Coarsening Dynamics in Elastically Anisotropic Phase-Separating Alloys with XPCS

Pfau B.[1], **Stadler L.-M.**[1], **Sepiol B.**[1], **Weinkamer R.**[2], **Zotone F.**[3], **and Vogl G.**[1]

[1] Fakultät für Physik, Strudlhofgasse 4, A-1090 Wien, Austria, email: pfau@ap.univie.ac.at, [2] Max-Planck-Institute of Colloids and Interfaces, D-14424 Potsdam, Germany,
[3] European Synchrotron Radiation Facility, BP 220, F-38043 Grenoble Cedex, France

Coarsening in Ni-Al-Mo

In the late stage of phase-separation in alloys coarsening occurs. The main driving force for this process is the interface energy. Additionally, if the lattice constants of the precipitates (a_p) and the matrix (a_m) do not match, elastic interactions play a crucial role. Our aim is to study the dynamical properties of these processes.

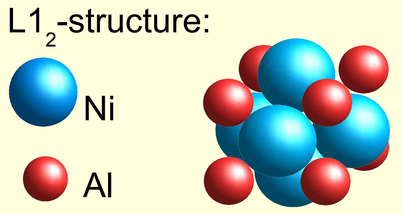
Two separating phases:

- Ni-rich: disordered fcc (matrix)
- Ni_3Al: $L1_2$-ordered (precipitates)

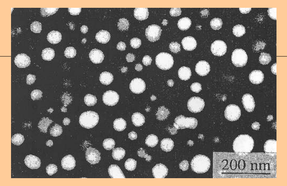
→ Misfit (δ) controlled by Mo content

$$\delta = \frac{a_p - a_m}{a_m}$$

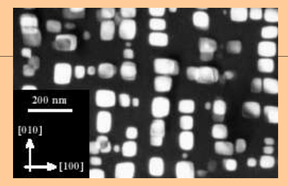
$L1_2$-structure:



Misfit and elastic anisotropy define shape and alignment of the precipitates in the matrix



Misfit δ = 0
shape: spherical
alignment: random
Picture: M. Fährmann et al, Acta metall. mater. **43**, 1007 (1995).

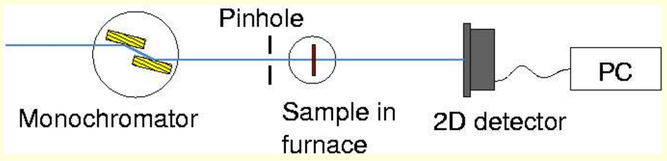


Misfit |δ| > 0
shape: cuboidal or plate-like
alignment: along elastic soft directions <001>
Picture: J.-M. Schneider, B. Schönfeld, B. Demè, and G. Kostorz, J. Appl. Chryst. **33**, 465 (2000).

XPCS
X-ray Photon Correlation Spectroscopy

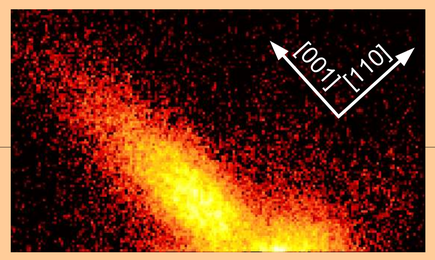
Scattering of **coherent radiation** at a disordered sample causes a highly modulated diffraction pattern, a so-called **speckle pattern**. This interference pattern changes with the motion of the scattering centres in the coherently illuminated material. By analysing the **temporal correlations** of **intensity fluctuations** information about the **dynamics** in the sample is gained.

Measurements in small-angle X-ray scattering geometry.

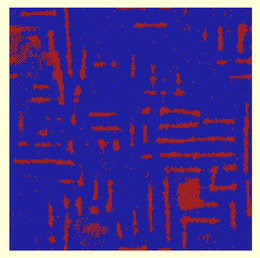


SAXS-pattern with speckles

δ=0 δ=+0.65%

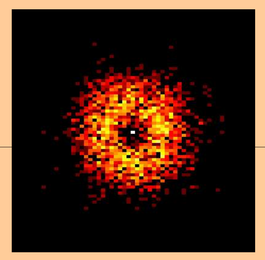


MCS
Monte Carlo Simulations



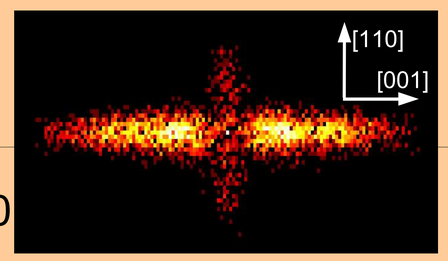
top view on a (001) cut, positive lattice misfit, 2000MCS

The model:
- two types of atoms in an fcc lattice
- atoms connected with springs
- elastic and chemical interaction
- 96x96x96 lattice
- periodic boundary conditions



Simulated pattern

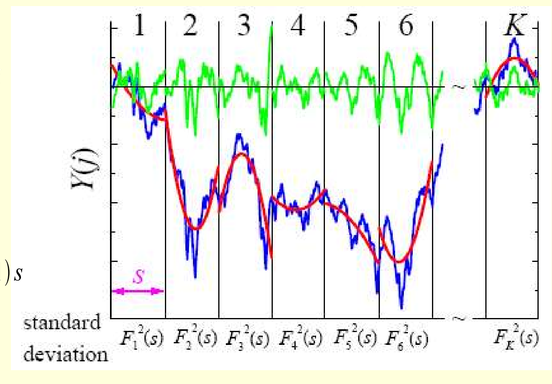
δ=0 δ>0



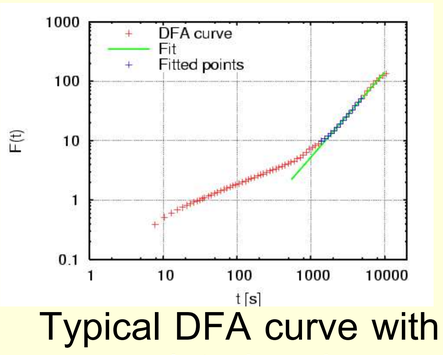
DFA
Detrended Fluctuation Analysis

DFA procedure:

- Recording of time-dependent intensity fluctuations
- Calculate the "profile" of the fluctuation $Y(j) = \sum_{i=1}^{j} I_i$
- Split the record into *K* segments
- Perform a polynomial fit in each segment $P_n(j)$
- Determine the variance $F_n^2(s) = \langle (Y(j) - P_n(j))^2 \rangle_{j=(n-1)s}^{ns}$
- Average over all segments $F(s) = \left[\frac{1}{K} \sum_{n=1}^{K} F_n^2(s) \right]^{\frac{1}{2}}$

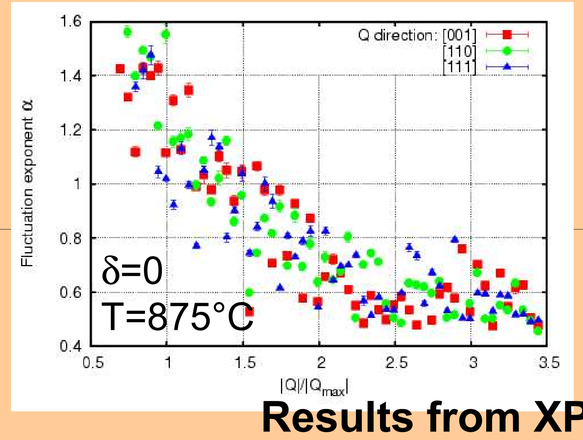


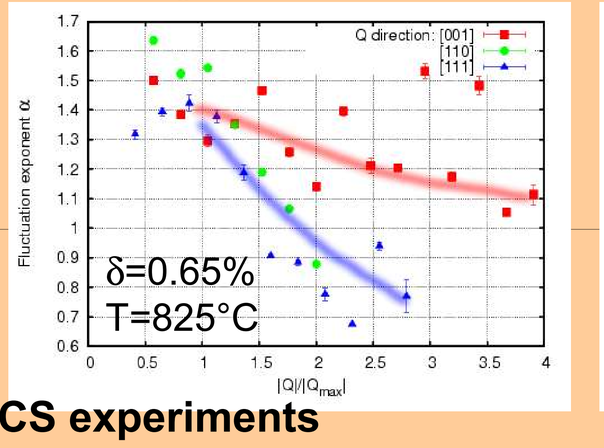
- Fit fluctuation exponent α
  $F(s) \propto t^{\alpha}$
- Random uncorrelated fluctuations: $\alpha = 0.5$
- Random walk fluctuations: $\alpha = 1.5$



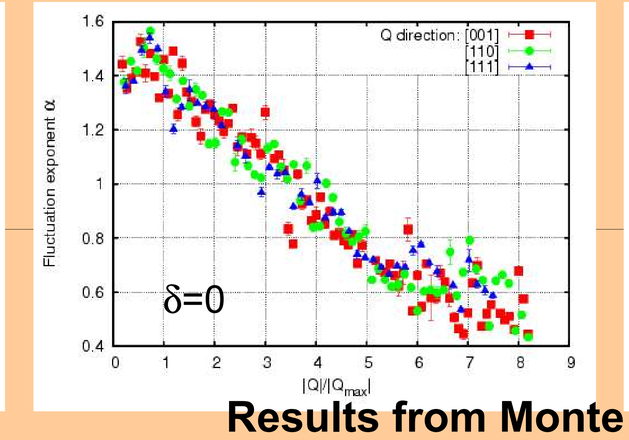
Typical DFA curve with uncorrelated noise on shorter time scales and a fit to the correlated part.

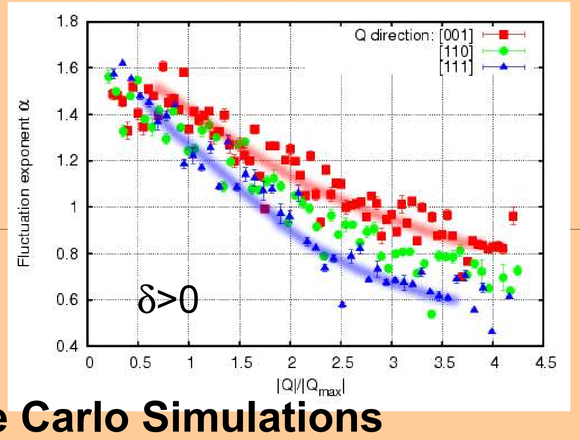
The dependence of α on the scattering vector **Q** indicates different dynamics in different crystallographic directions.





Results from XPCS experiments





Results from Monte Carlo Simulations

Preliminary conclusion: Precipitate atoms are locked along the elastic soft directions.