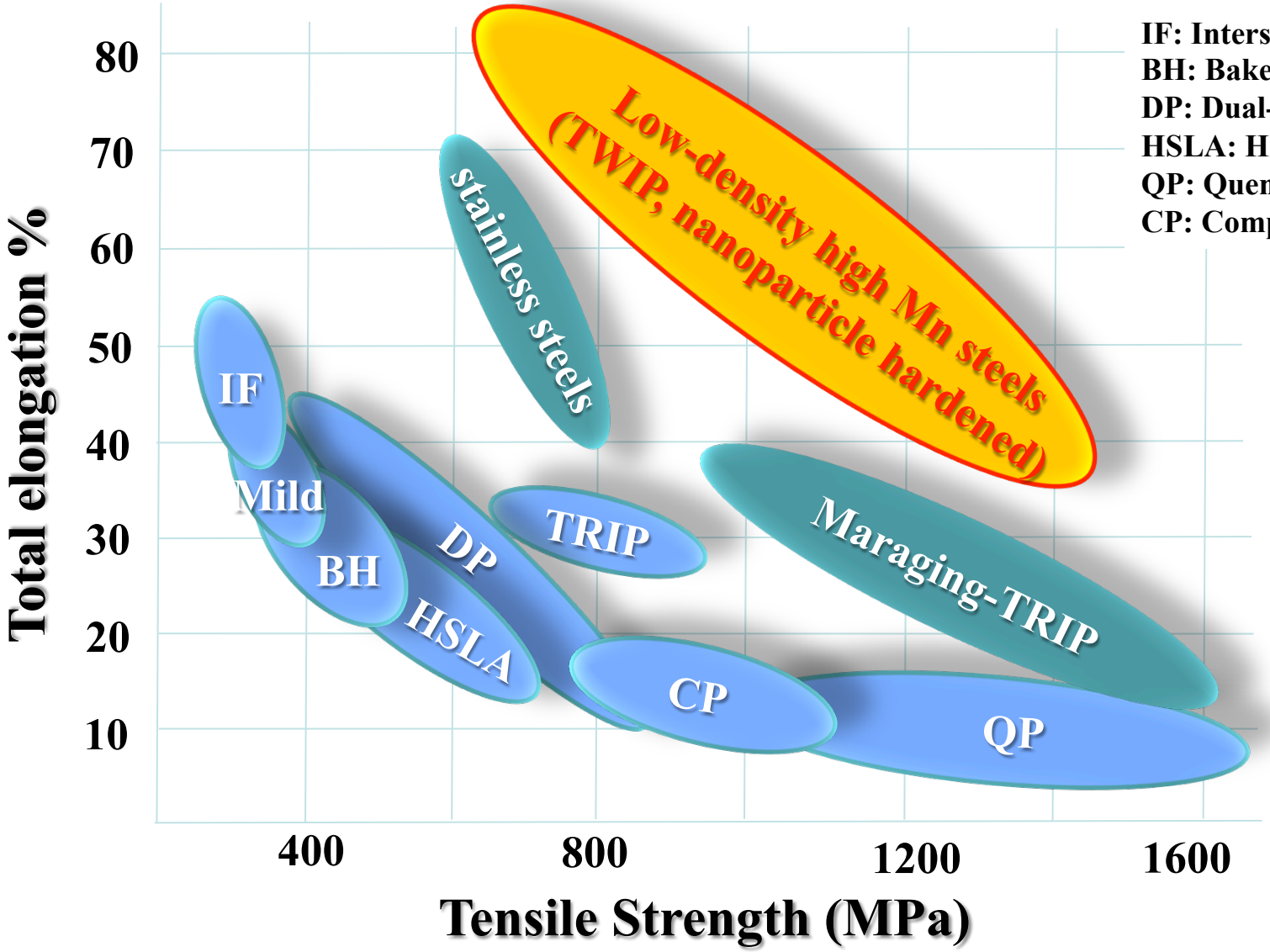
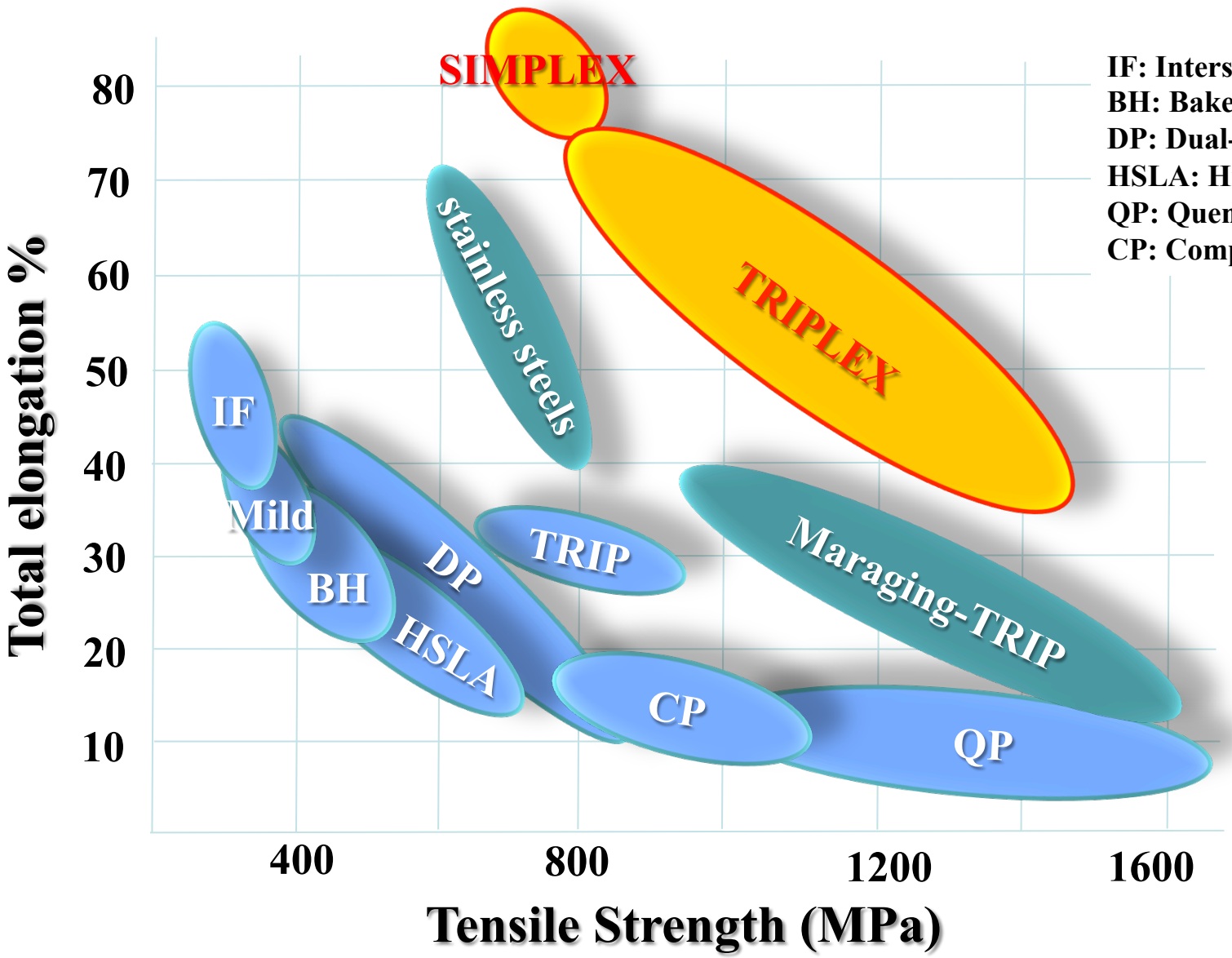
Advanced High Strength Steels

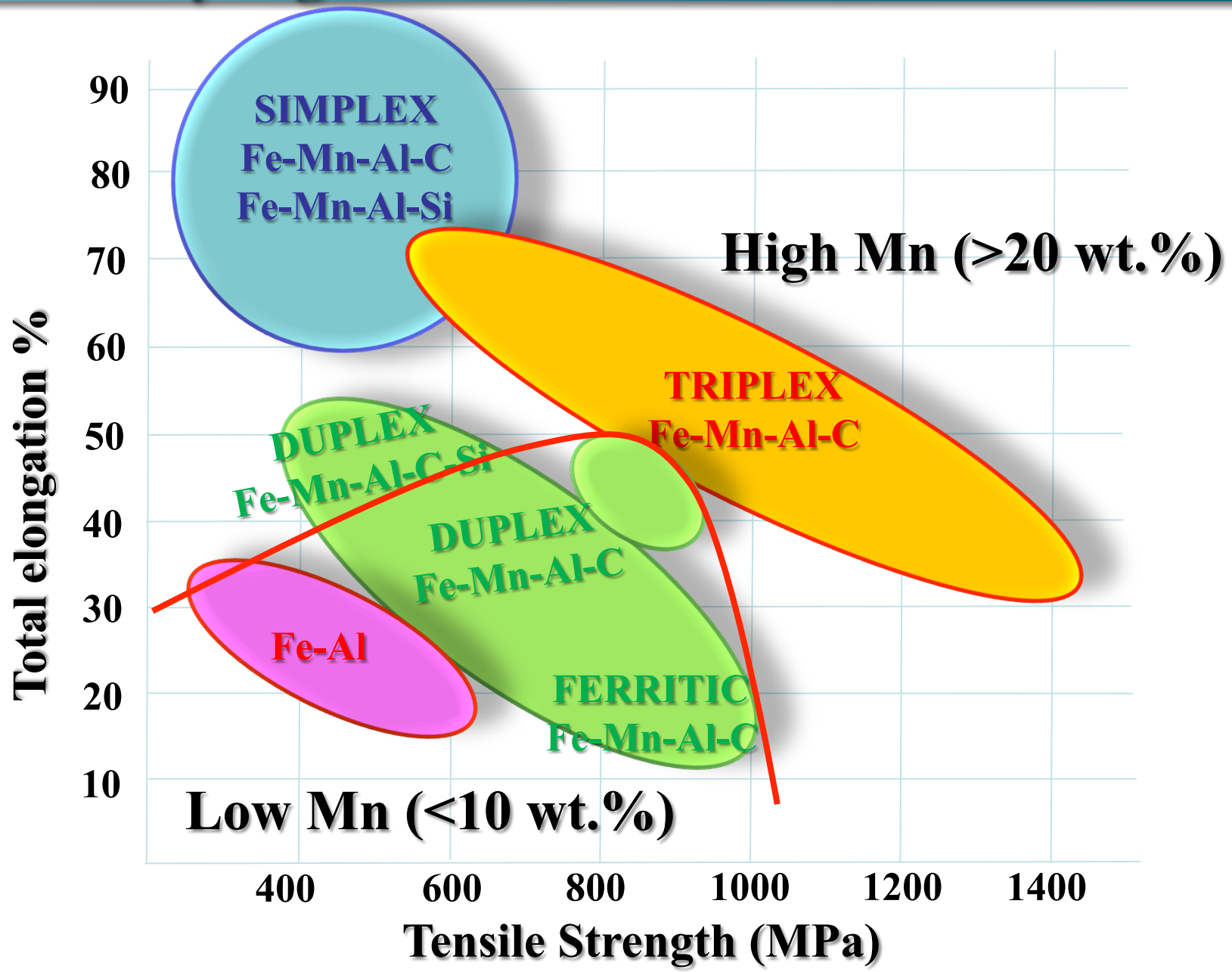


Advanced High Strength Steels

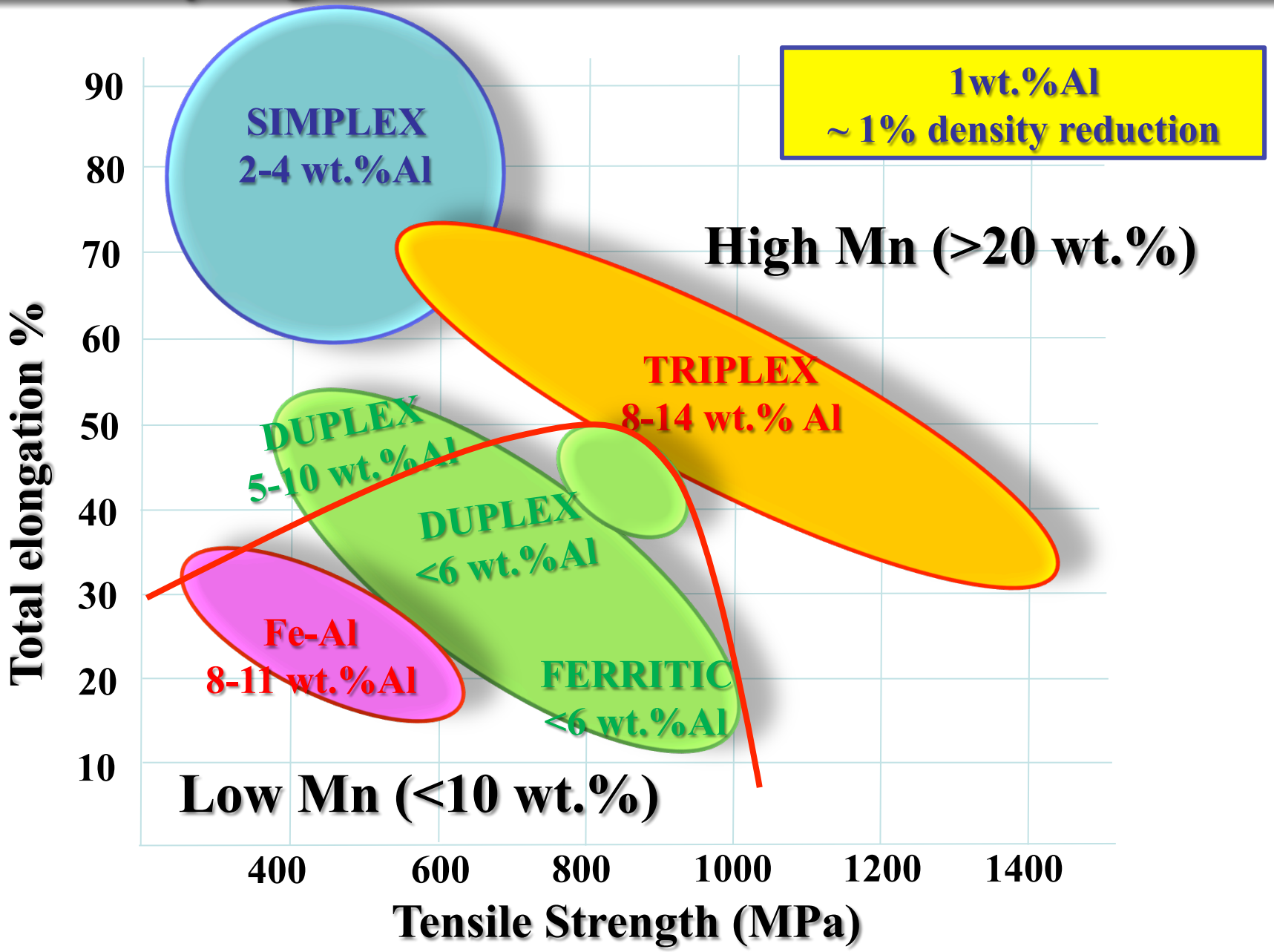


IF: Interstitial free
BH: Bake hardening
DP: Dual-phase
HSLA: High-strength low-alloy
QP: Quench & partitioned
CP: Complex phase

Low density high-Mn steels



Low density high-Mn steels



Simplex steels

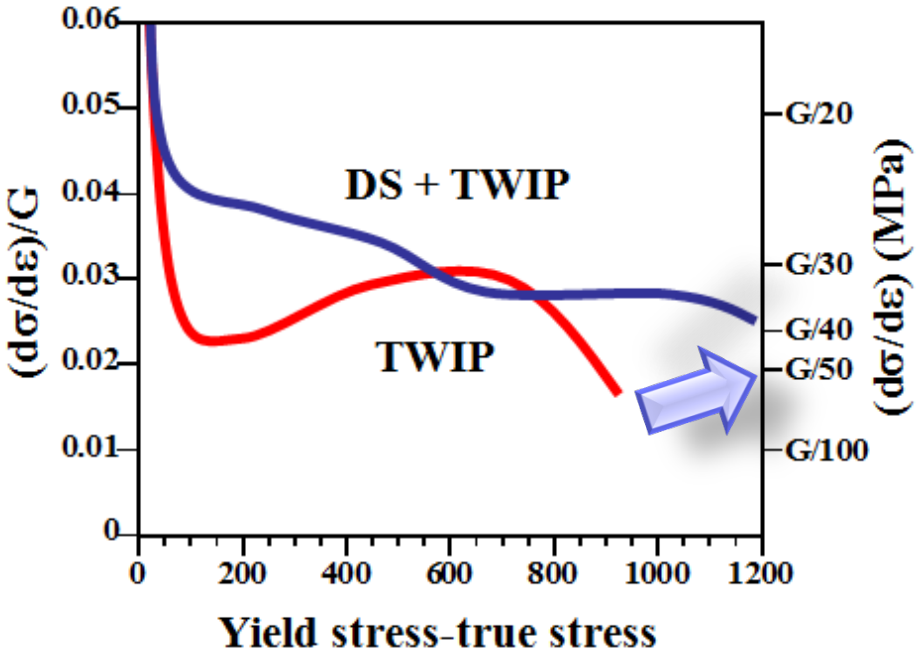
SIMPLEX = Austenite in solid solution

Fe-Mn-Al-C
Fe-Mn-Al-Si

Mn: 20-30 wt.%
Al< 4 wt.%

C: 0.5-1.2 wt.%
Si: 2-4 wt.%

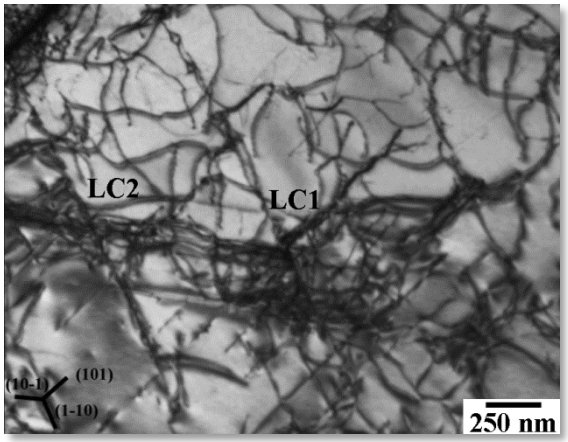
Multiple strain hardening behavior
dislocation substructure (DS) + deformation twinning (TWIP)

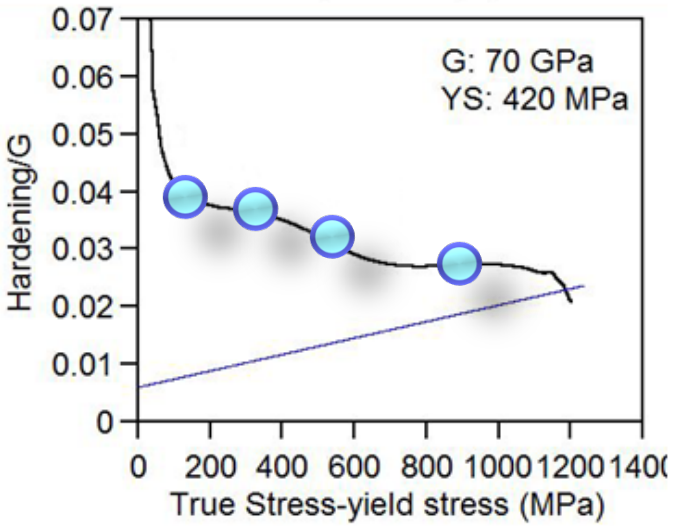


Gradual increase of work hardening capacity: Work hardening exhaustion at high stress/strain levels

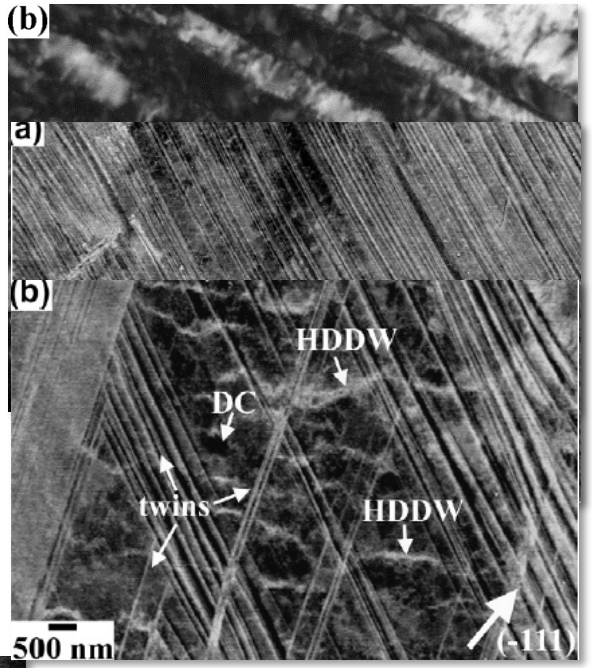
Simplex steels: Strain hardening mechanisms

Lomer-Cottrell locks



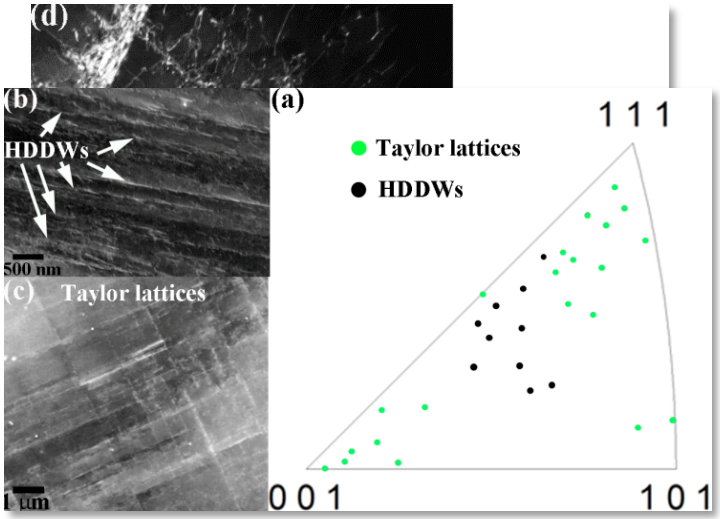


Nanotwins

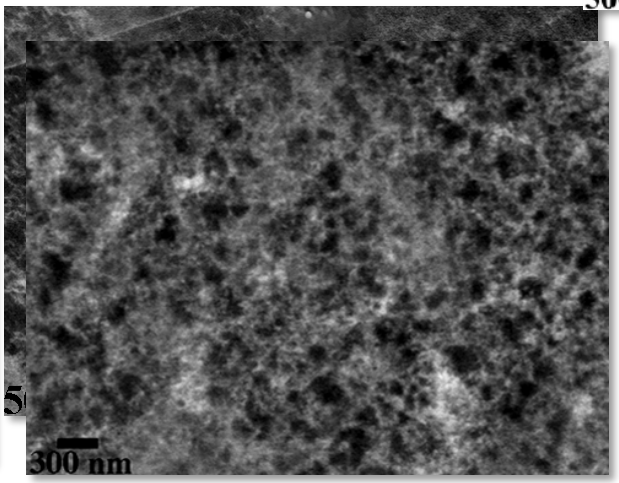


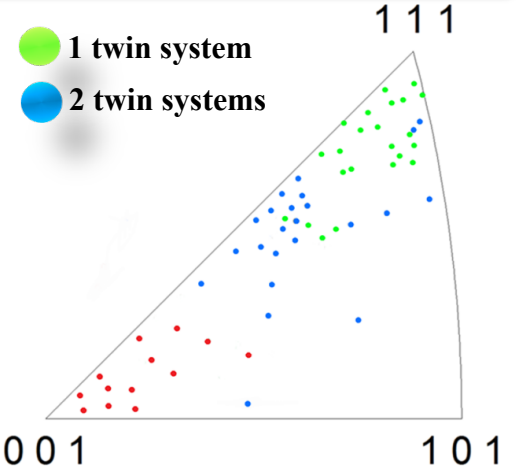
Fe-27Mn-4Al-5C (at.%)

HDDWs, Taylor lattices

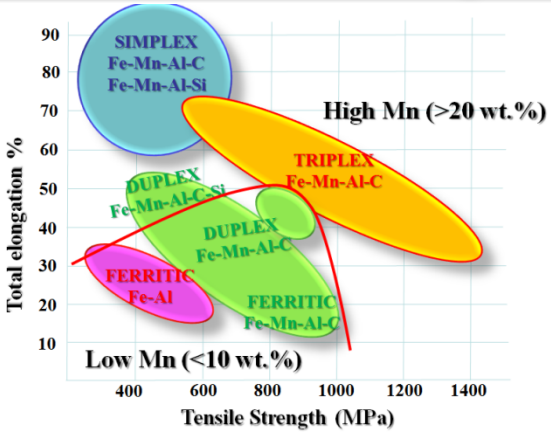


Cell blocks, cells

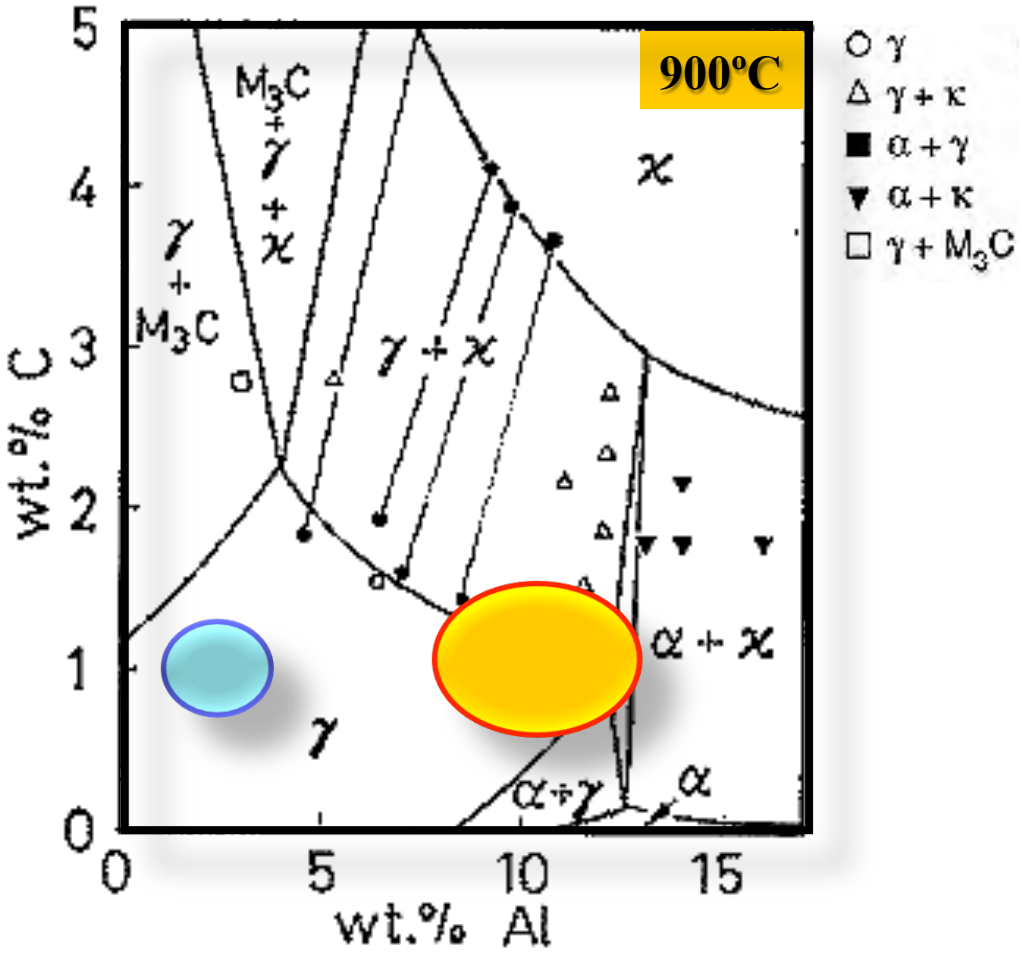




Fe-Mn-Al-C phase diagram

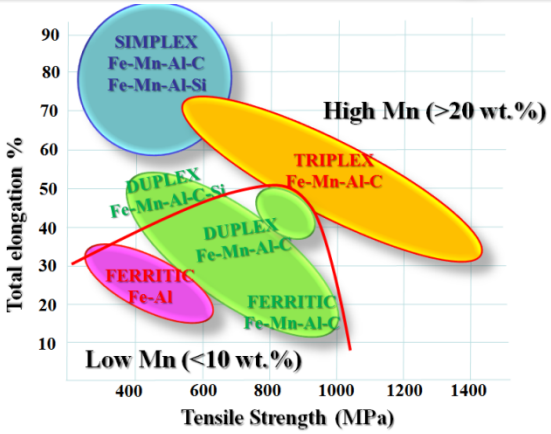


Fe-30wt.%Mn



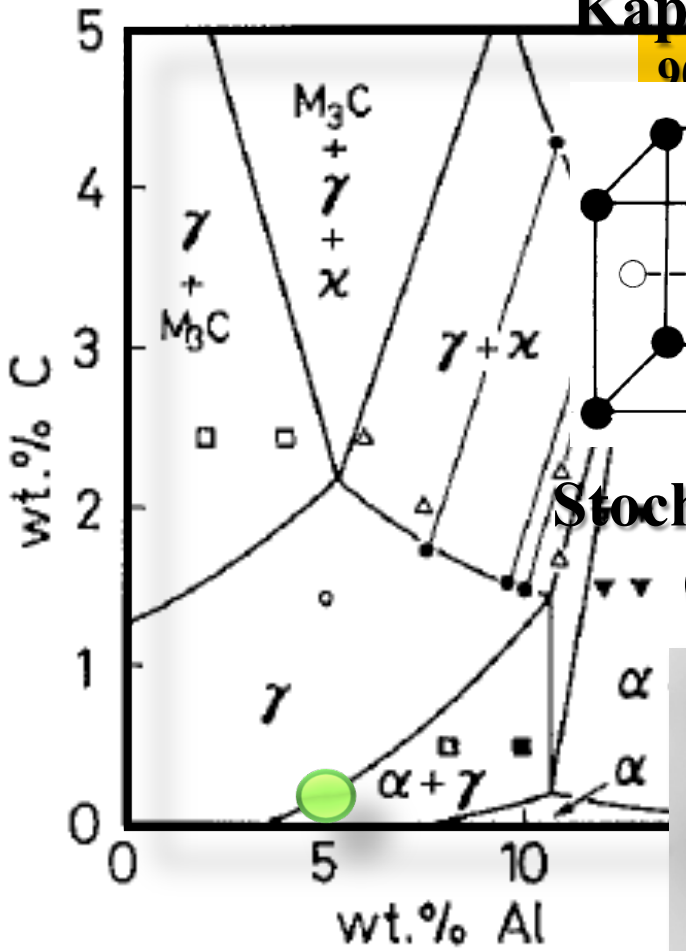
Source: K. Ishida et al., ISIJ Inter. 30 (1990) 680

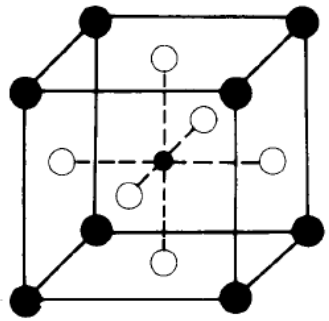
Fe-Mn-Al-C phase diagram



Fe-20wt.%Mn

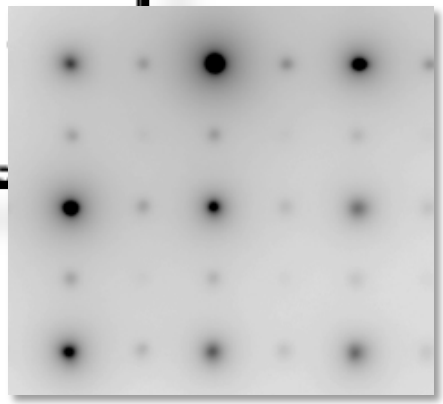
Kappa: ordered L'1$_2$





Stochiometric structure

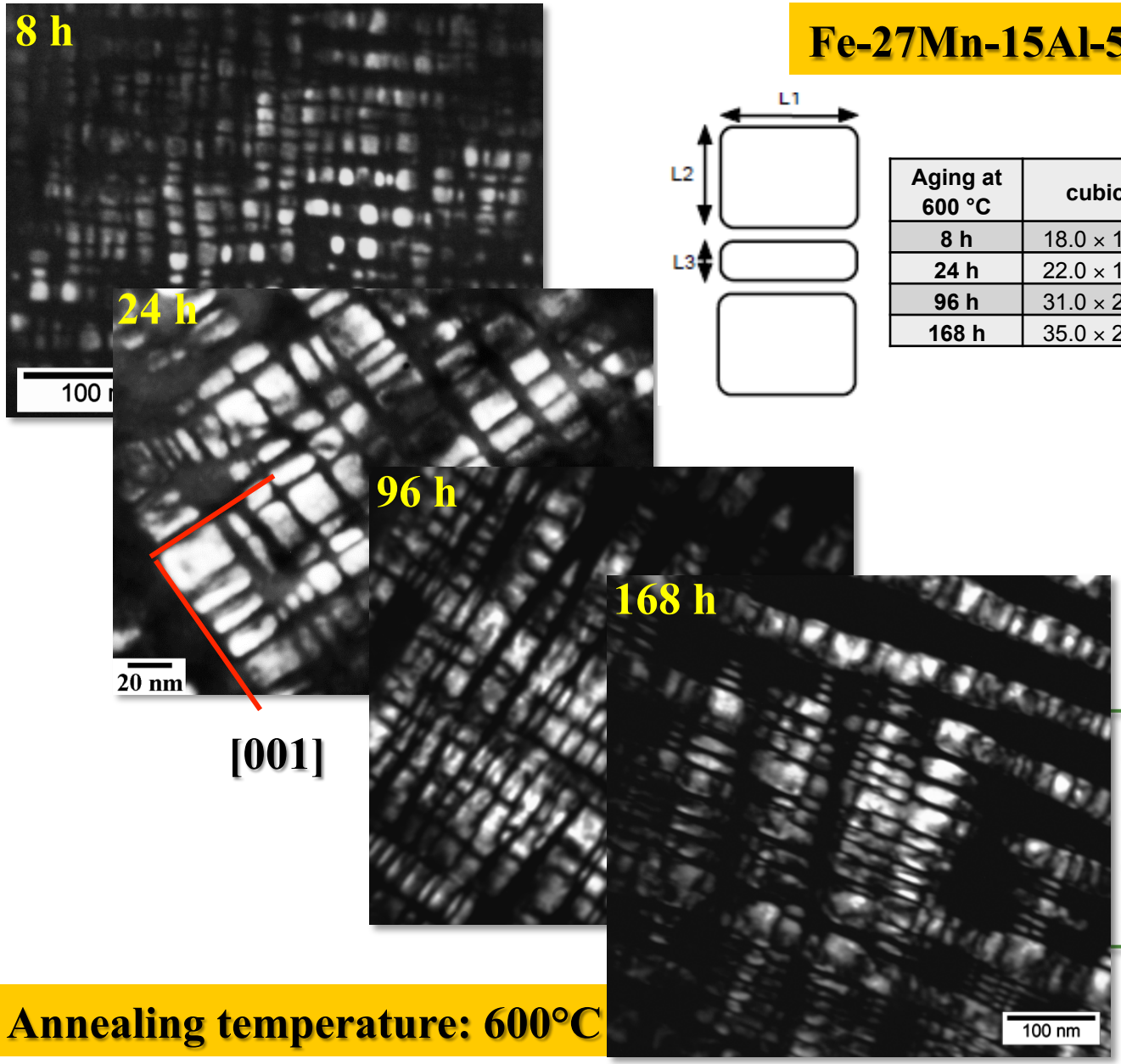
(Fe, Mn)$_3$AlC$_x$



[001]

Source: K. Ishida et al., ISIJ Inter. 30 (1990) 680

κ carbides in austenitic matrix



[001]

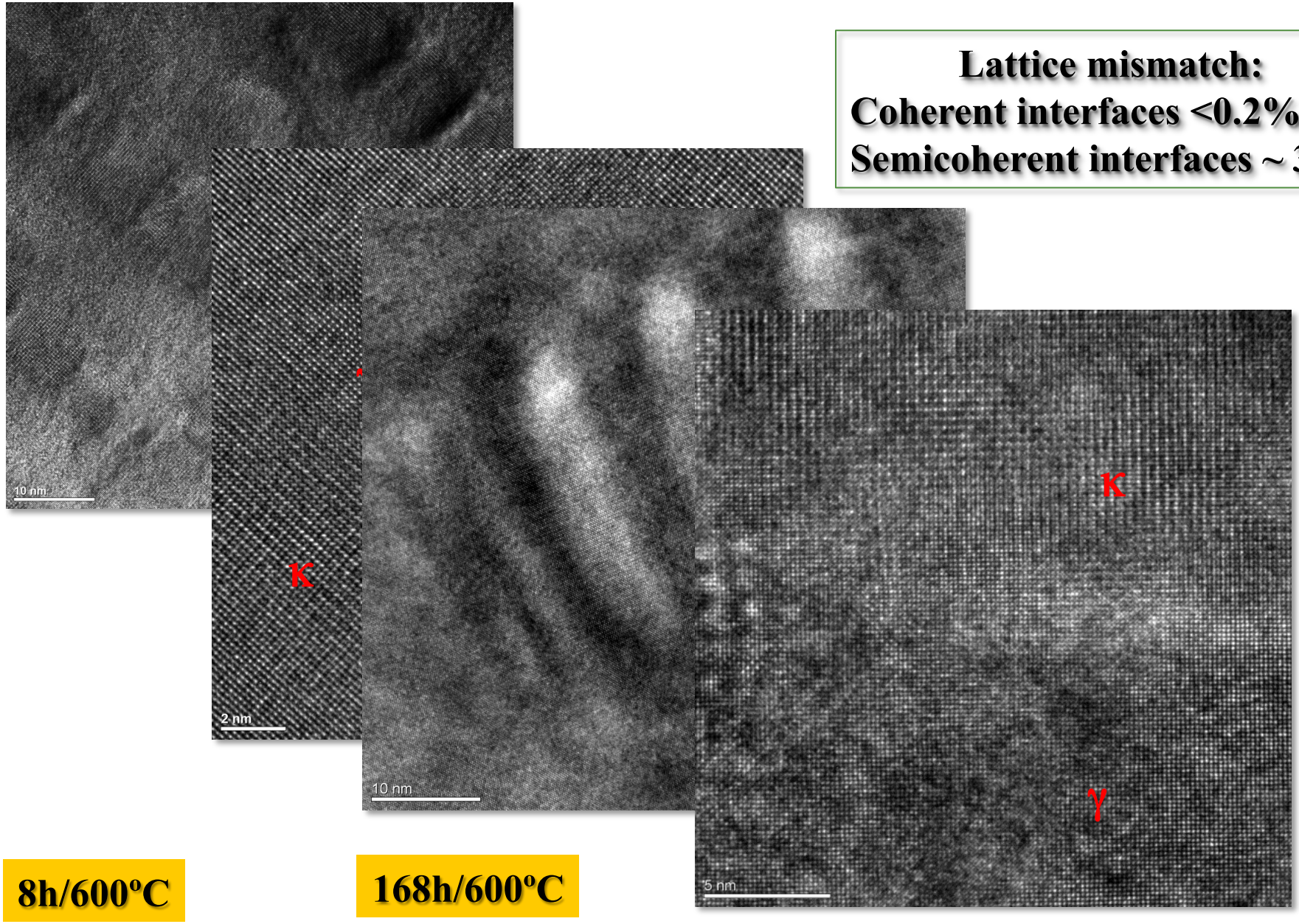
Fe-27Mn-15Al-5C (at.%)

Aging at 600 °C	cubic-like	S_1	plate-like	S_2
8 h	18.0 × 16.0 nm	1.1	19.0 × 7.0 nm	2.7
24 h	22.0 × 17.0 nm	1.3	24.0 × 7.5 nm	3.2
96 h	31.0 × 20.7 nm	1.5	35.7 × 7.5 nm	3.4
168 h	35.0 × 22.0 nm	1.6	38.5 × 11.0 nm	3.5

-Cube-cube orientation
-High thermal stability
-Coherent and semicoherent interfaces

Annealing temperature: 600°C

γ/κ interfaces

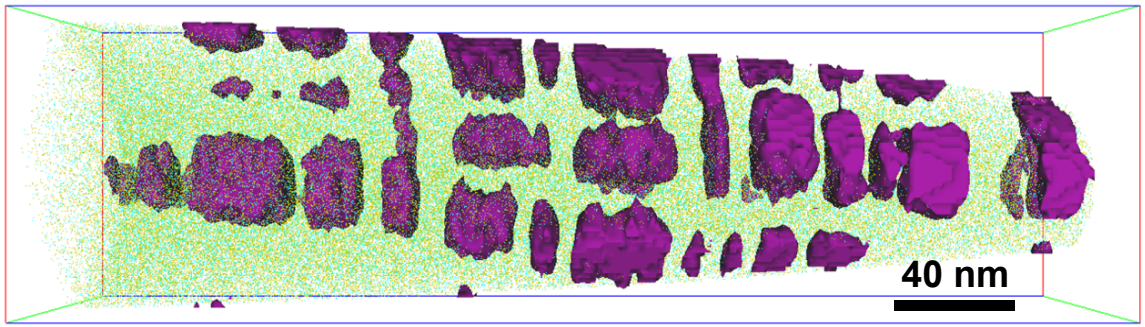


Lattice mismatch:
Coherent interfaces <0.2%
Semicoherent interfaces ~ 3%

8h/600°C

168h/600°C

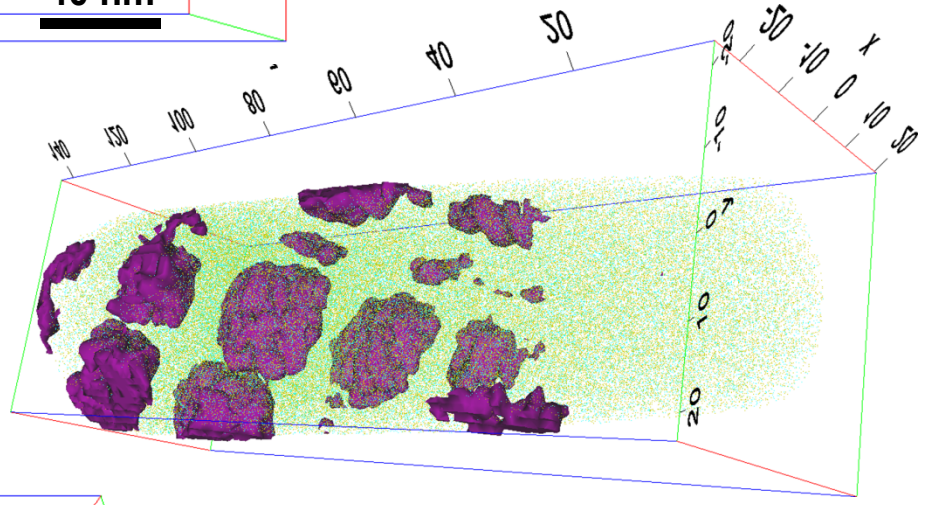
Analysis of κ carbides by 3D-APT

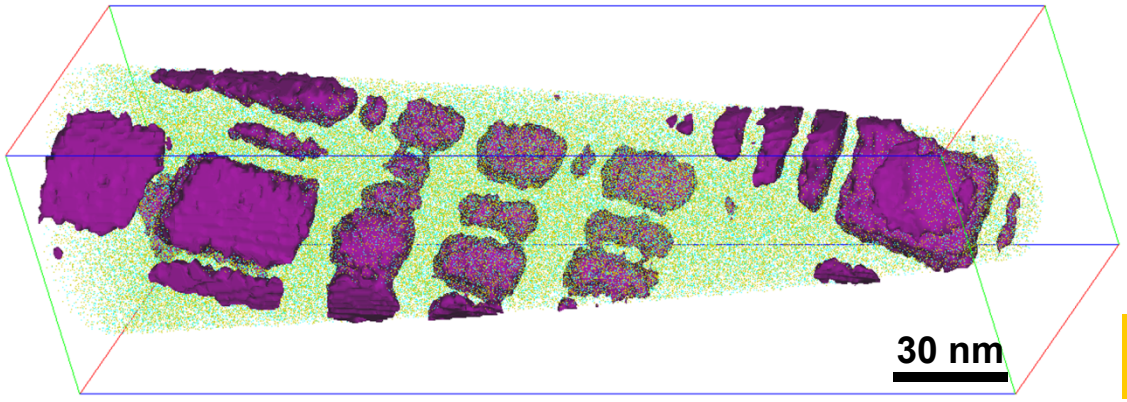


24 h

9 at.% C
isoconcentration surface

96 h

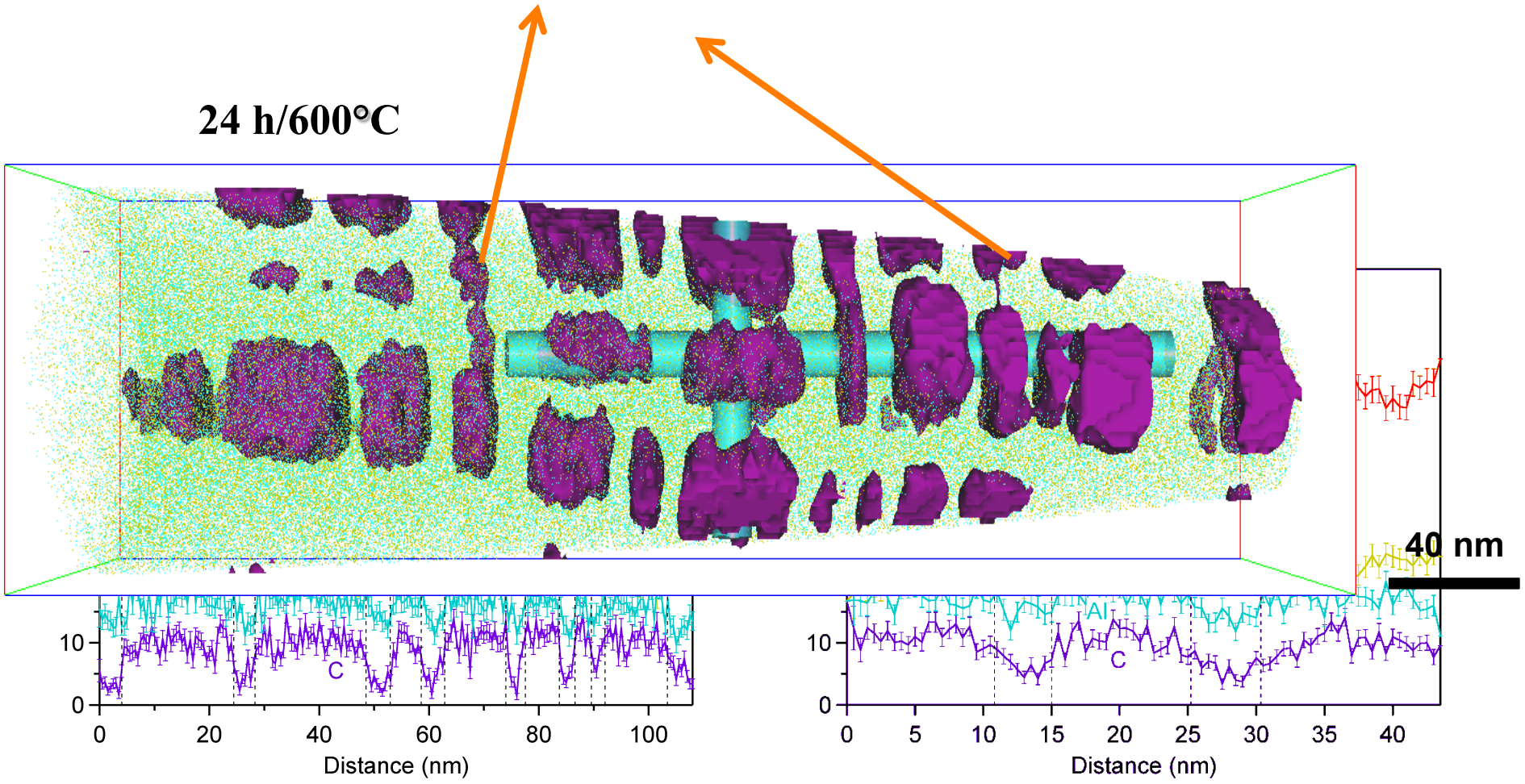




168 h

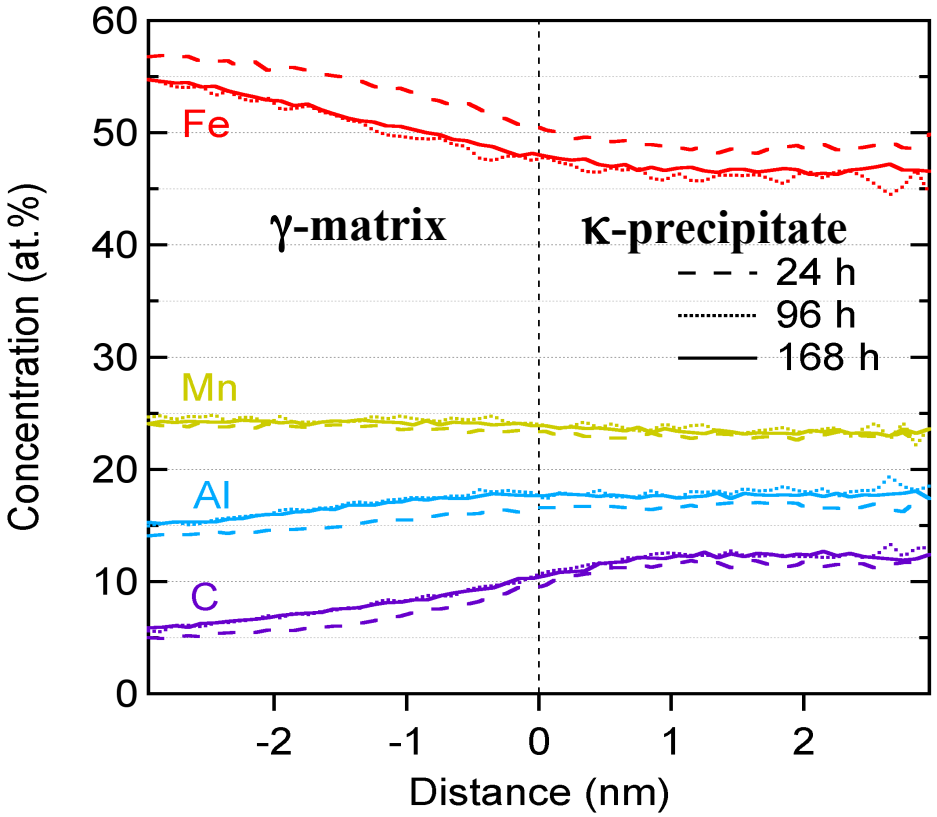
Annealing temperature: 600°C

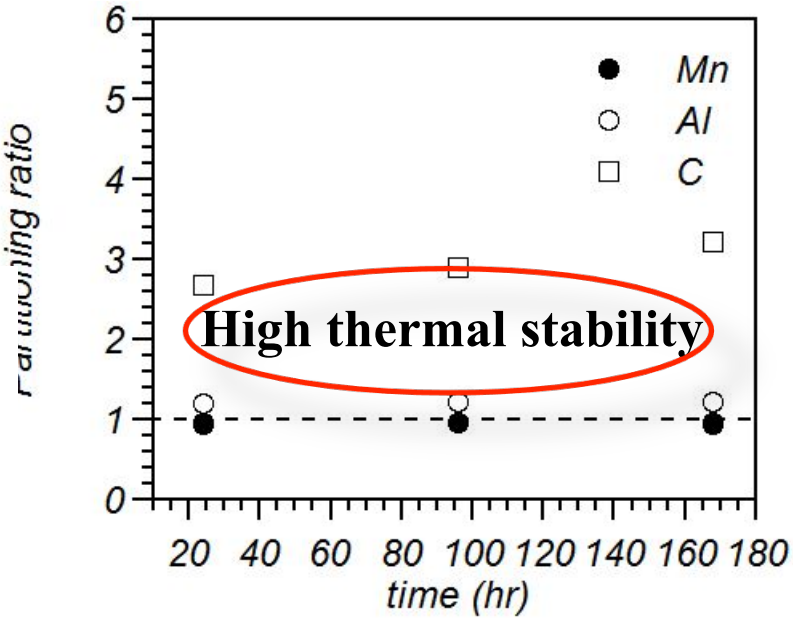
Composition profiles of γ/κ interfaces

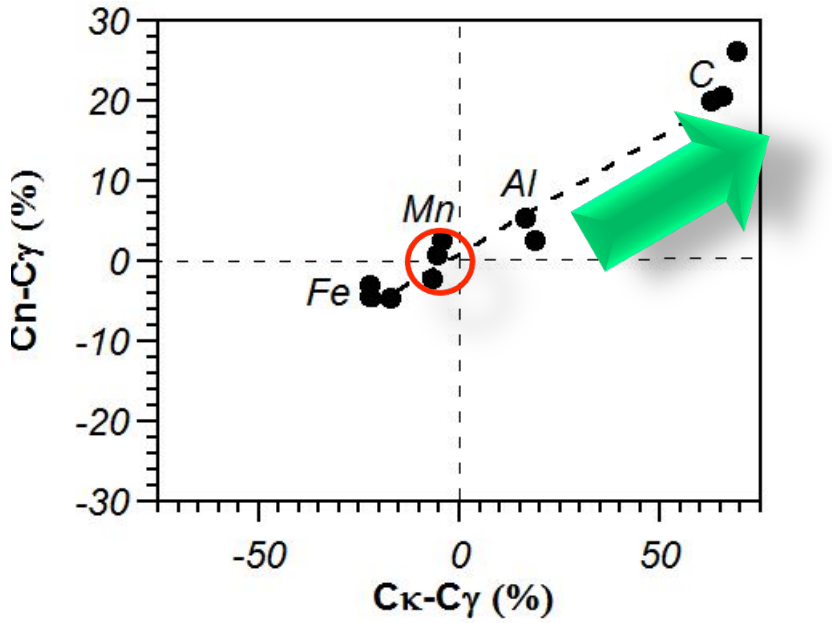


Partiotining behavior of γ/κ

Concentration profiles: proxigram

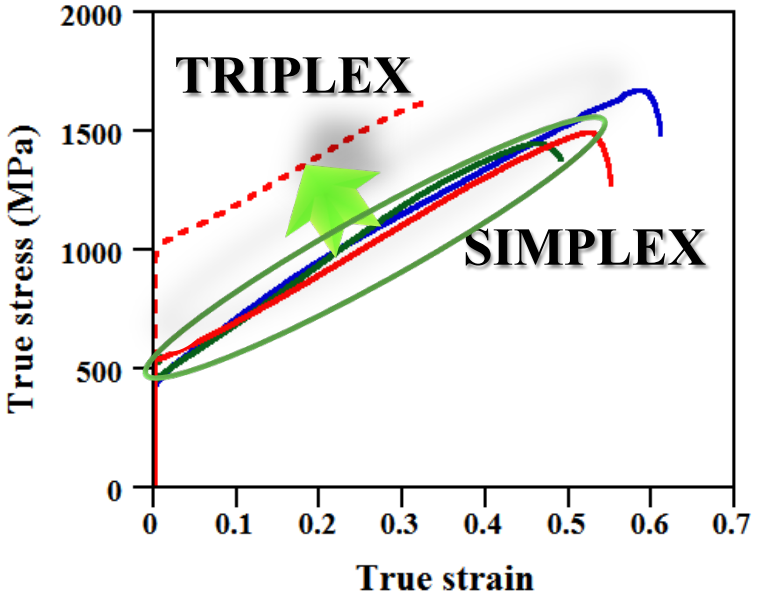




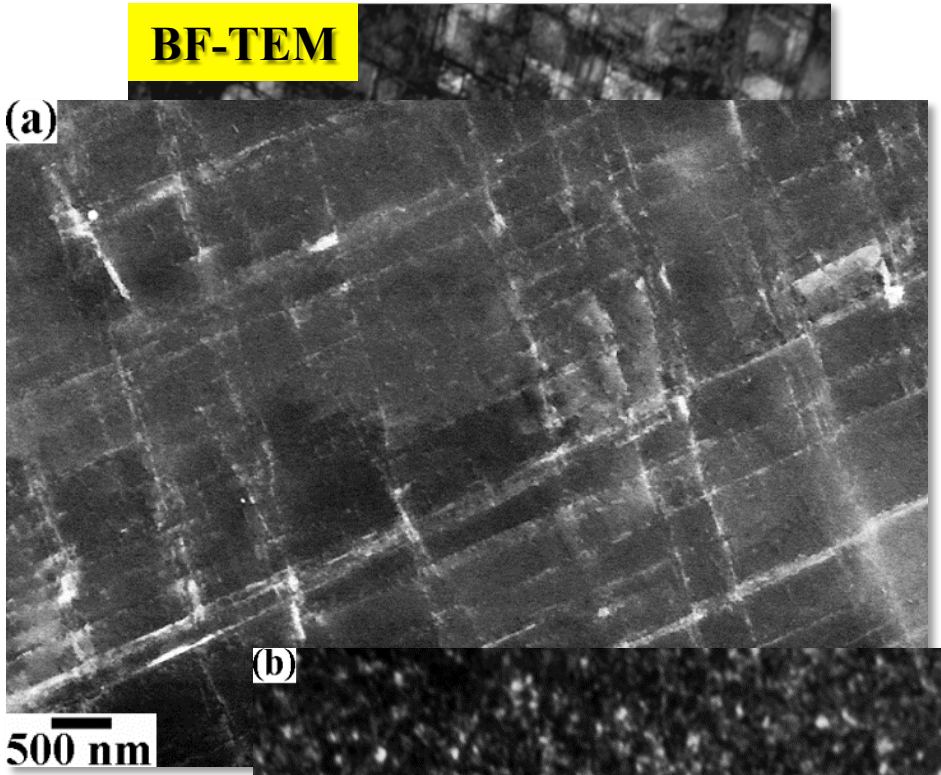


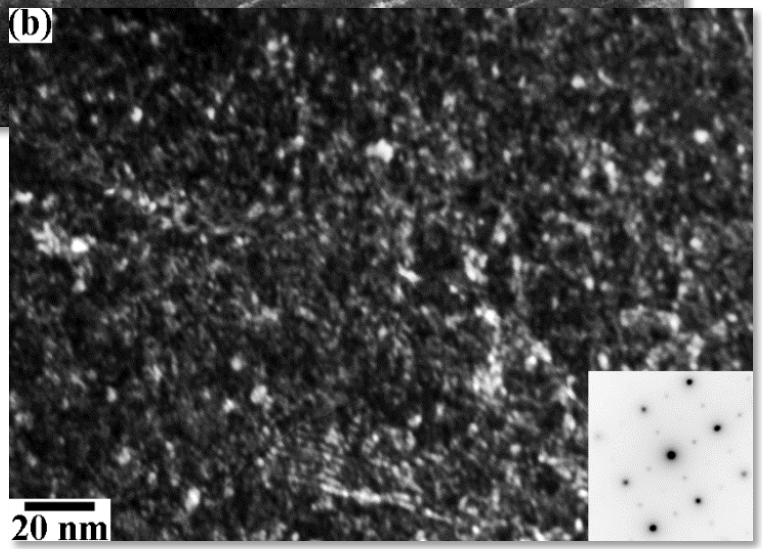
Annealing temperature: 600°C

Deformation mechanisms of Triplex steels

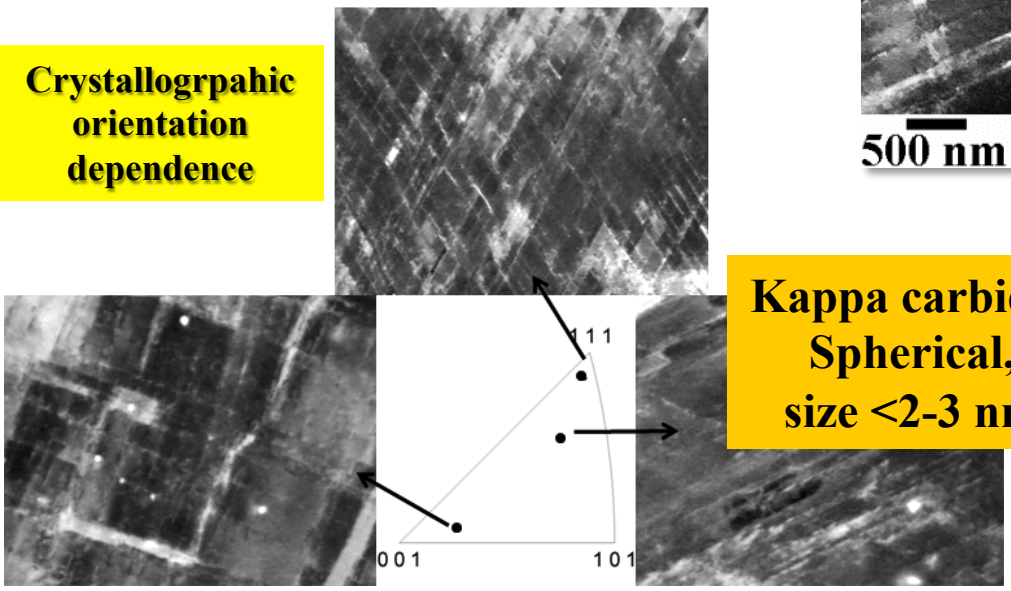


Early stages of κ formation (1 h/450°C)





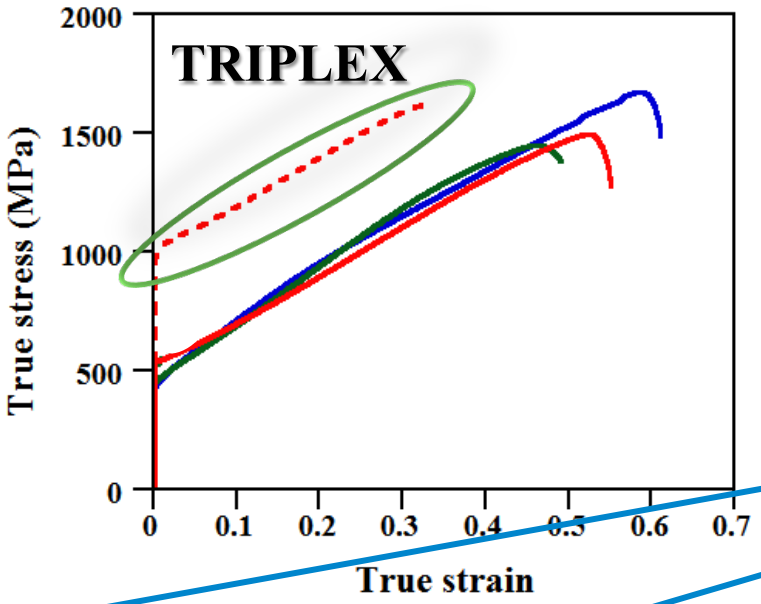
Crystallogrpahic orientation dependence



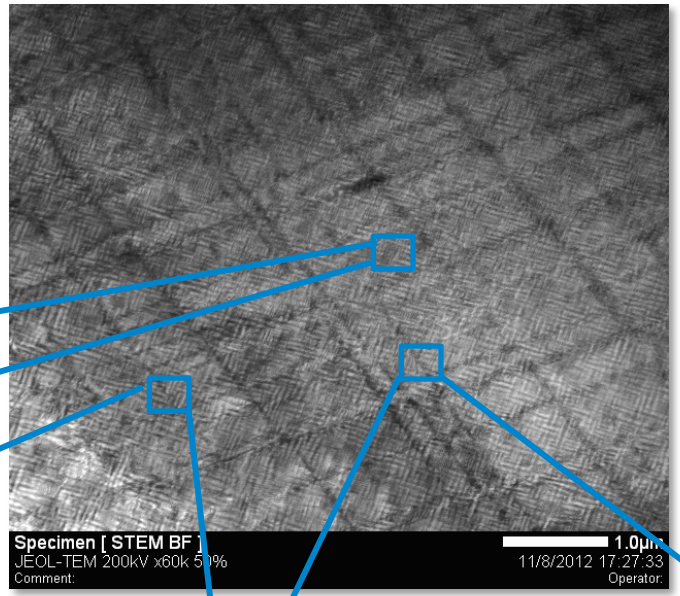
Kappa carbides
Spherical,
size <2-3 nm

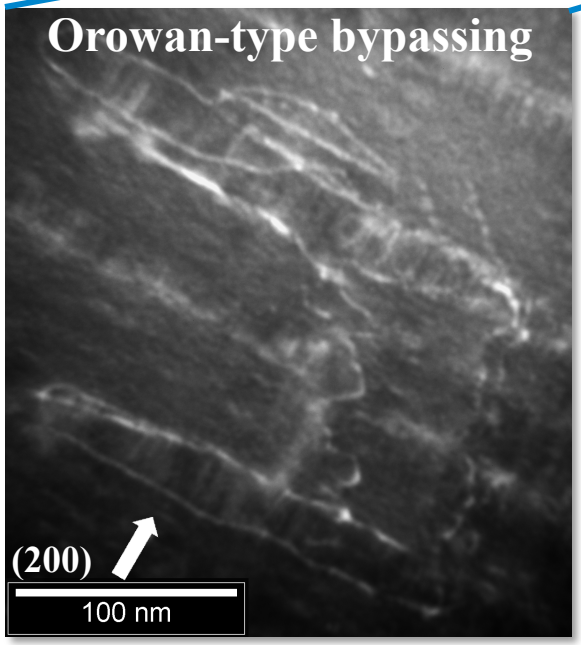
I. Gutierrez-Urrutia, D. Raabe , Scripta Mater. 68 (2013) 343

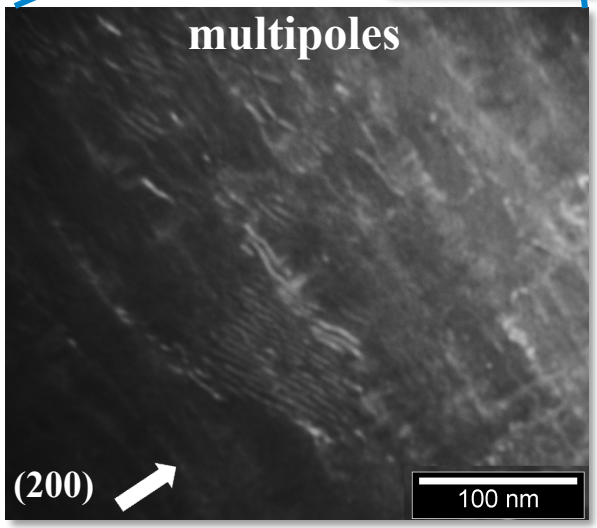
Deformation mechanisms of Triplex steels

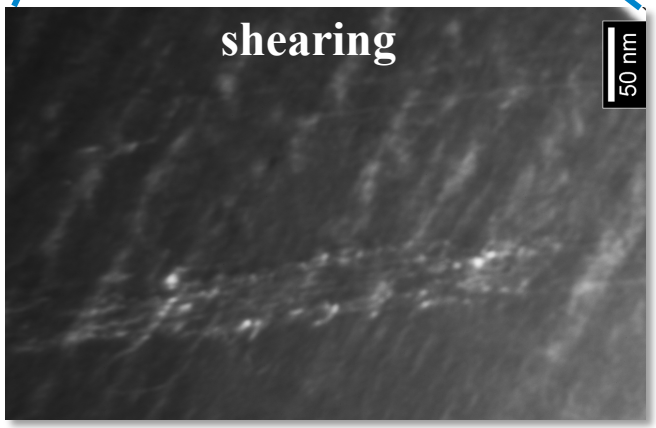


Homogeneous distribution of κ carbides (24 h/600°C)

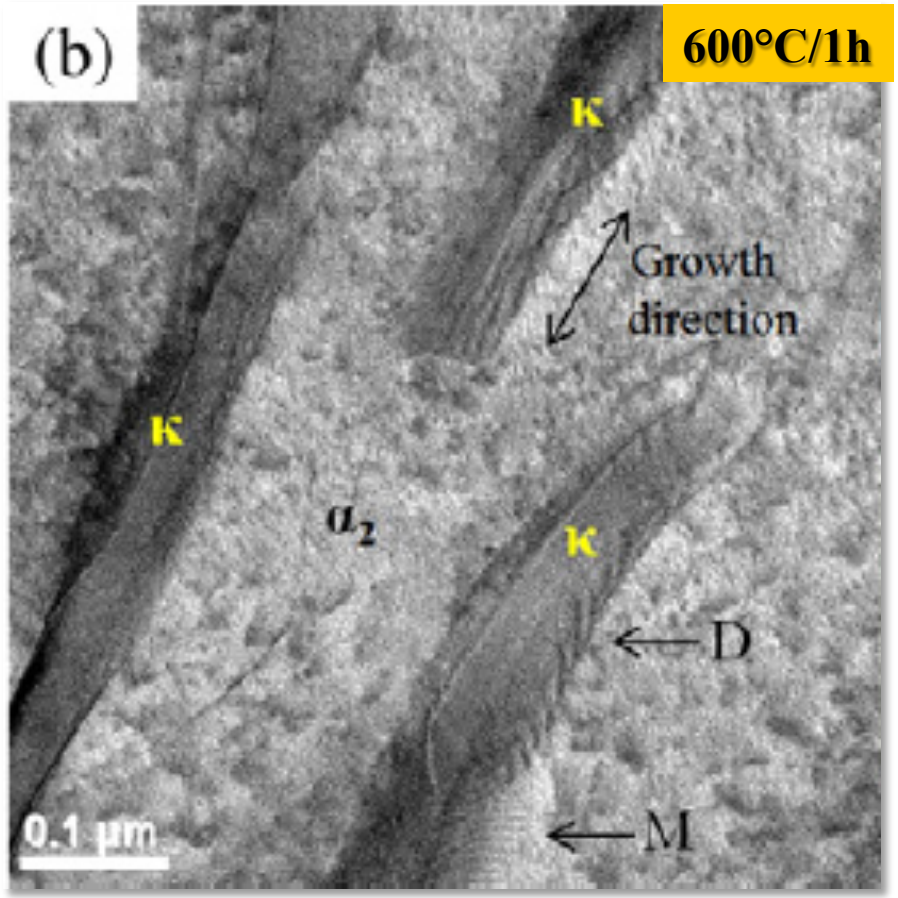




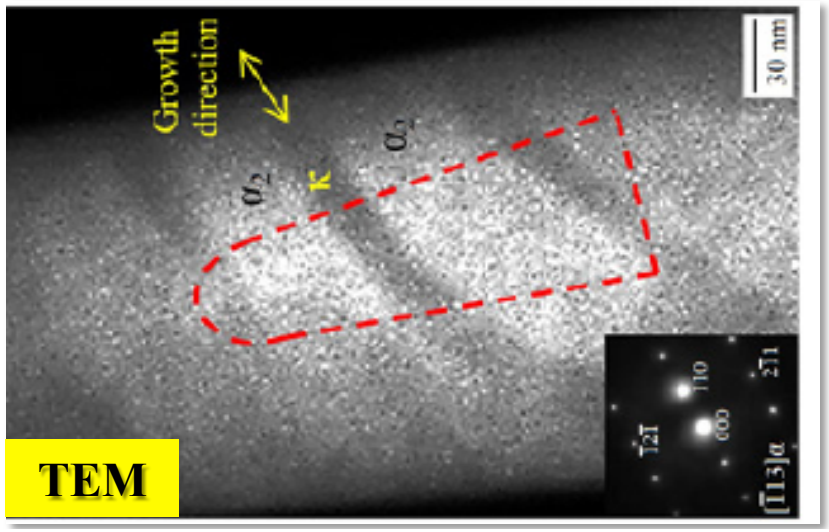


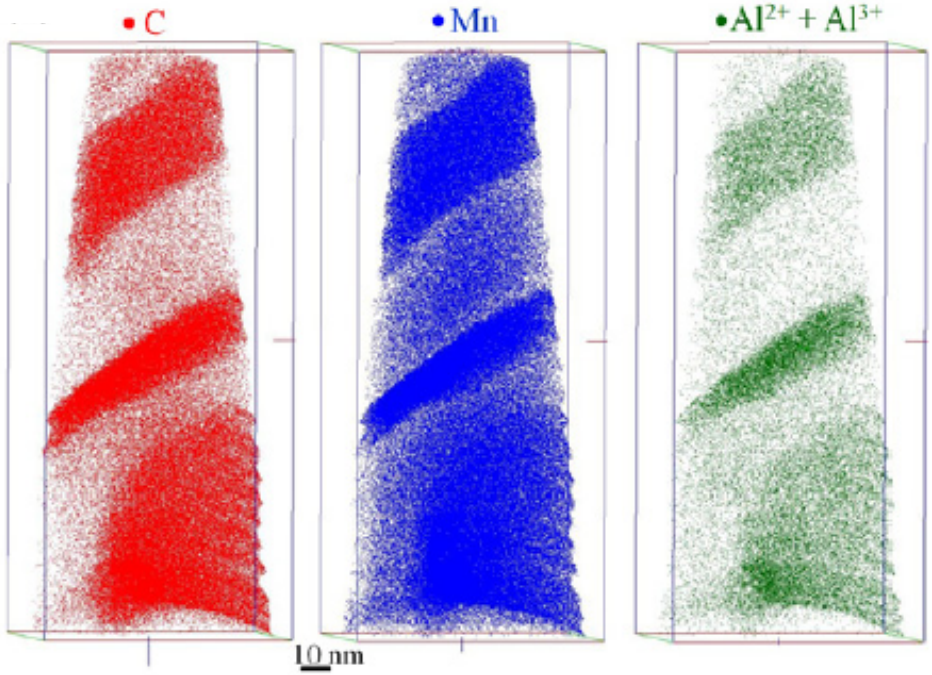


κ carbides in ferritic matrix



STEM



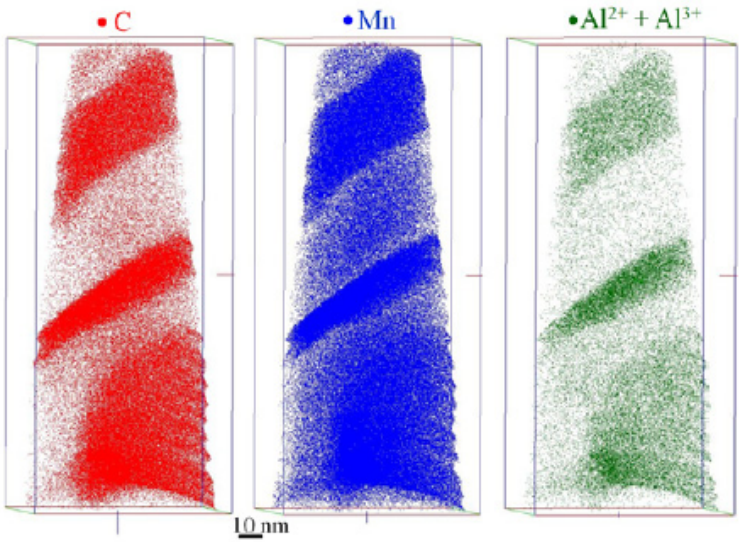


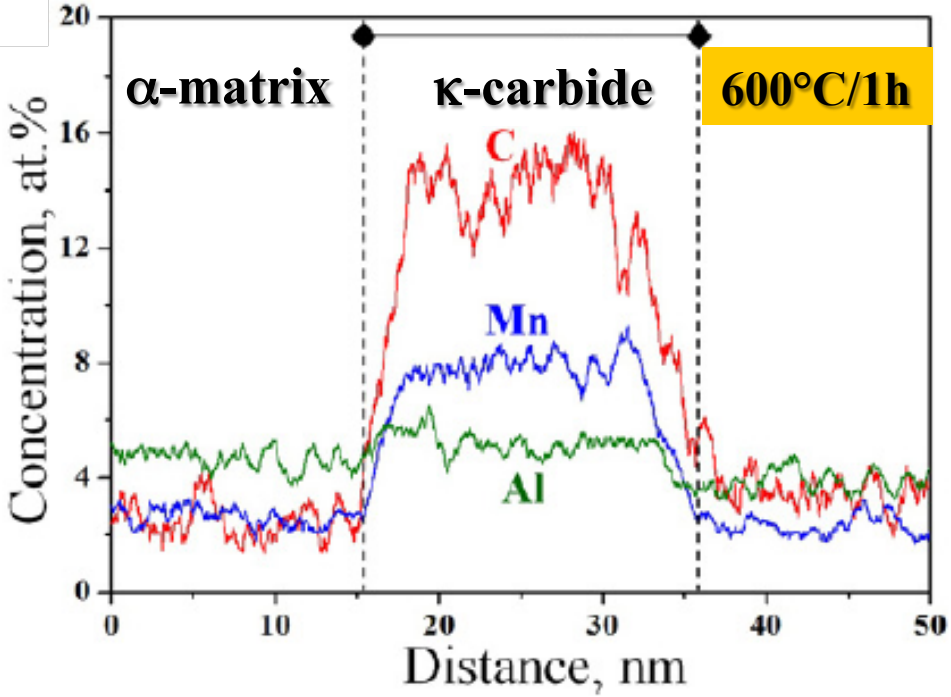
APT

Fe-3.2Mn-10Al-1.2C (at.%)

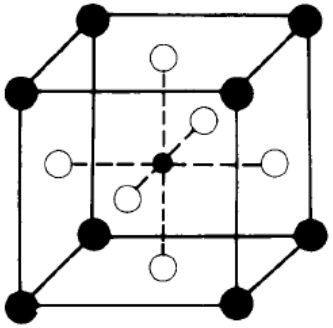
Source: J-B. Seol et al., Scripta Mater. 68 (2013) 348

α/κ interfaces



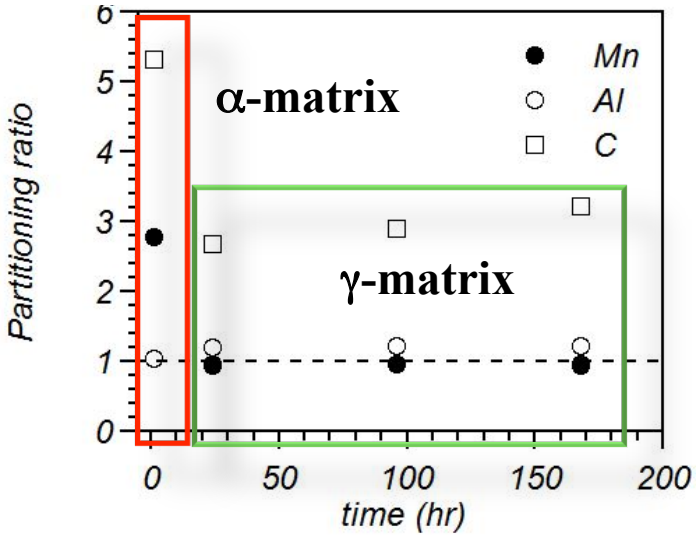


Non –stochiometric structure of kappa



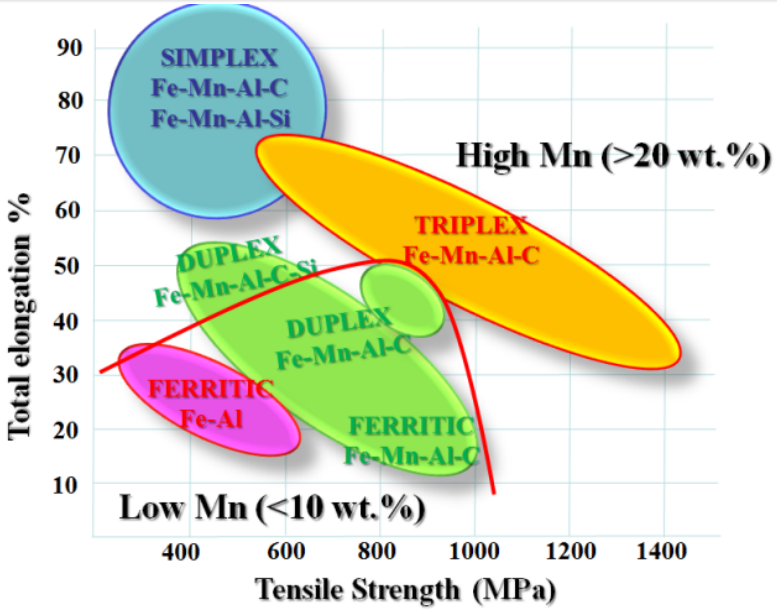
- ○ Fe, Mn
- ● Al, Fe (temperature dependent)
- • C

$(Fe, Mn)_3(Fe, Al)C_x$

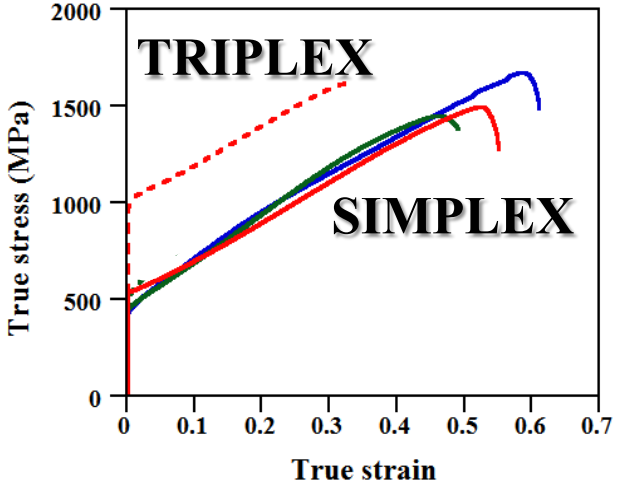


Source: J-B. Seol et al., Scripta Mater. 68 (2013) 348

conclusions

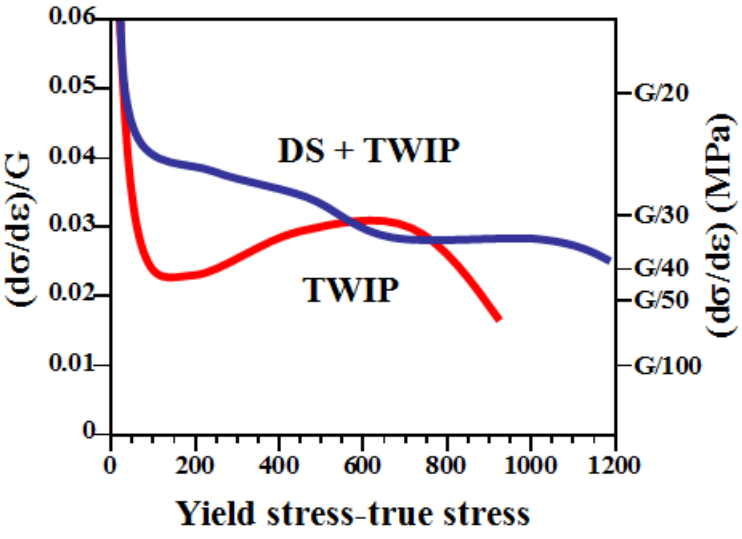


-High strength and ductile
-Low density steels



SIMPLEX: γ
TRIPLEX: γ + (α) + κ

SIMPLEX



TRIPLEX