Experimental Investigation of Plastic Grain Interaction
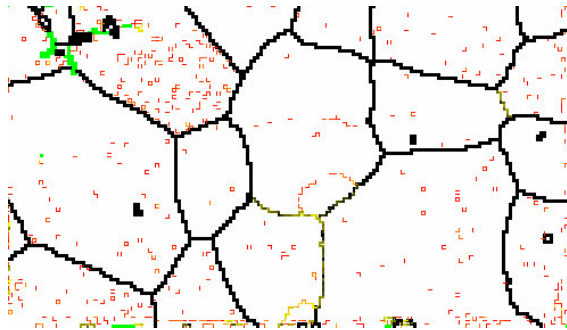
M. Sachtleber, Z. Zhao, D. Raabe

Max-Planck-Institut für Eisenforschung
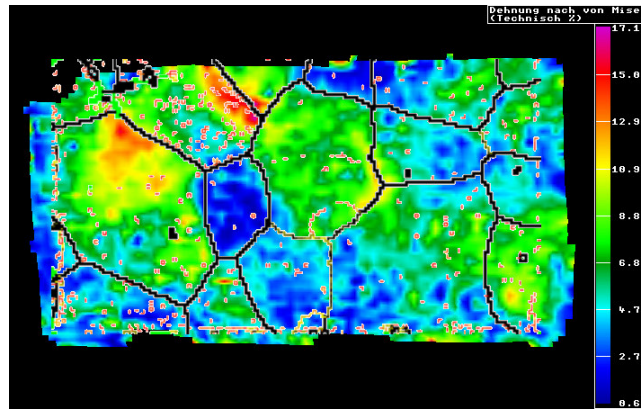Max-Planck-Str. 1, 40237 Düsseldorf, Germany, sachtleber@mpie.de

Orientation Mapping

Photogrammetry

Strain Mapping

FEM-Mesh

FEM-Simulation

100 || ND
110 || ND
111 || ND

100 || RD
110 || RD
111 || RD
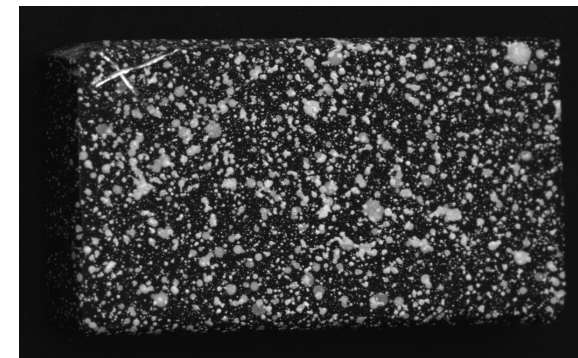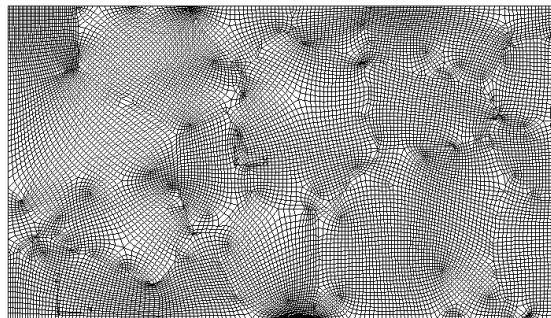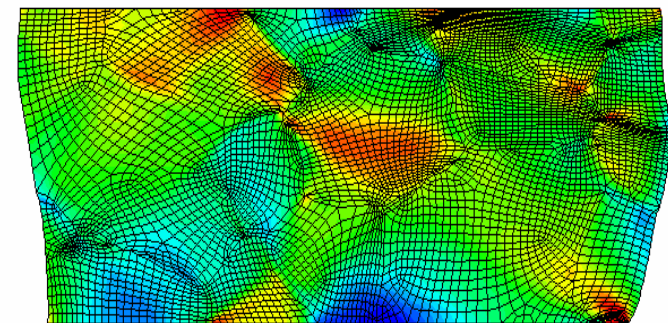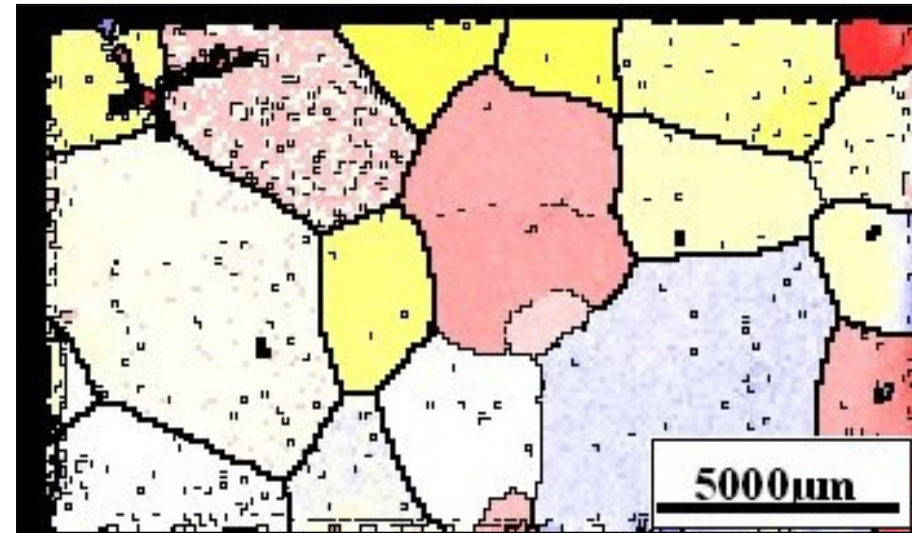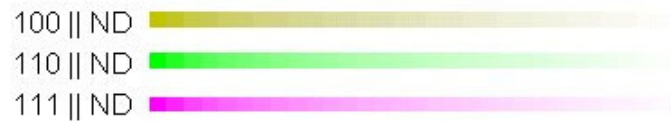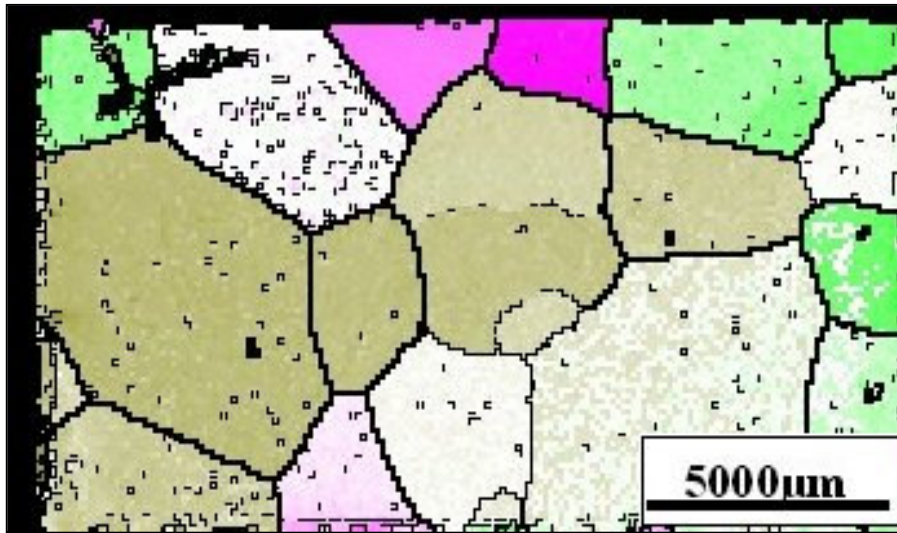
➡ 99,9% Al

➡ Columnar grain morphology (quasi 2D)

➡ Grain diameter $\underline{d}$ = 3.5 mm

➡ OM scan step size 100µm

▬▬▬ grain boundaries > 15°

——— grain boundaries >5°

3%

8%

13%

Dehnung nach von Mises
(Technisch %)

5mm

y

z   x

y

z → x

1 5 8 11 12 15
16
9 13
17
2 6
3
10 14 18
4 7
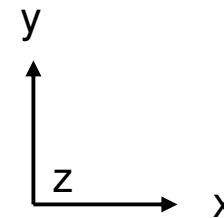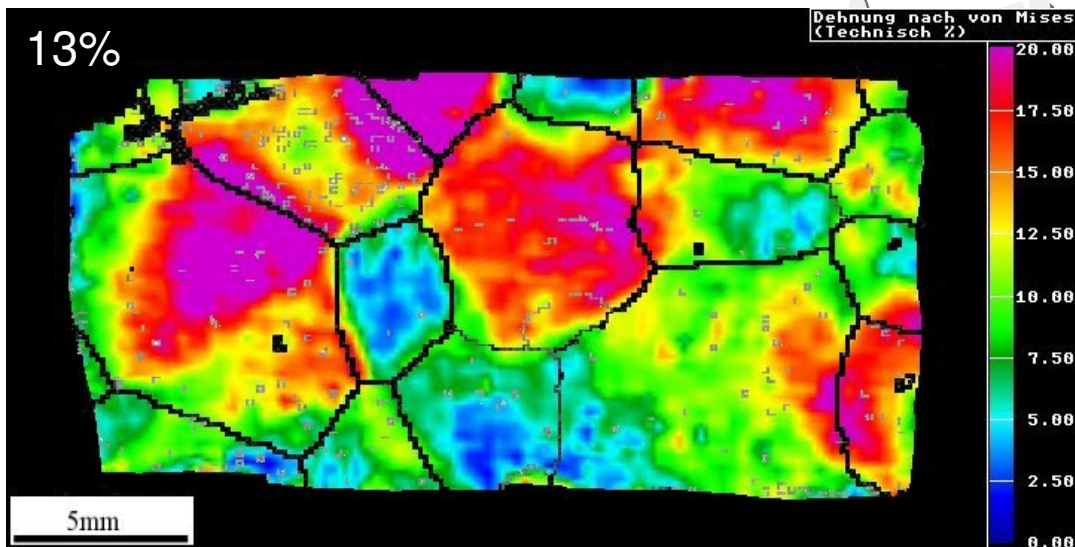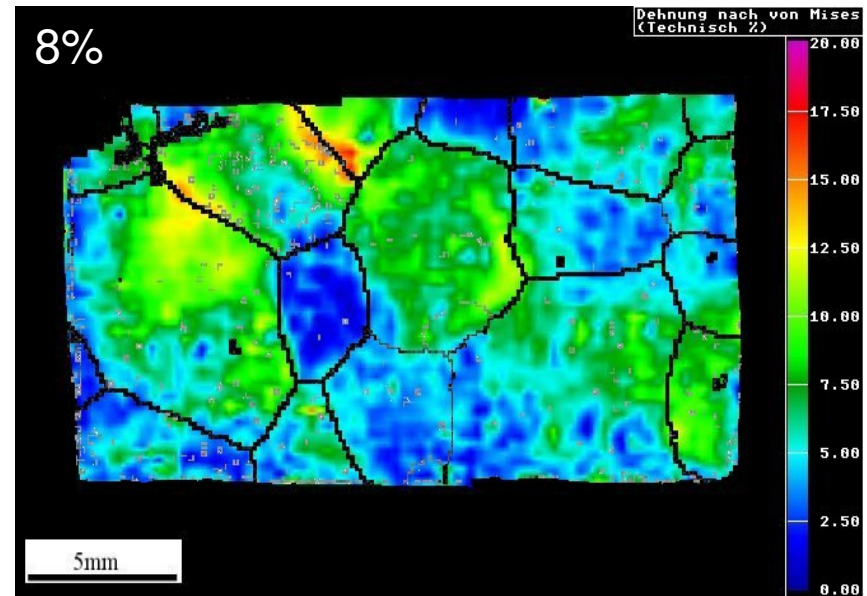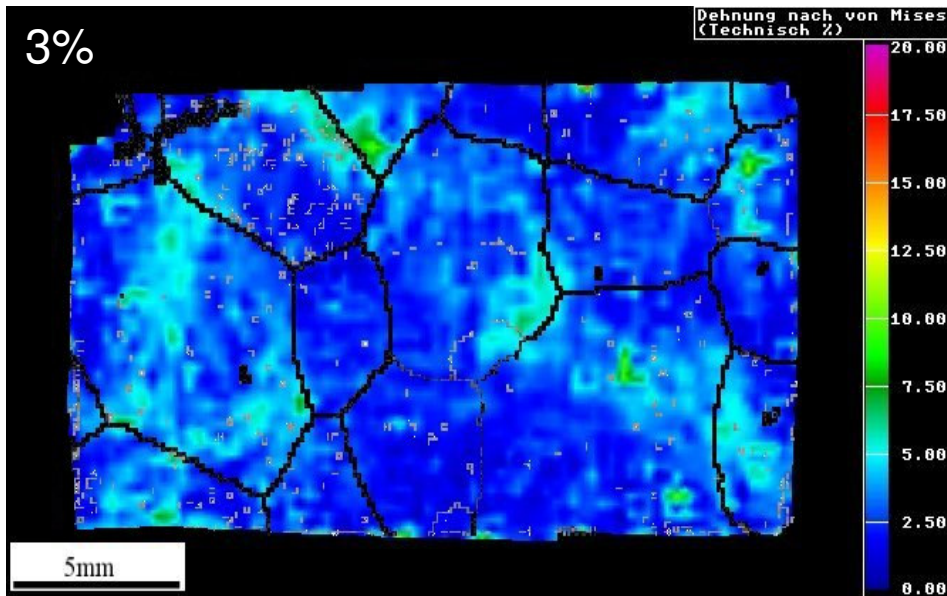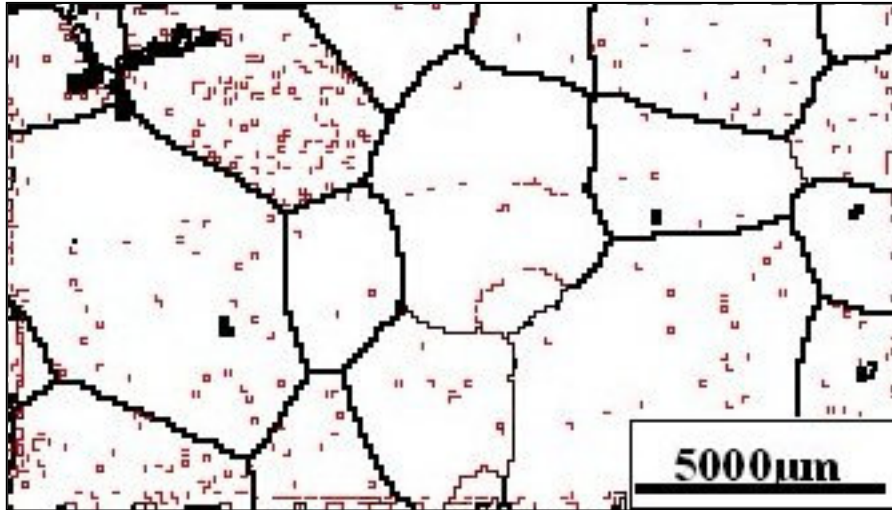
bilinear element, 4 nodes, 4 integration points
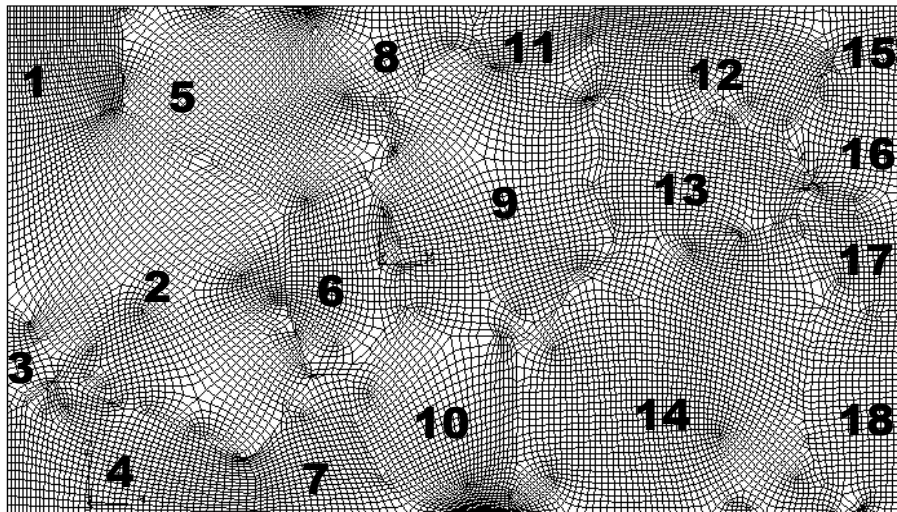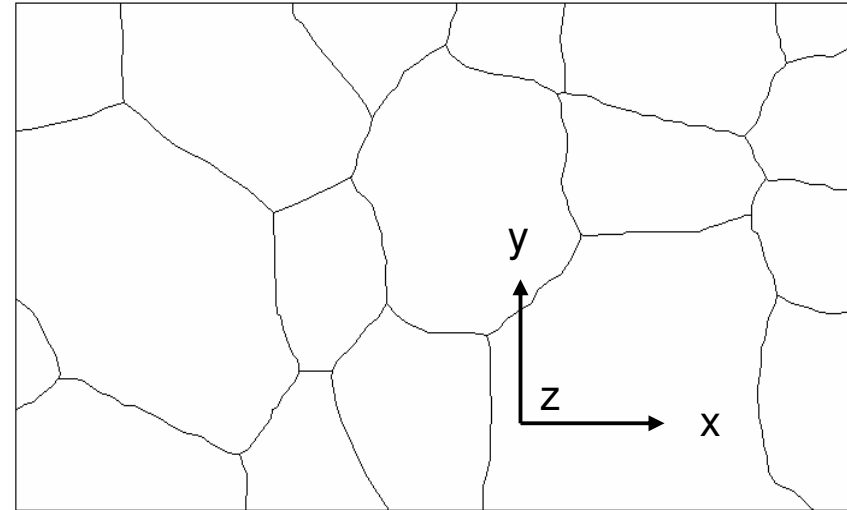
5705 elements

12 slip systems {1_11}<110> & visopastic hardening

fully implicit time-integration crystal plasticity method

[Kalidindi et. al.]

Continuum FEM Simulation

Crystal Plasticity FEM Simulation
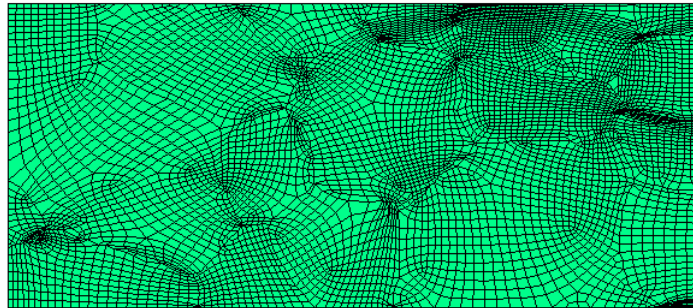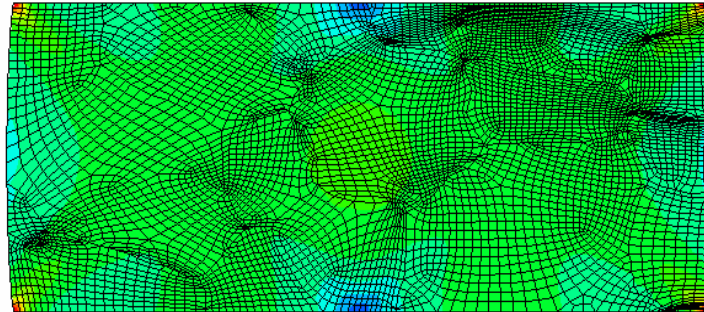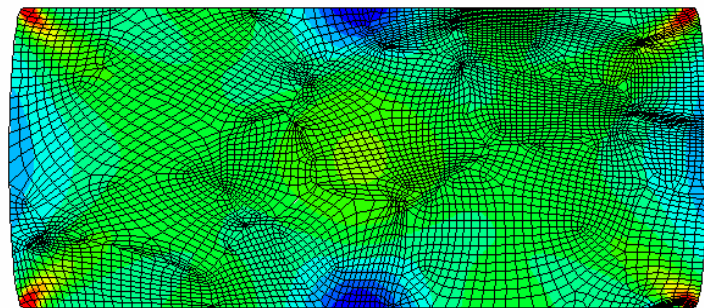

μ = 0.0

μ = 0.0001

μ = 0.1

μ = 0.1

μ = 0.2

μ = 0.2

von Mises strain

```
+6.943e-01
+3.500e-01
+3.182e-01
+2.864e-01
+2.545e-01
+2.227e-01
+1.909e-01
+1.591e-01
+1.273e-01
+9.545e-02
+6.364e-02
+3.182e-02
+0.000e+00
```

y

z

x
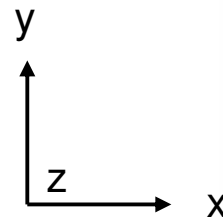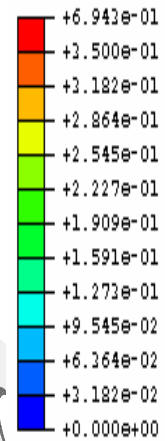
CONTINUUM AND CRYSTAL PLASTICITY SOLUTIONS
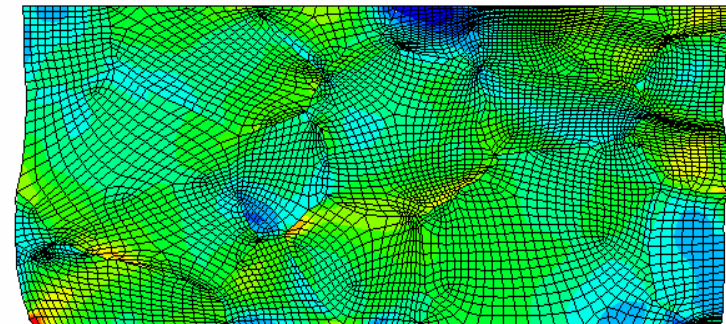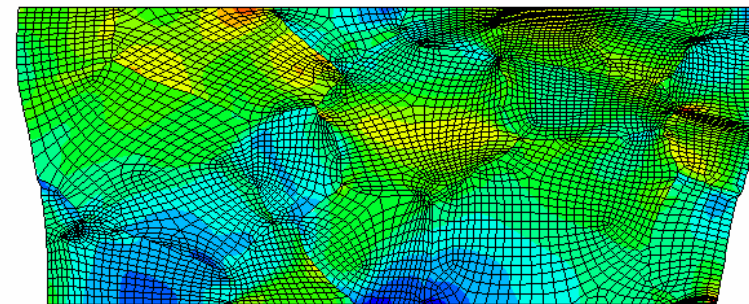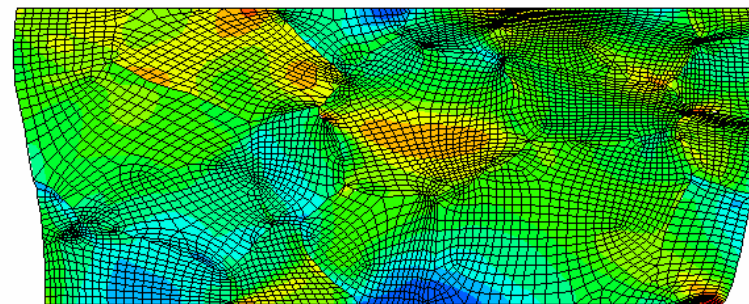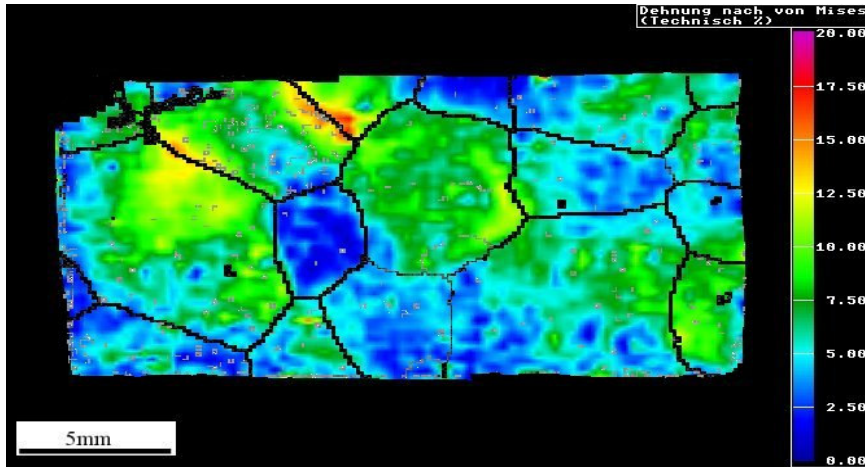
Experimental Strain Mapping

Continuum FEM Simulation (µ = 0,2)
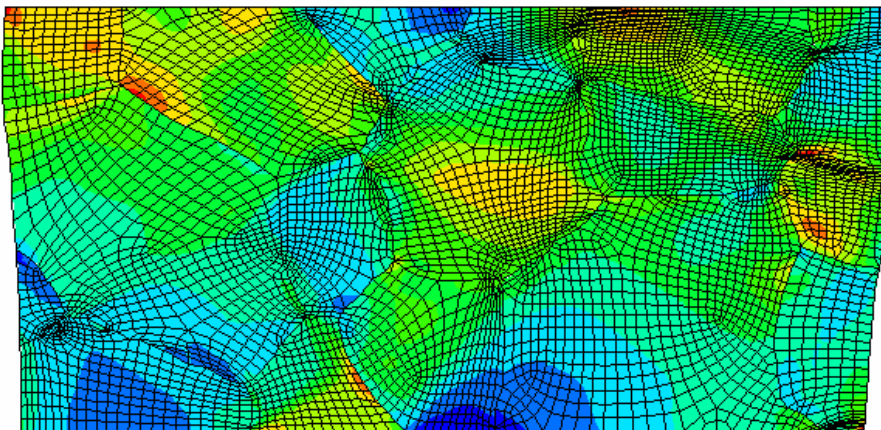
Cristal Plasticity FEM Simulation (µ = 0,1)
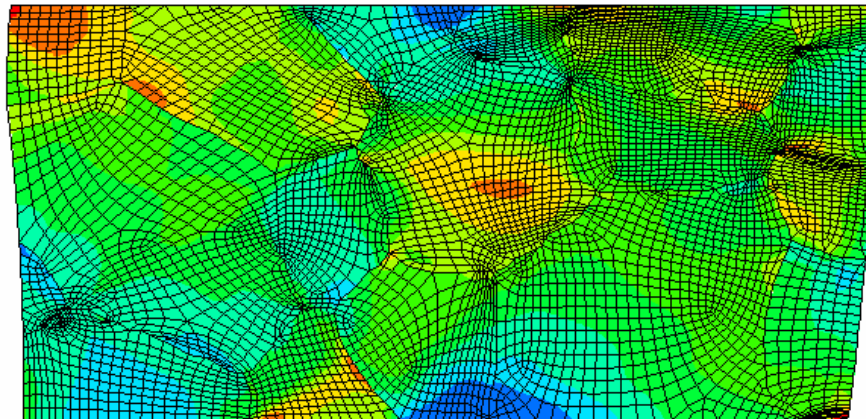
Cristal Plasticity FEM Simulation (µ = 0,2)

von Mises Strain

Continuum FEM Simulation

0.300
0.281
0.262
0.244
0.225
0.206
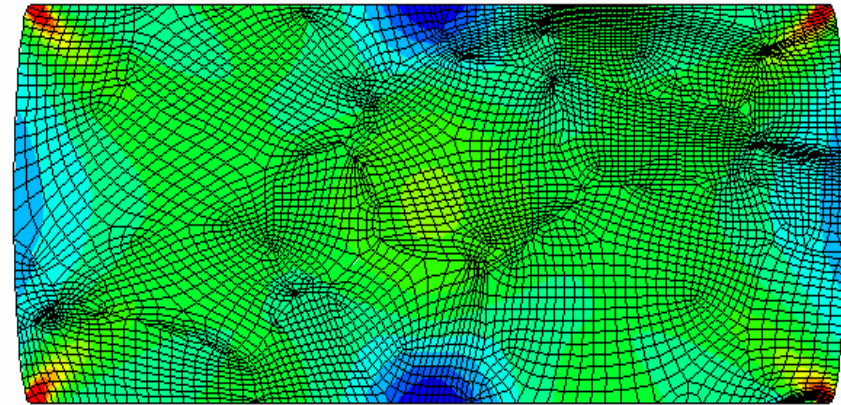0.187
0.169
0.150
0.131
0.113
0.094
0.075
0.056
0.037
0.019
0
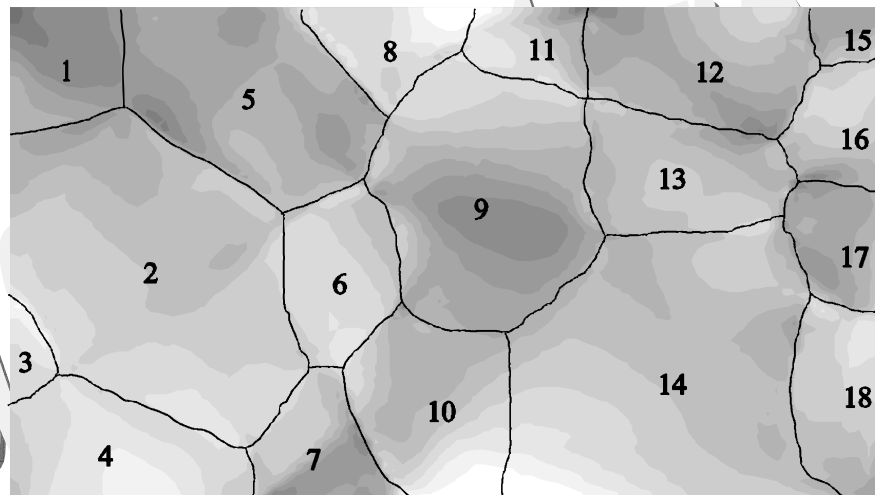
➡ von Mises strain

➡ 8% hight reduction

➡ µ = 0,2

Cristal Plasticity FEM Simulation

COMPARISON OF FEM AND CPFEM
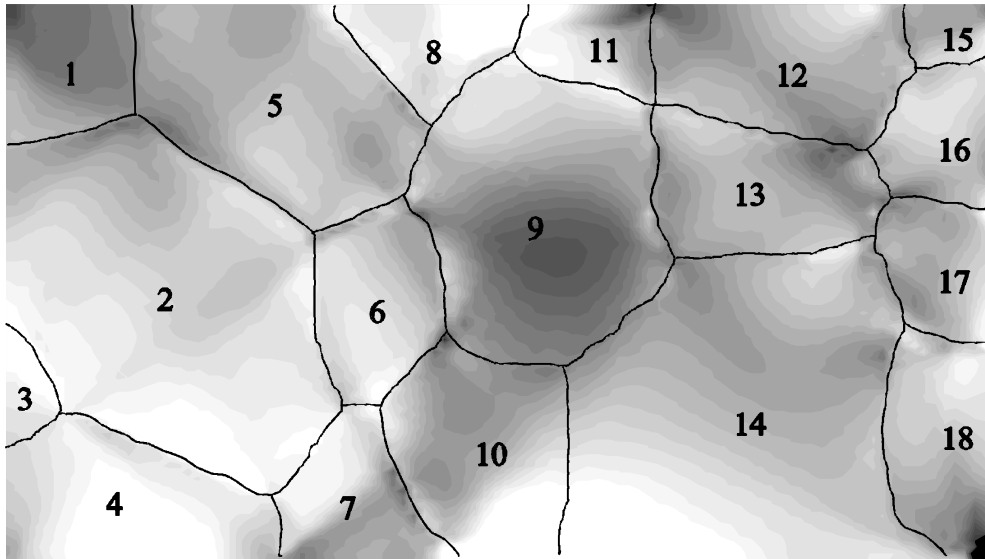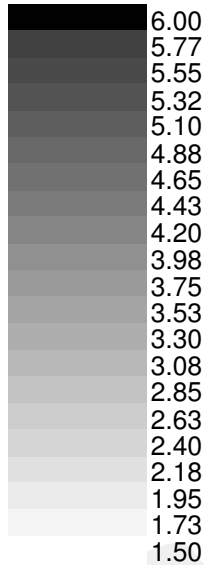
macromechanic
Taylor-Factor

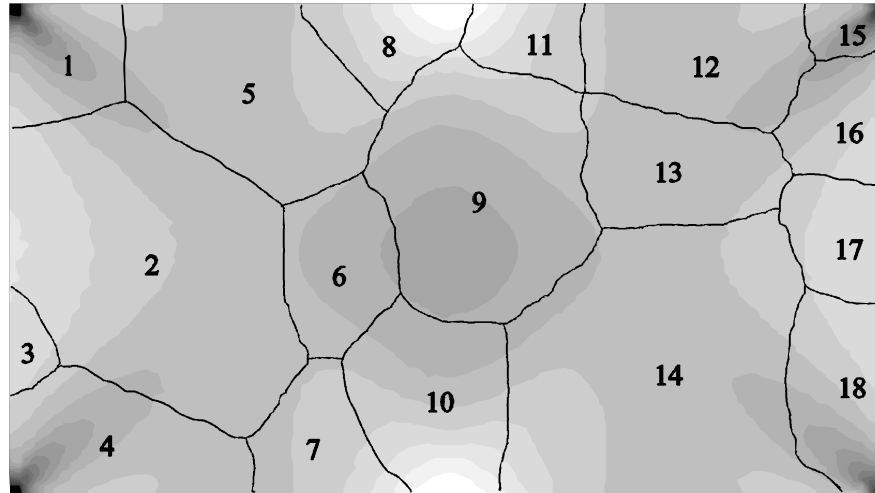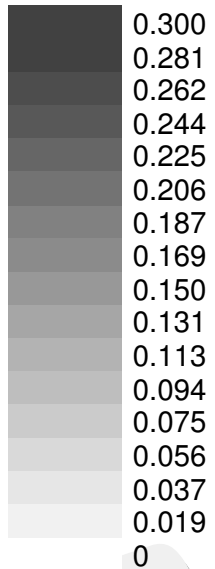$$\sum \gamma^{\text{local}} \Big/ \langle \varepsilon_{vM} \rangle^{\text{global}}$$

micromechanic
Taylor-Factor

$$\sum \gamma^{\text{local}} \Big/ \langle \varepsilon_{vM} \rangle^{\text{local}}$$

change in micromecha-
nical Taylor factor

TAYLOR FACTOR GRADIENT

Sachtleber, Raabe
Plasticity 2002

→ Heterogeneity in accumulated plastic strain (90% from mean)
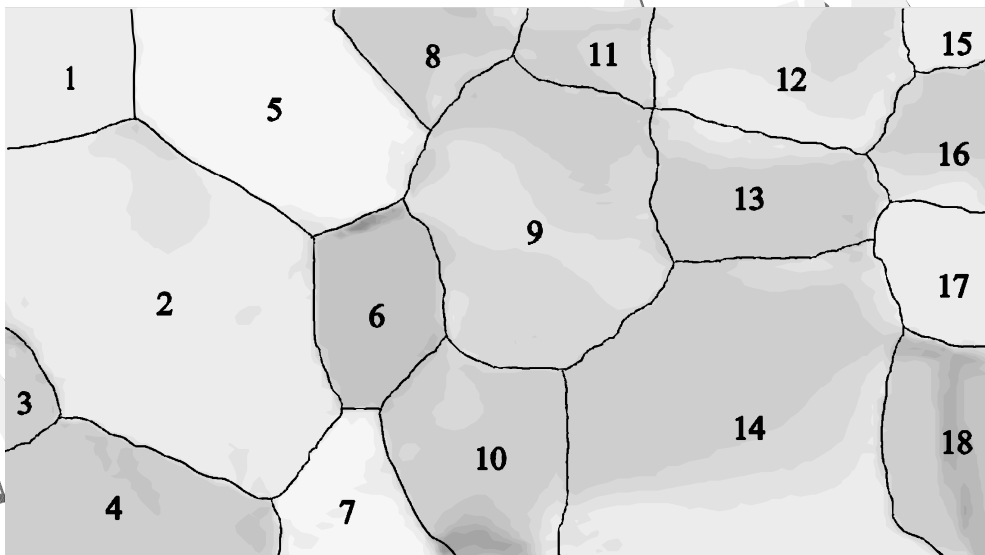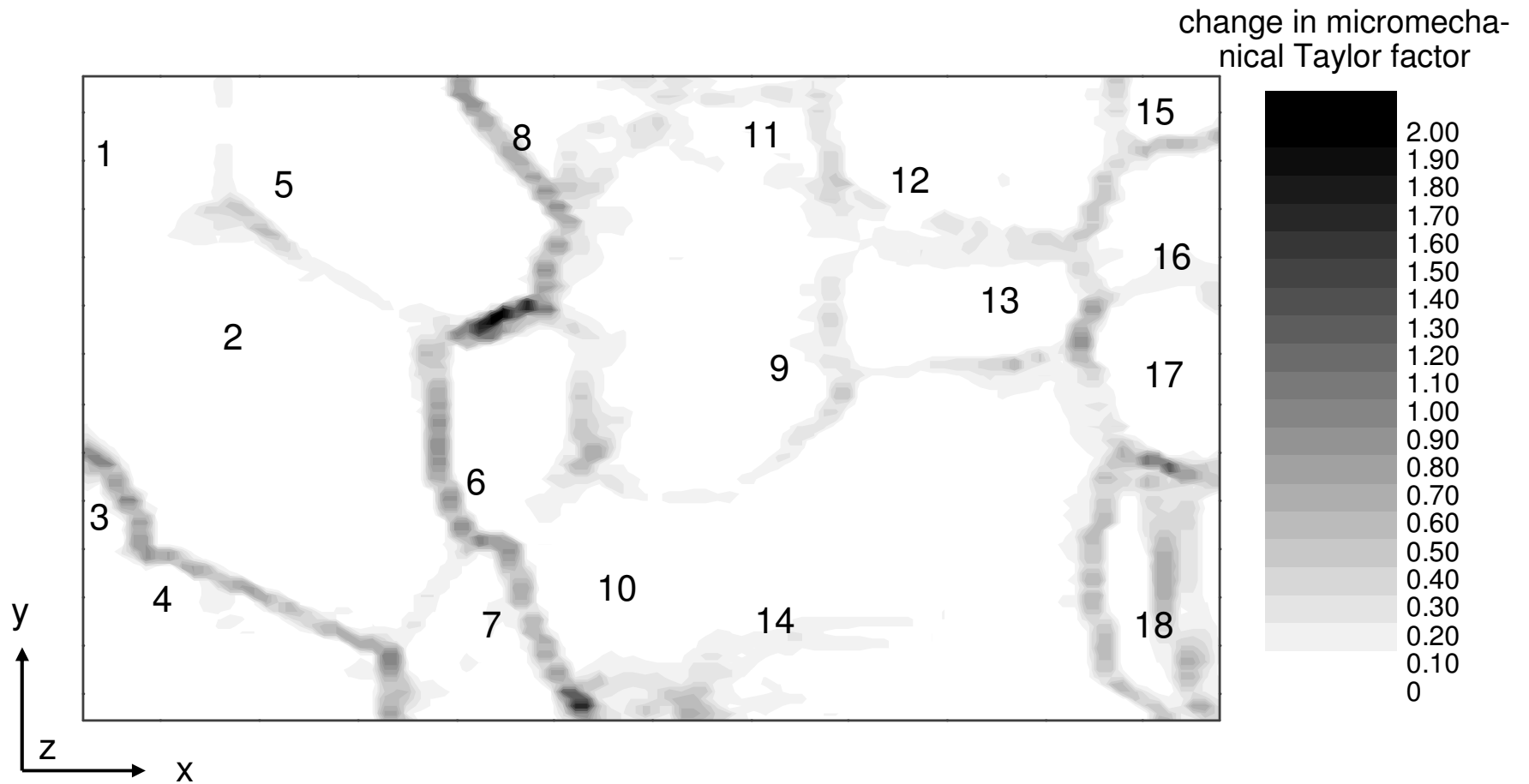
→ Grain scale heterogeneity is determined by two factors:

      1. Macroscopic boundary conditions (geometry, friction)

      2. Local crystal kinematics

"Micromechanical and macromechanical effect in grain scale polycrystal plasticity experimentation and simulation",
D. Raabe, M. Sachtleber, Z. Zhao, F. Roters, S. Zaefferer: *Acta mater.*,49 (2001) 3433 - 3441

Sachtleber, Raabe
Plasticity 2002

CONCLUSION