TMS2011

Effect of Elastic Stress on Phase Separation in Fe-20%Cr-6%Al-0.5%Ti ODS alloy

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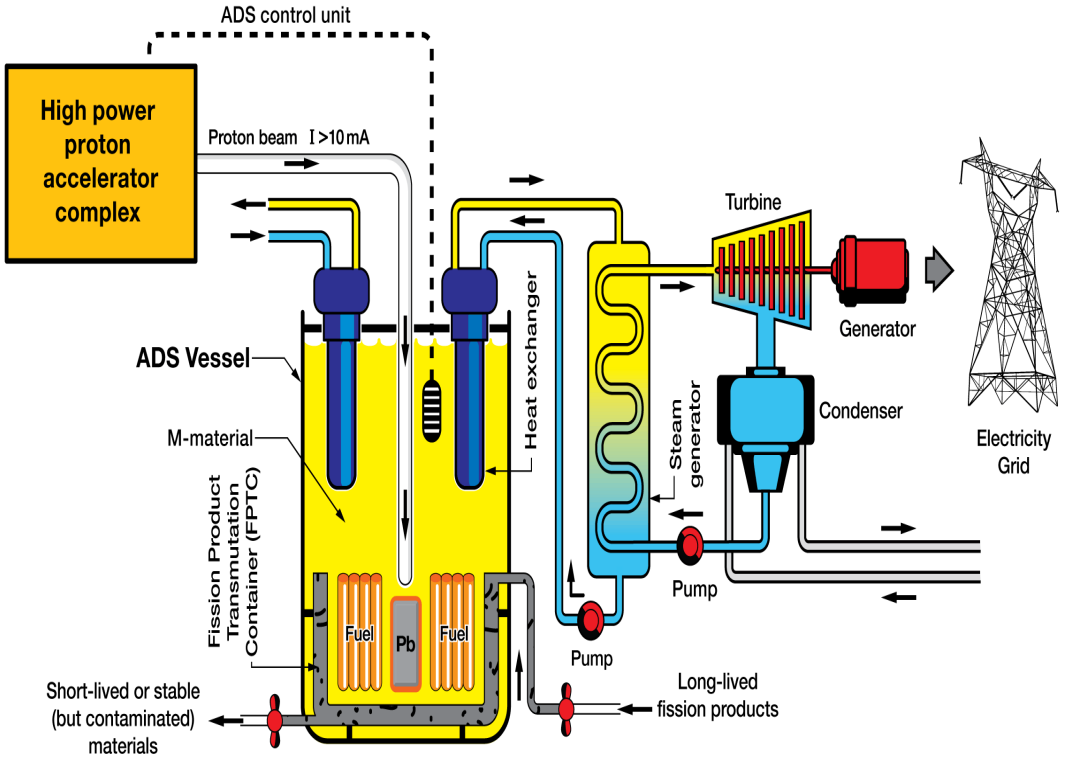


(S.R. Hashemi-Nezhad, University of Sydney, Australia)

- Fe-Cr-Al-Ti ODS alloys have promising properties for beam windows in subcritical accelerator driven systems (ADS) nuclear reactors.
- Phase separation of α (Fe-rich) - α' (Cr-rich) + β' (Fe-Ti-Al precipitate) during service affect mechanical properties.

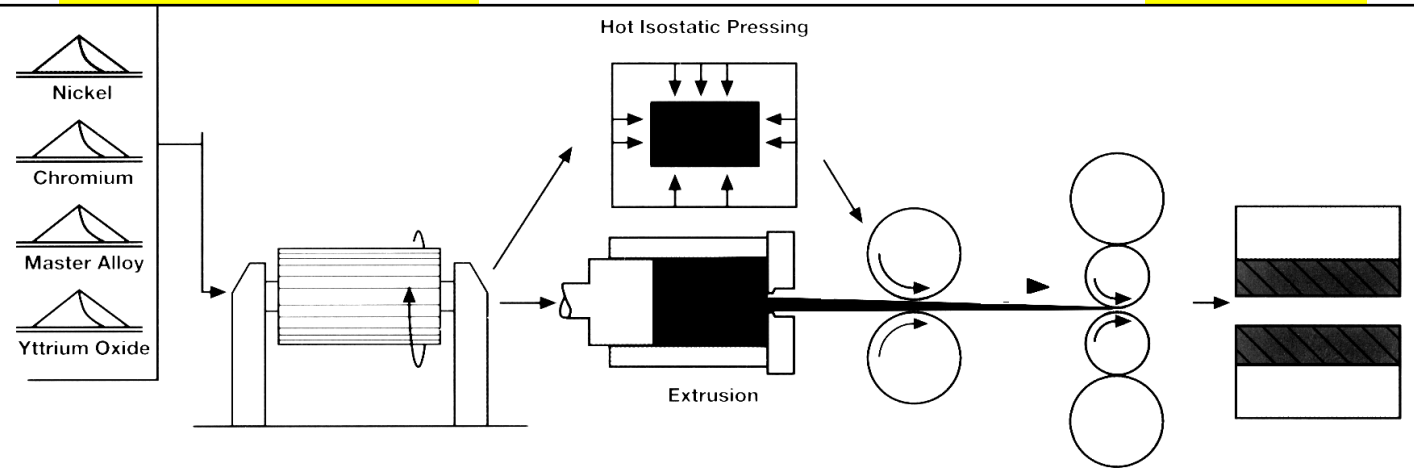
- TMS2008 (New Orleans) → Fe-Cr Phase separation kinetics
- TMS2010 (Seattle) → Fe-Cr and Fe-Ti-Al precipitation kinetics
- TMS2011 (San Diego) → Effect of elastic stress on Fe-Cr/Fe-Ti-Al precipitation

Material

PM 2000^{tm} is a commercial Fe-base ODS alloy manufactured by PLANSEE in Lechbruck, Germany

Chemical composition of PM 2000

	Cr	Al	C	O	N	Ti	Y
wt. %	18.6	5.5	0.04	0.09	0.006	0.54	0.39
at. %	18.5	10.5	0.17	0.28	0.022	0.58	0.23



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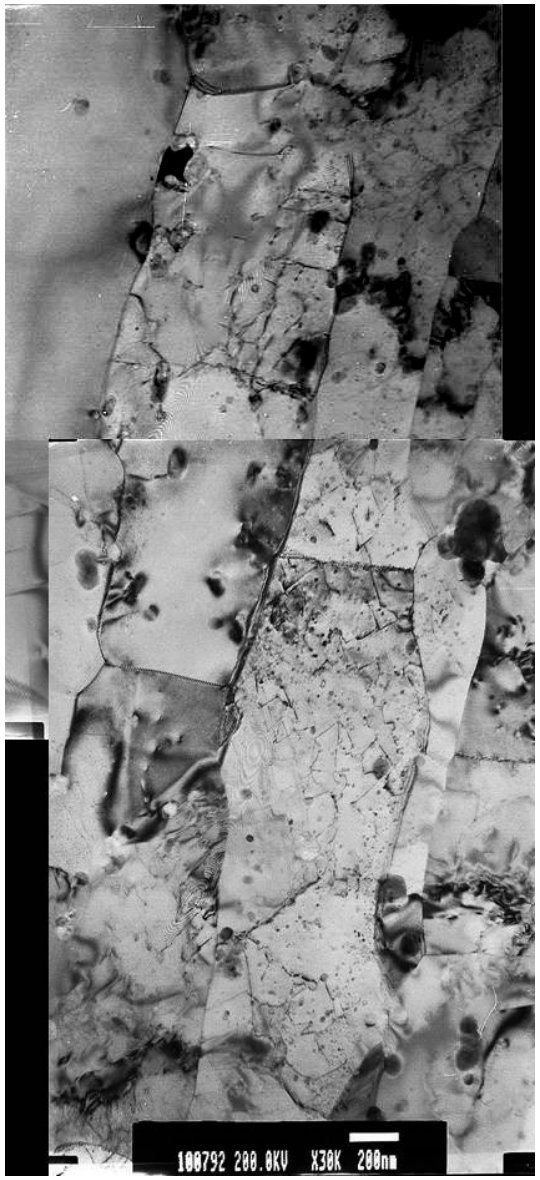
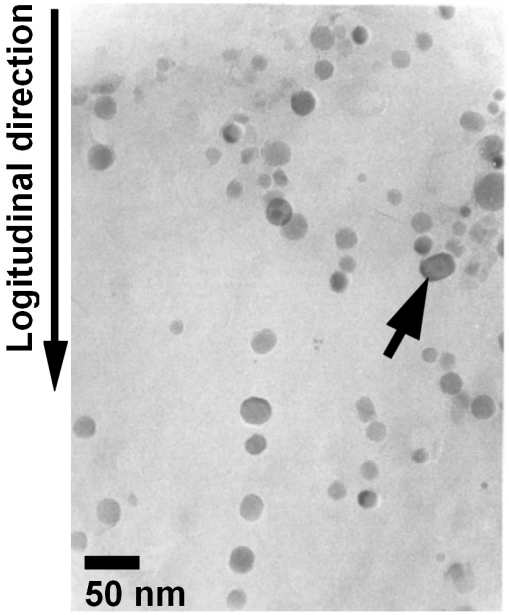


a)



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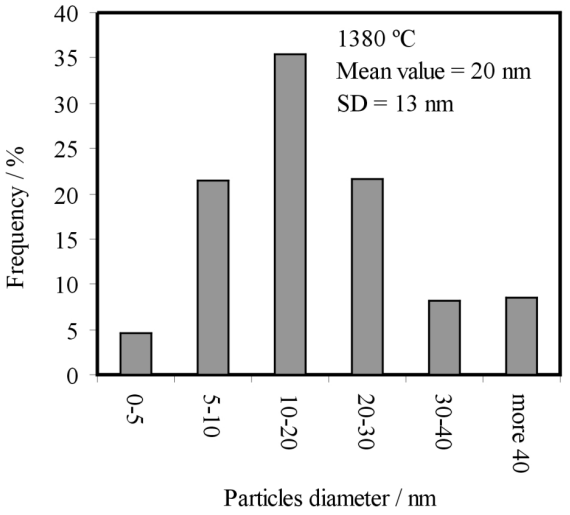

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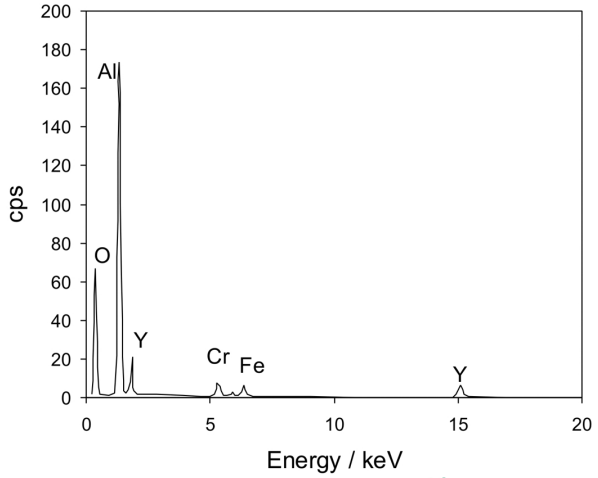

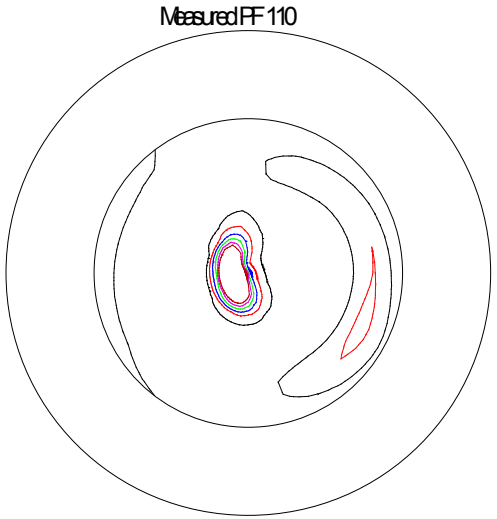

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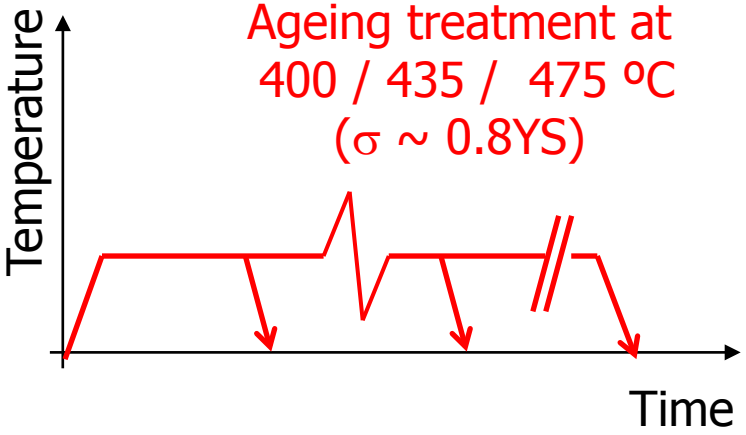
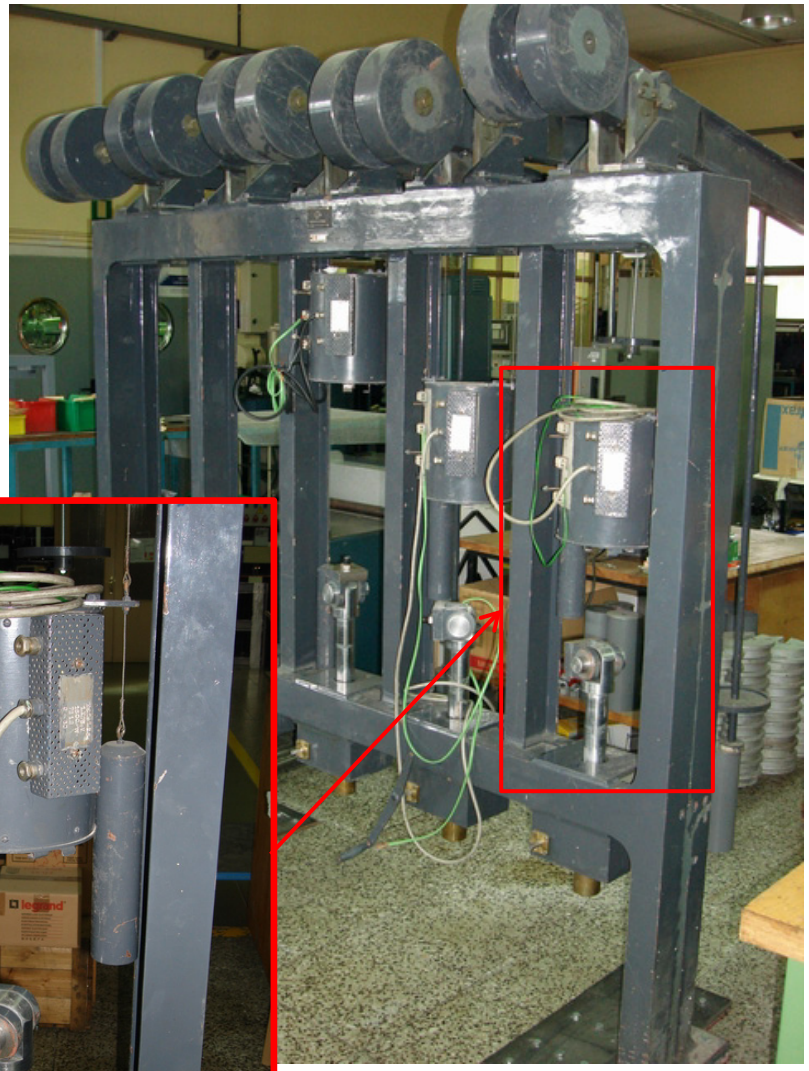
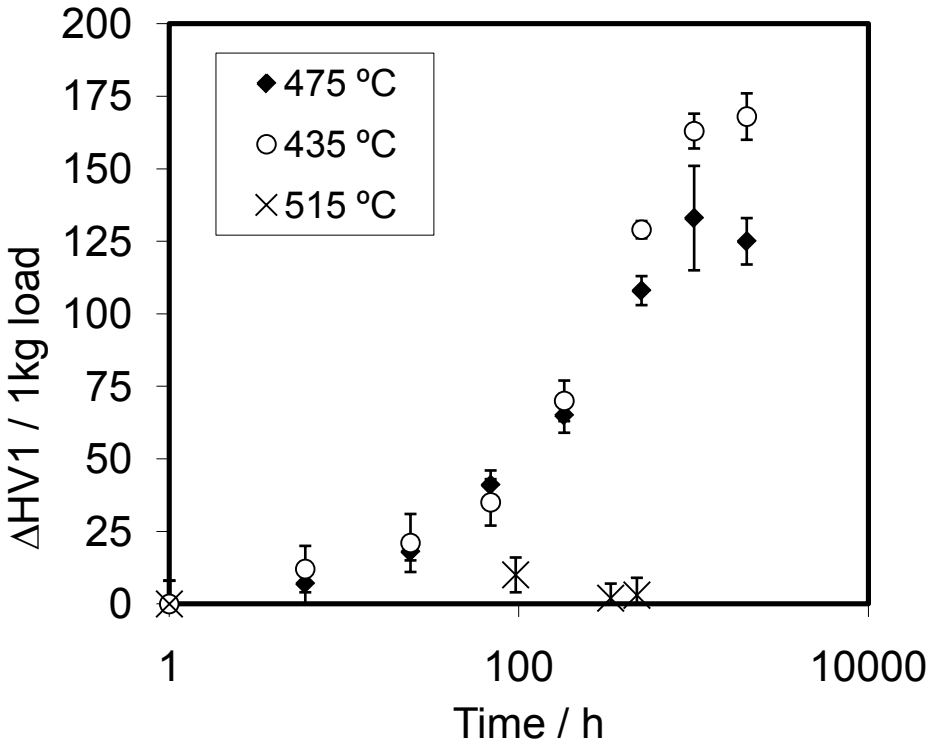


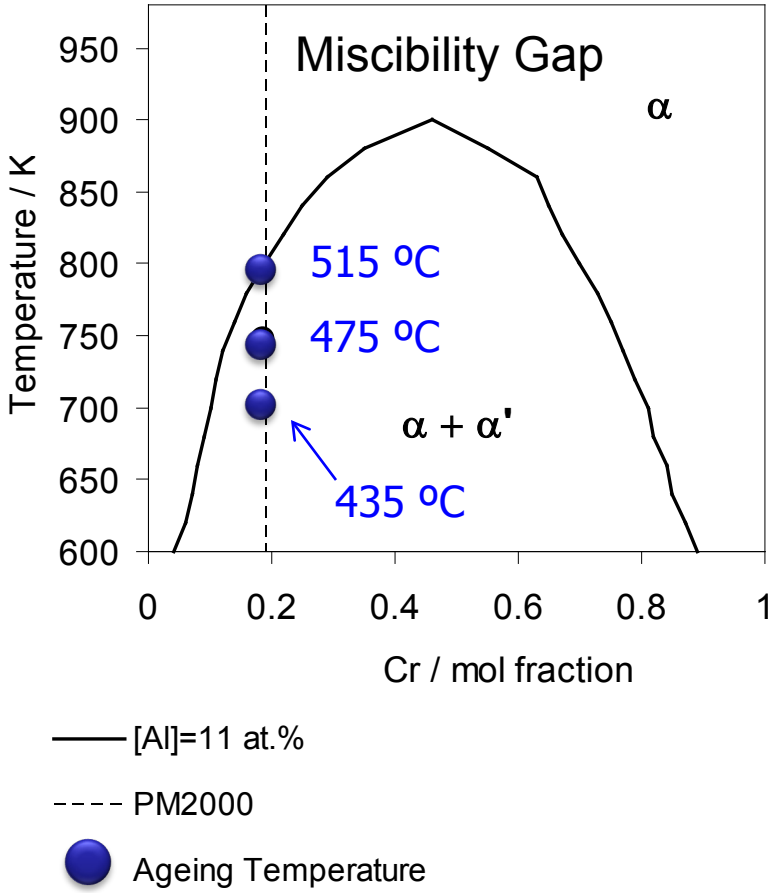


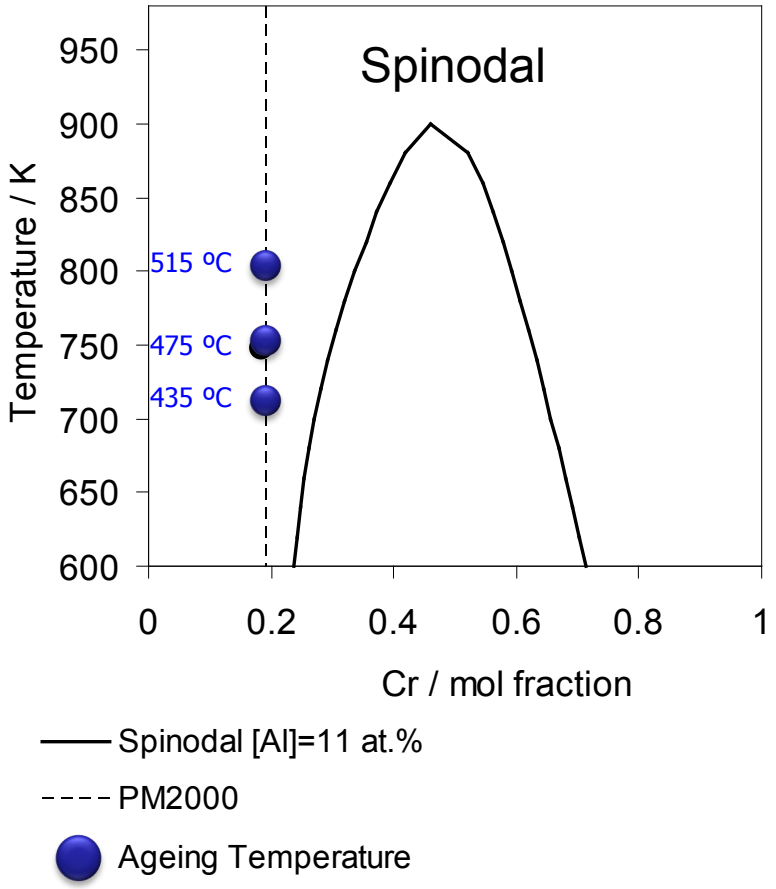
Hardness evolution

A continuous increase in hardness with respect to the initial state (before ageing), ΔHV1, was observed.



Thermodynamic analysis



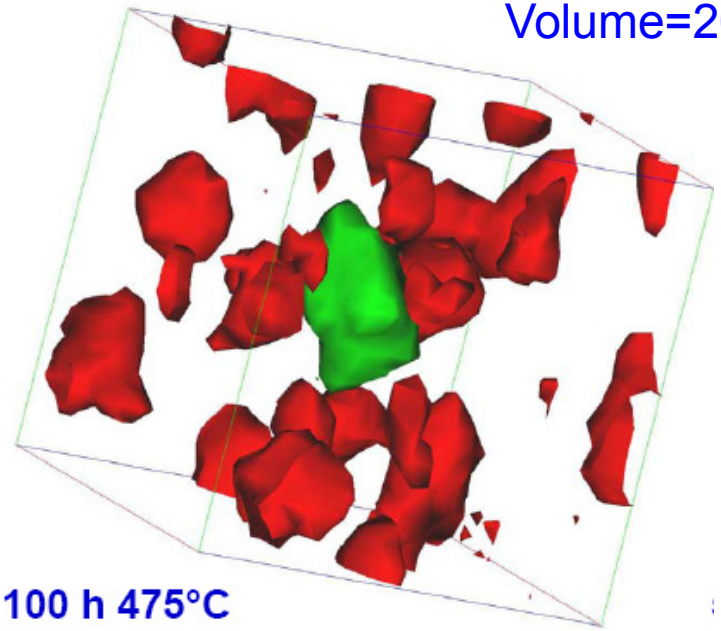


APT Results

Red 30% Cr isoconcentration surface revealing the distribution and spherical morphology of Cr-rich α′ phase.

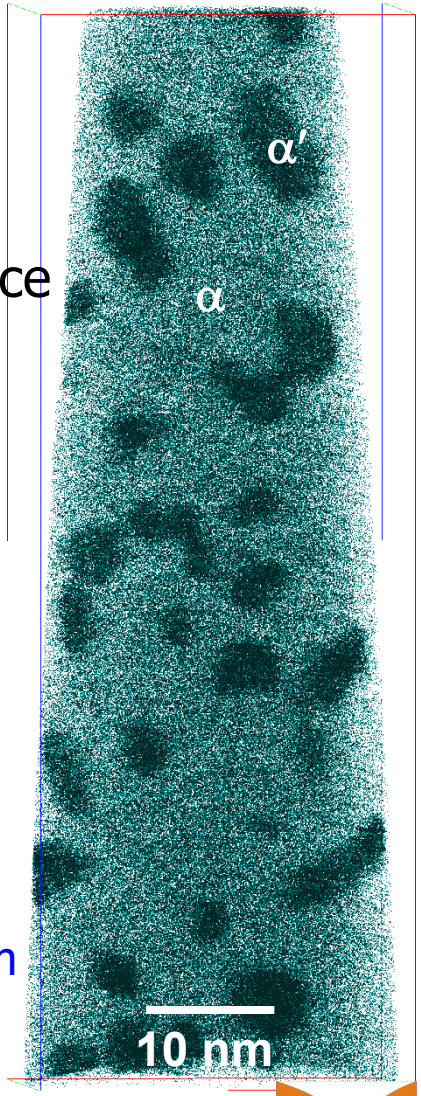
Green 5% Ti isoconcentration surface revealing the existance of 3.2 nm in diameter nanoclusters of Fe(Ti,Al) (β′ phase)

Volume=20x20x20 nm



100 h 475°C

Cr atom map

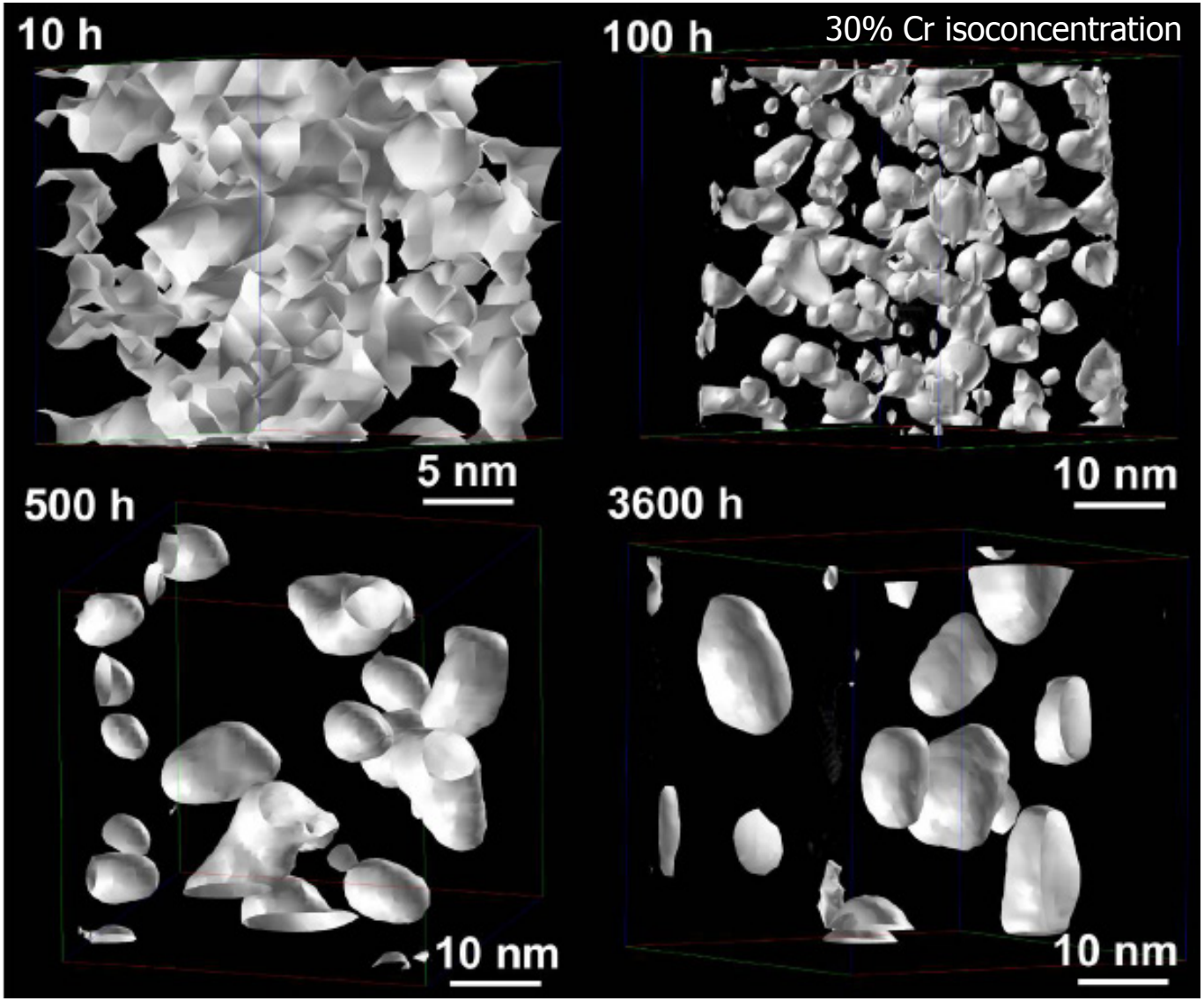


Volume=30x30x127 nm
2040 h 475 °C

APT Results

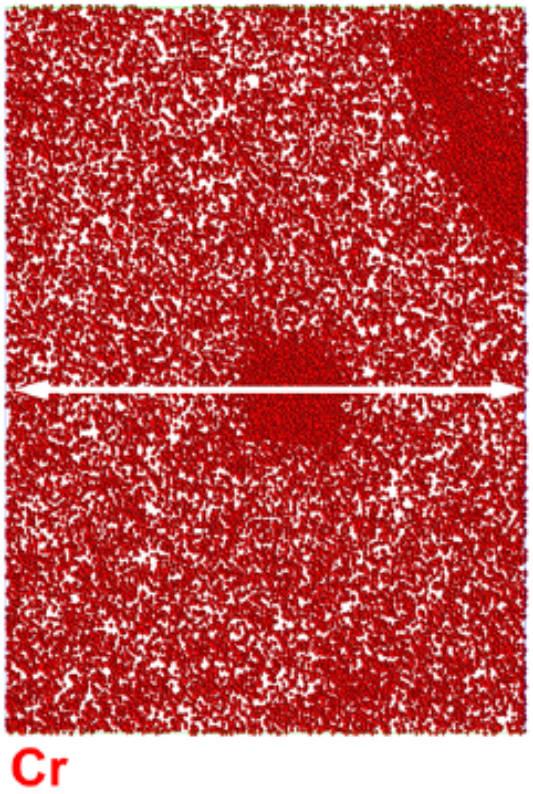
α′ phase evolution with time at 475 ºC

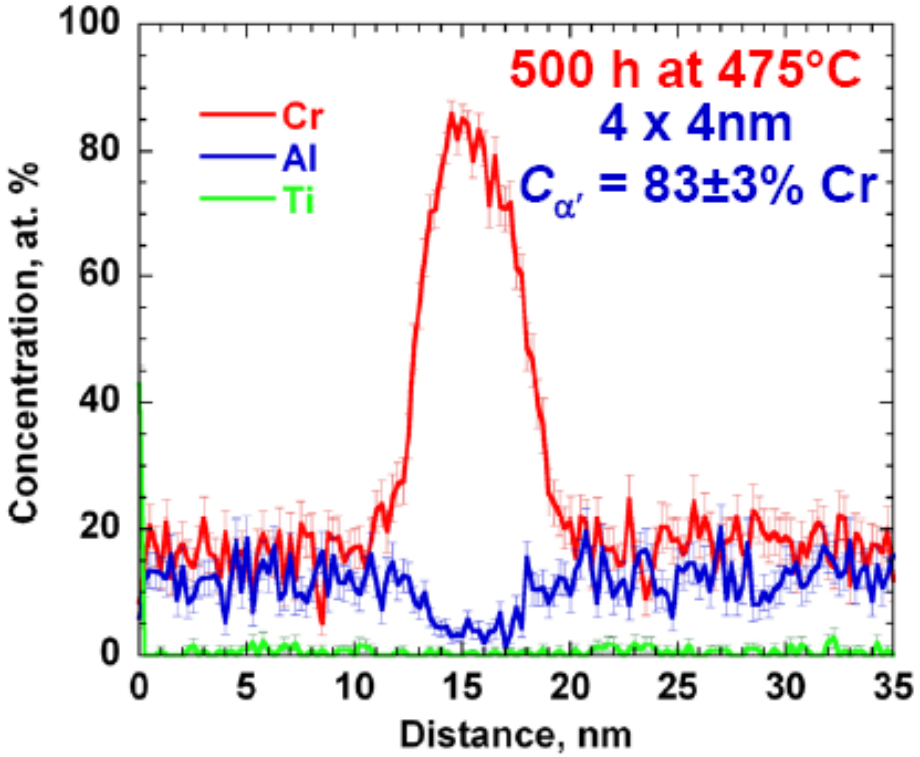
α´ phase exhibits some interconnectivity at early stages, but it becomes spheriodal and its size increases on further ageing.



APT Results

α' phase composition

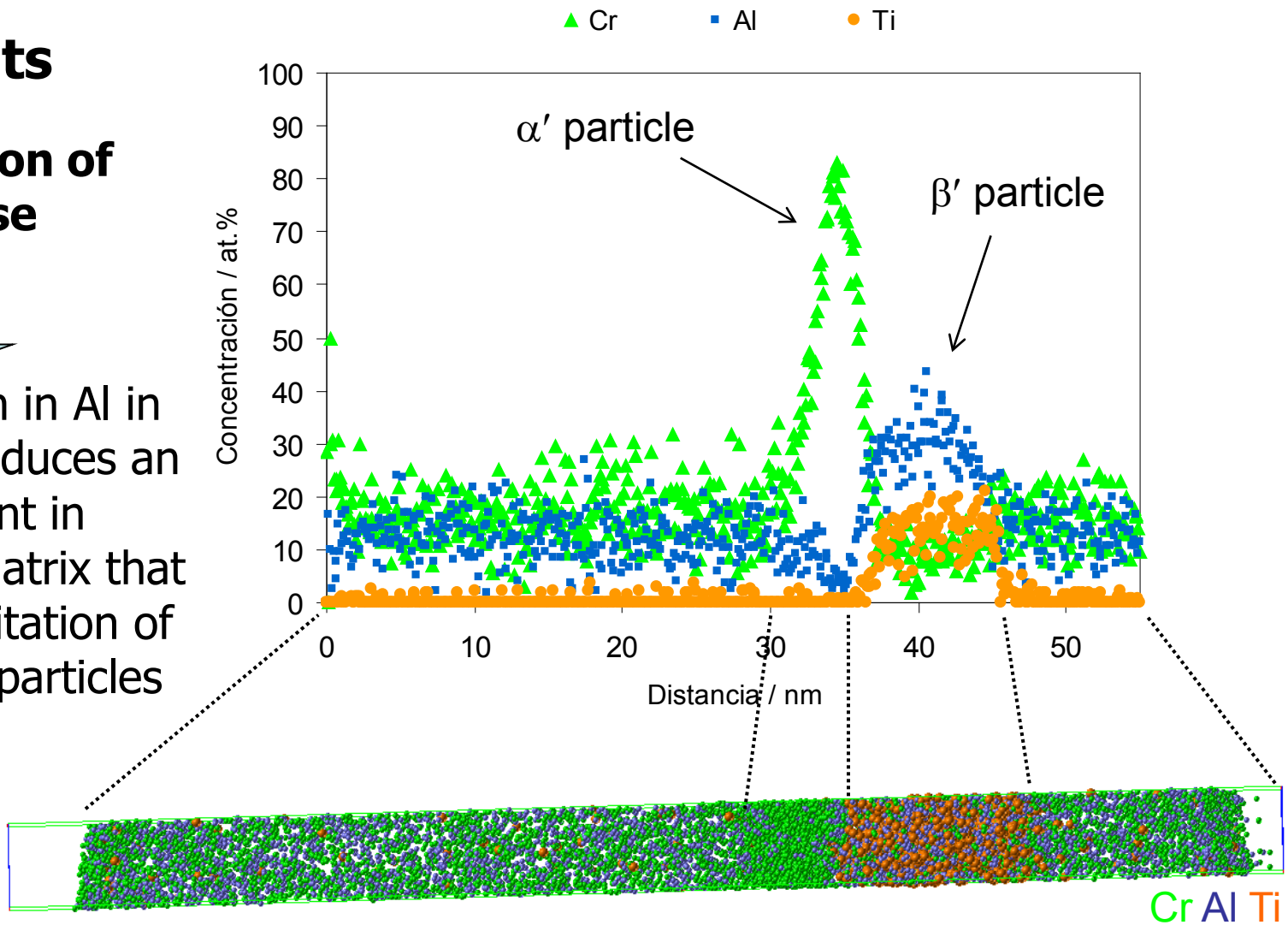




APT Results

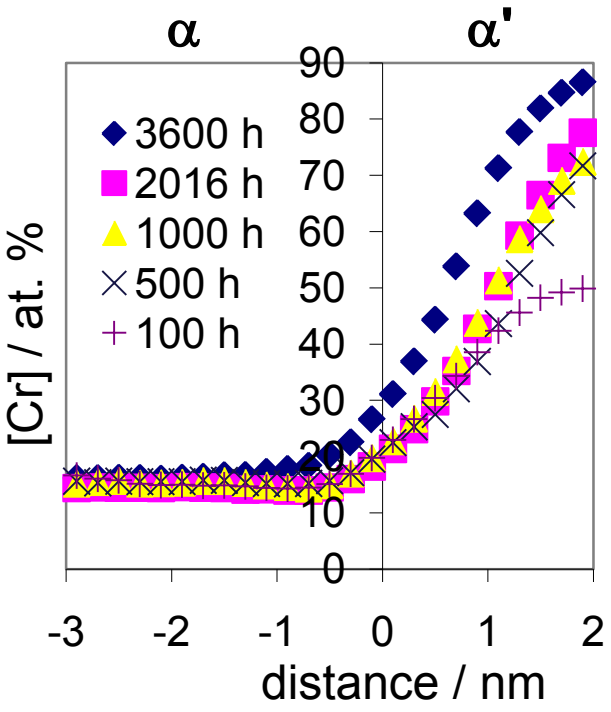
Precipitation of β′ phase

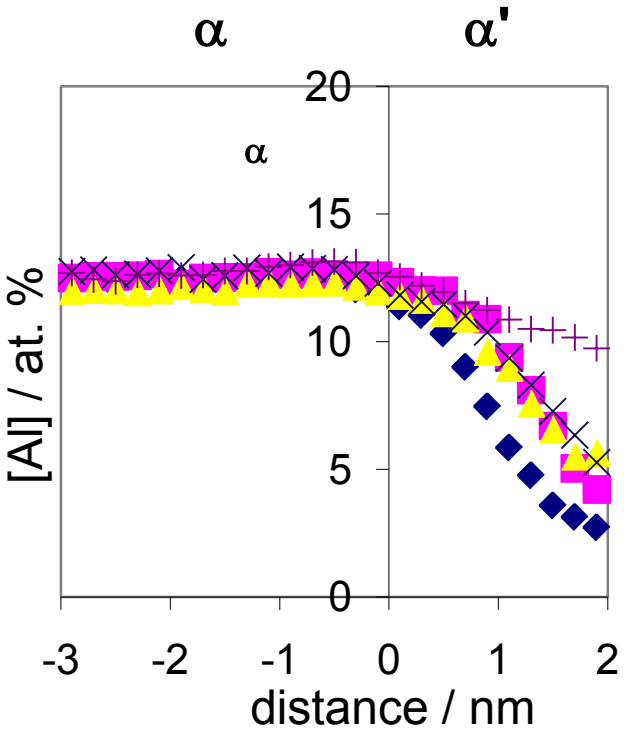
The depletion in Al in α´ particles induces an enrichment in surrounding matrix that causes precipitation of nanosized β′ particles

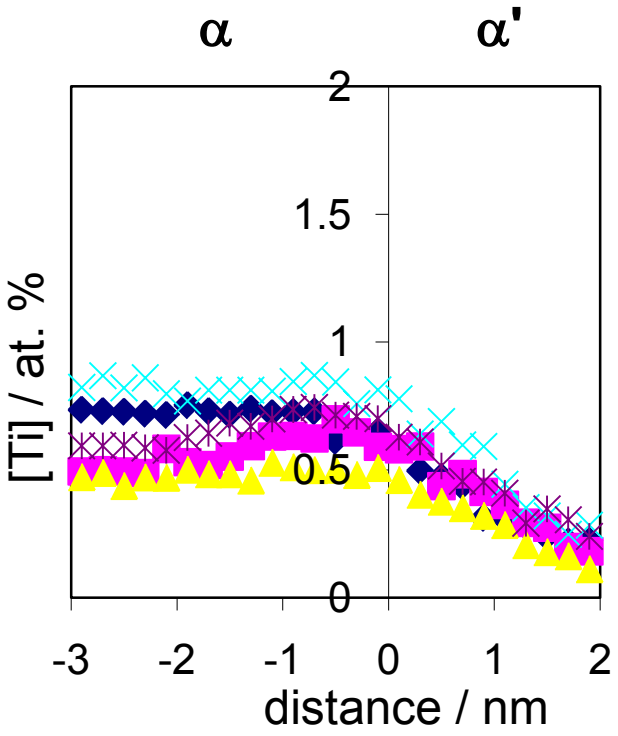


α-α′ phase separation

Proximity histograms analysis

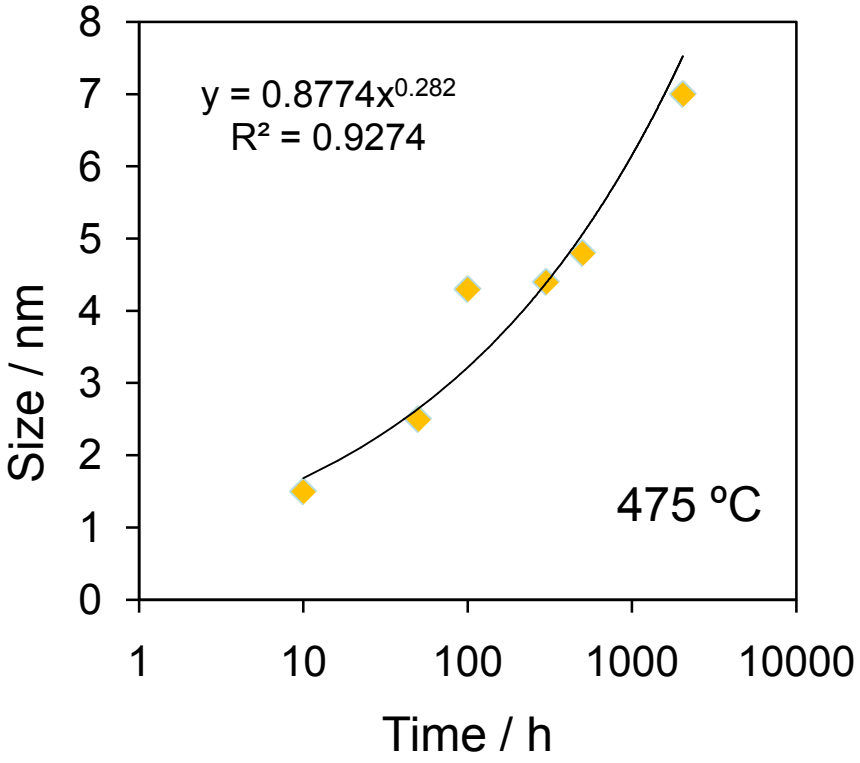




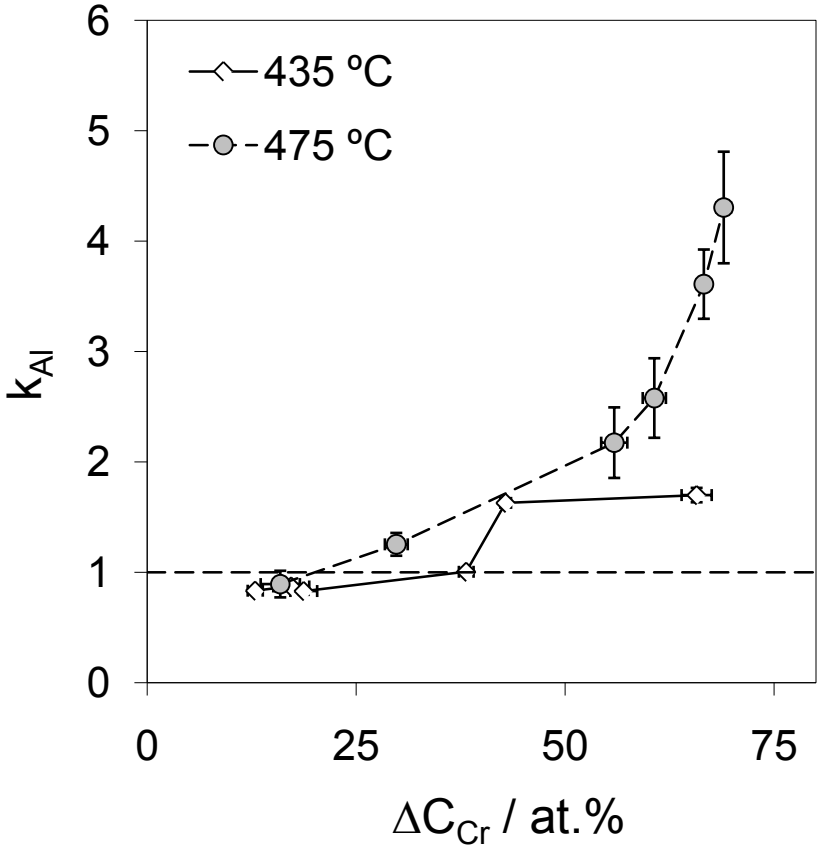


475 ºC

α′- size



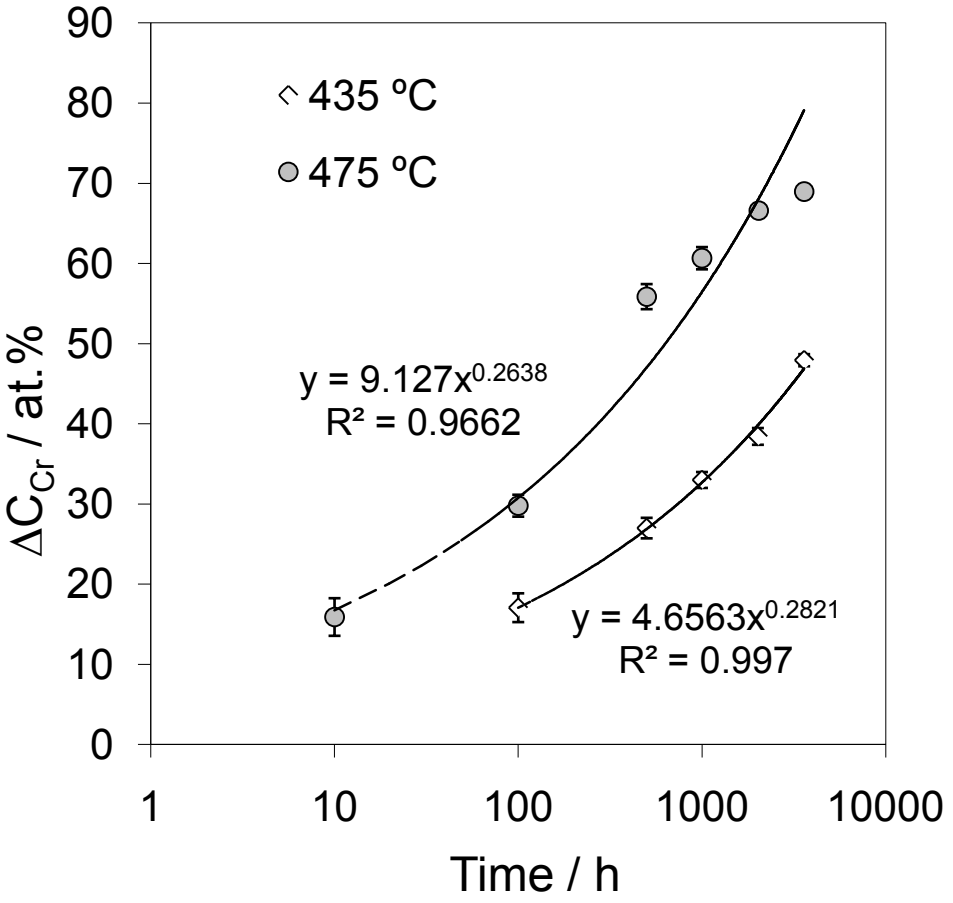
$k_{Al} = [Al]_{\alpha} / [Al]_{\alpha'}$



α-α′ phase separation kinetics

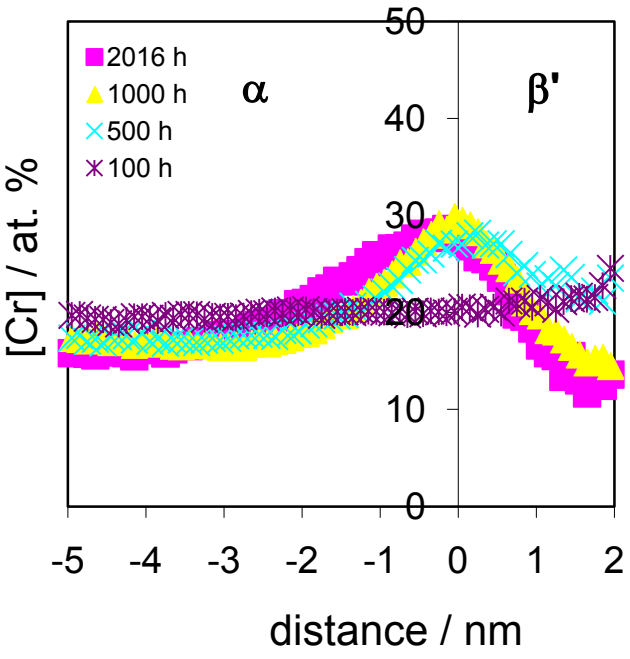
The kinetics of α - α´ phase separation process in PM 2000 were determined from the analysis of proximity histogram

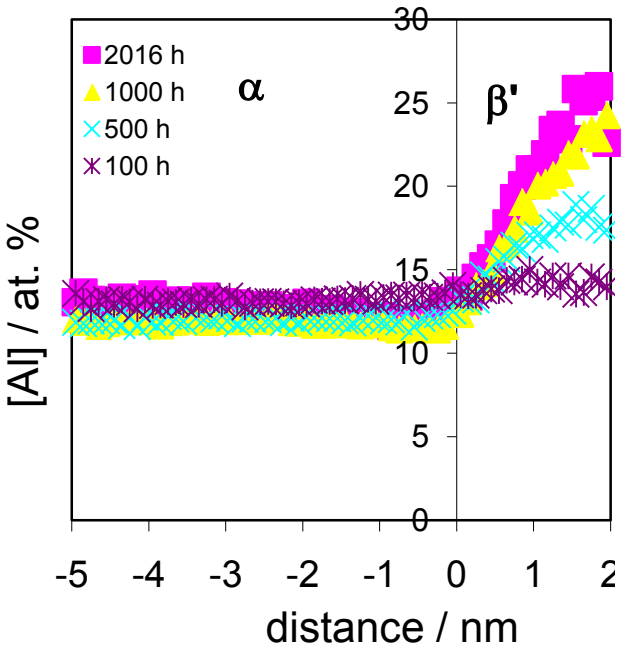
The size of the α´ increases with a time exponent of 0.32 which is consistent with the mean precipitate size R(t) varying as $\sim t^{1/3}$ predicted by the LSW theory.

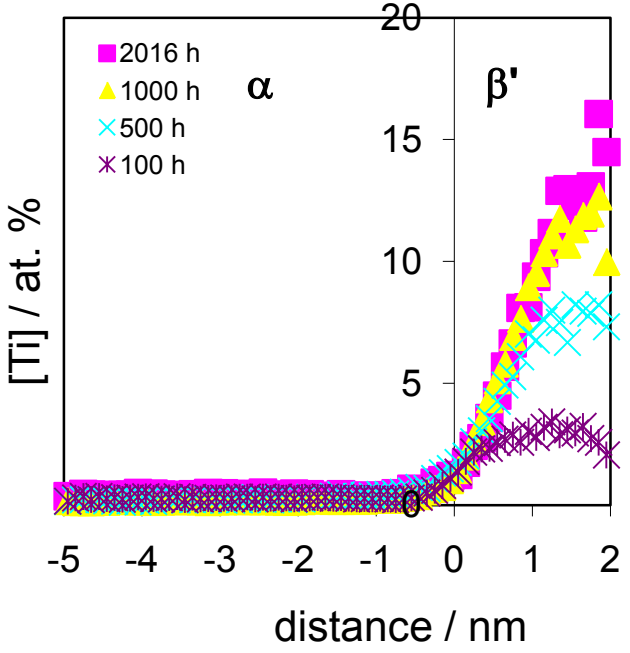


β′ precipitation

Proximity histograms analysis



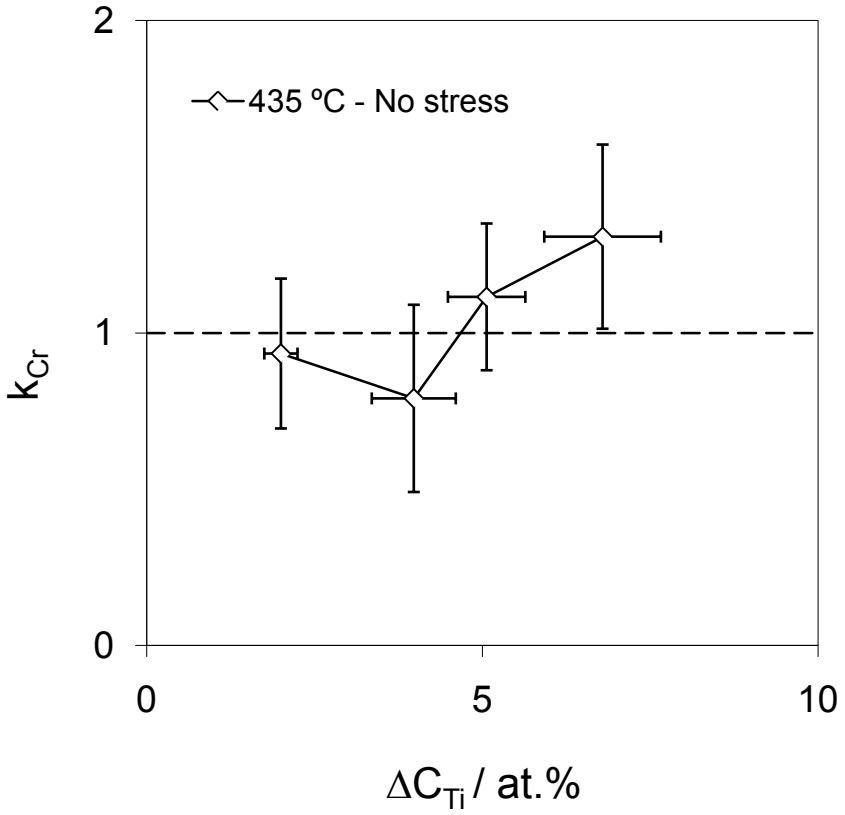




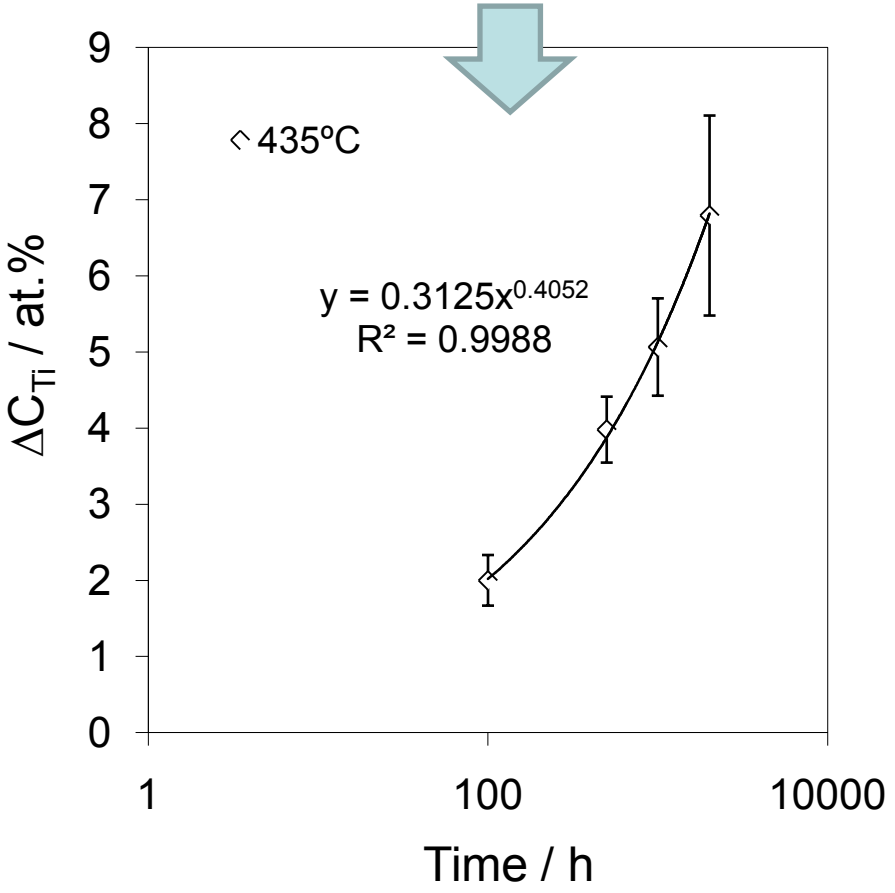
435 ºC

β′ precipitation kinetics

$k_{Cr} = [Cr]_{\alpha} / [Cr]_{\beta'}$

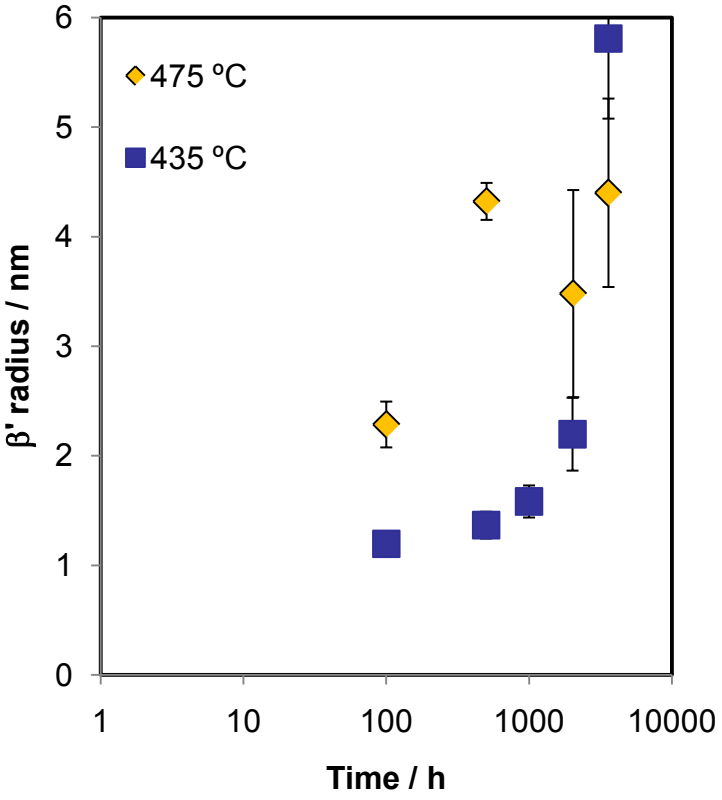


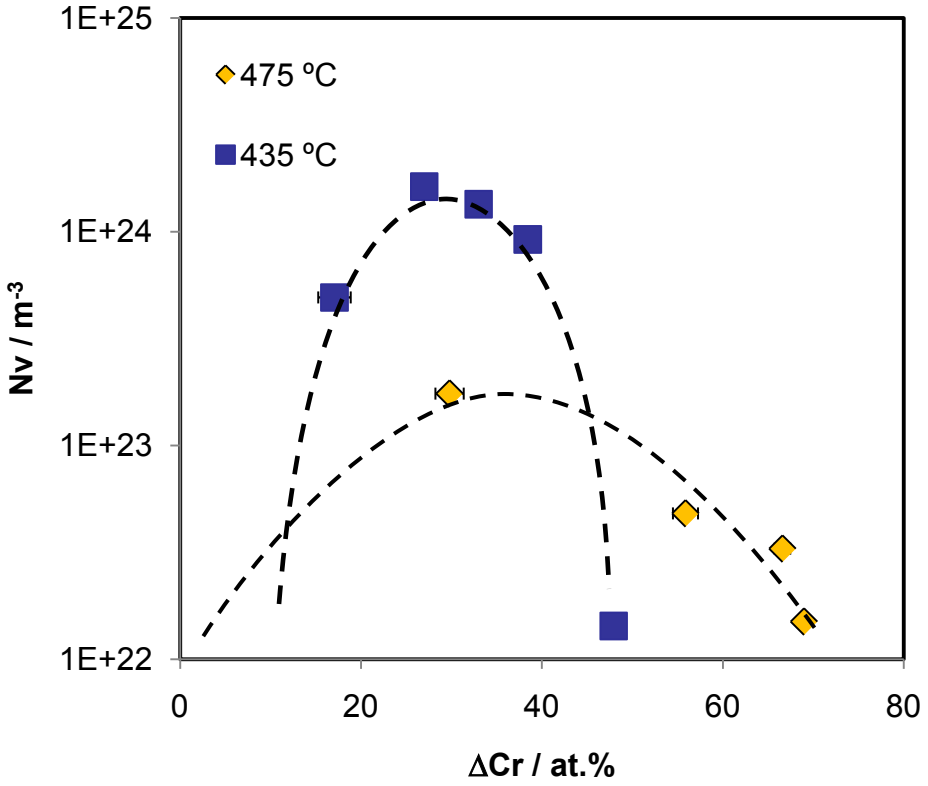
The kinetics of β´ precipitation were determined from the analysis of 1at.%Ti- proximity histogram



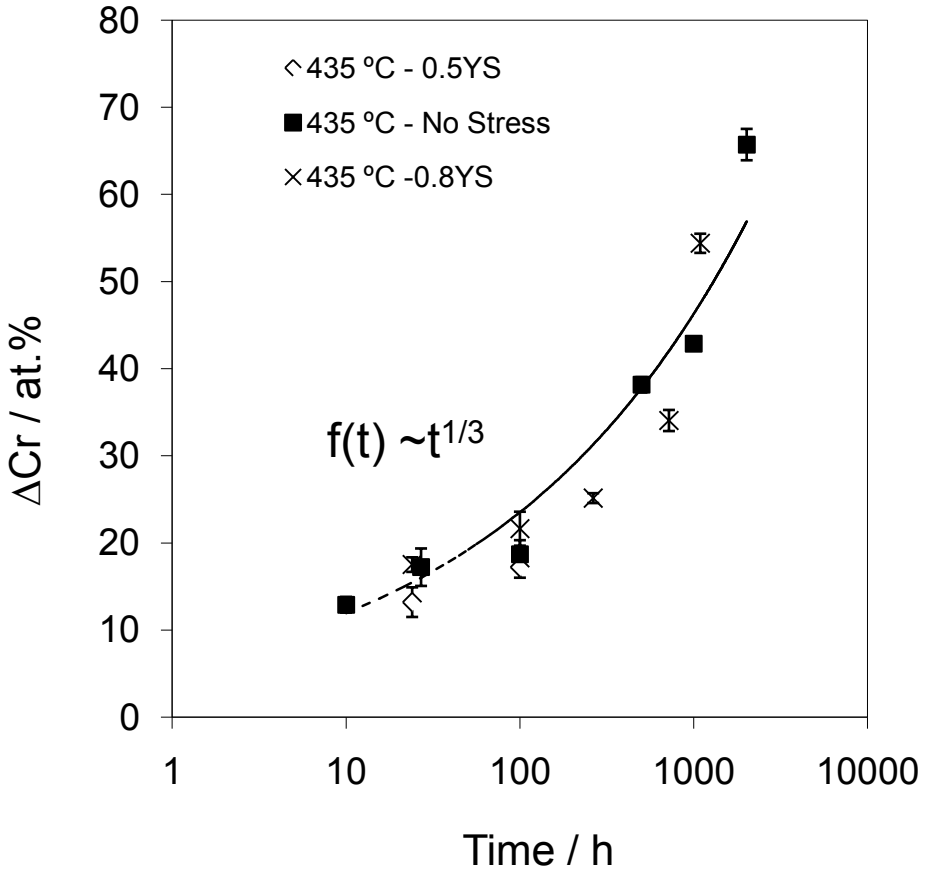
β′- size

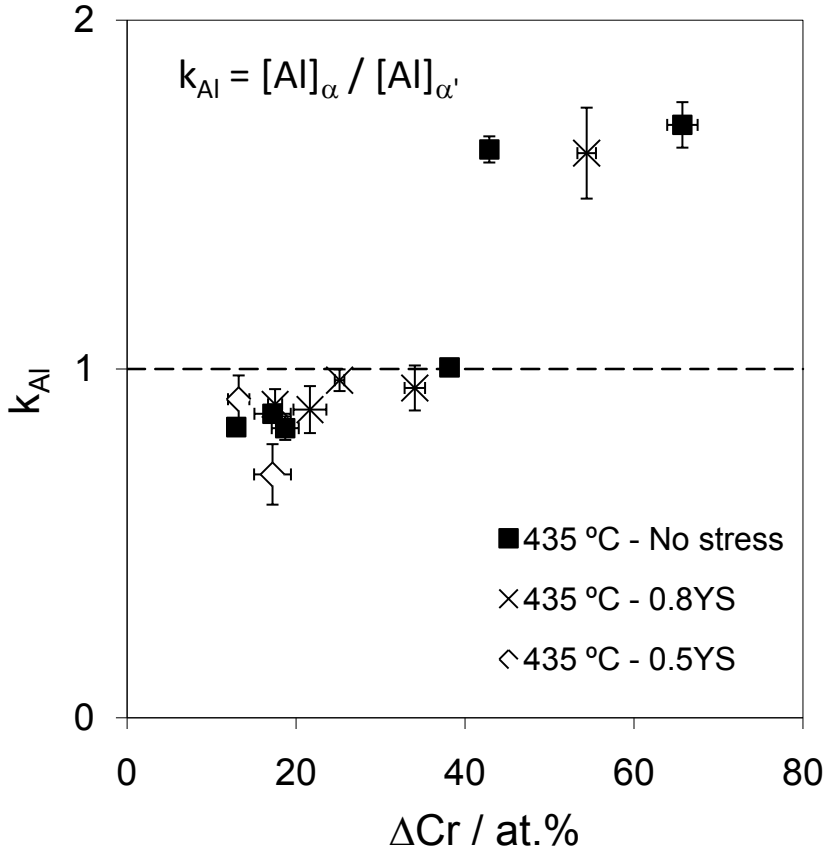
Maximum separation method



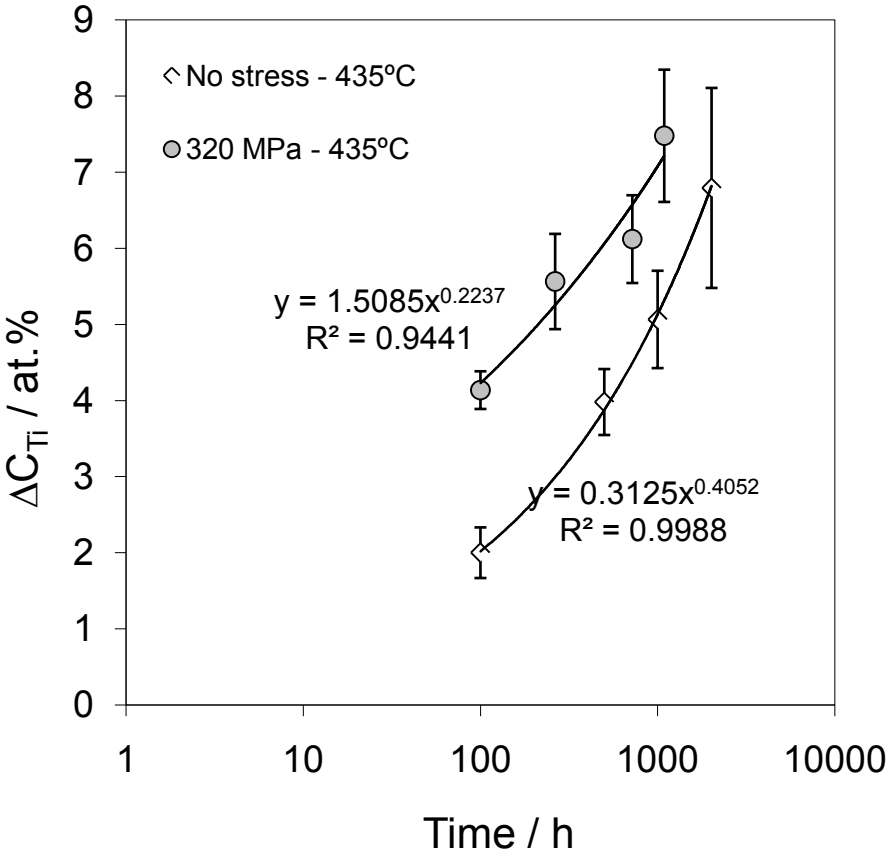


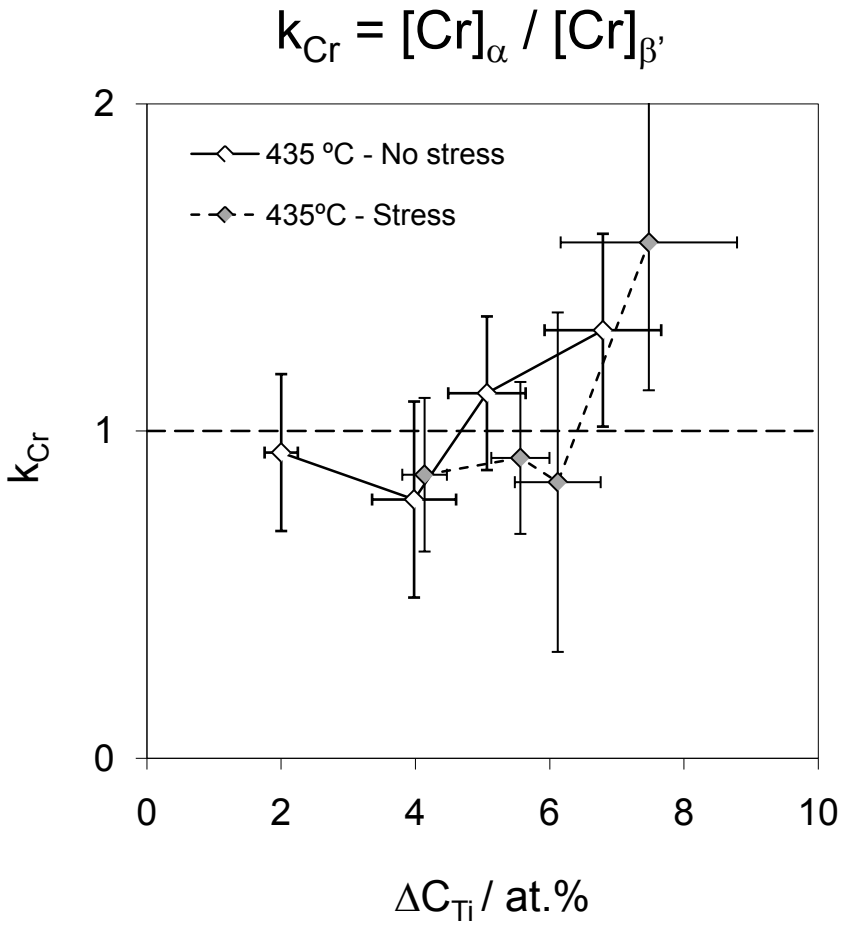
Effect of Stress: α-α′ phase separation



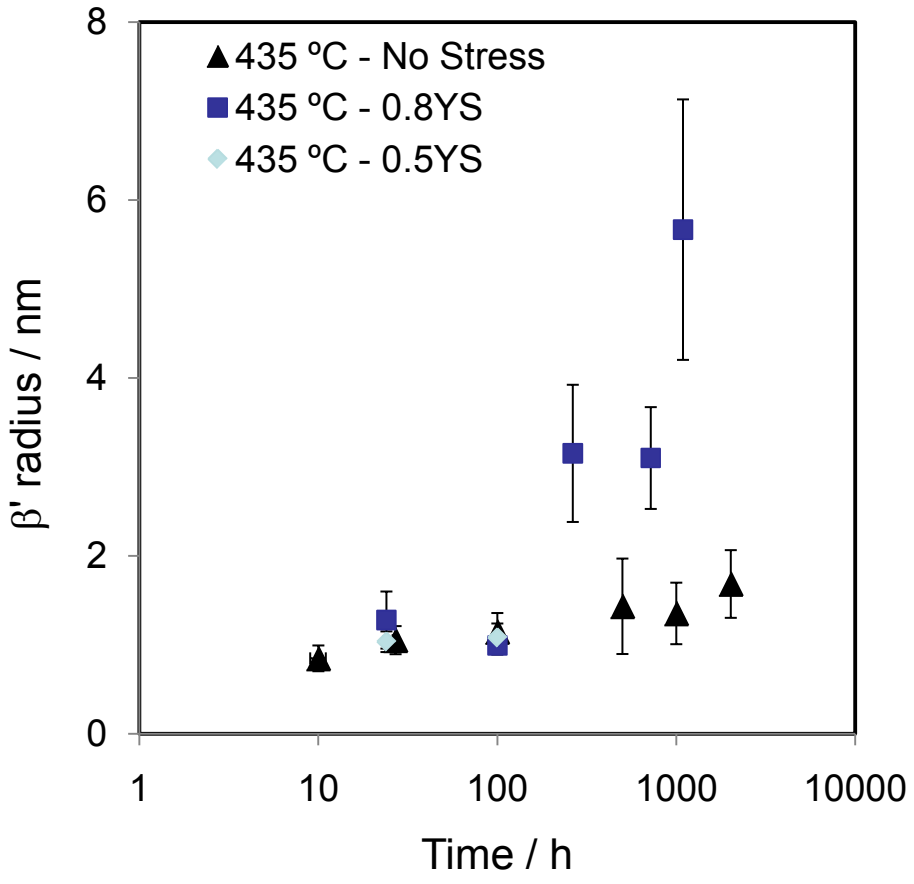


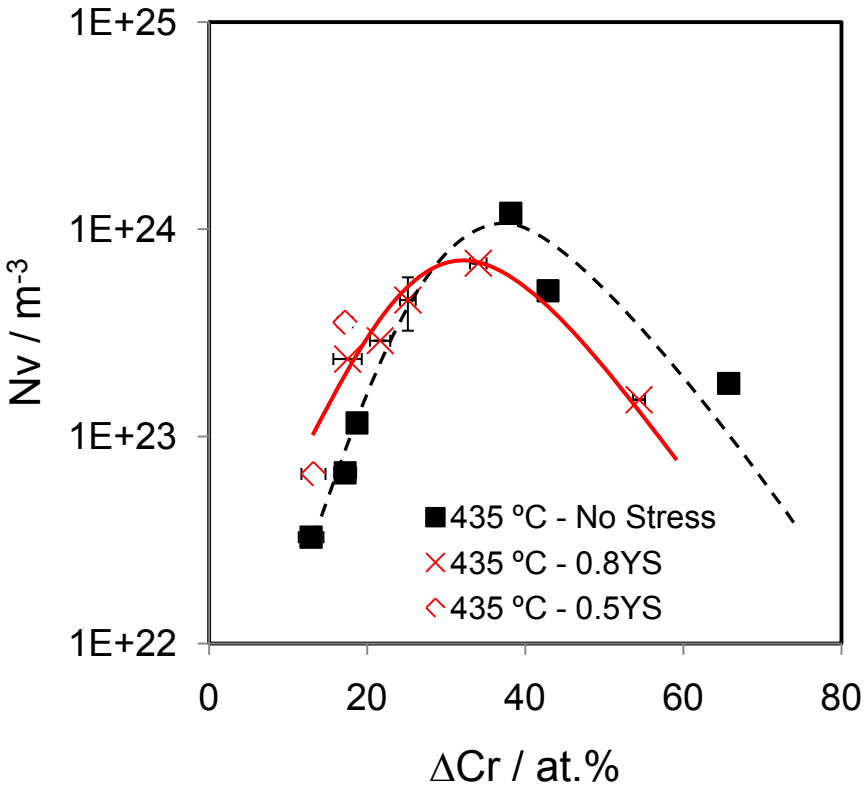
Effect of Stress: β′ precipitation



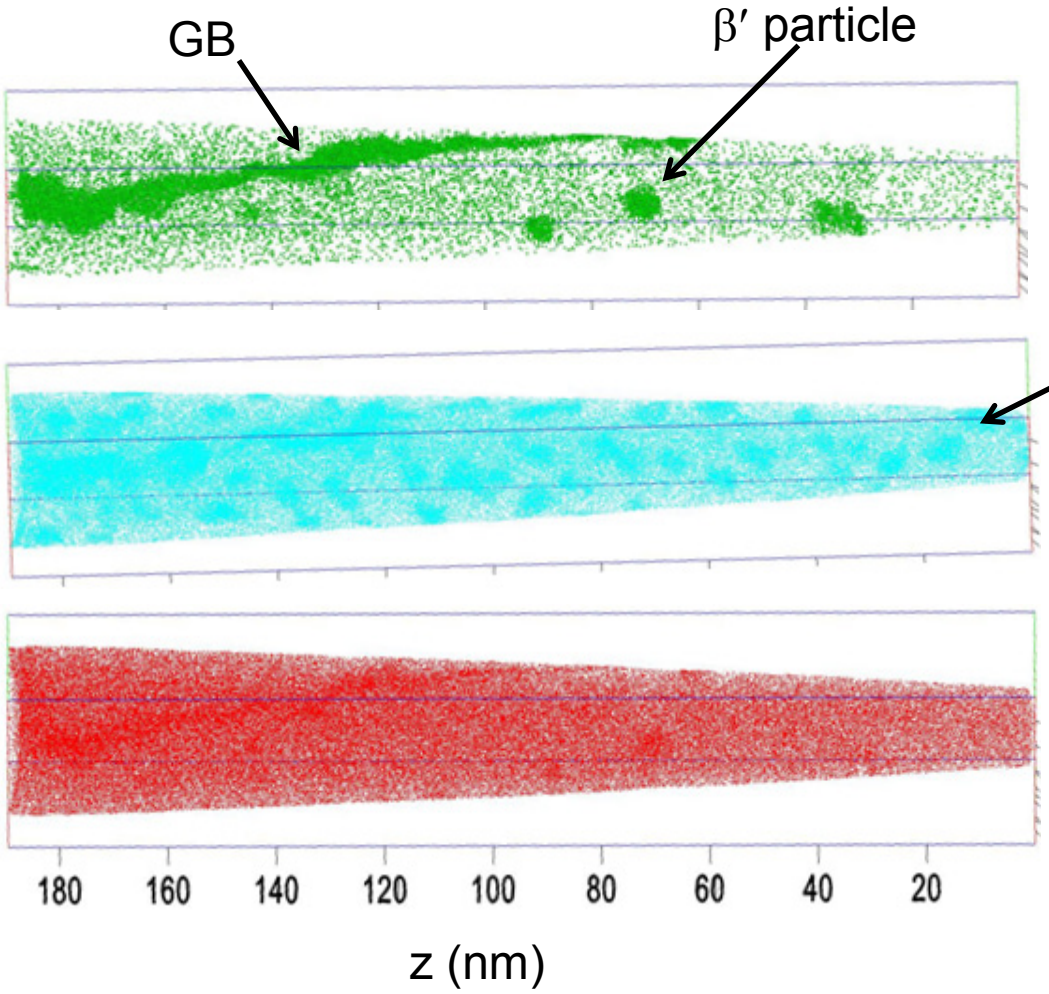


Effect of Stress: β′ precipitation





Effect of Stress: grain boundary segregation



$\sigma = 0.8YS$

Conclusions

1. Atom probe tomography revealed the nanometer-scaled phase separation betweeen α and α' phases during isothermal aging at 435 and 475 ºC.

2. Proximity histograms analysis revealed that the faster phase separation kinetics without stress applied is 475 ºC.

3. Al is rejected from the α' to the matrix during the phase separation. This leads to the precipitation of Fe-Ti-Al intermetallics (β' phase).

4. The maximum separation method estimated the size and number density of β' particles. The β' particles are more abundant and finer at 435 ºC than that at 475 ºC.

5. Elastic stress does not affect α - α' phase separation kinetics, but significant coarsening in β' phase precipitation is observed.

6. It was observed Ti and Al segregation at the grain boundary during elastic stressed ageing treatments.