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Plastic Strain and Variant Selection during Diff usional Transformation in Steels

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POSTECH
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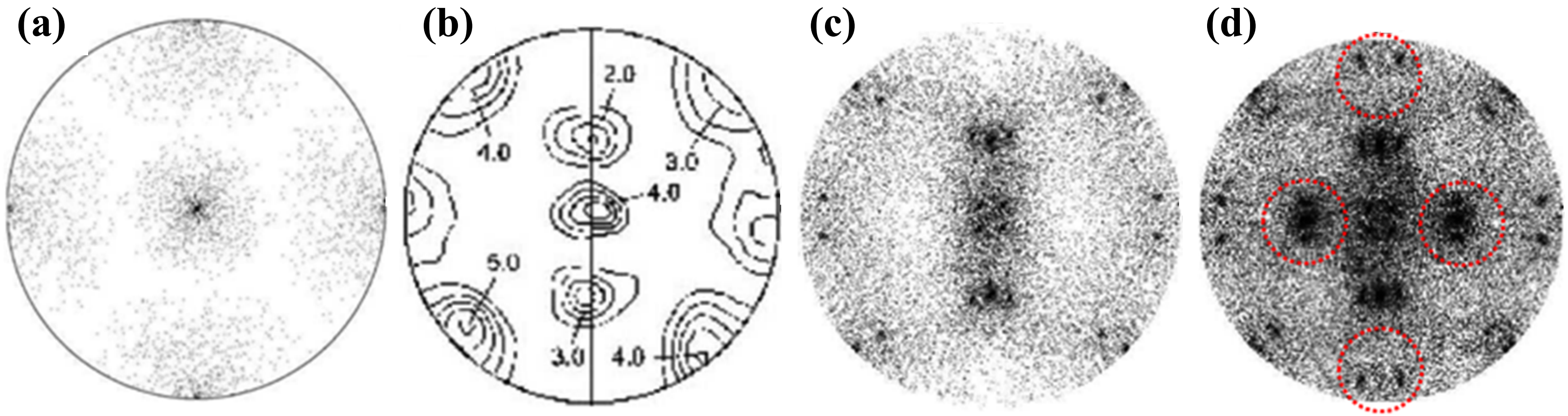
Reviews : *Variant selection in displasive transformation*

The interaction energy U between the stress and the plate of martensite : $U = \sigma_N \zeta + \tau s$

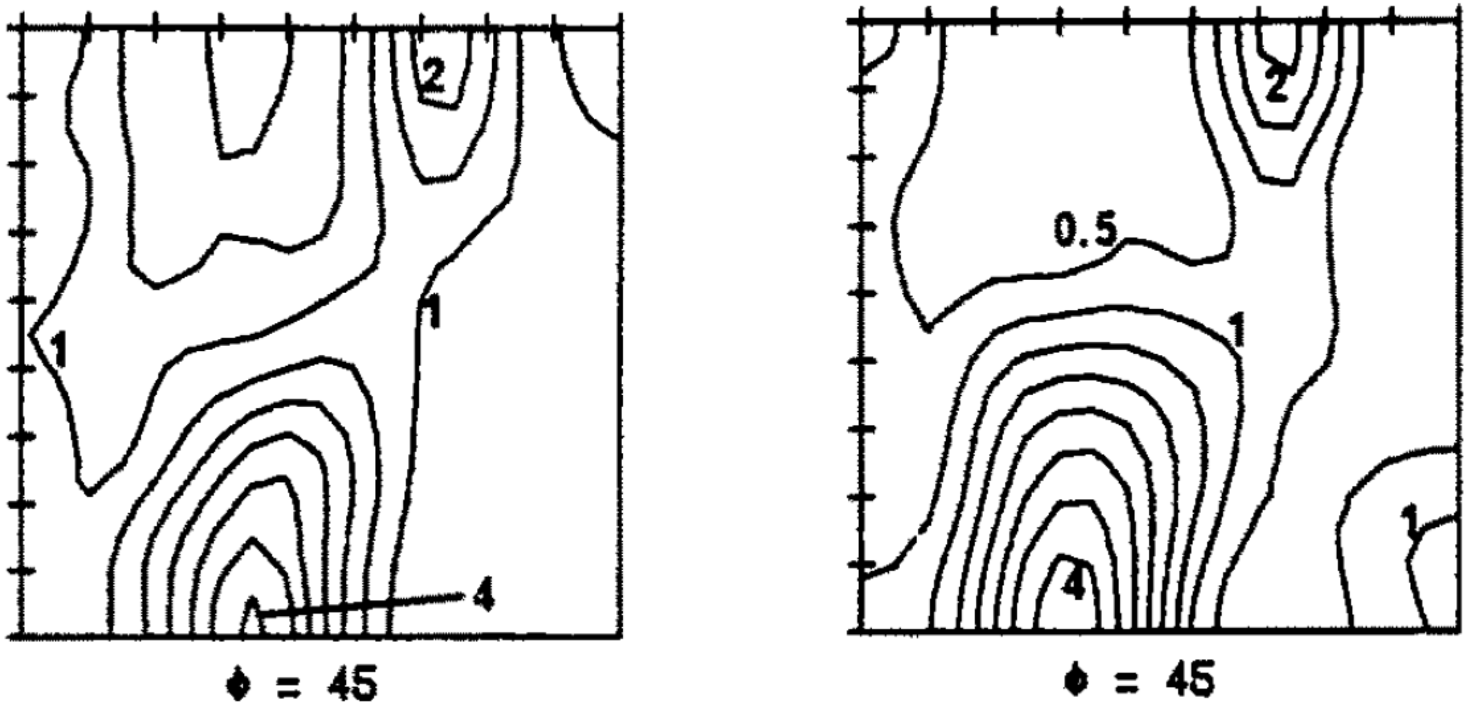


100-pole figure of martensite for the transformation of Cube oriented austenite grains. (b) is the experimental result and (c) shows favored variants of martensite and (d) show s all possible variants.*

- Shape deformation model (J.R. Pater et al., 1953) : Maximum work (Stress-Displacive shear)
- Active slip system model (J. Nutting et al, 1967) : Maximum resolved shear stress
- Bain strain model (Furubayashi et al., 1988) : Maximum work (Stress-Bain strain)

* Scripta Materialia 55 (2006) 779-781

Reviews : *Variant selection in reconstructive transformation*

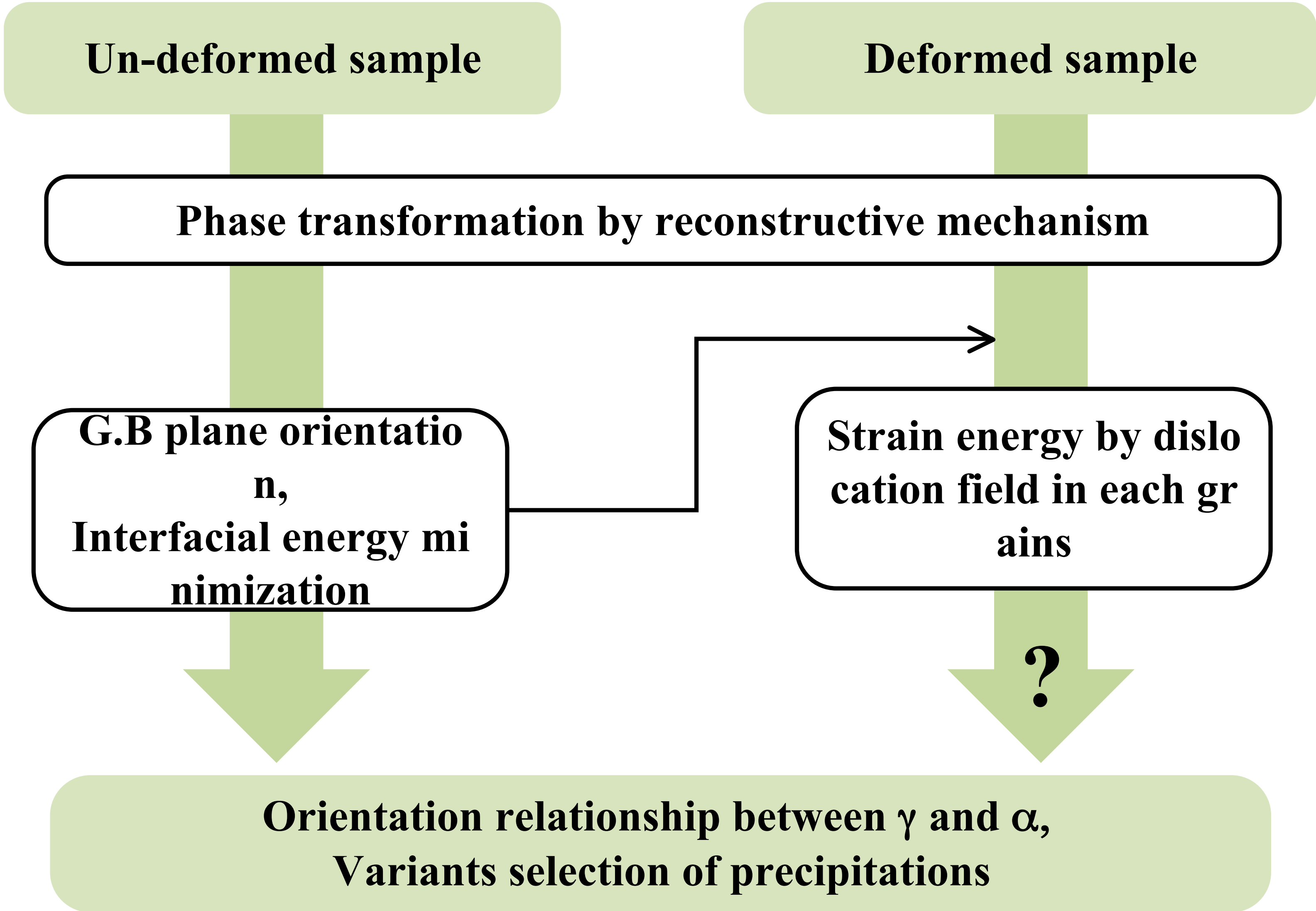


(a) is ODF(Φ=45°) of ferrite obtained in hot rolled 0.12C-1.47Mn-0.05Nb steel.
(b) was calculated result from KS orientation relationship*

‘Complicated metallurgical variables’ (H. J. Bunge, 1983)

*Acta Metall. 24 (1976), 159

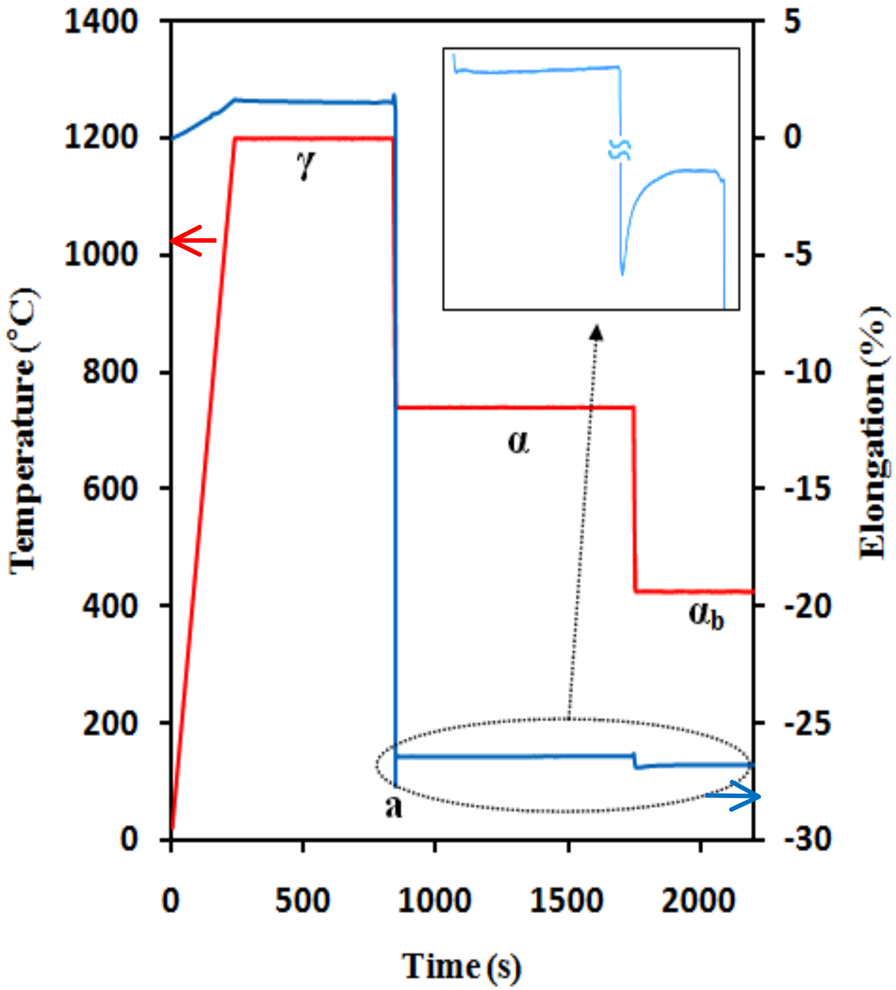
Research Aim



Experimental procedures

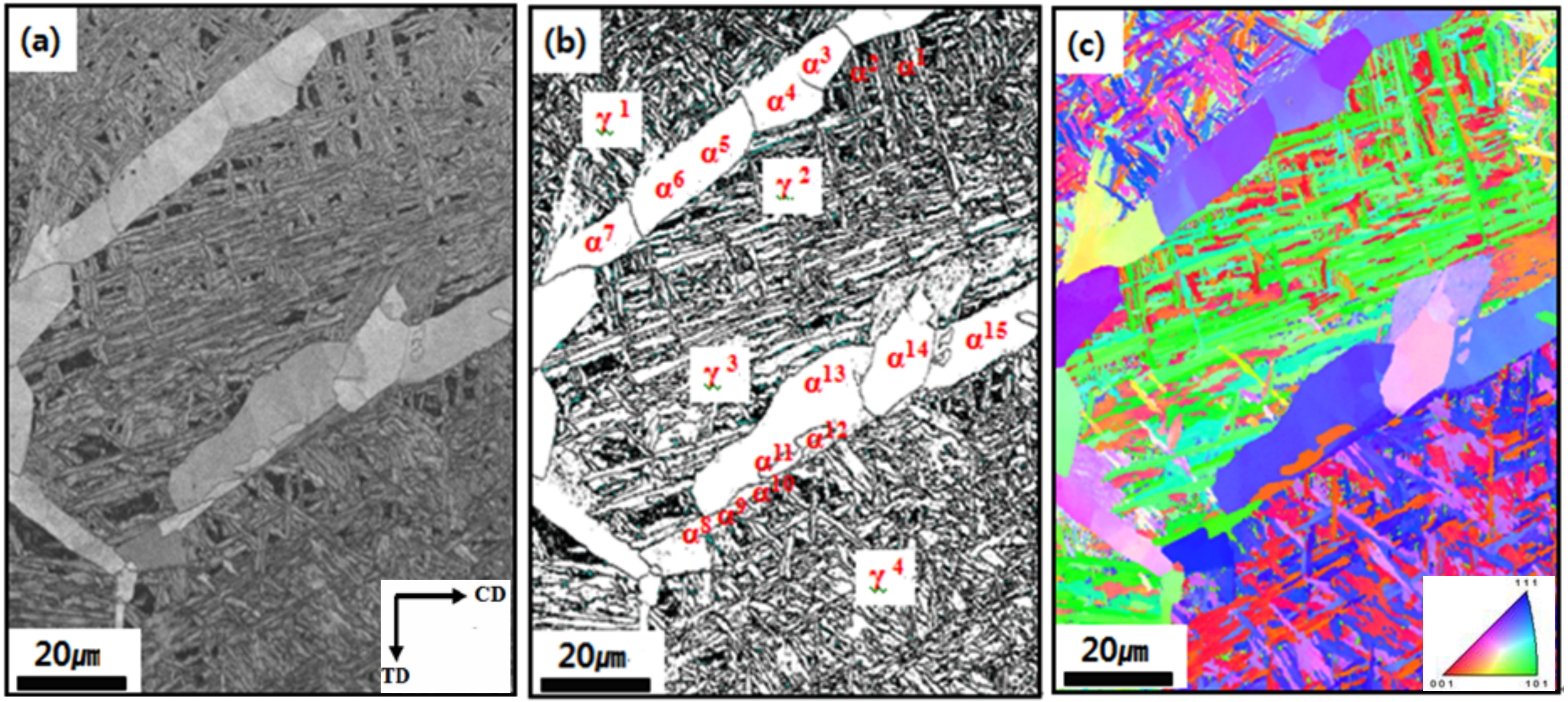
(in wt.%)

C	Si	Mn	Al	Fe
0.595	0.98	1.01	1.50	Balance



- BHAR DIL-805
- EBSD : Scanning Electron Microscope
  ZEISS SUPRA™ (Step size : 0.2㎛)
- Software : OIM data collection, analysis 5. 0

Results : *Un-deformed sample*

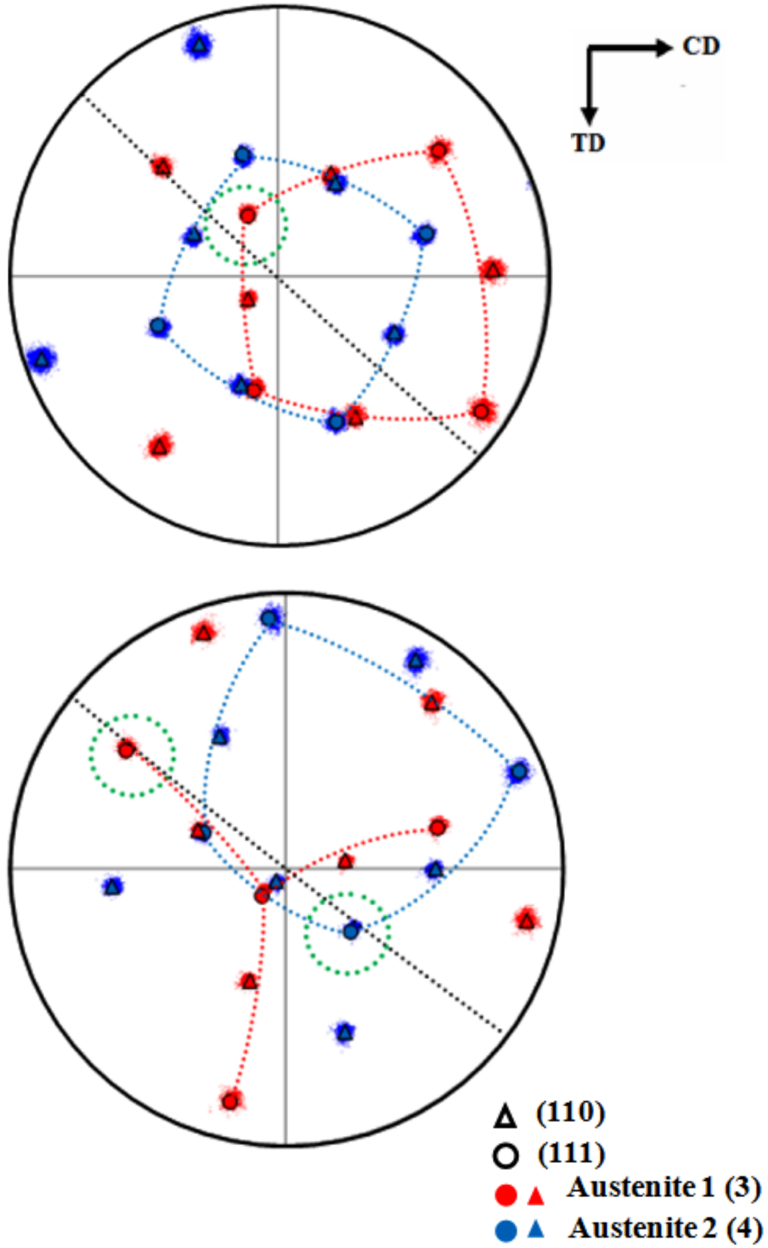


- $\alpha_1 \sim \alpha_7$: group 1 (precipitated at $\gamma_1/\ \gamma_2$ grain boundary)
- $\alpha_8 \sim \alpha_{15}$: group 2 (precipitated at $\gamma_3/\ \gamma_4$ grain boundary)

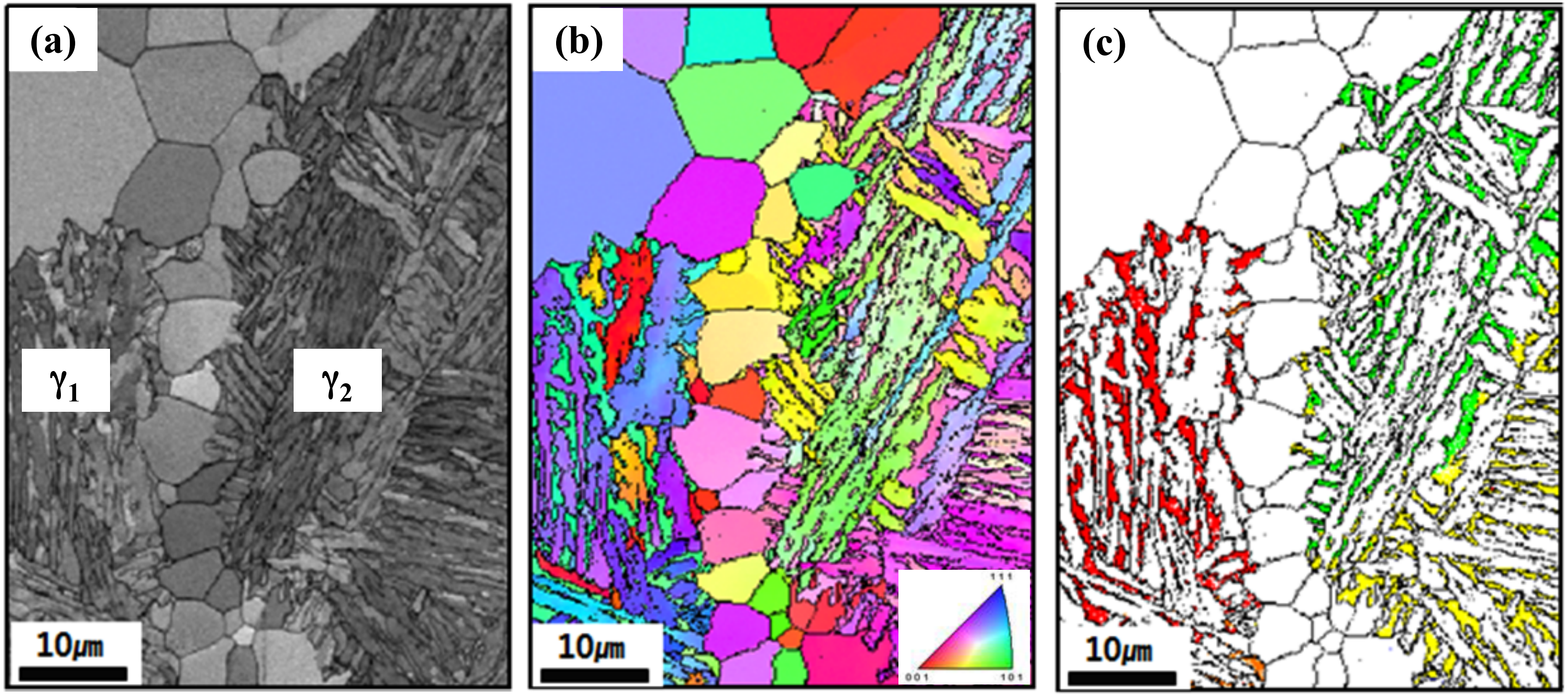
IQ map (a), Phase map (b) and Inverse pole figure (c) of scanned area

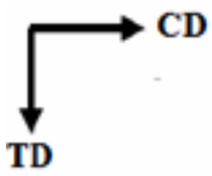
Results : *Un-deformed sample*

Grain	Deviation angle from KS relationship	
Group1	With respect to γ^1	With respect to γ^2
α^1	**1.73°**	17.3°
α^2	**1.50°**	18.3°
α^3	**4.37°**	18.4°
α^4	**2.05°**	19.8°
α^5	**3.30°**	18.1°
α^6	**2.13°**	19.3°
α^7	**4.89°**	19.8°
γ^1		41.7°
γ^2	41.7°	
Group2	With respect to γ^3	With respect to γ^4
α^8	27.6°	**7.9°**
α^9	**2.02°**	27.8°
α^{10}	28.2°	**2.19°**
α^{11}	28.3°	**2.87°**
α^{12}	28.1°	**1.74°**
α^{13}	17.5°	**1.22°**
α^{14}	**4.30°**	25.3°
α^{15}	13.4°	**6.24°**
γ^3	38.0°	
γ^4		38.0°



Results : *Deformed sample*

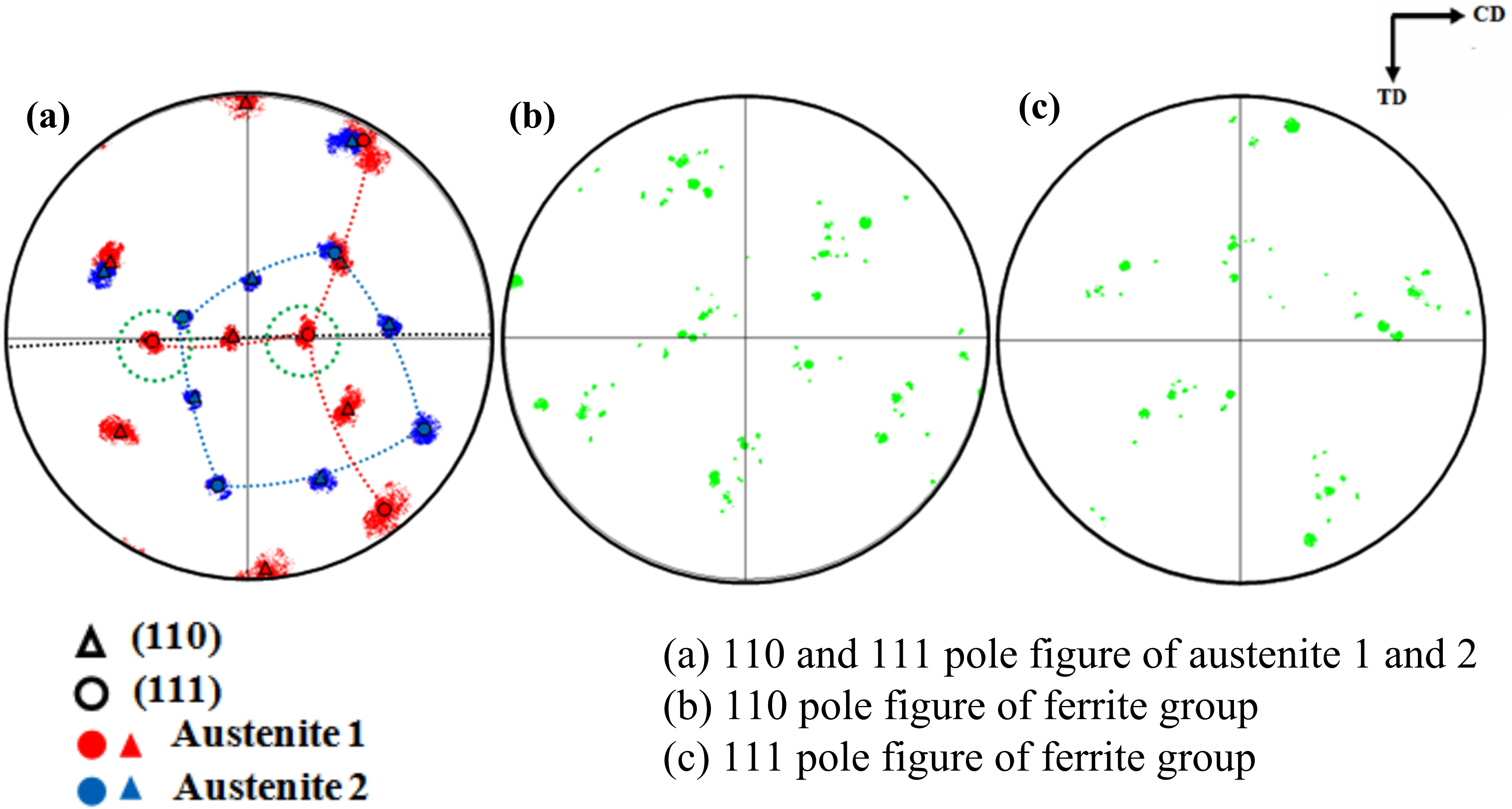




Min	Max	Total Fraction	Partition Fraction
2.28626	2.56353	0.000	0.000
2.56353	2.84081	0.026	0.026
2.84081	3.11808	0.031	0.031
3.11808	3.39536	0.001	0.001
3.39536	3.67263	0.033	0.033

IQ image (a), Inverse pole figure(b) and Taylor factor map (c)

Results : *Deformed sample*

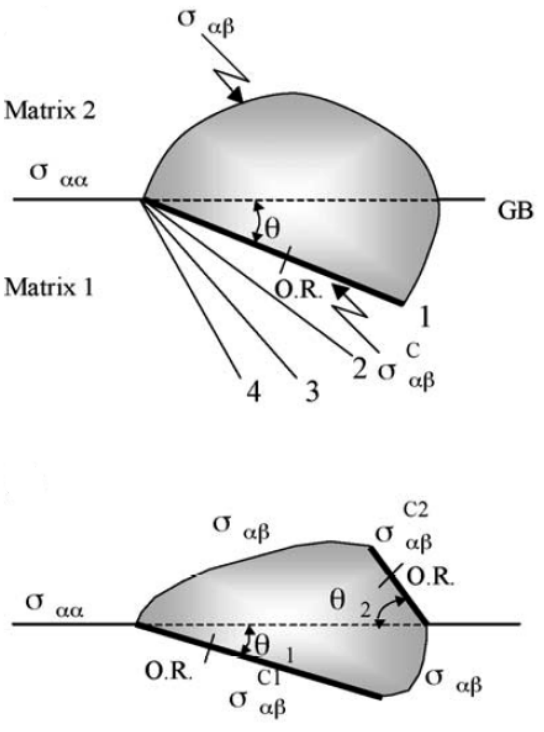


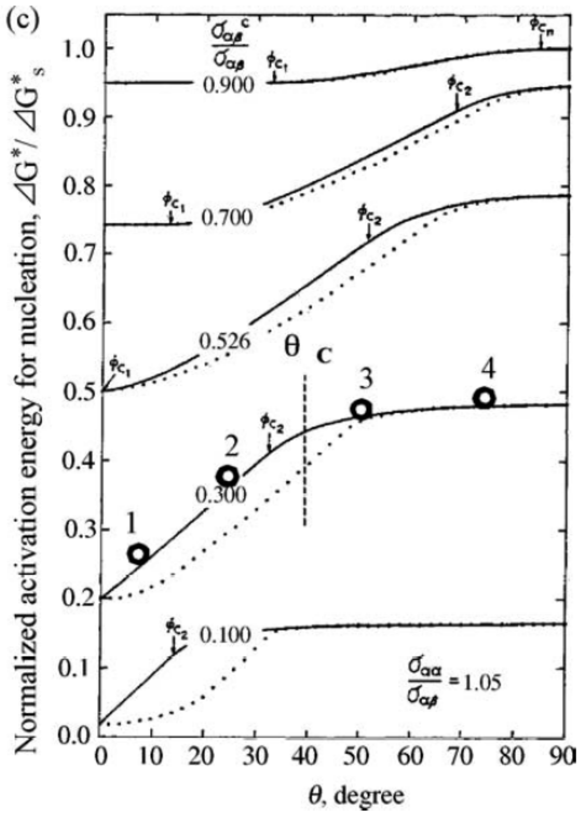
(a) 110 and 111 pole figure of austenite 1 and 2
(b) 110 pole figure of ferrite group
(c) 111 pole figure of ferrite group

{111} of γ_1 // Grain boundary plane

All ferrite has KS-type with γ_2

Discussion : *Grain boundary plane orientation*





Activation energy according to the tilt angle (ɵ) for nucleation (*)

$$\Delta G^* = \frac{-1}{4\Delta G_V}\frac{E^2}{V}$$

ΔG_V : volume free energy change

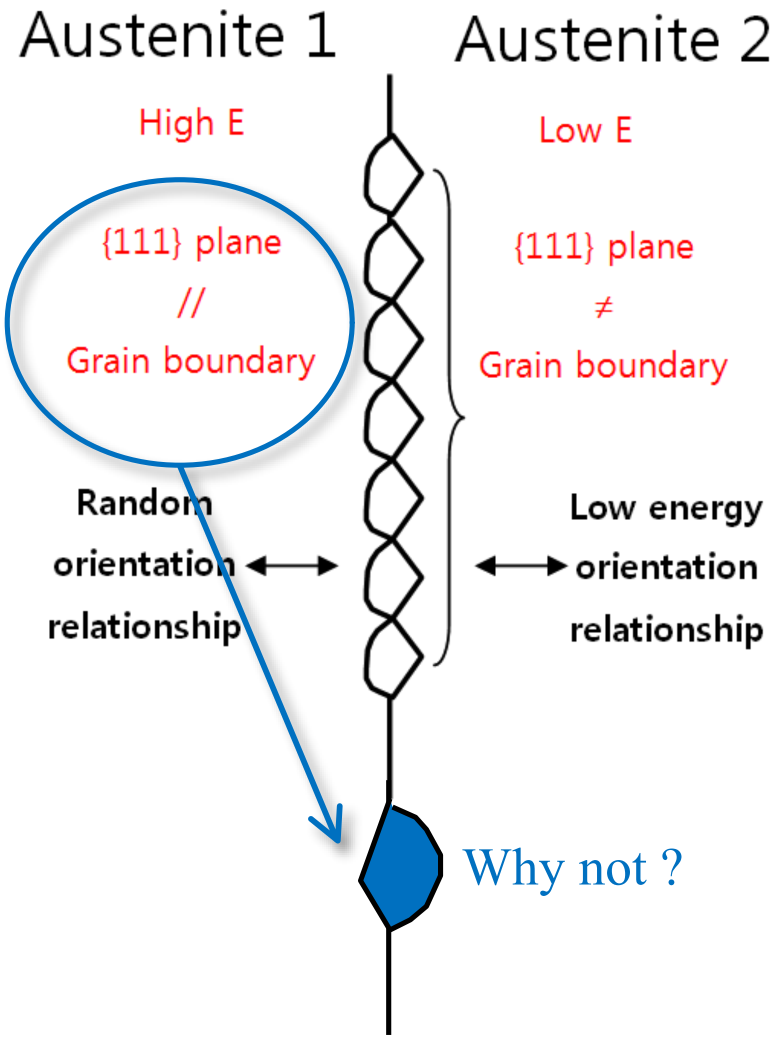
E : changes of an interface energy

V : volume of the critical nucleus

Low energy interface (facetted) // Matrix grain boundary

* Acta metal. 23:799, 1979

Discussion : *Dominant factor in strained sample*



Case I : 'Nucleation selection' dominant

$$\Delta G = -\frac{4\pi}{3} r^3 (\Delta G_v + W) + 4\pi r^2 \sigma_{\gamma\alpha}$$

$$\Delta G^* = \frac{\Gamma \sigma_{\gamma\alpha^3}}{(\Delta G_v + W)^2}$$

Benefit by Strain E ↑ >> Loss of Interfacial E↑

→ Ferrite should have KS with γ_1

(Austenite free energy increase : $\gamma_1 > \gamma_2$)

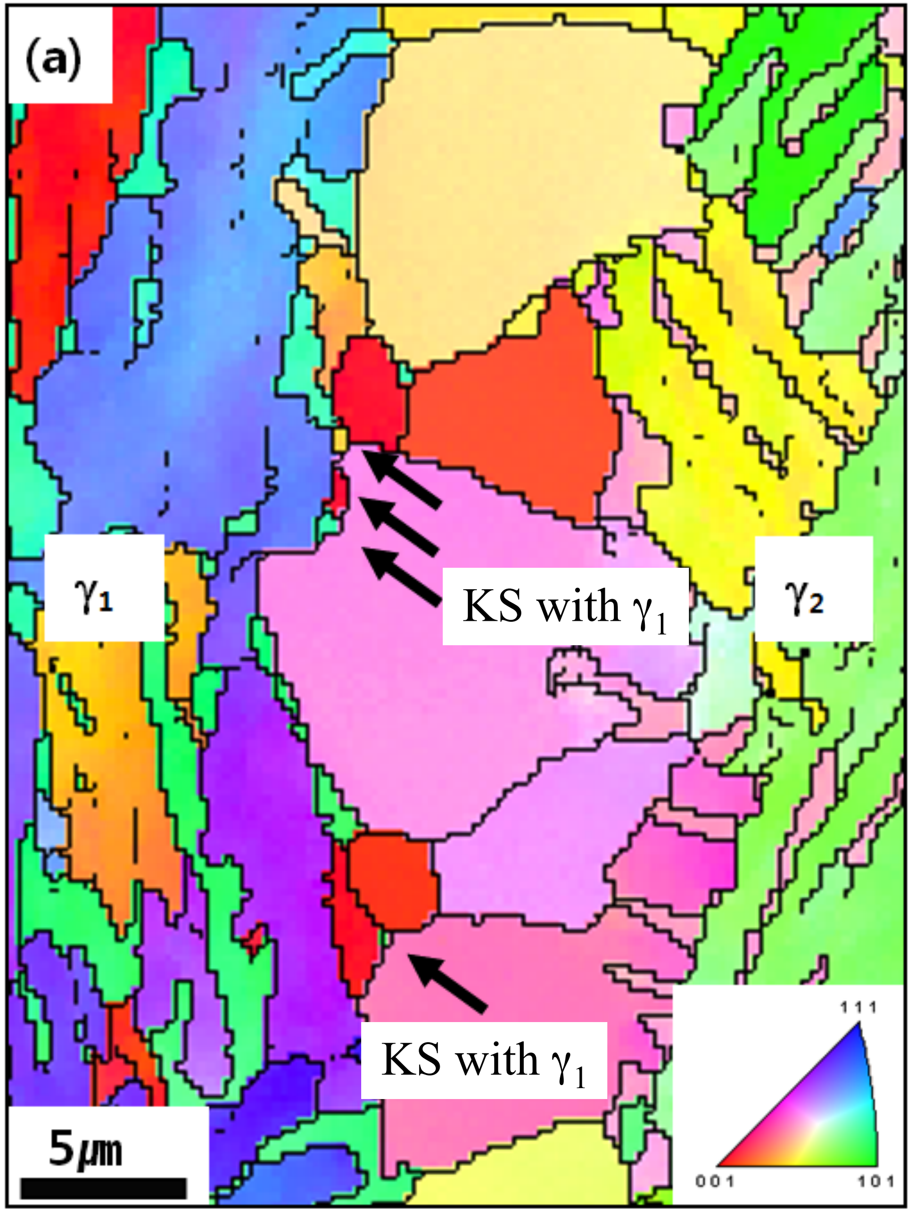
Case II : 'Growth selection' dominant

Existence of very small ferrite which have KS-type with γ_1

→ All possible nuclei conditions in early stage of nucleation

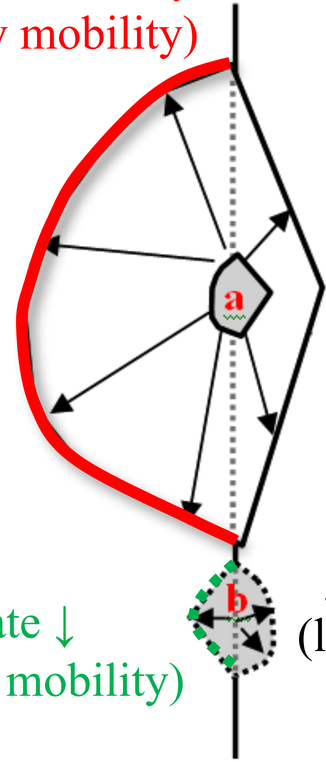
At high energy boundaries and incoherent boundaries when $\dfrac{\Delta G_s^1 - \Delta G_s^2}{\overline{\Delta G_s}} \gg 0$

Discussion : *Growth selection*



Case (b) is more advantageous in activation m inimization, however !

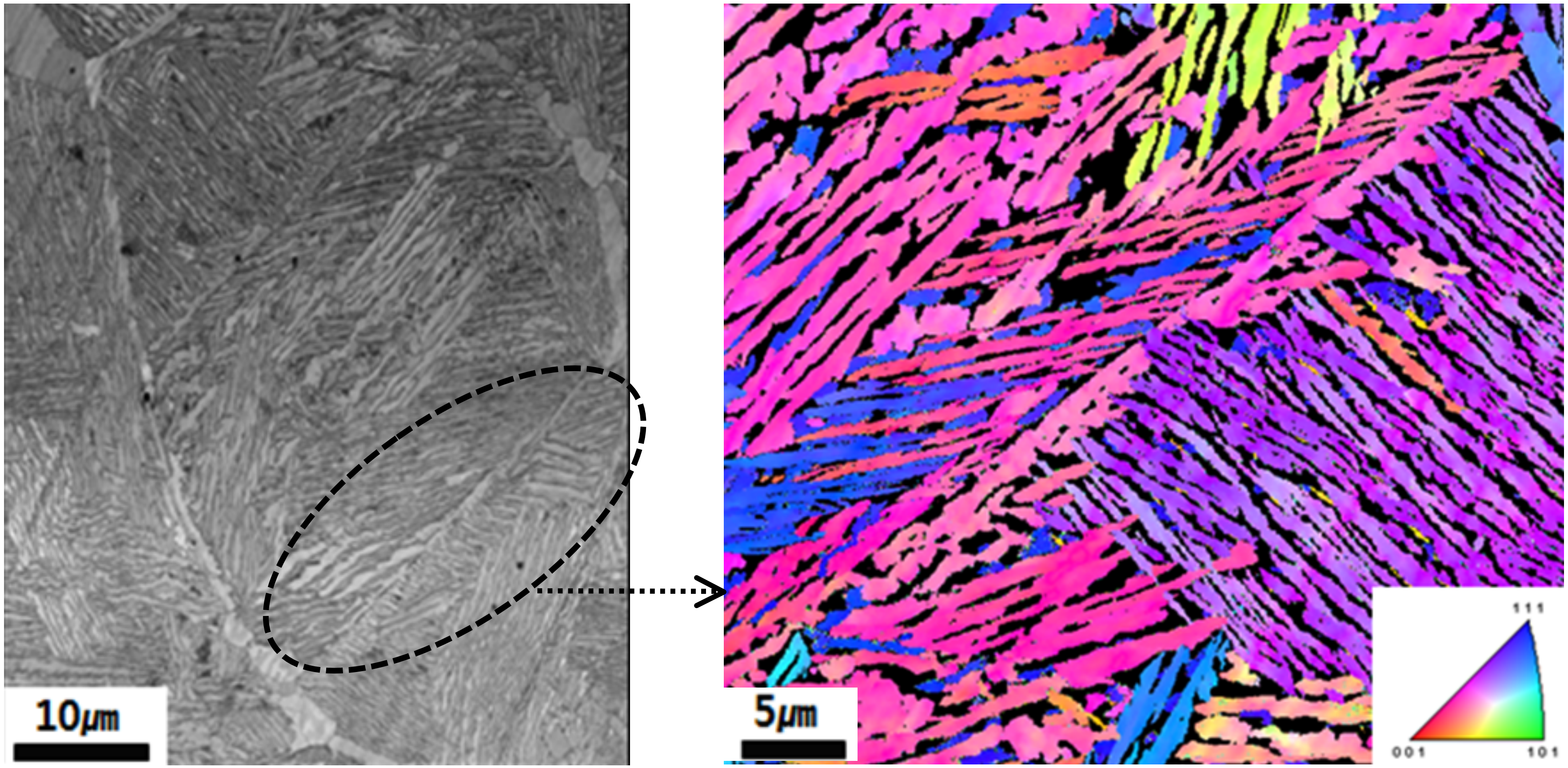
growth rate ↑ ↑
(high dislocation density, high boundary mobility)



growth rate ↓
(low boundary mobility)

growth rate ↓
(low dislocation density)

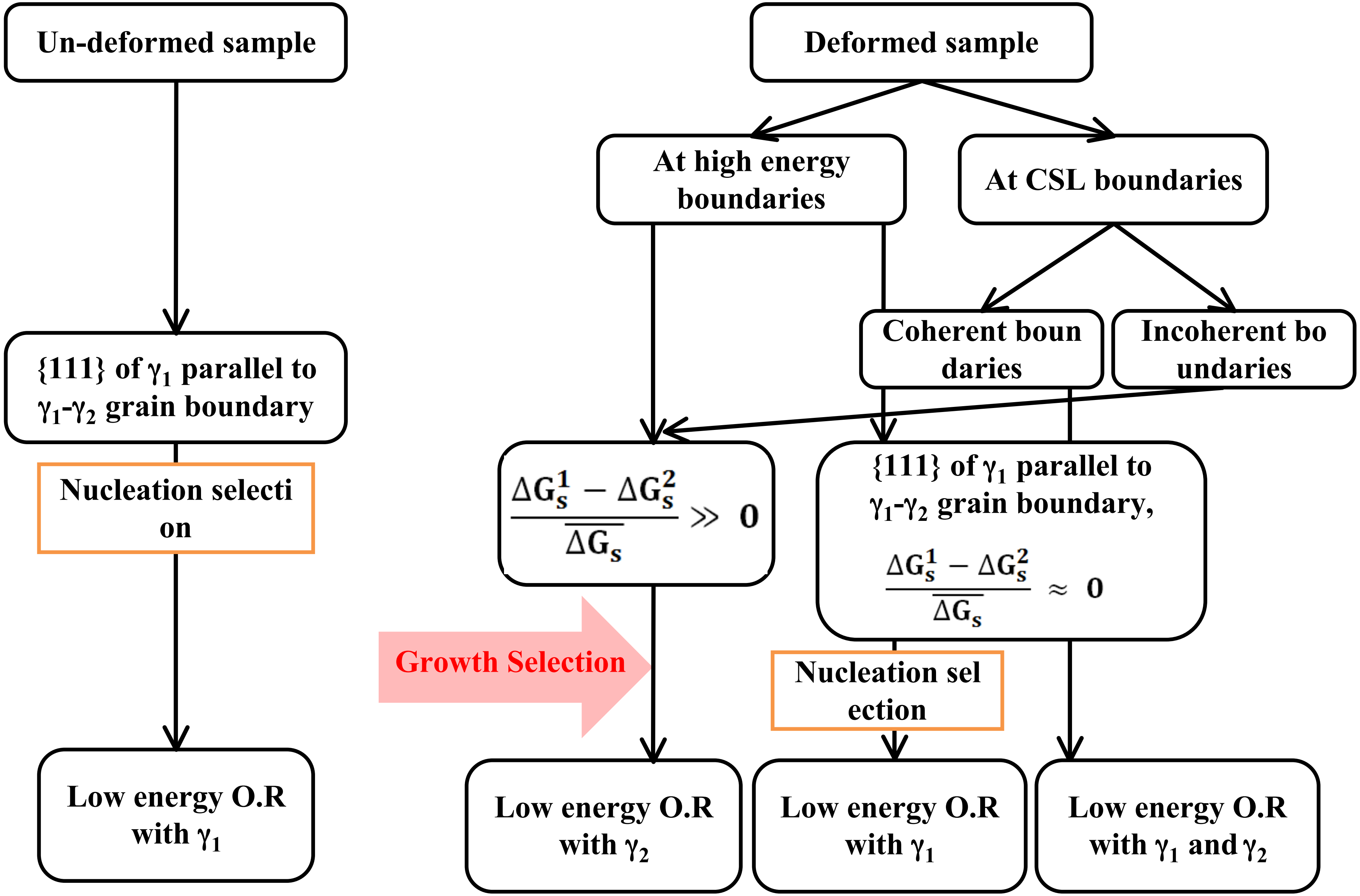
Discussion : *Growth selection*



- ‘Double orientation relationship’ irrespective of Taylor factor
- γ/γ boundary E ↓ (Very stable)
- Boundary mobility ↓ (Both semi-coherent boundaries)

→ Invisible difference in growth rate between both sides

Summary



Un-deformed sample
{111} of γ_1 parallel to γ_1-γ_2 grain boundary
Nucleation selecti on
Low energy O.R with γ_1
Deformed sample
At high energy boundaries
At CSL boundaries
Coherent boun daries
Incoherent bo undaries
$\frac{\Delta G_s^1 - \Delta G_s^2}{\overline{\Delta G_s}} \gg 0$
{111} of γ_1 parallel to γ_1-γ_2 grain boundary,
$\frac{\Delta G_s^1 - \Delta G_s^2}{\overline{\Delta G_s}} \approx 0$
Growth Selection
Nucleation sel ection
Low energy O.R with γ_2
Low energy O.R with γ_1
Low energy O.R with γ_1 and γ_2

Thank you for your listening !