

New self-reinforcing metals for the future green car

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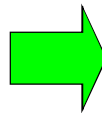
Delft University of Technology (The Netherlands)

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Automotive industry: demand for light-weight solutions



Increasing mobile
global society

Reduced Greenhouse
Gas (GHG) emissions

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Automotive industry: demand for light-weight solutions

The future **green** car:

Safer

More comfortable

Friendly to the environment
(less resources, less GHG emissions)

Affordable to be manufactured

Functional materials:

High strength

High formability

Lighter

Little or no increase
in manufacturing costs

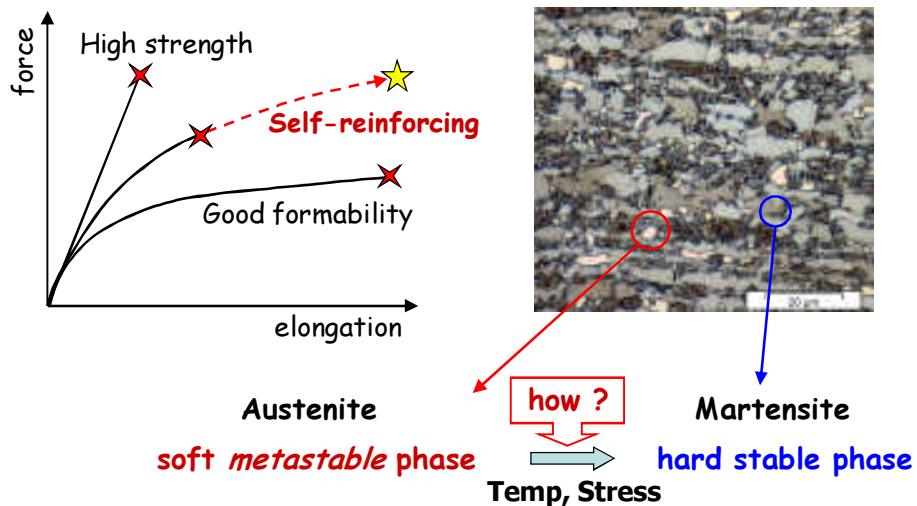
SEARCH FOR NEW FUNCTIONAL MATERIALS

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Solution: new self-reinforcing metals

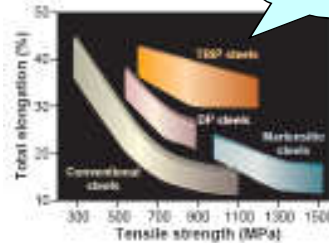
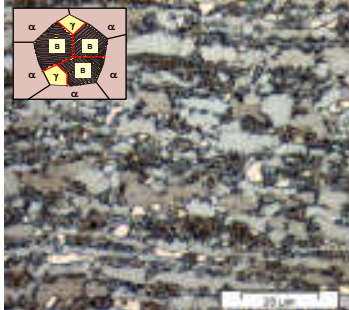


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Example: low-alloyed TRIP steels



- Complex combination of several phases
 - TRIP effect: presence of metastable austenite phase
- ↓
- Sensitive to environmental changes (Temperature, stresses)

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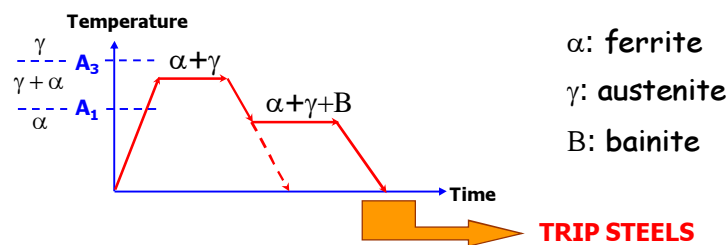
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Industrial production

Selection of proper alloying elements: Mn, Si, Al, P, ...
(suppress carbide formation)

and

Optimize a relatively complex process route



Metastable austenite at room temperature: carbon enrichment

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Current challenge

Accurate design & control of the stability of metastable austenite

We experimentally know:

- Average chemical composition
- Average grain size
- Orientation

Average information
is not enough

We need:

Control the stability of **each individual metastable grain**

SMART FUNCTIONAL MATERIAL

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New approach: use of synchrotron radiation

Why synchrotron X-rays?

1. High energy → large penetrating power: in-situ experiments

10% transmission thickness:

@80 keV: 40 mm for Al, 5 mm for Fe

@50 keV: 20 mm for Al, 2 mm for Fe

@ 8 keV: 2 mm for Al, 10 μm for Fe (Cu-K α)

2. Small beam size → high spatial resolution: individual grains

beam sizes: 5 - 500 μm (single crystal analysis of polycrystalline samples)

3. High intensity → high sampling rate: kinetic studies

exposure times: ~ 1 s

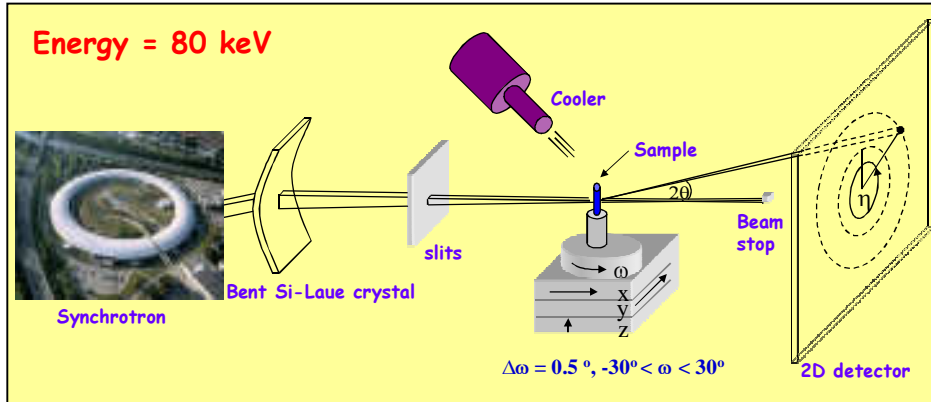
sampling rate: ~ 5 s

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Pioneering experiments: in-situ 3D X-ray Microdiffraction



Beam size: 17×17 (S), 28×29 (M) & 39×39 (L) μm^2

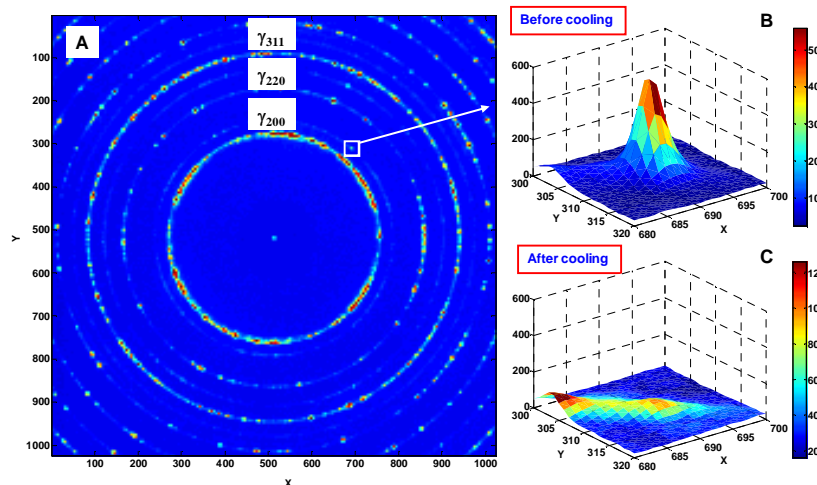
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ID11 beamline (ESRF, France)



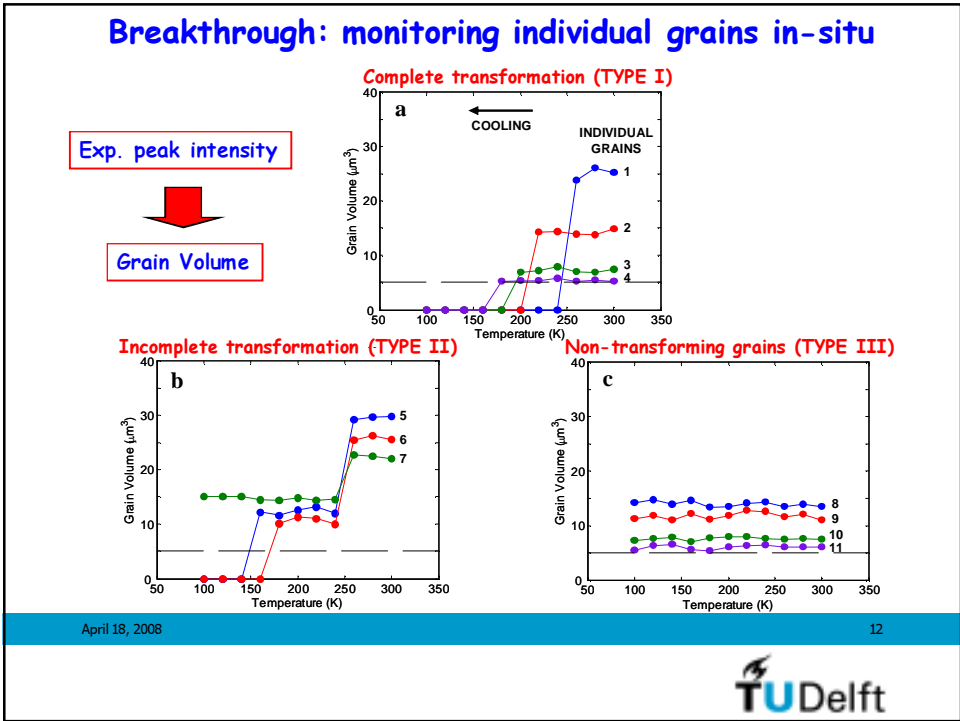
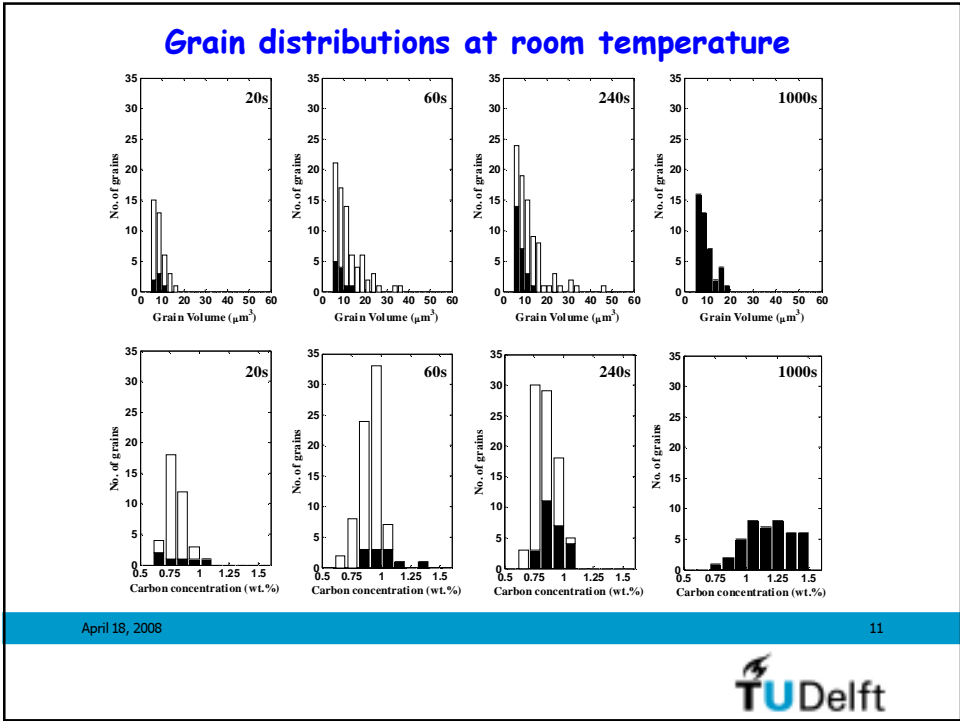
Probing individual metastable grains



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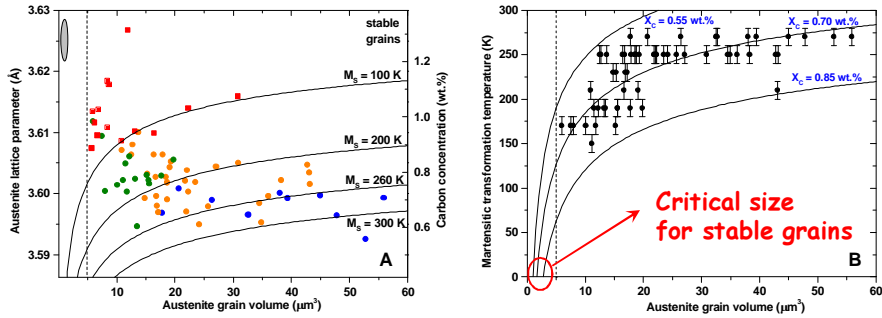
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Microstructural control of austenite stability

Stability of **individual** grains: martensitic transformation temperature (M_S)



Austenite stability controlled by **carbon content** (x_C) and **grain size** (V_γ)

$$M_S = M_{S0} - Ax_C - BV_\gamma^{-\frac{1}{3}}$$

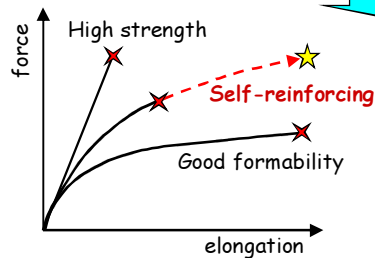
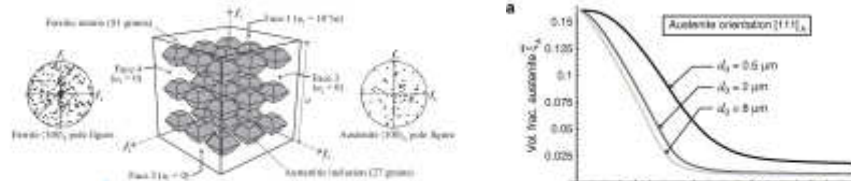
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Transition to industrial scale

Quantitative single-grain results: input for multiscale modeling



Model-based design of new self-reinforcing metals

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Conclusions

- New self-reinforcing metals offer outstanding combinations of strength and formability, that meet the current demands for light-weight solutions in the automotive industry.
- These new metals are based on the presence of metastable phases that smartly respond to environmental changes (temperature, stresses).
- Pioneering experiments with synchrotron radiation open the door to a microstructural control of the stability of each individual metastable grain in the material.
- Realistic multiscale models can now be built and used to design & control the mechanical response on new self-reinforcing metals.

References

E. Jimenez-Melero et al., *Scripta Mat.* 56 (2007) 421 & *Acta Mat.* 55 (2007) 6713

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