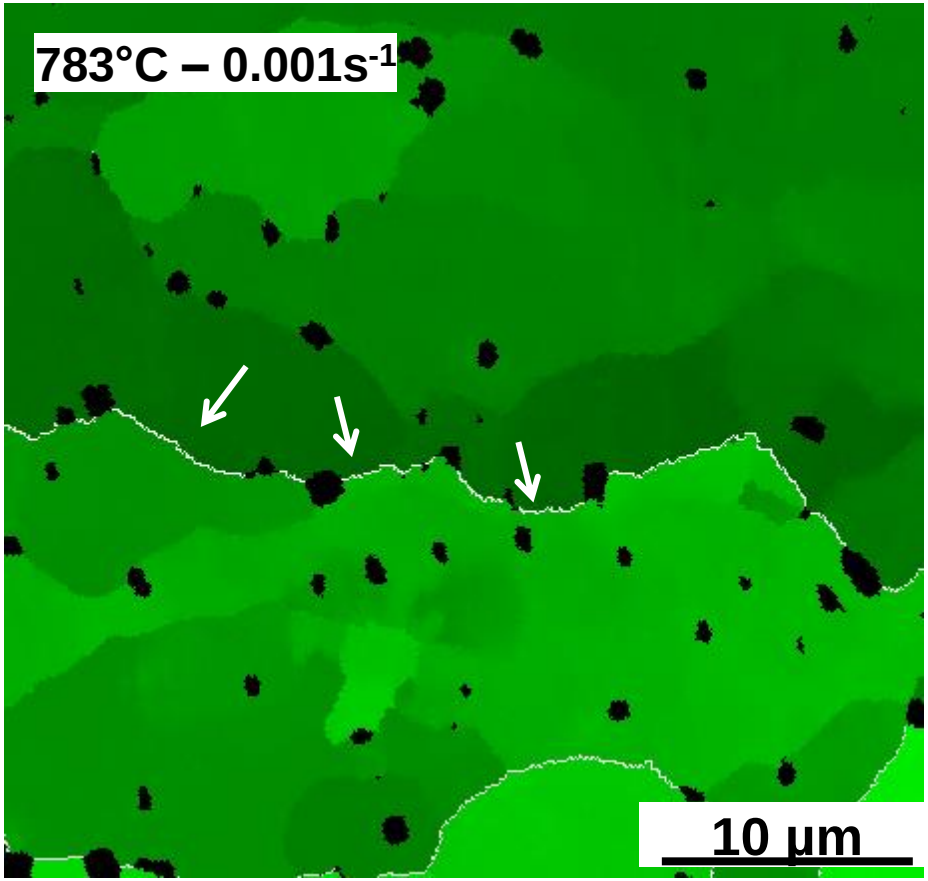




Deformation in alpha + beta (Ti55531)

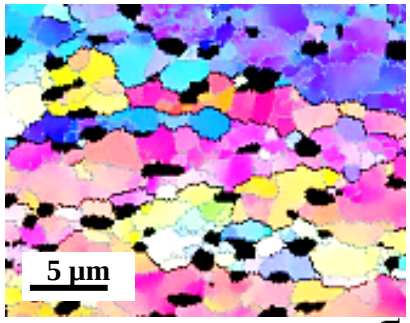
Low Taylor factor (dark) → lower stored energy
→ better orientation for the deformation

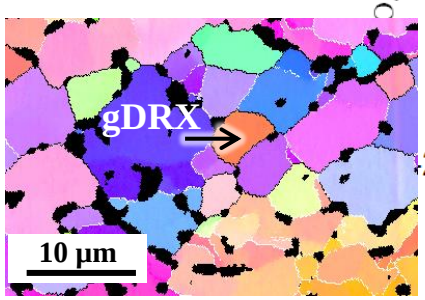


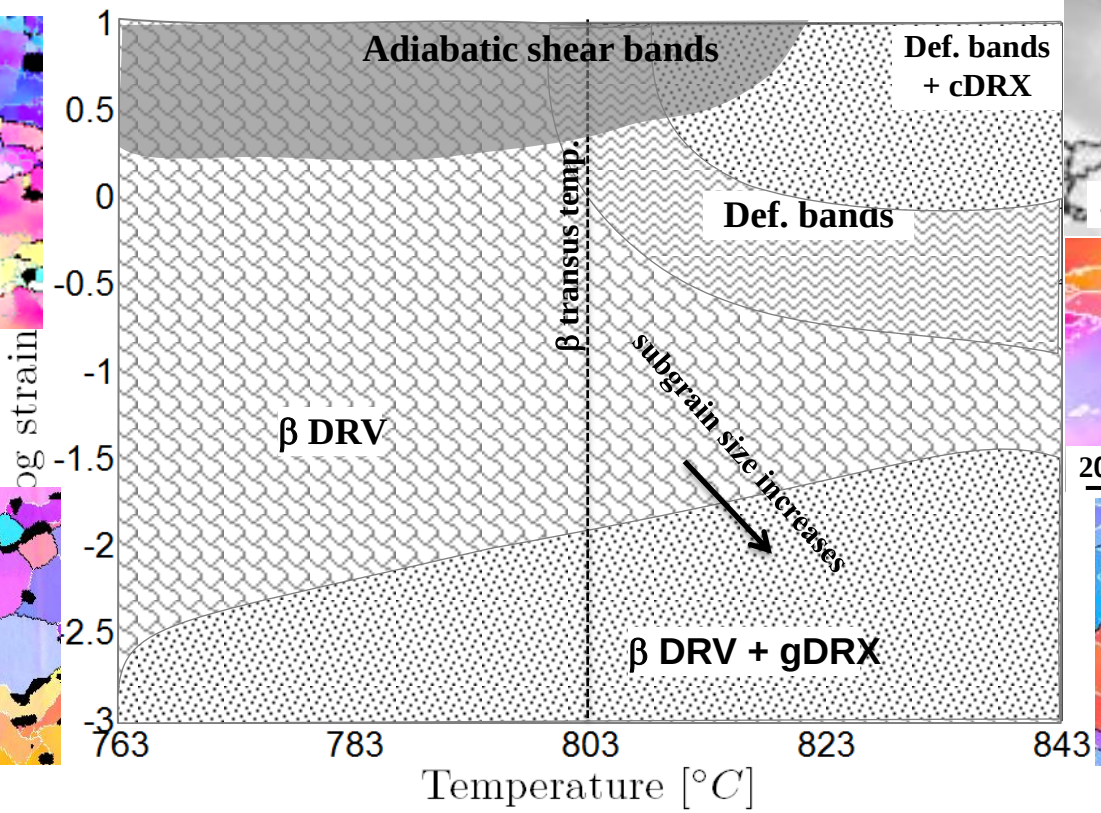


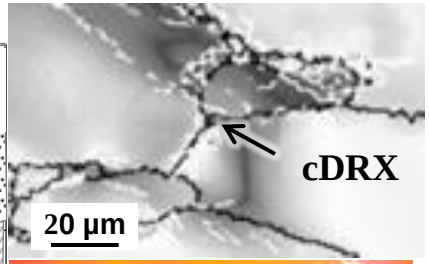
Deformation behaviour Ti55531

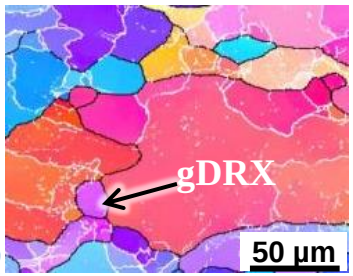
α–β interaction











Dikovits, M.; Poletti, M. C.; Warchomicka, F. G. Metallurgical and materials transactions / A 45 (2014) 1586 - 1596

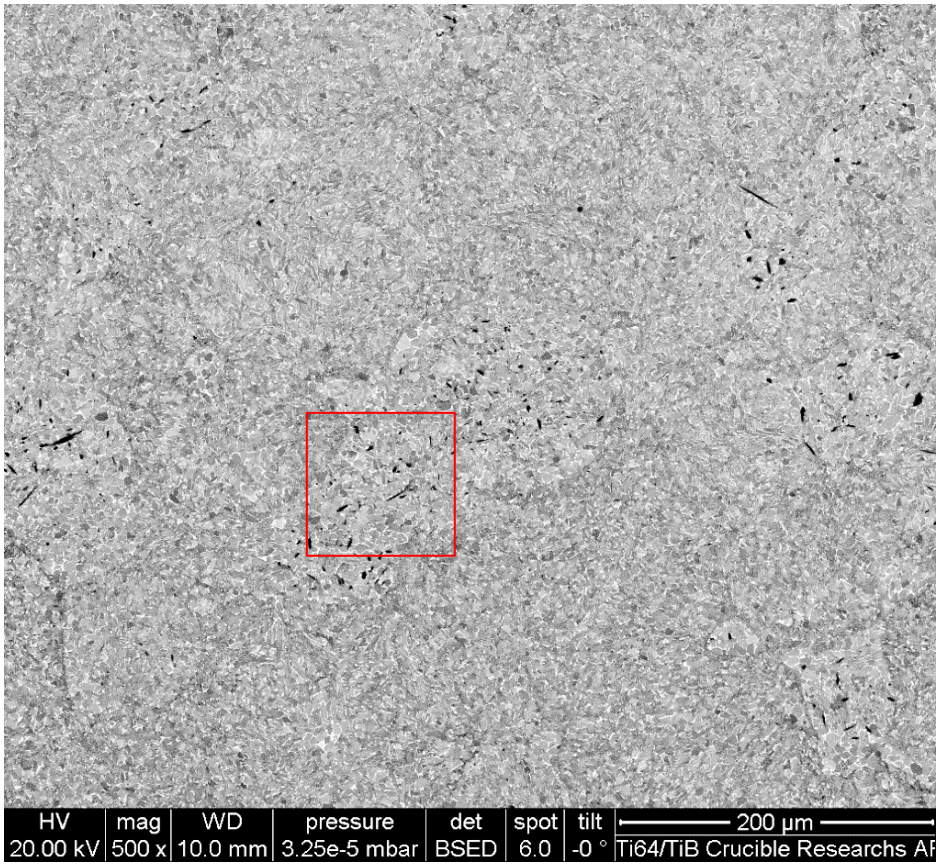
Deformation of titanium alloys

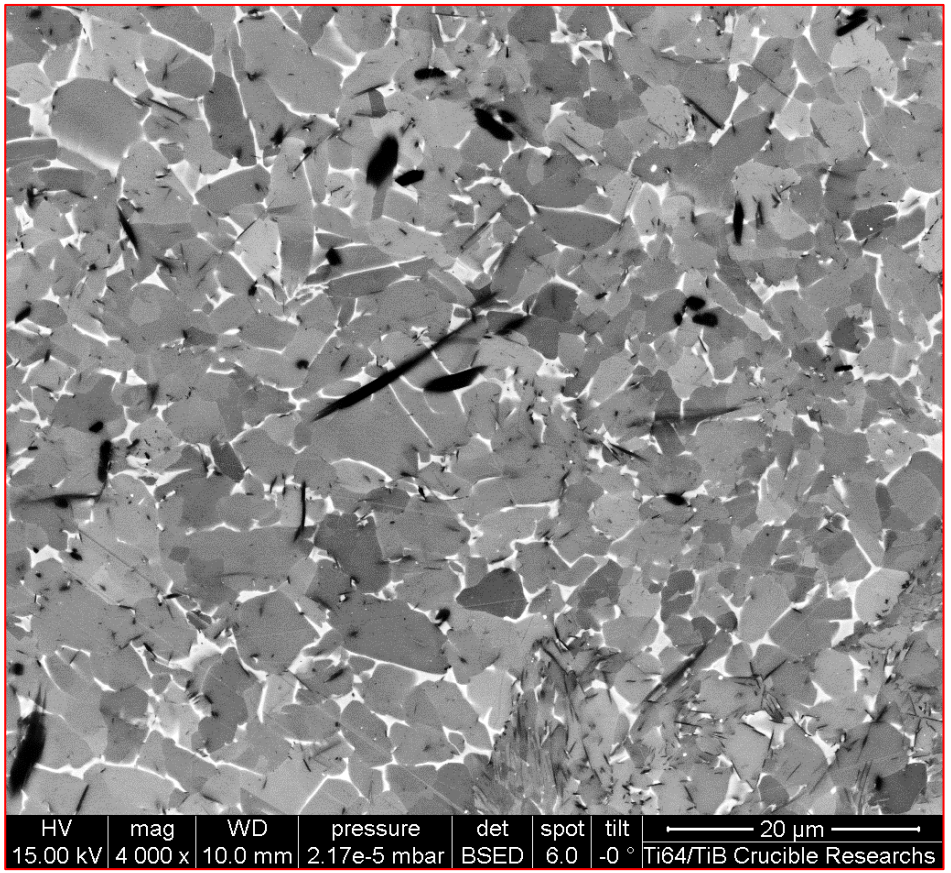
- DRV in beta, followed either by gDRX or cDRX
- SRX of beta → fast, main mechanism for beta grain refinement
- cDRX of alpha
- SRX of alpha + phase transformation

Developed subgrains and grains small at low T and high $\dot{\varepsilon}$

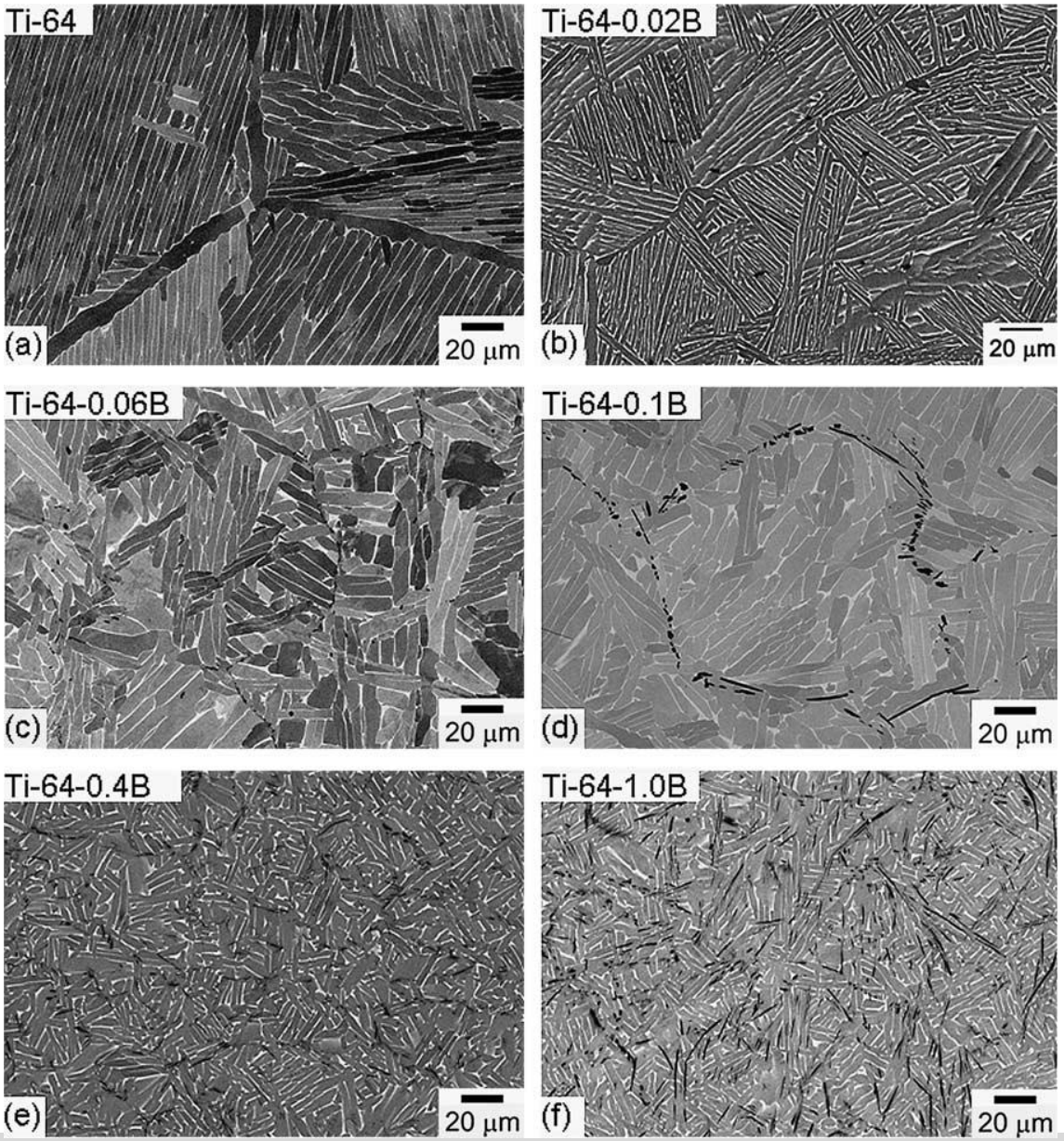
→ stored energy large

Grain refinement by TiB (PM)



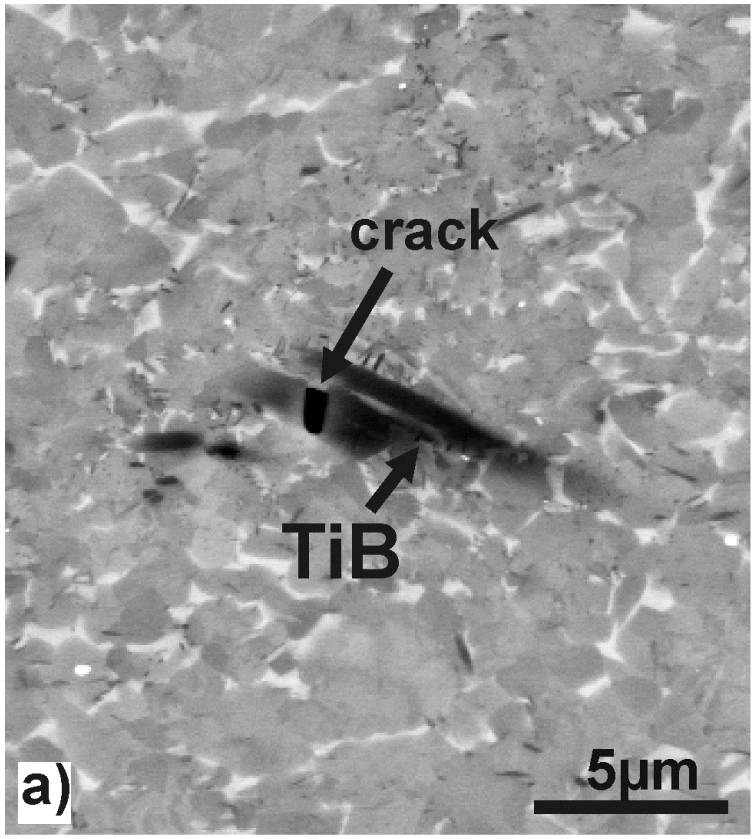


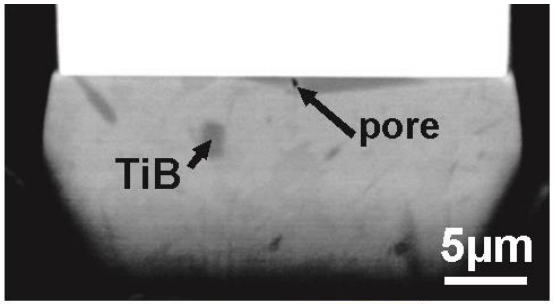
Grain refinement by TiB addition (cast)

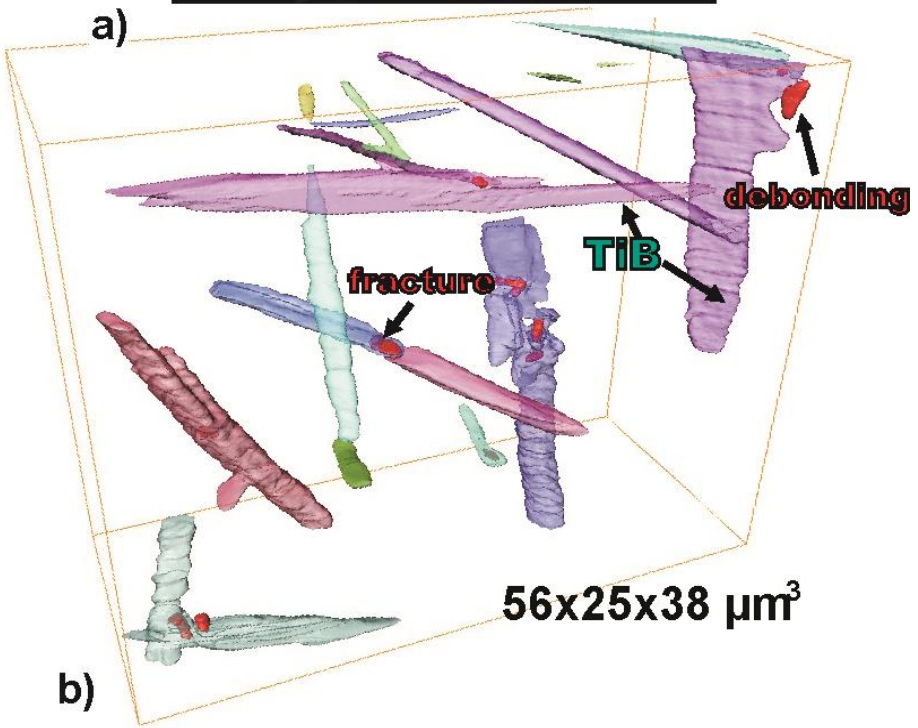


Scripta Materialia 53 (2005) 1421–1426. S. Tamirisakandala a,b,*, R.B. Bhat a,c, J.S. Tiley a, D.B. Miracle.

Deformation in the presence of TiB

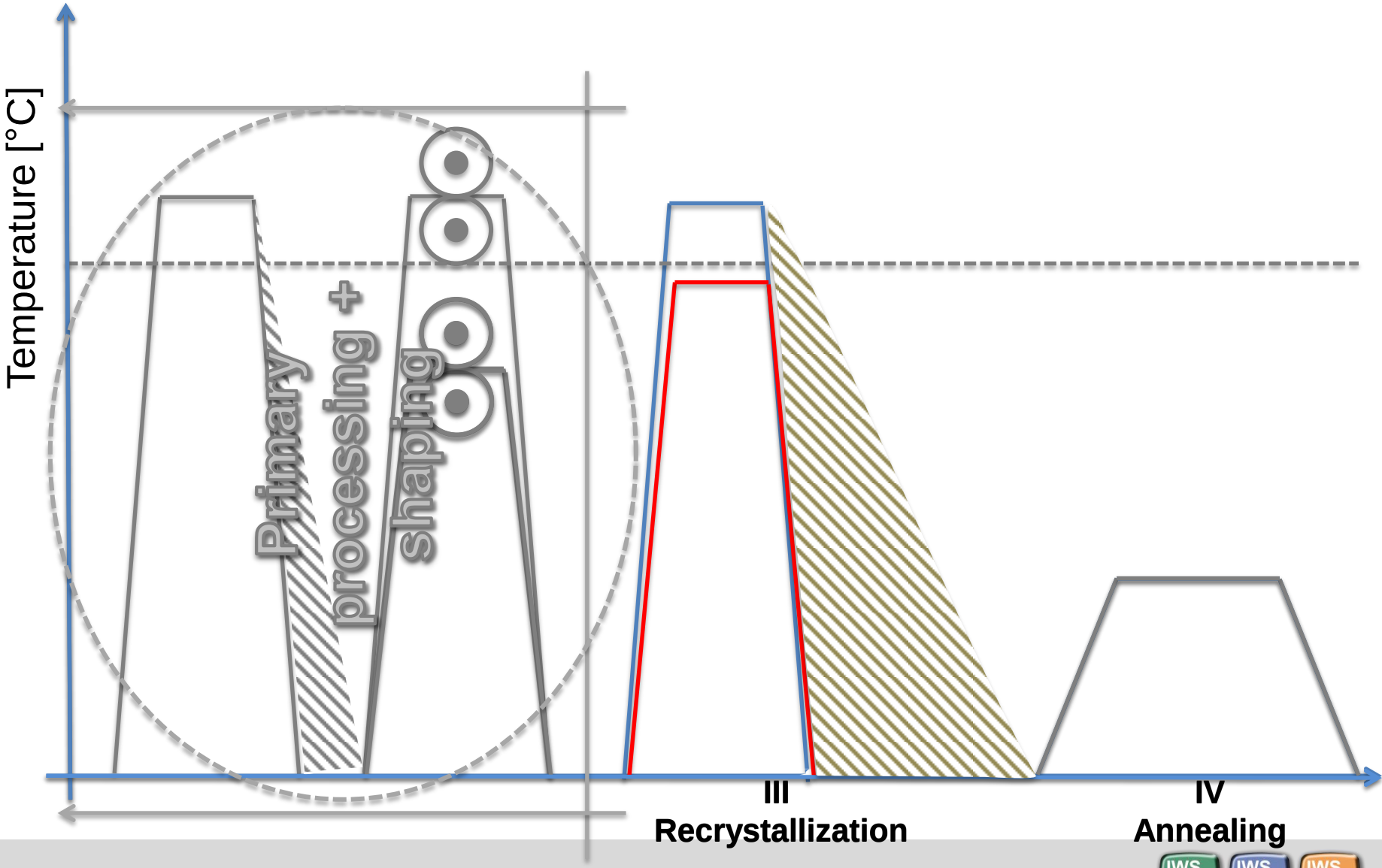




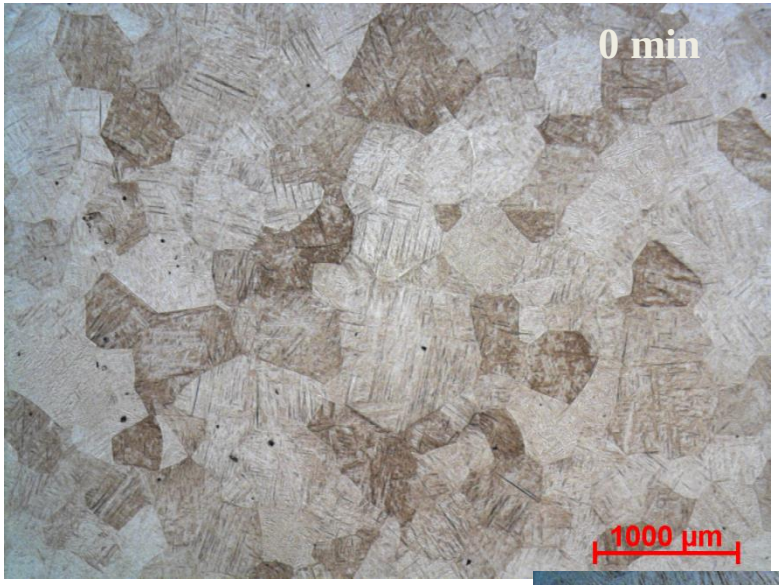


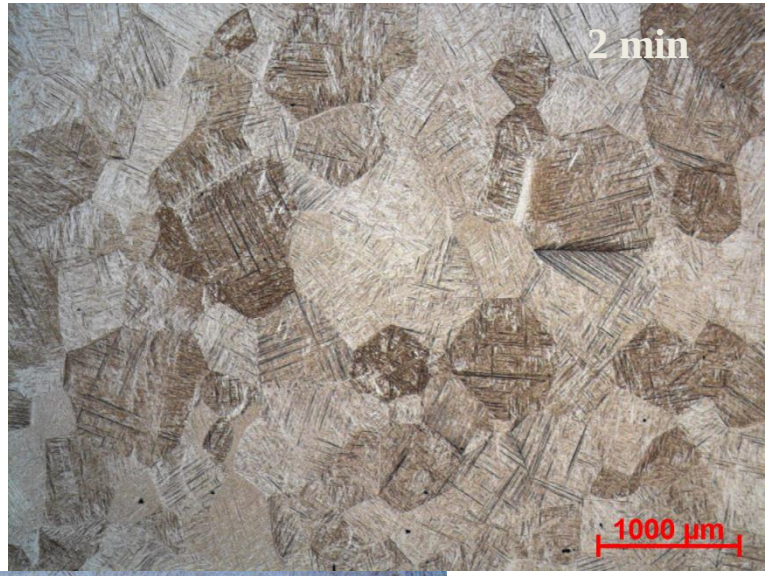
C. Poletti, G. Requena, D. Tolnai, P. Cloetens, A. Steiger-Thirsfeld.. Int. J. Mat.Res. (formerly Z. Metallkd.) 101 (2010). 1151-1157

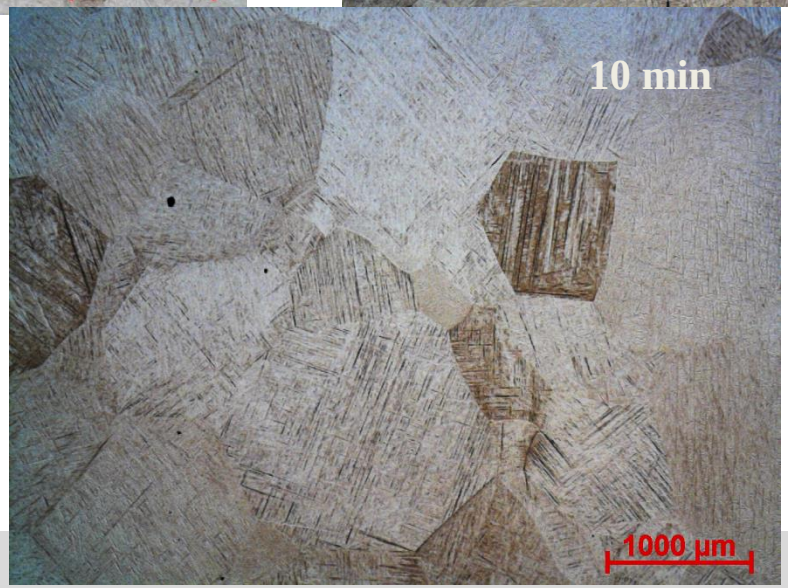
Heat treatments after deformation



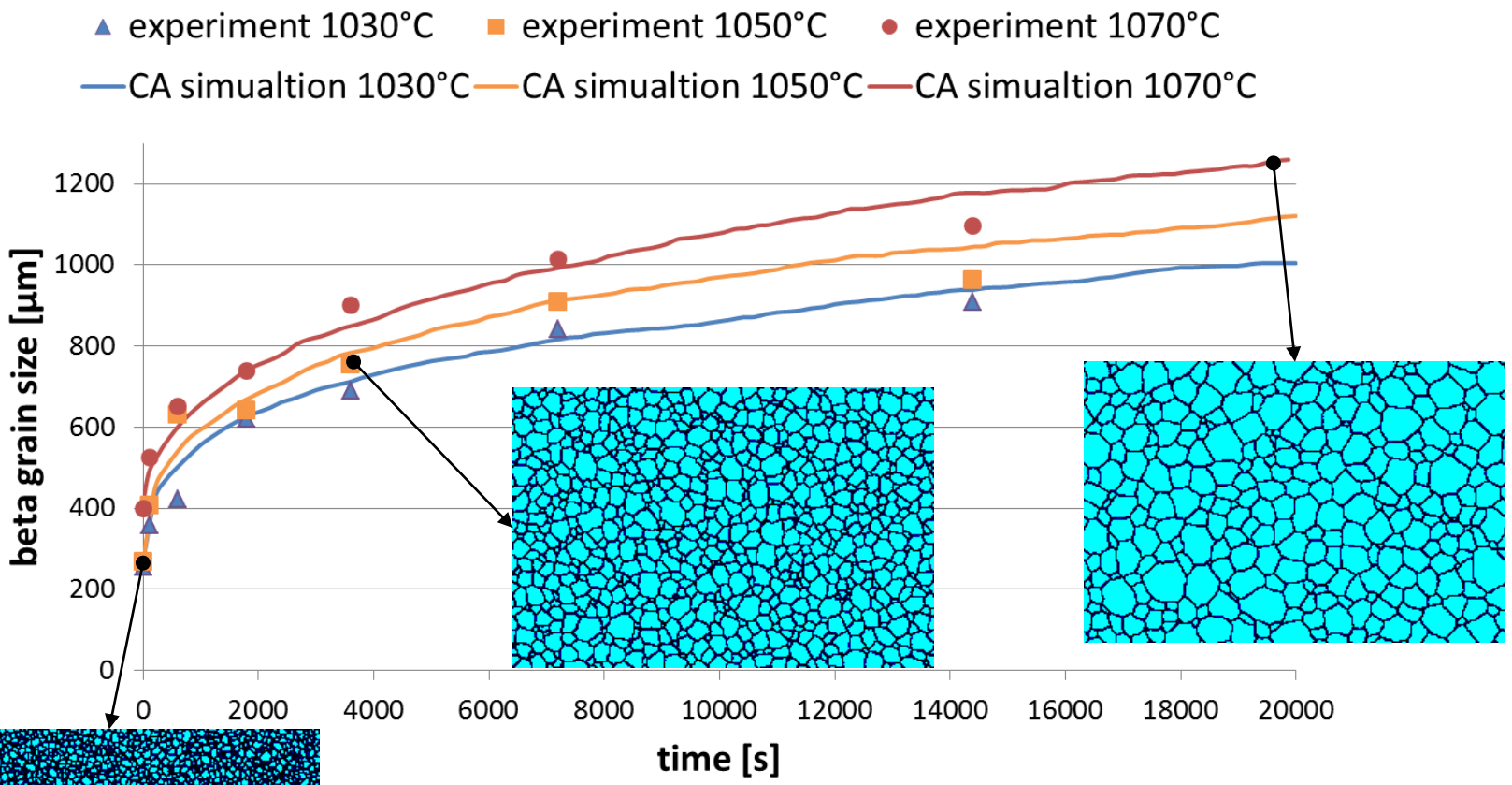
Heat treatment in beta







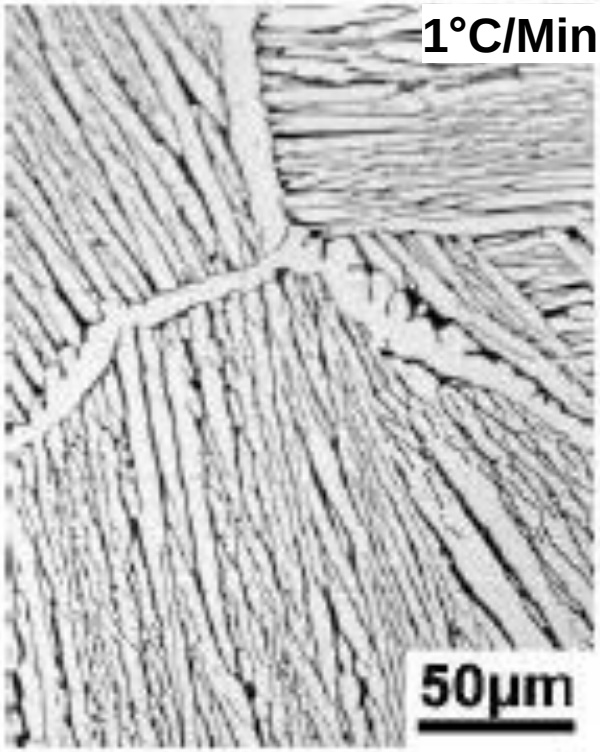
Heat treatment in beta

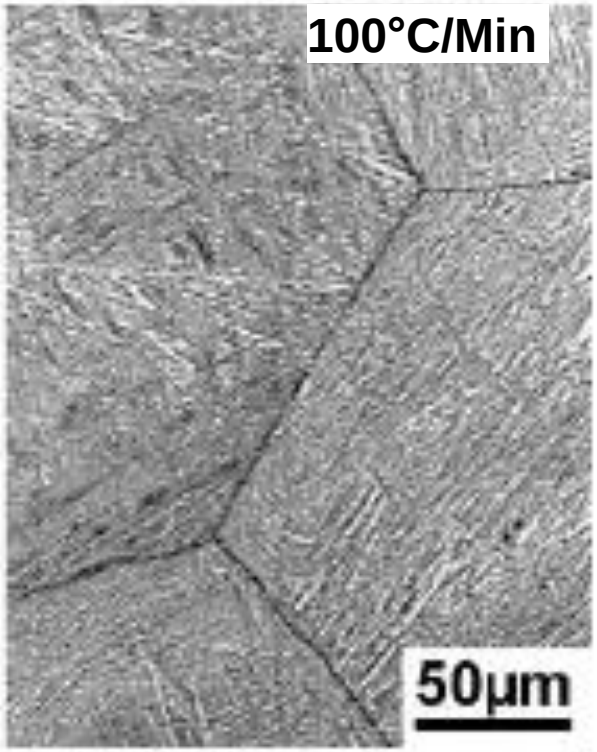


$$D^n - D_0^n = K\,t\exp\left(\frac{-Q}{RT}\right)$$

Krumphals, A., Poletti, C., Warchomicka, F., Stockinger, M., Sommitsch, C. (2014) International Journal for Multiscale Computational Engineering

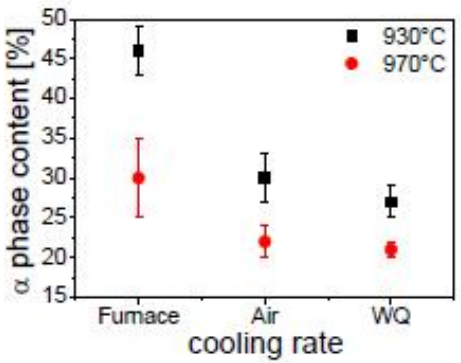
Cooling from beta

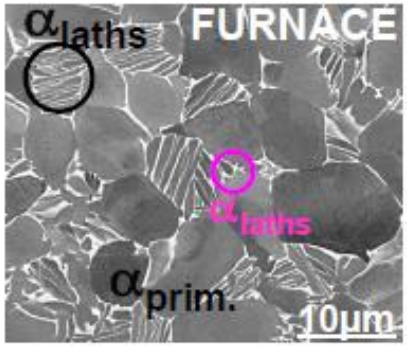


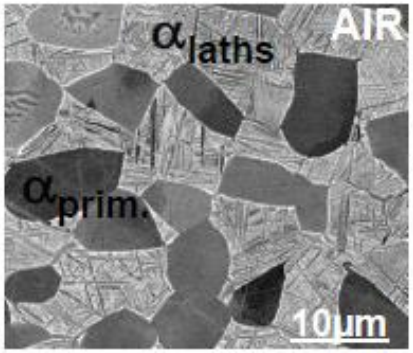


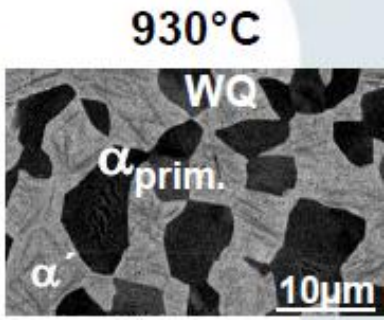
-„Titan und Titanlegierungen“. M. Peters, C. Leyens. Wiley-VCH, 2002

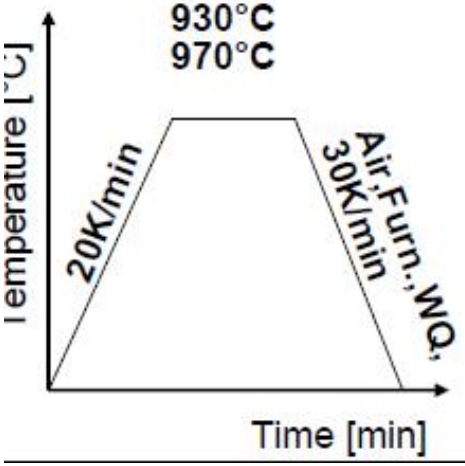
Cooling from alpha + beta

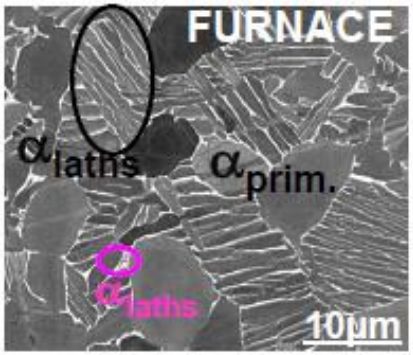


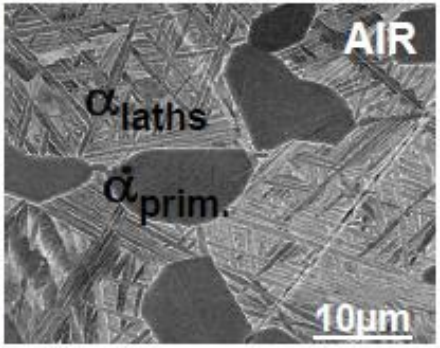


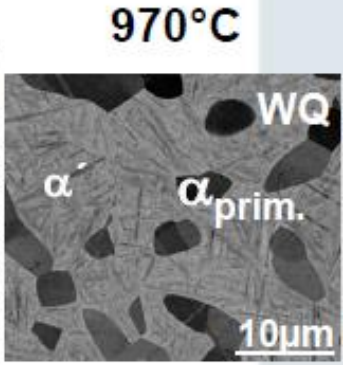






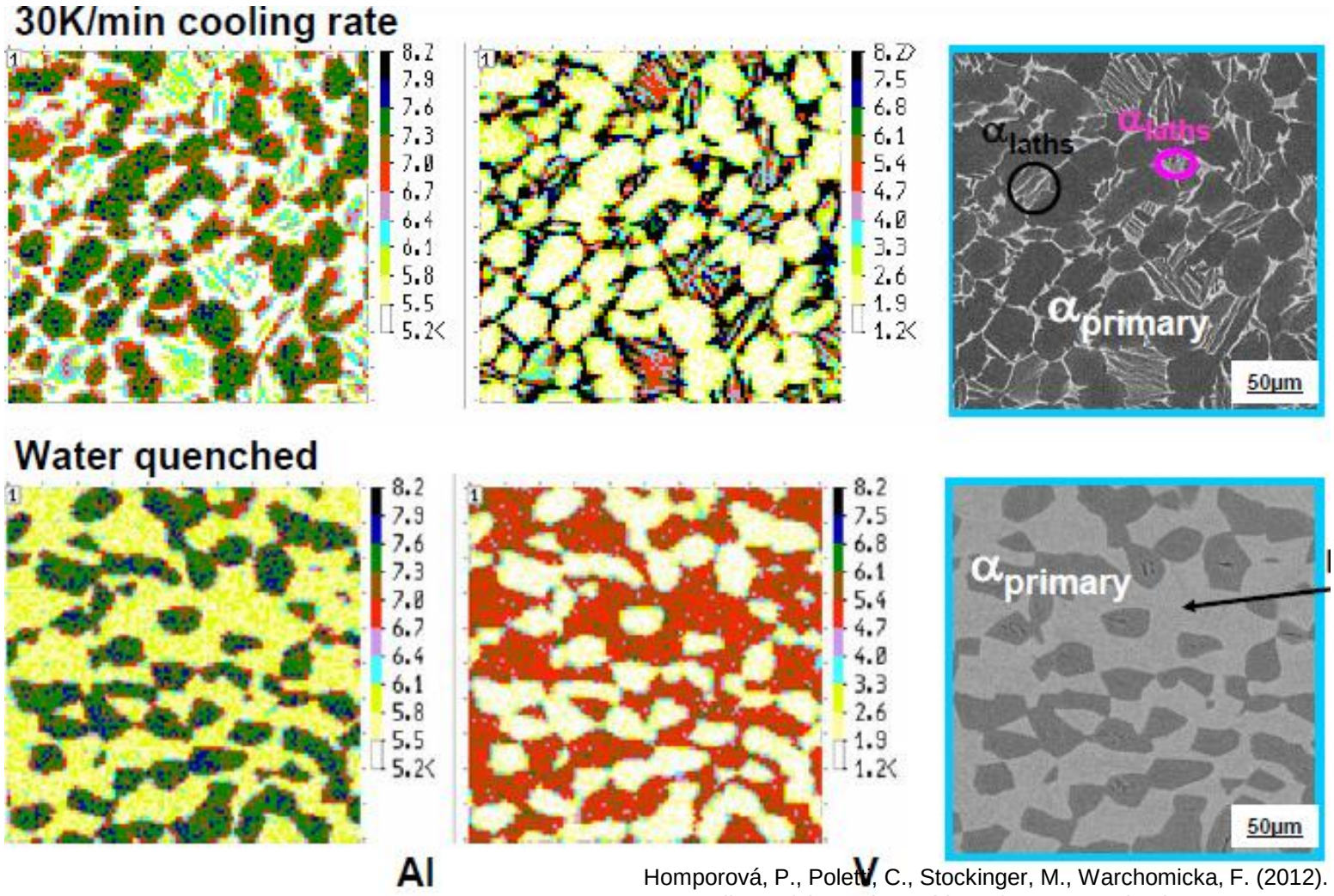






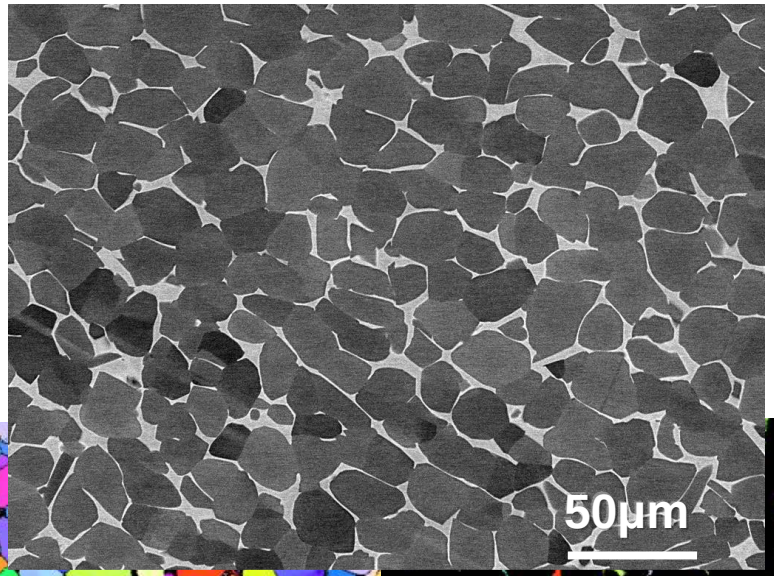
Homporová, P., Poletti, C., Stockinger, M., Warchomicka, F. (2012). Ti 2011 - Proceedings of the 12th World Conference on Titanium

Cooling from alpha + beta

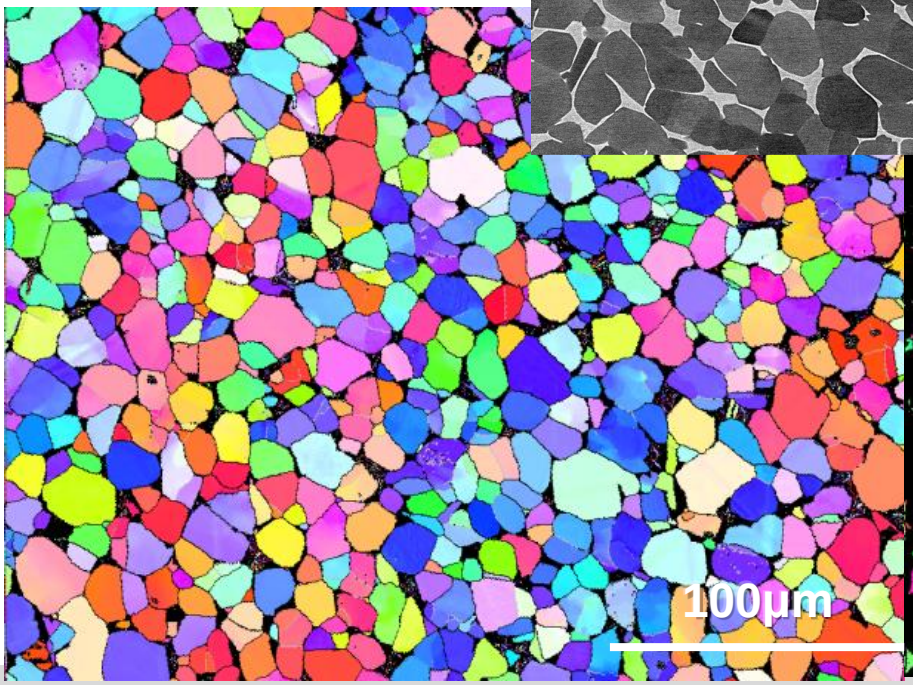


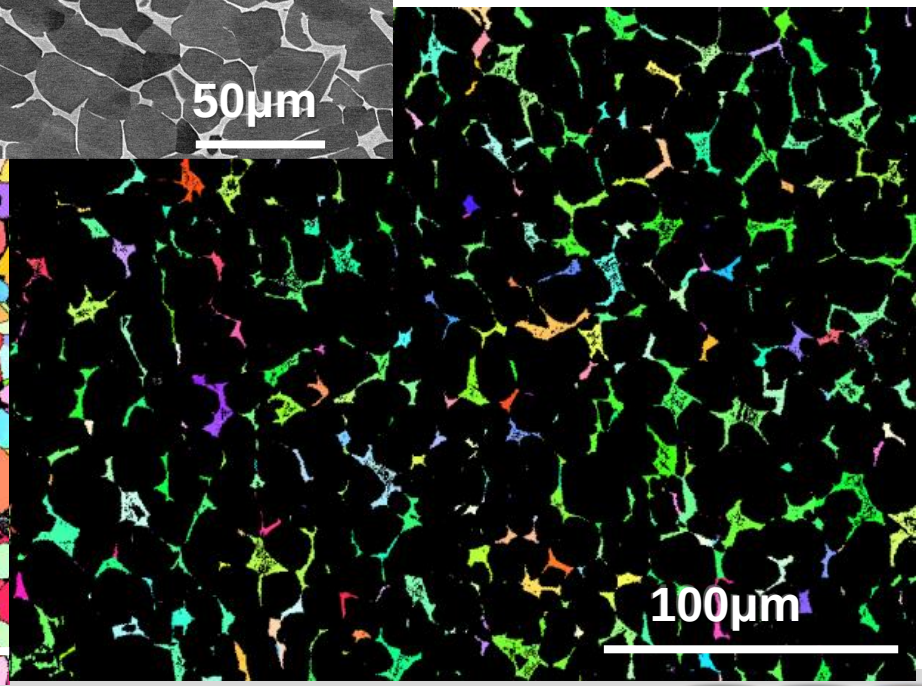
Homporová, P., Polet, C., Stockinger, M., Warchomicka, F. (2012). Ti 2011 - Proceedings of the 12th World Conference on Titanium

Recrystallized microstructure (globular)

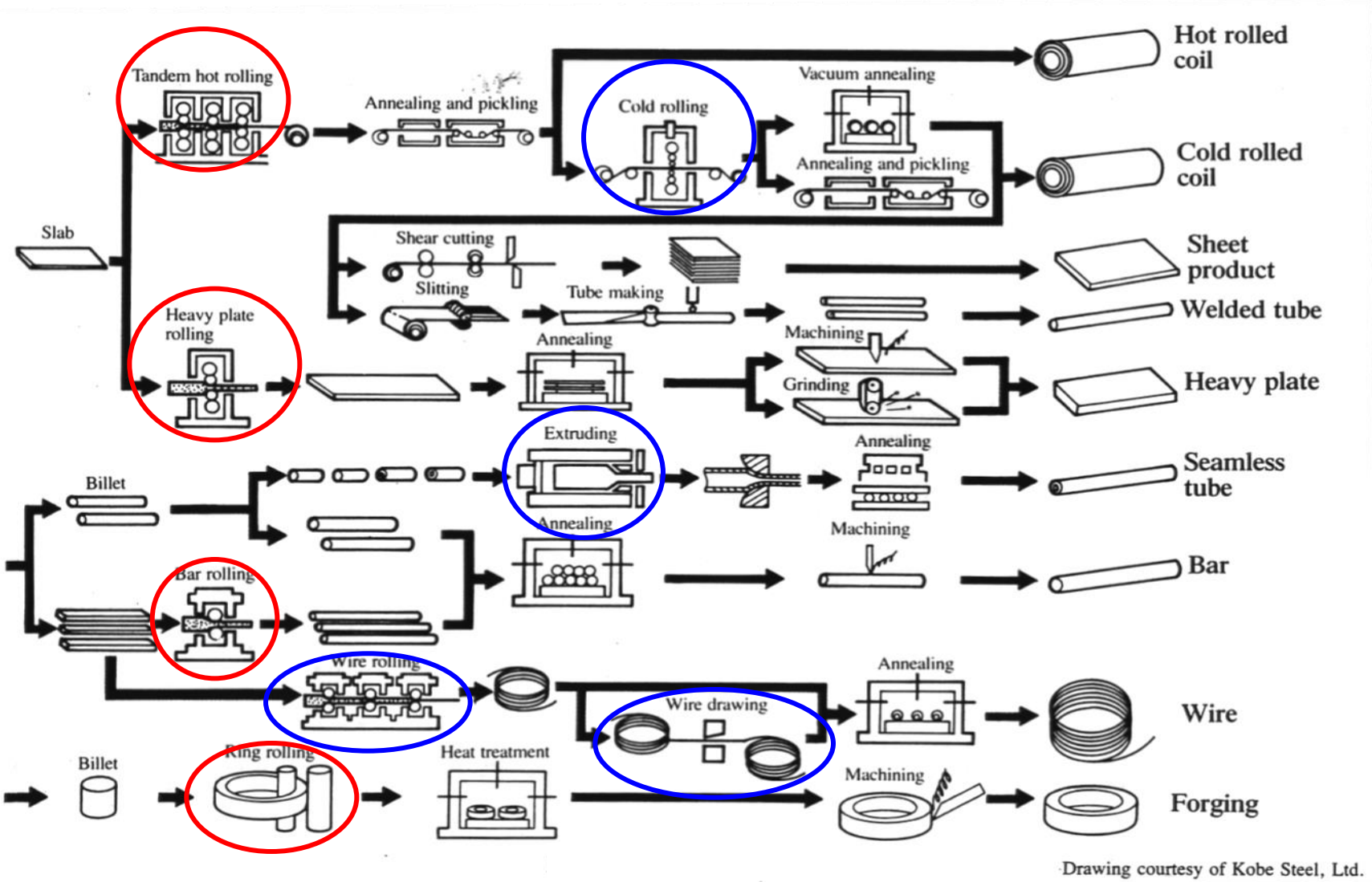


Pere Barriobero. Master thesis.
TUVienna 2010



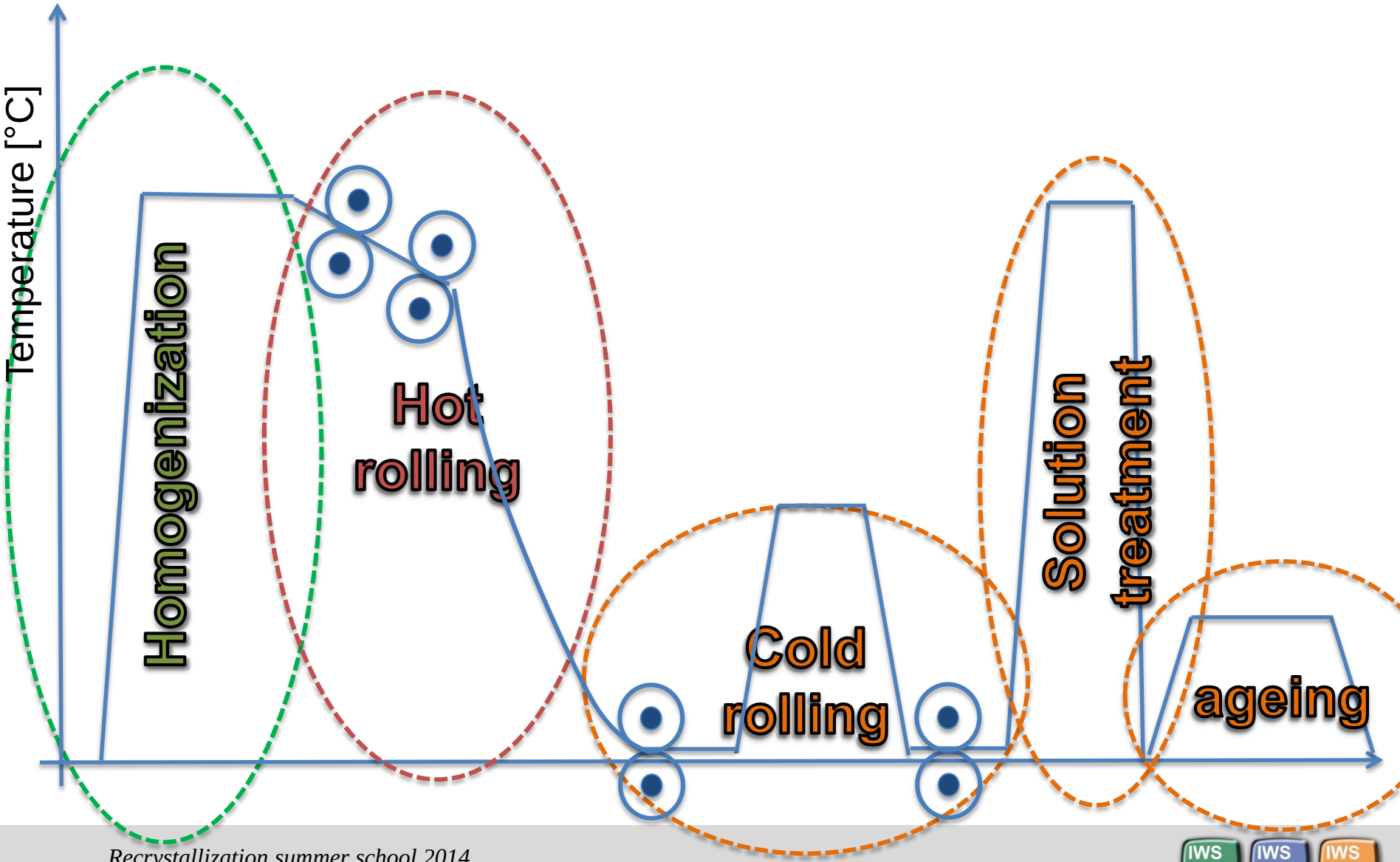


Forming of titanium alloys

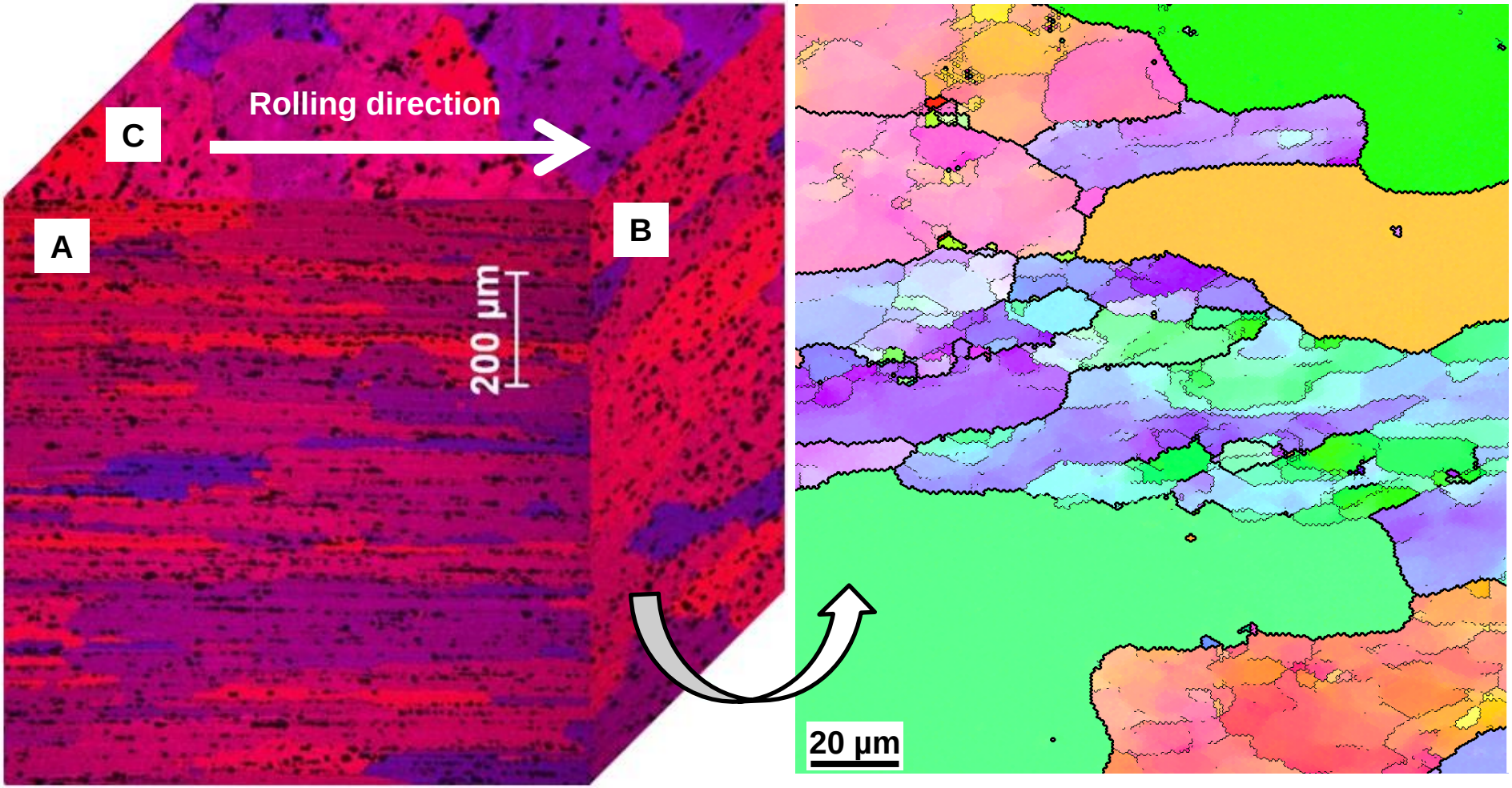


Processing of aluminium alloys

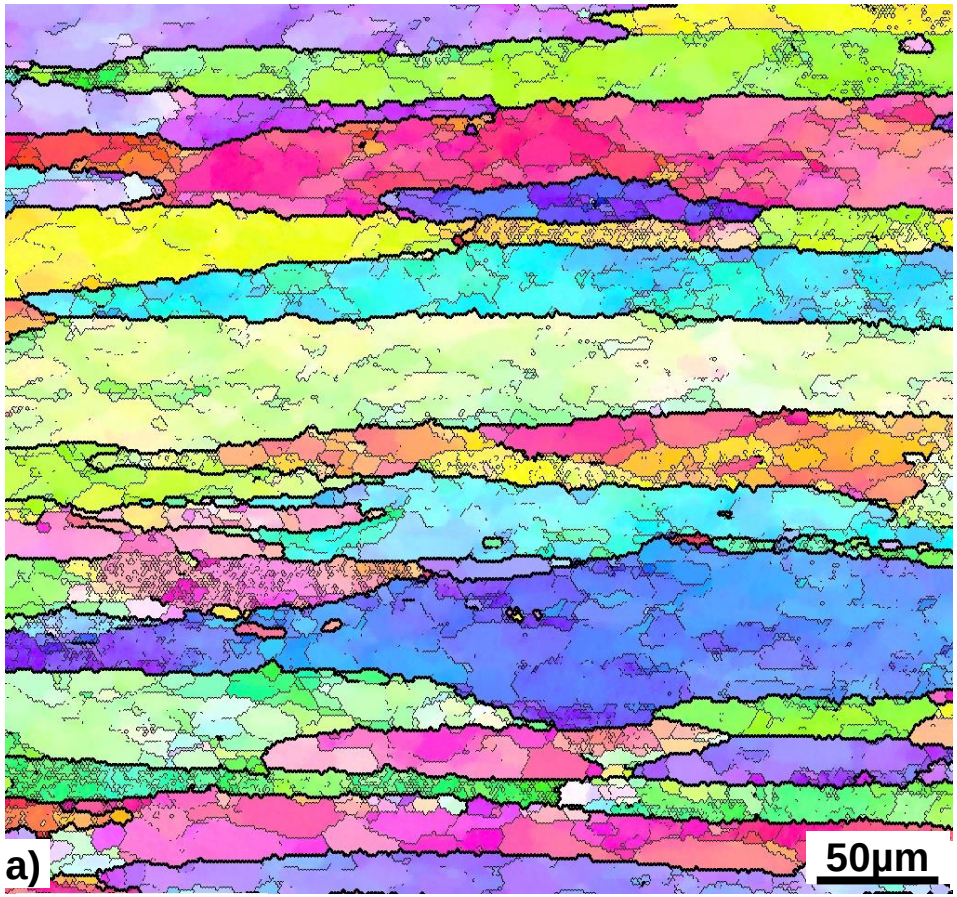
Processing of aluminium alloys: general

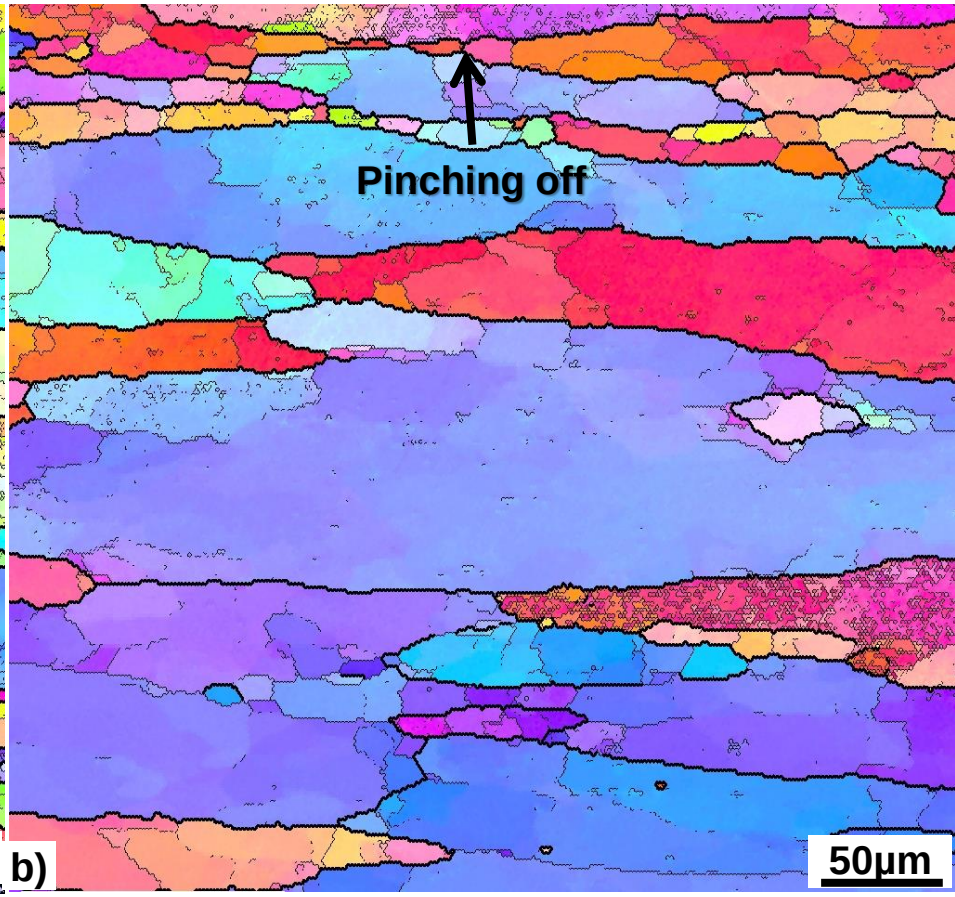


Microstructure of the plate

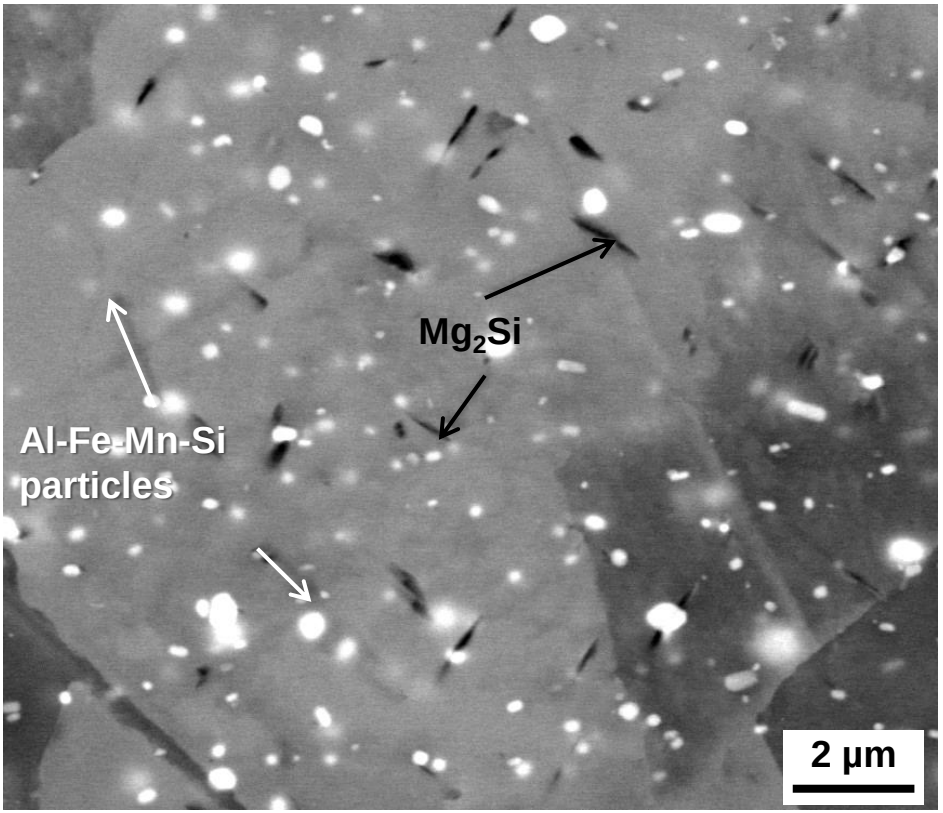


Microstructure by hot rolling

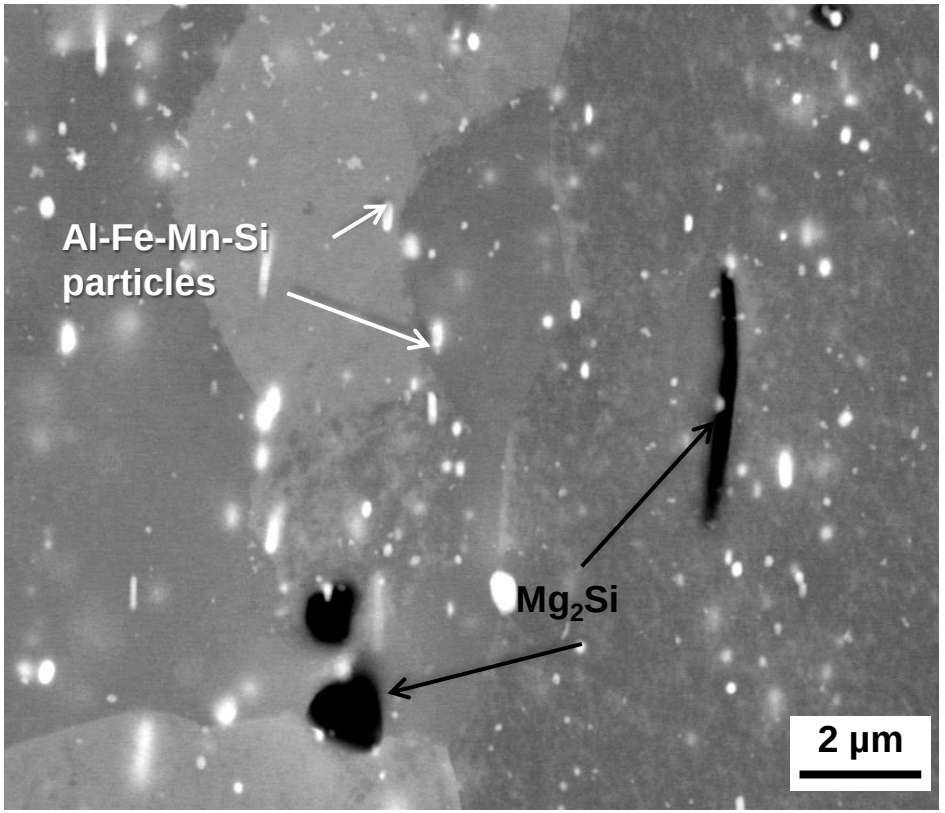




Particles and precipitates

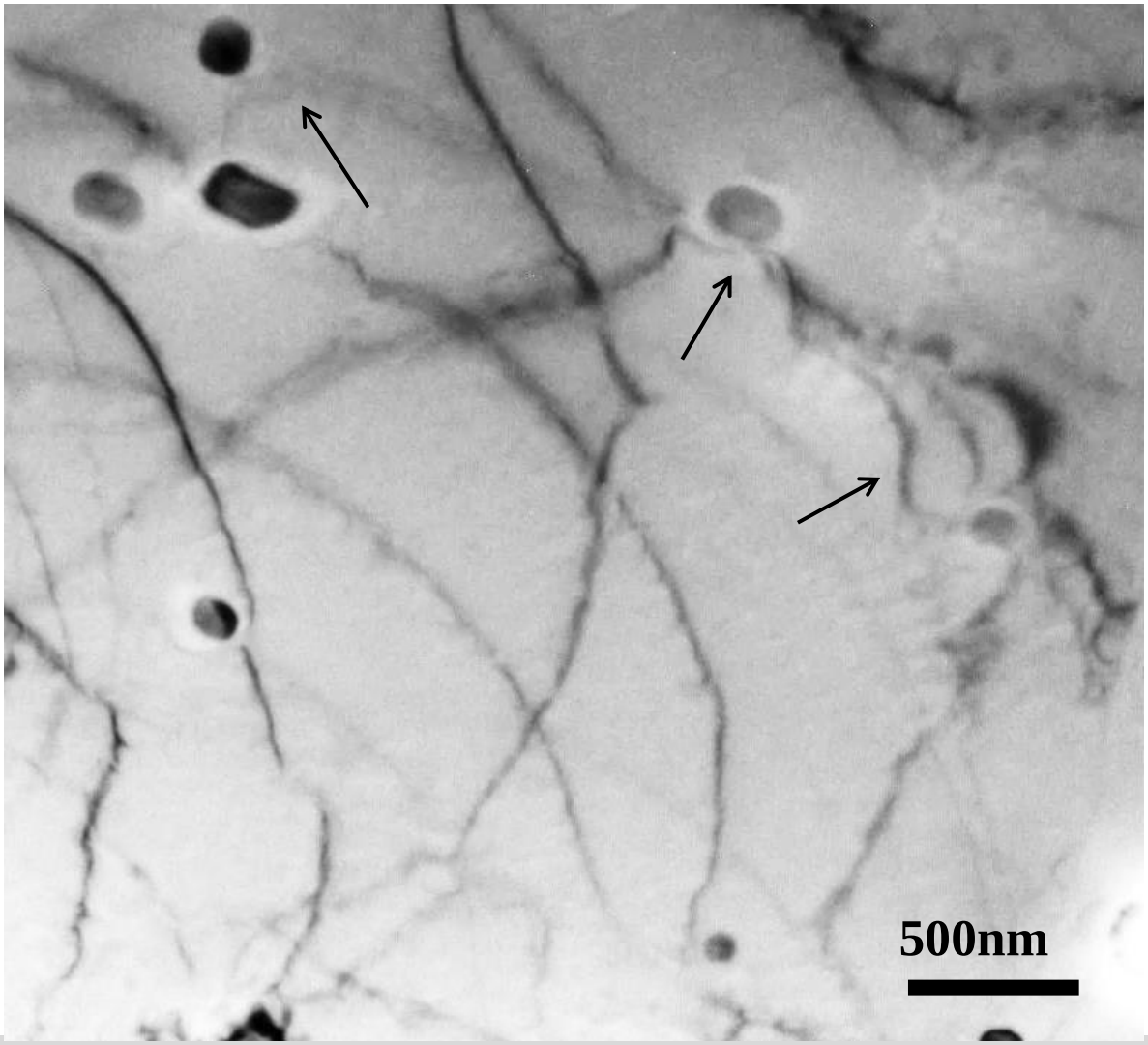


300°C



500°C

Particles – dislocations interaction



Poletti, C., Wójcik, T., Sommitsch, C Metallurgical and Materials Transactions A (2013) Volume 44, Issue 3, pp 1577-1586

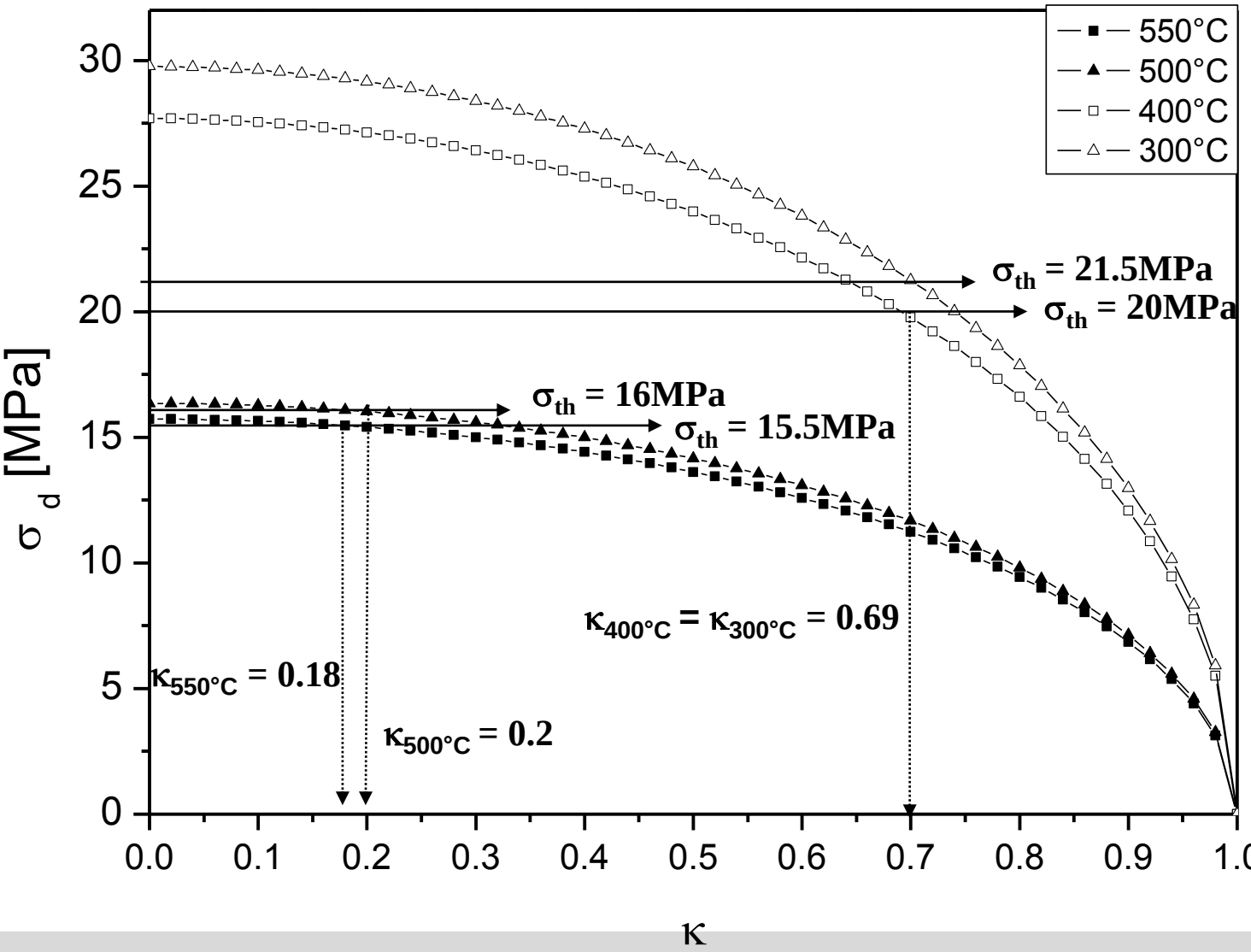
Threshold stress

$$A_{p1}\left(\frac{\sigma}{G}\right)^{n_{p1}} = \dot{\varepsilon}\exp(Q/RT) = Z_p$$

$$A_1 \sinh\left(\alpha_1\left(\frac{\sigma}{G}\right)\right)^{n_1} = \dot{\varepsilon}\exp(Q/RT) = Z$$

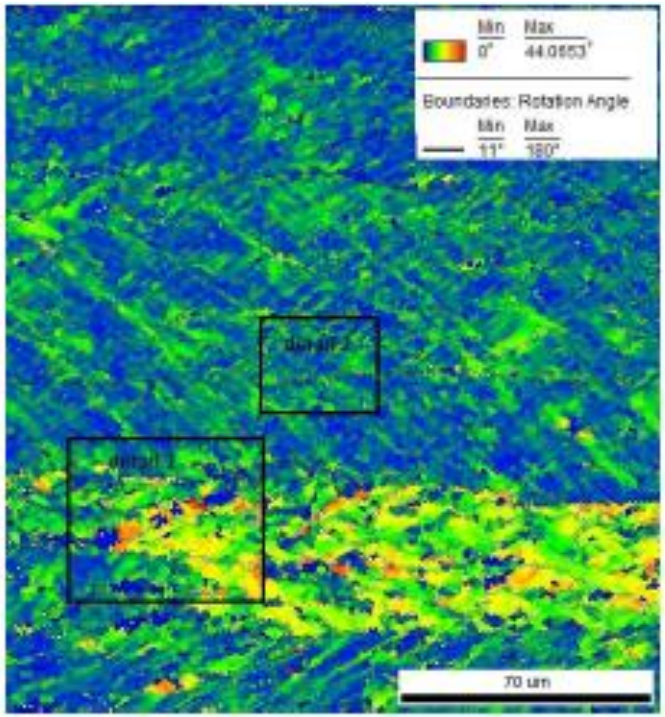
$$A_2 \sinh\left(\alpha\left(\frac{\sigma - \sigma_{th}}{G}\right)\right)^{n} = \dot{\varepsilon}\exp(Q/RT) = Z$$

Detachment stress and relaxation factor

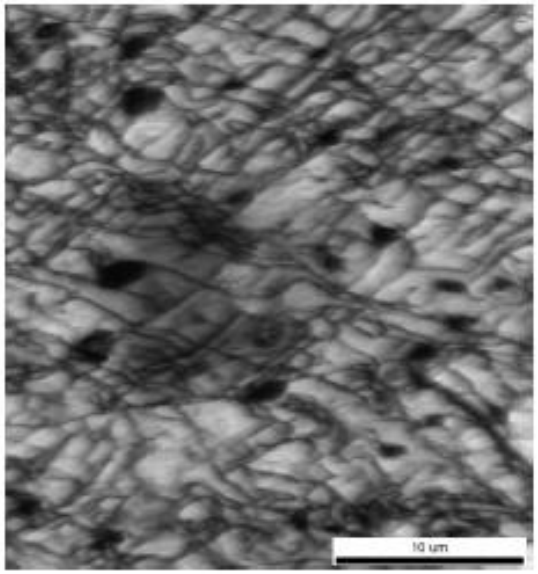


Poletti, C., Wójcik, T., Sommitsch, C Metallurgical and Materials Transactions A (2013) Volume 44, Issue 3, pp 1577-1586

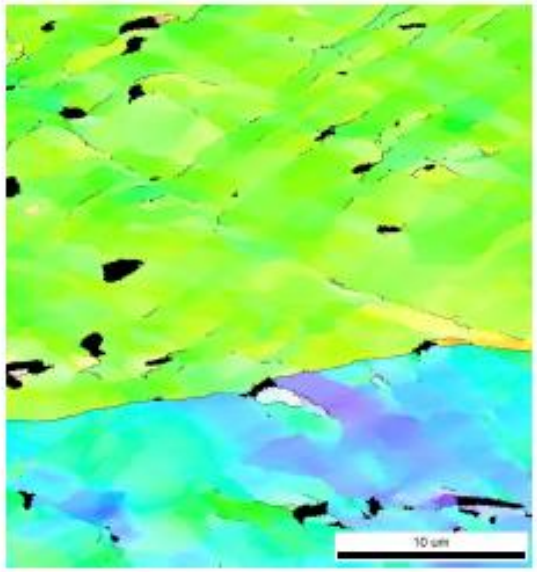
Cold deformation and particles



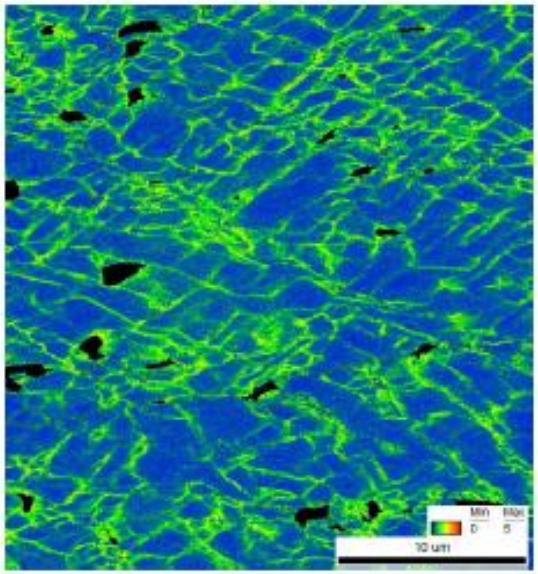
(b) GROD map



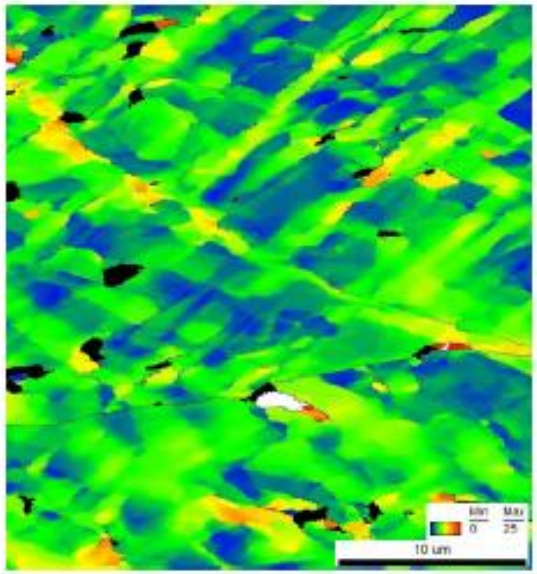
(a) IQ map



(b) IPF map



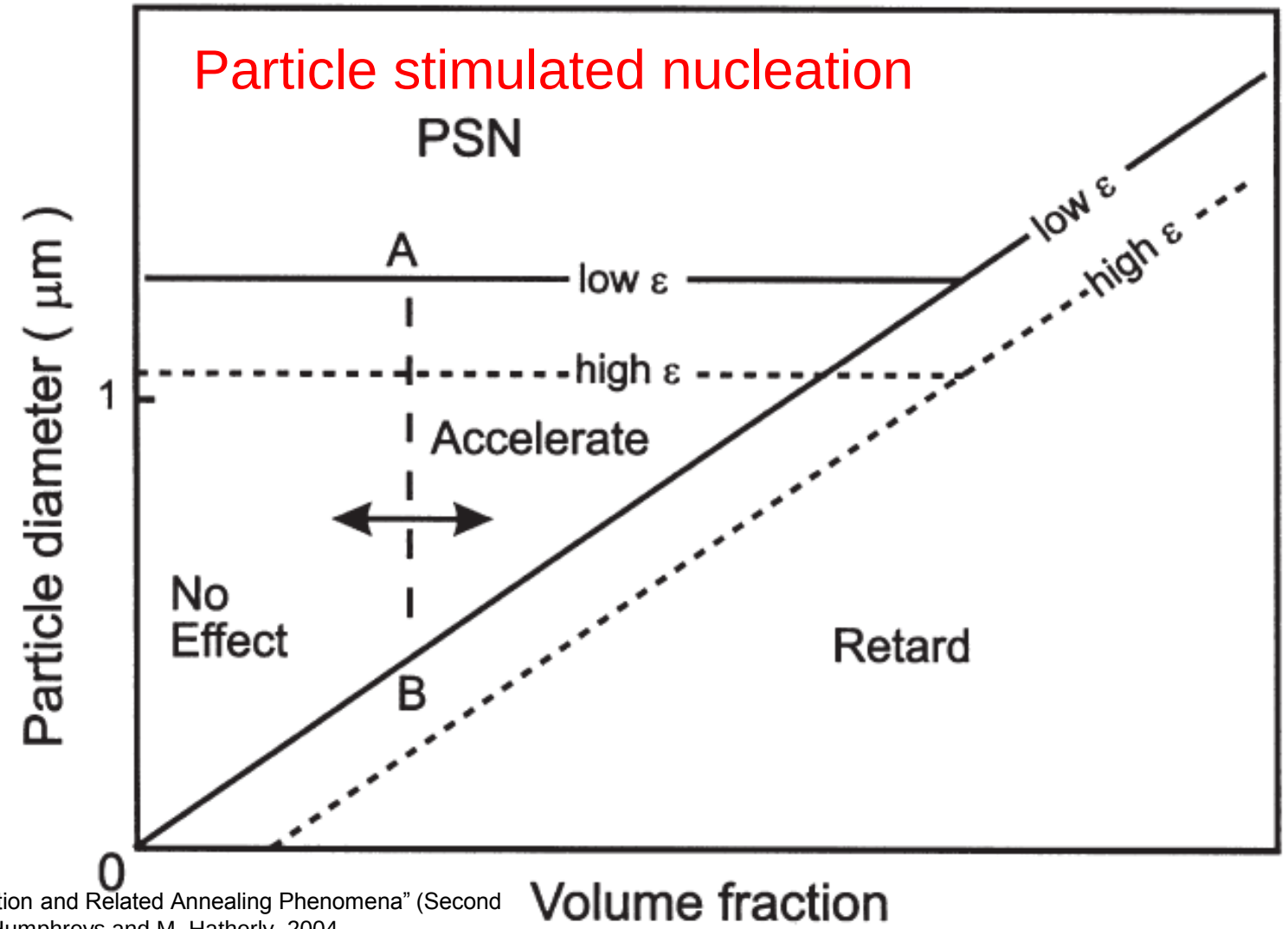
(c) Kernel map



(d) GROD map

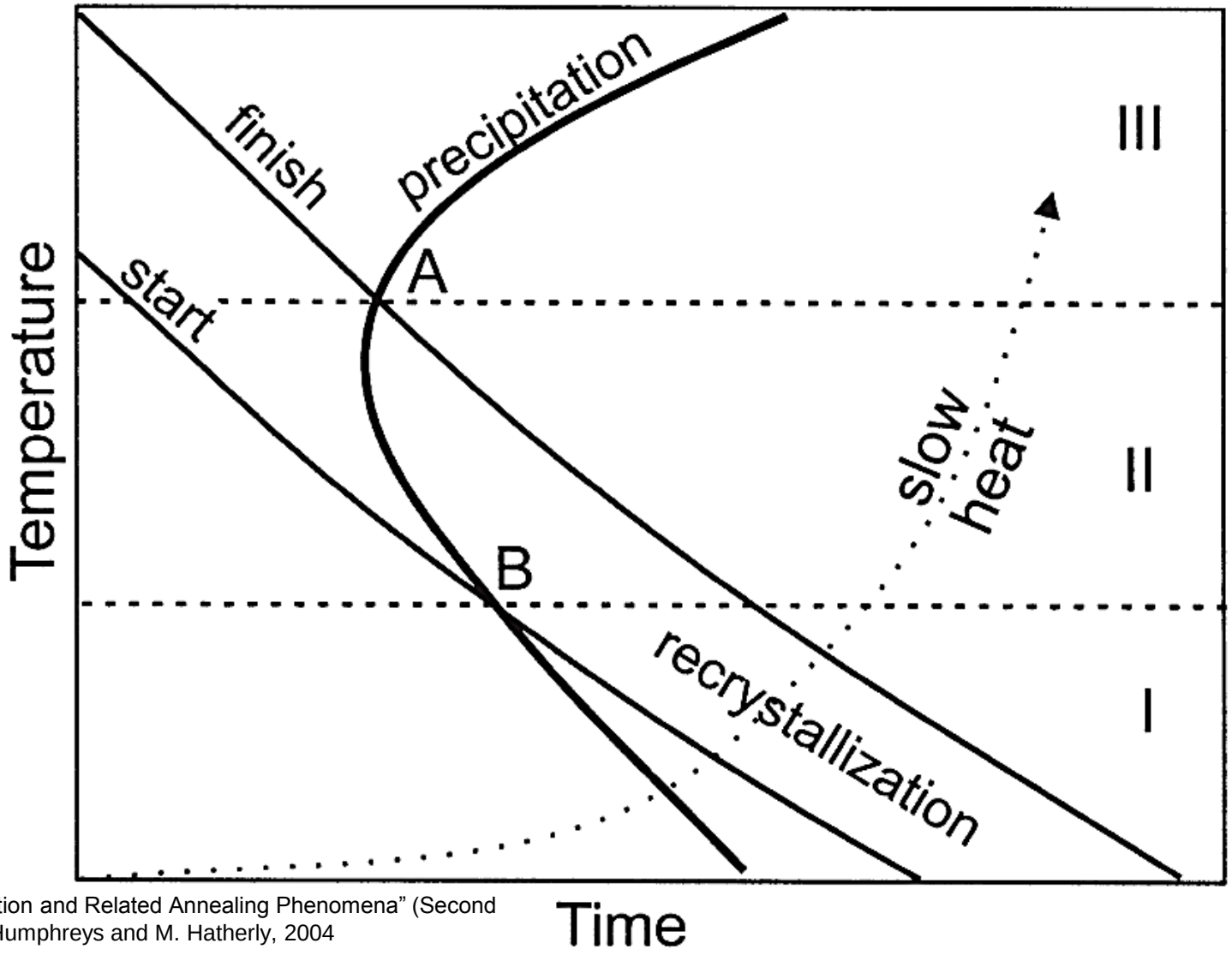
Peter Loidolt. Mater Thesis Tu Graz. 2014

Size of particles and effects on RX



„ Recrystallization and Related Annealing Phenomena" (Second Edition), F.J. Humphreys and M. Hatherly, 2004

Precipitation and recrystallization



„ Recrystallization and Related Annealing Phenomena" (Second Edition), F.J. Humphreys and M. Hatherly, 2004

Outlook

Challenges

To understand, describe and model

- Behaviour of secondary phases during deformation
- Heterogeneities
- Mechanisms during thermomechanical processing
- Overlapping effects → synergetic process

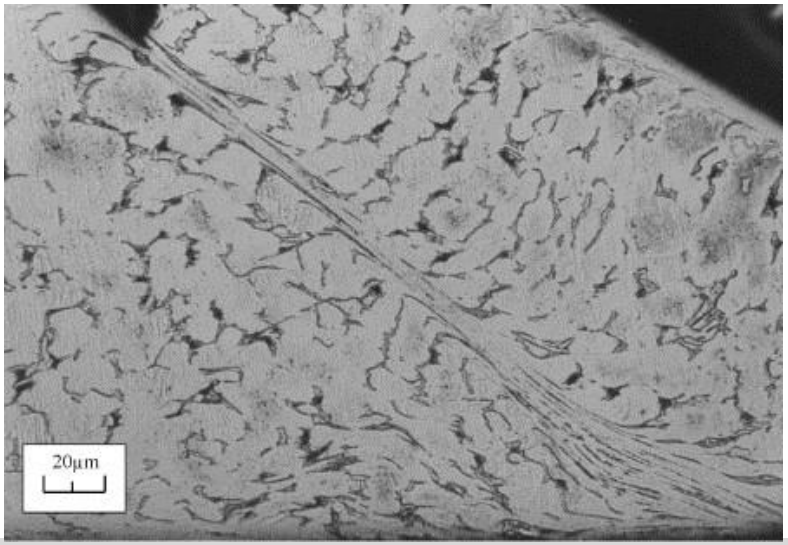
Further considerations: instabilities

i. Tensile instabilities

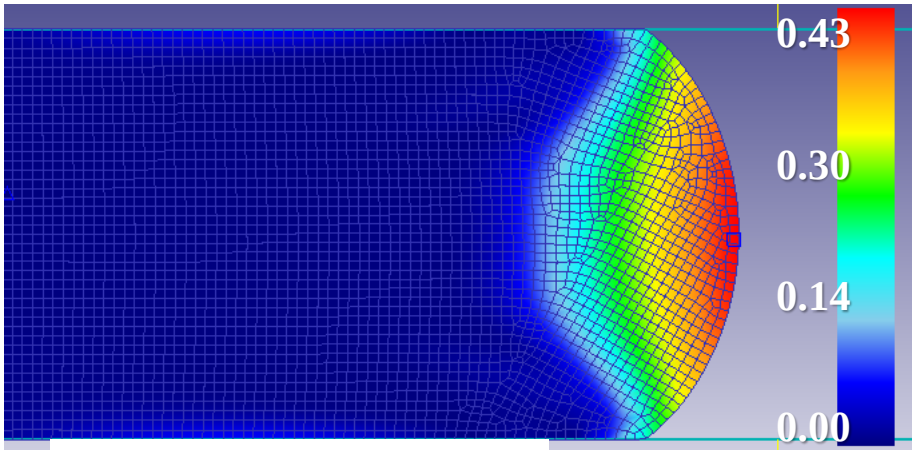
ii. Strain distribution due to friction

iii. Stress softening due to adiabatic flow

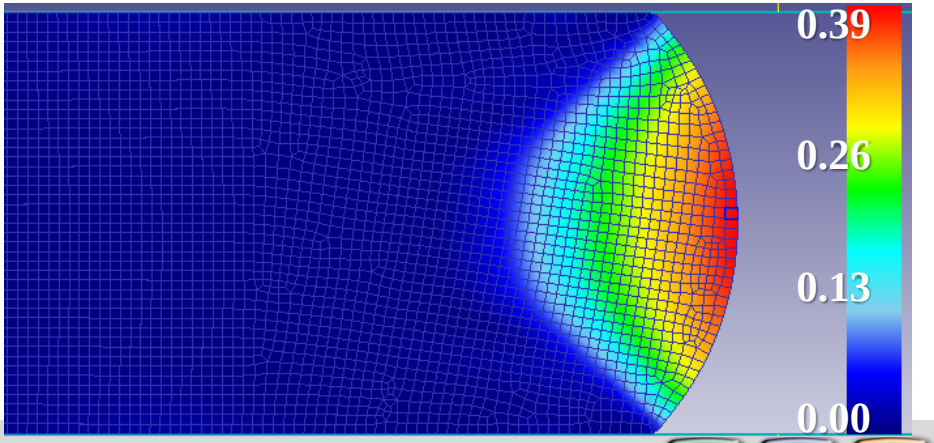
iv. Heat transfer die - workpiece



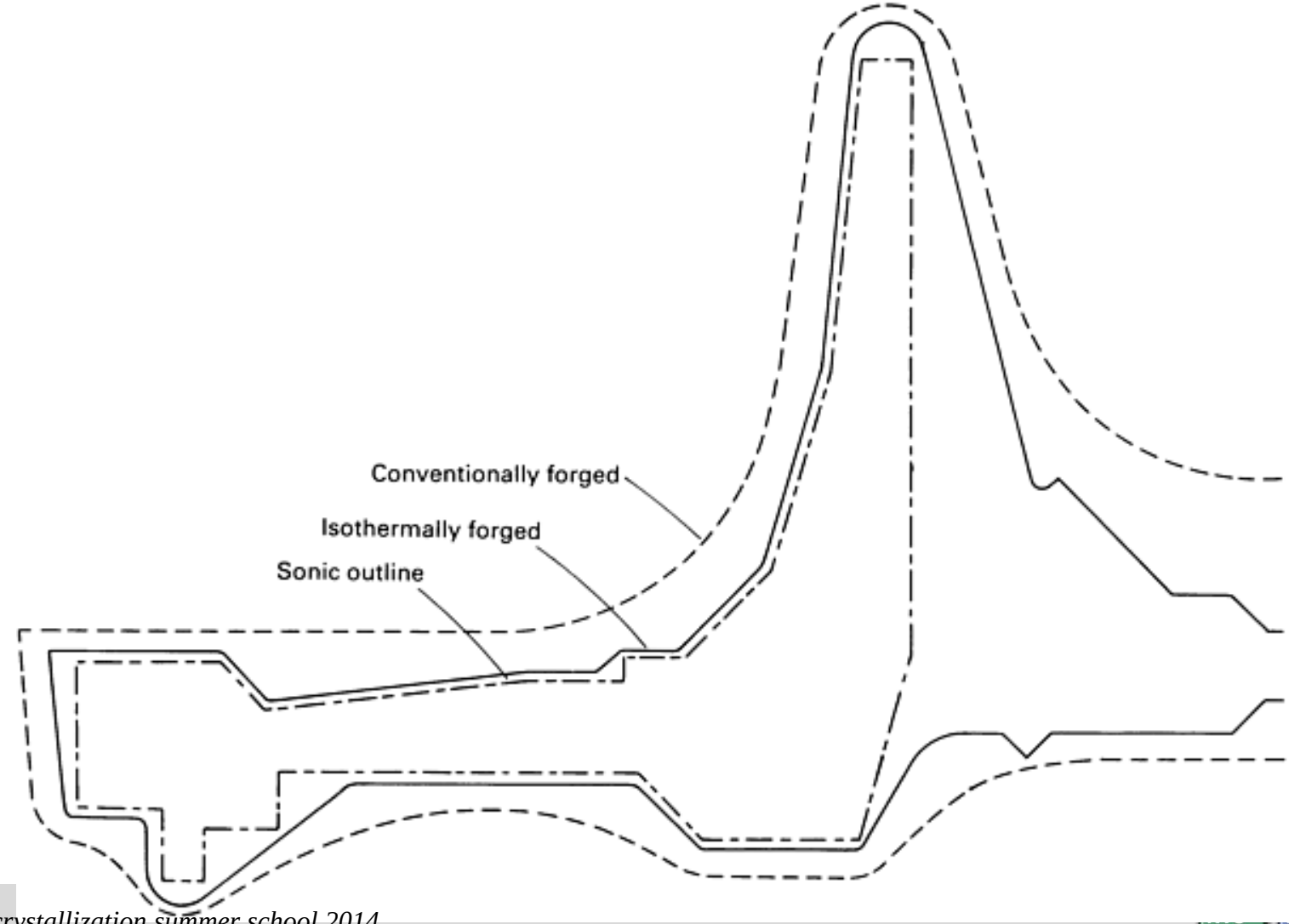
Hot workpiece, cold die



Hot workpiece, hot die



Hot die and isothermal forging



Close die forging