The role of orientation relationships during nucleation of austenite

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Motivation

- Nucleation of austenite is very important to control the microstructure during heating.
- *E.g.* Savran *et al.* (Met. Trans. 41A 583 **2010**) showed its not just the reverse of cooling.
- Difficult to study *in-situ* due to the lack of availability of suitable techniques.

Motivation

- Nucleation rate of γ:

$$\frac{\dot{N}}{f_\alpha} \propto \frac{kT}{h}\exp\left[-\frac{\Delta G^*}{kT}\right]\exp\left[-\frac{Q_D}{kT}\right]$$

- Activation energy for nucleation:

$$\Delta G^* = \Psi / \Delta g_v^2$$

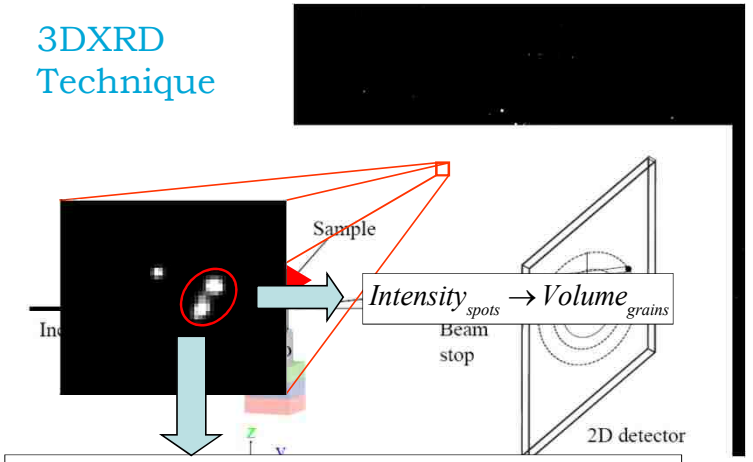
Motivation

Ψ parameter includes:

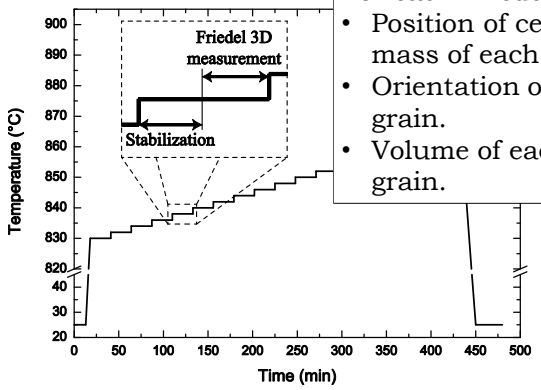
$$\Psi = \frac{4\left(\sum_i z_A^i \gamma^i\right)^3}{27 z_v^2}$$

- Factors for the shape of the nucleus
- Energy of the α-α interfaces being replaced.
  - **Ψ** ↑ with ↓ $\sigma_{\alpha\alpha}$
- Energy of the γ-α interfaces being formed.
  - **Ψ** ↑ with ↑ $\sigma_{\alpha\gamma}$

3DXRD Technique



Experiment

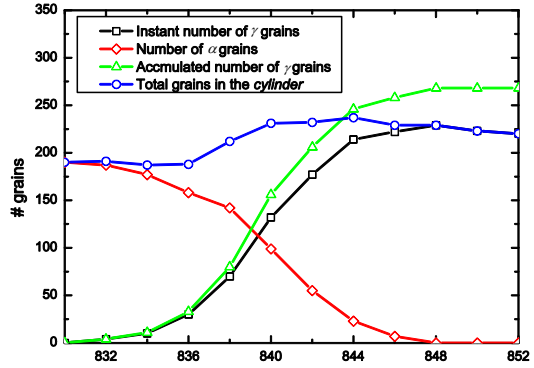


For each Friedel 3D:
- Position of centre-of-mass of each grain.
- Orientation of each grain.
- Volume of each grain.

Fe-0.01%C-0.87%Mn-0.083%Ti

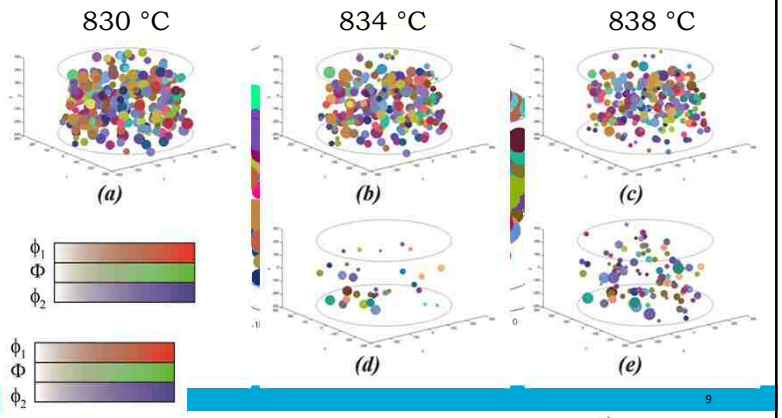
Results

Number of grains



Results

Evolution of microstructure



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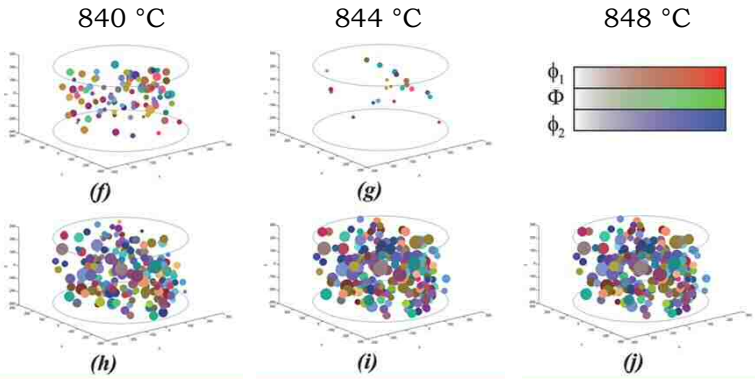
Results

Evolution of microstructure



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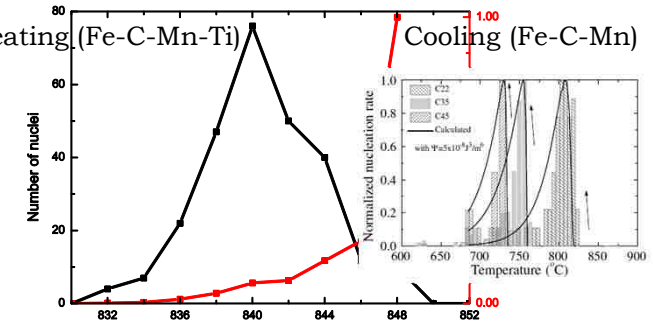
Results

Nucleation Rate

Heating (Fe-C-Mn-Ti)



$\Psi = 3.2 \times 10^{-7} J^3 m^{-6}$

Cooling (Fe-C-Mn)

$\Psi = 5 \times 10^{-8} J^3 m^{-6}$

$\frac{\dot{N}}{f_\alpha} \propto \frac{kT}{h}$

Offerman *et al.*, Nuclear Instruments and Methods in Physics Research B 246 (2006) **194**

Results

Orientation relationships

- Kurdjumov-Sachs (K-S)
- Nishiyama-Wassermann (N-W)

- For both K-S and N-W

$(110)_\alpha \quad (111)_\gamma$ } Maximum deviation < 3°

- For K-S

$[111]_\alpha \quad [110]_\gamma$

- For N-W

$[100]_\alpha \quad [110]_\gamma$ } Maximum deviation < 8°

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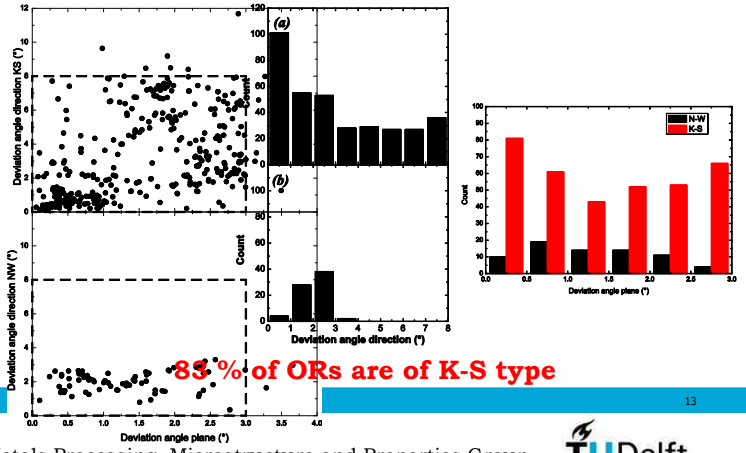
Results

Orientation relationships



83 % of ORs are of K-S type

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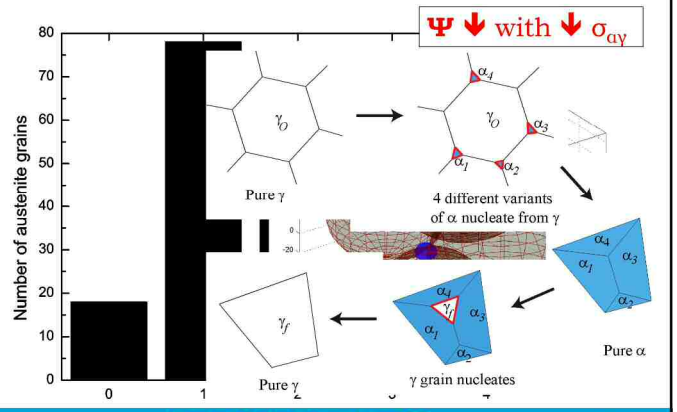
Results

OR with neighbours



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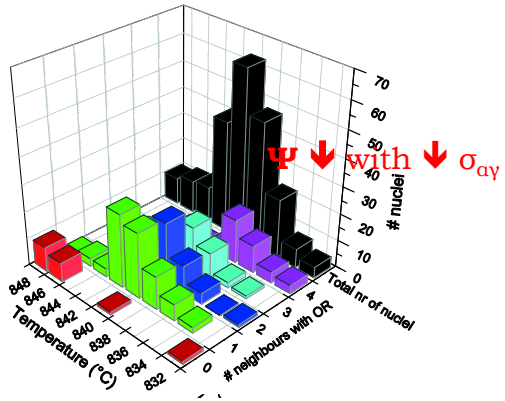
Results

OR with neighbors



$$\frac{\dot{N}}{f_\alpha} \propto \frac{kT}{h}\exp\left[-\frac{\Delta G^*}{kT}\right]\exp\left[-\frac{Q_D}{kT}\right] \qquad \Delta G^* = \Psi / \Delta g_v^2$$

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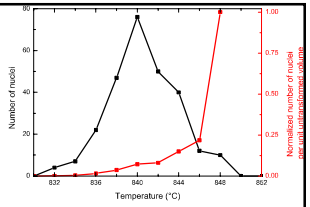
Conclusions



- New nuclei appear all throughout the transformation.
- The number of new nuclei (normalized) increases rapidly with increasing temperature.
- A number of γ grains (as big as 120 μm in diameter) are consumed during the transformation.
- The calculated value of **Ψ** is 10 times higher than that reported before for cooling in a different alloy.

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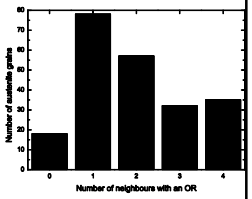
Conclusions

- K-S is much more abundant than N-W.
- 92 % of nuclei have OR with at least one α neighbor.



- Almost a third of the grains have OR with three or four α neighbors
  → requiring a very special microstructure.
- A simplified model based on orientation relationships and high nucleus densities is proposed for the formation of the special microstructure.

Conclusions

- The temperature of nucleation of γ grains is found to be dependent on the number of neighbors with an OR.