Architectured Microstructure in Steel

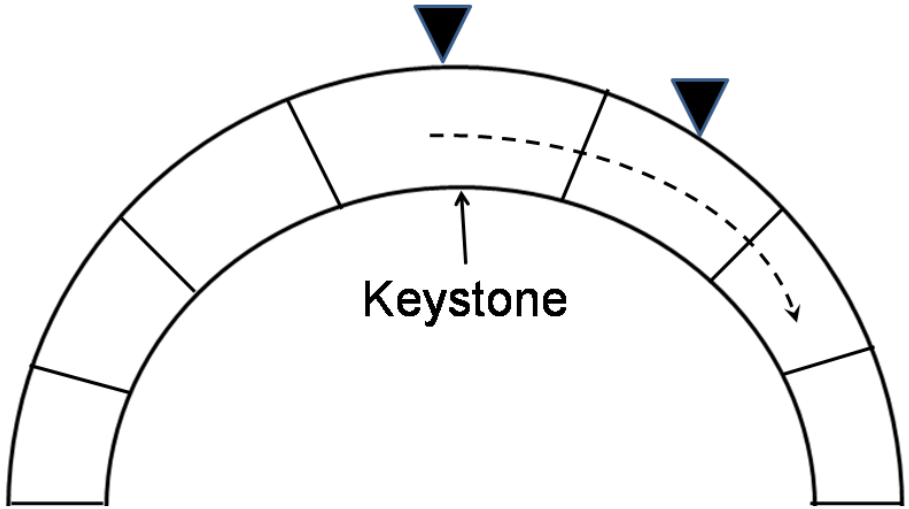
G.Anand*, P.Dey, P.Kok, D.Chakraborty, P.P. Chattopadhyay*

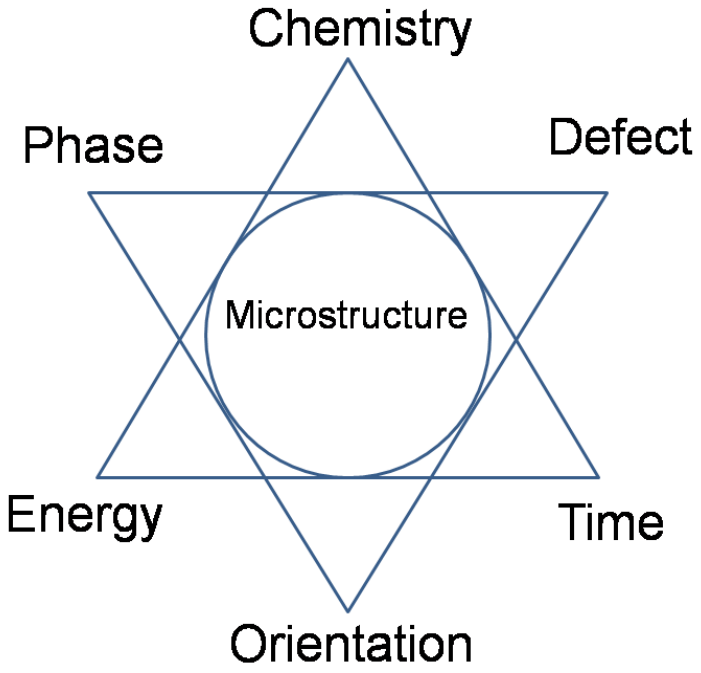
*Bengal Engineering and Science University, Shibpur, India

Acknowledgements:

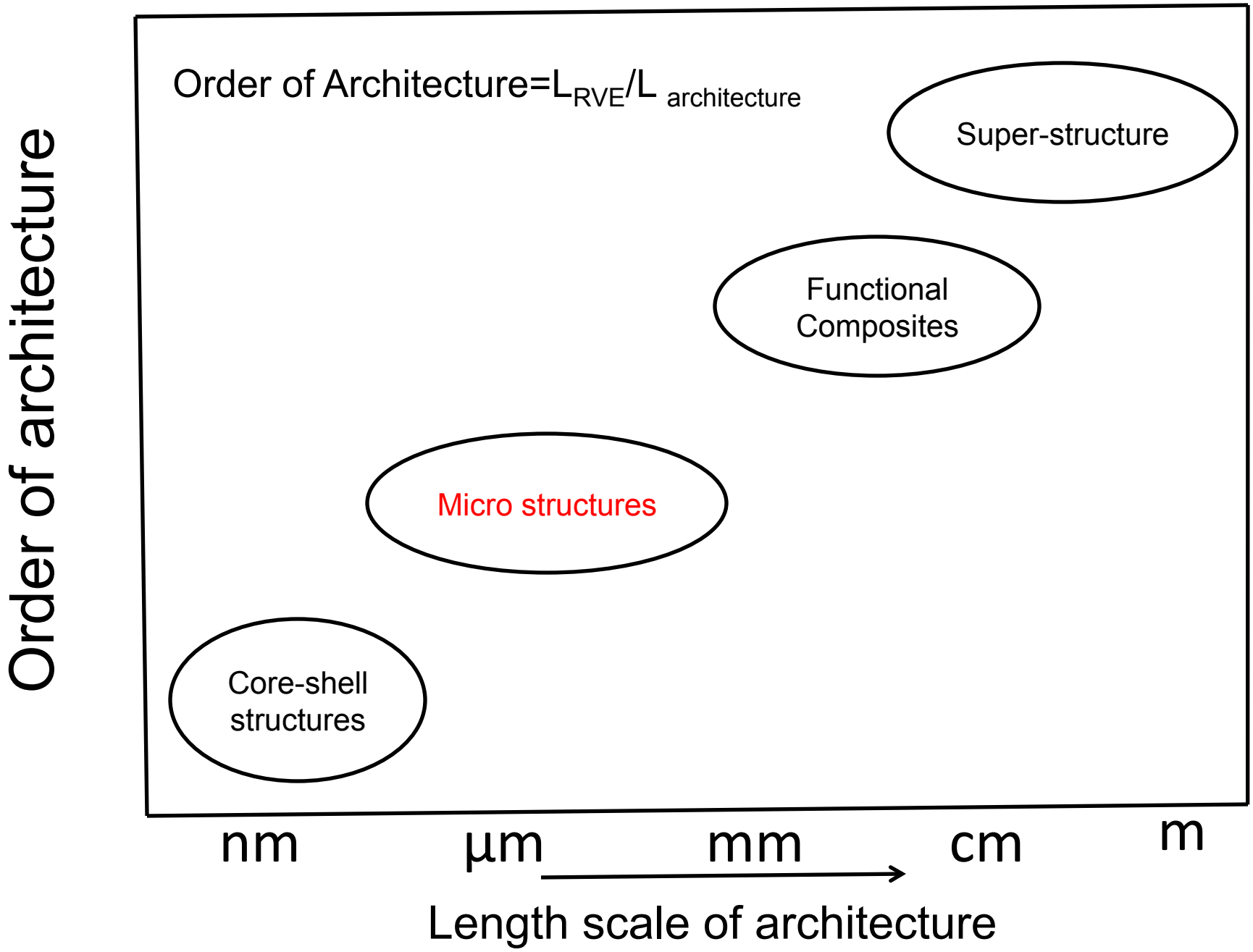
Ministry of Steel, Government of India and Indian Institute of Metals

Architecture and Microstructure

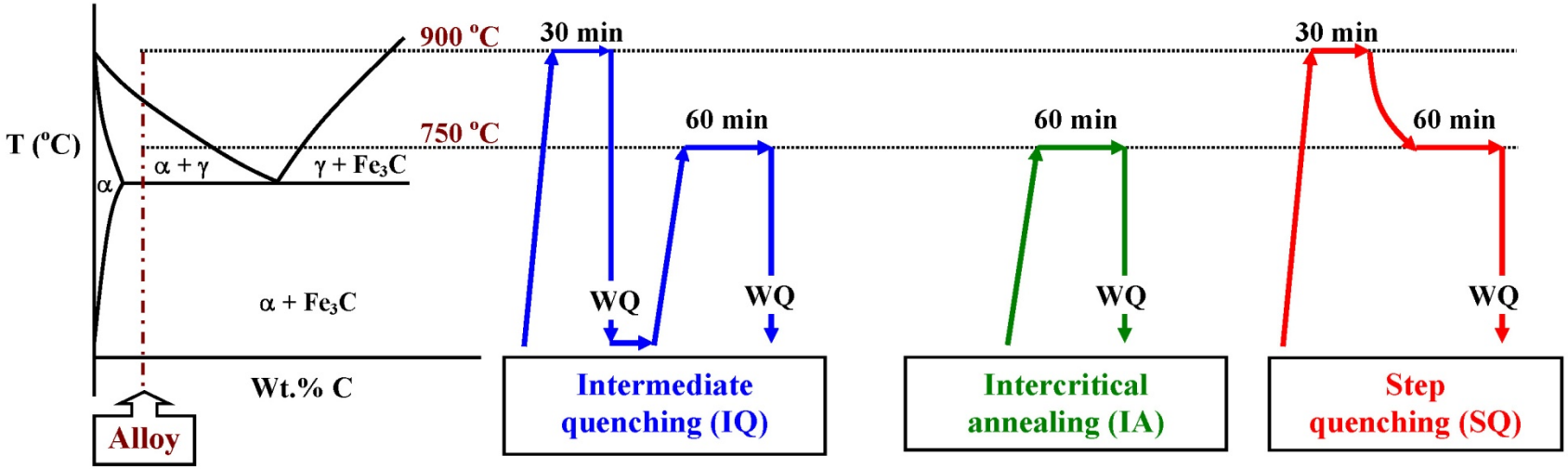


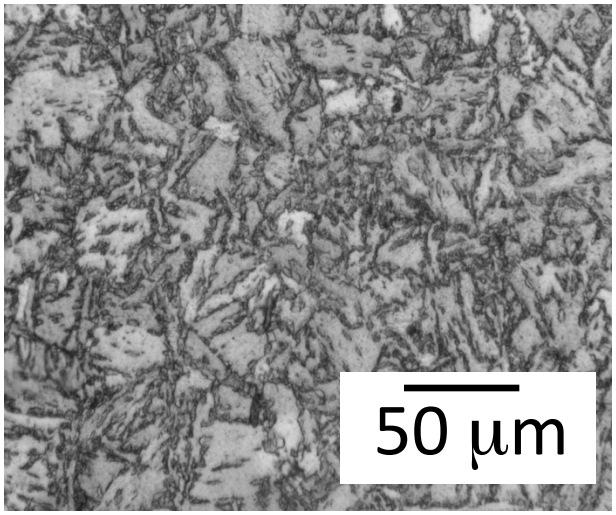


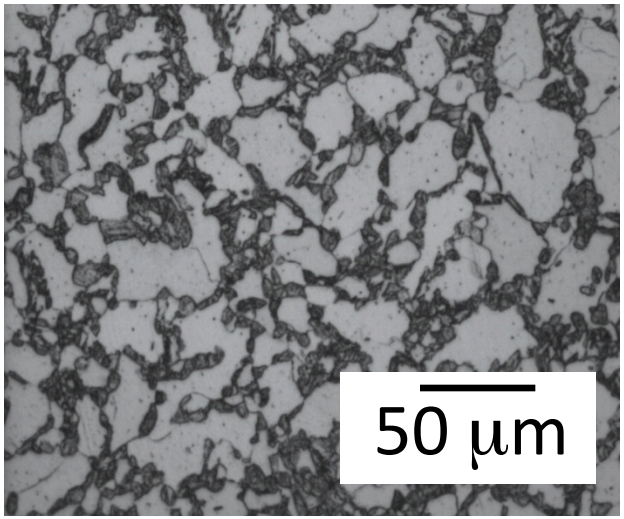
Integration is the key

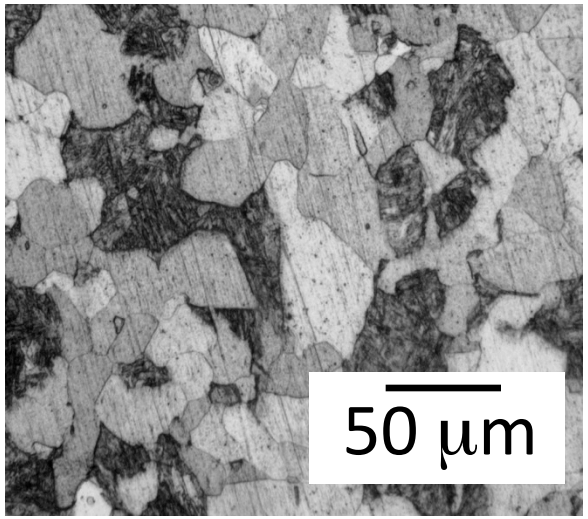

Order of Architecture=$L_{RVE}/L_{architecture}$
Super-structure
Functional Composites
Micro structures
Core-shell structures
Order of architecture
nm
µm
mm
cm
m
Length scale of architecture

Architecturing martensite morphology in DP steel



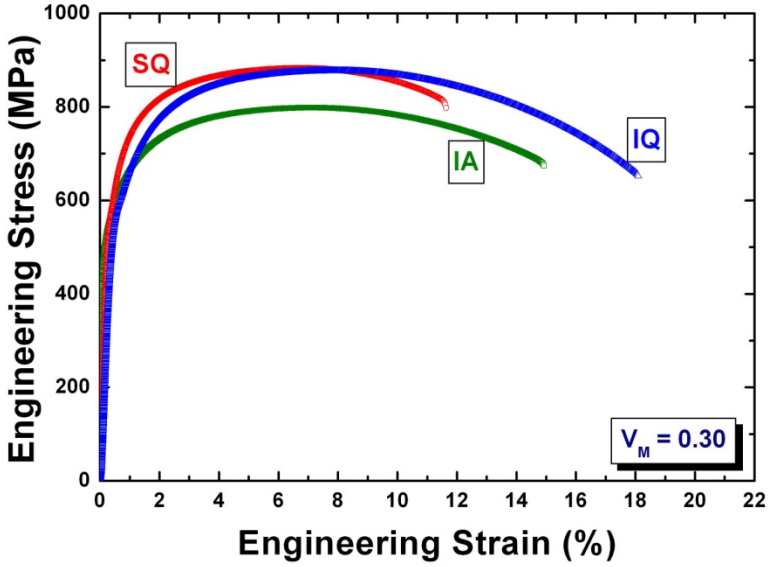


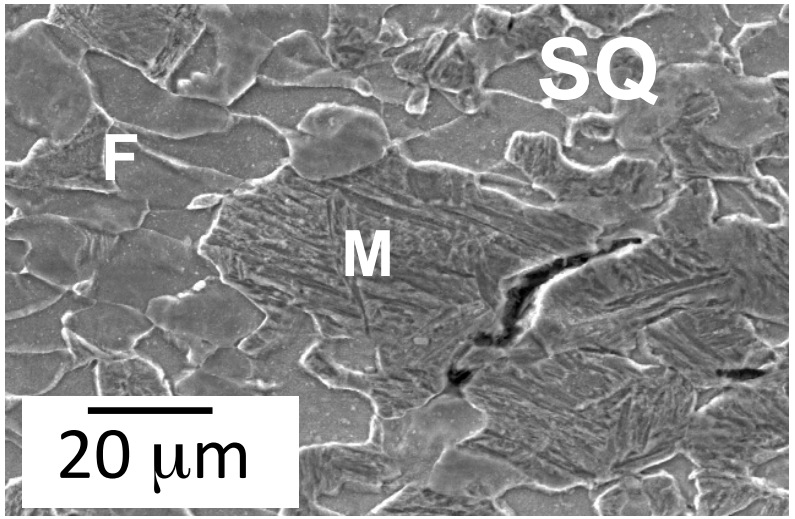


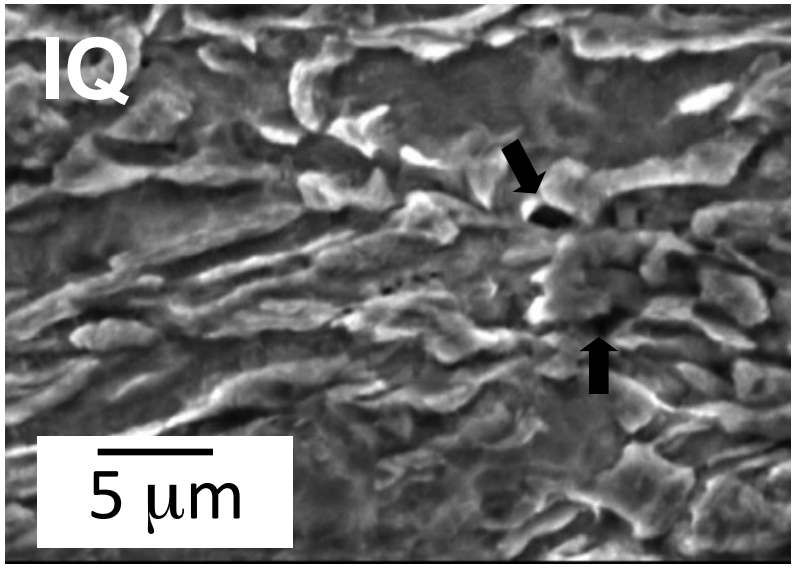


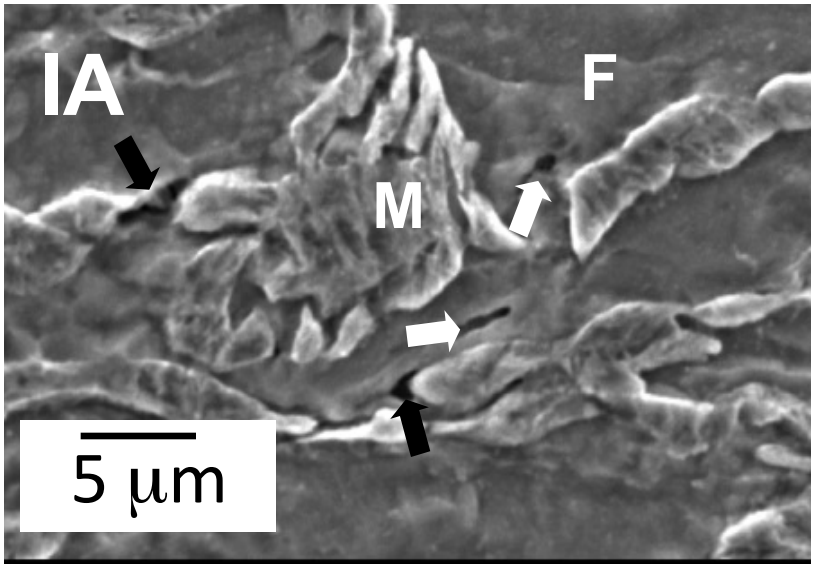
Reference: D. Das and P. P. Chattopadhyay, J. Mat. Sci., 44 (2009) 2957

Architecturing martensite morphology in DP steel





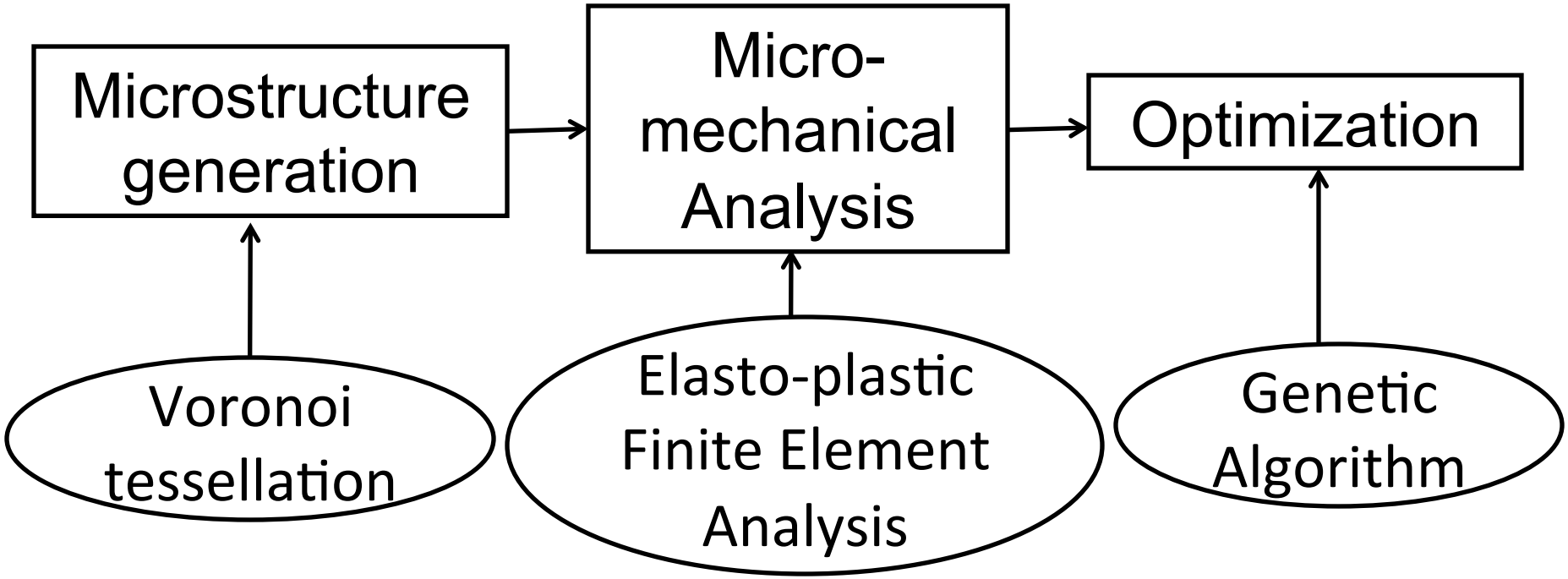




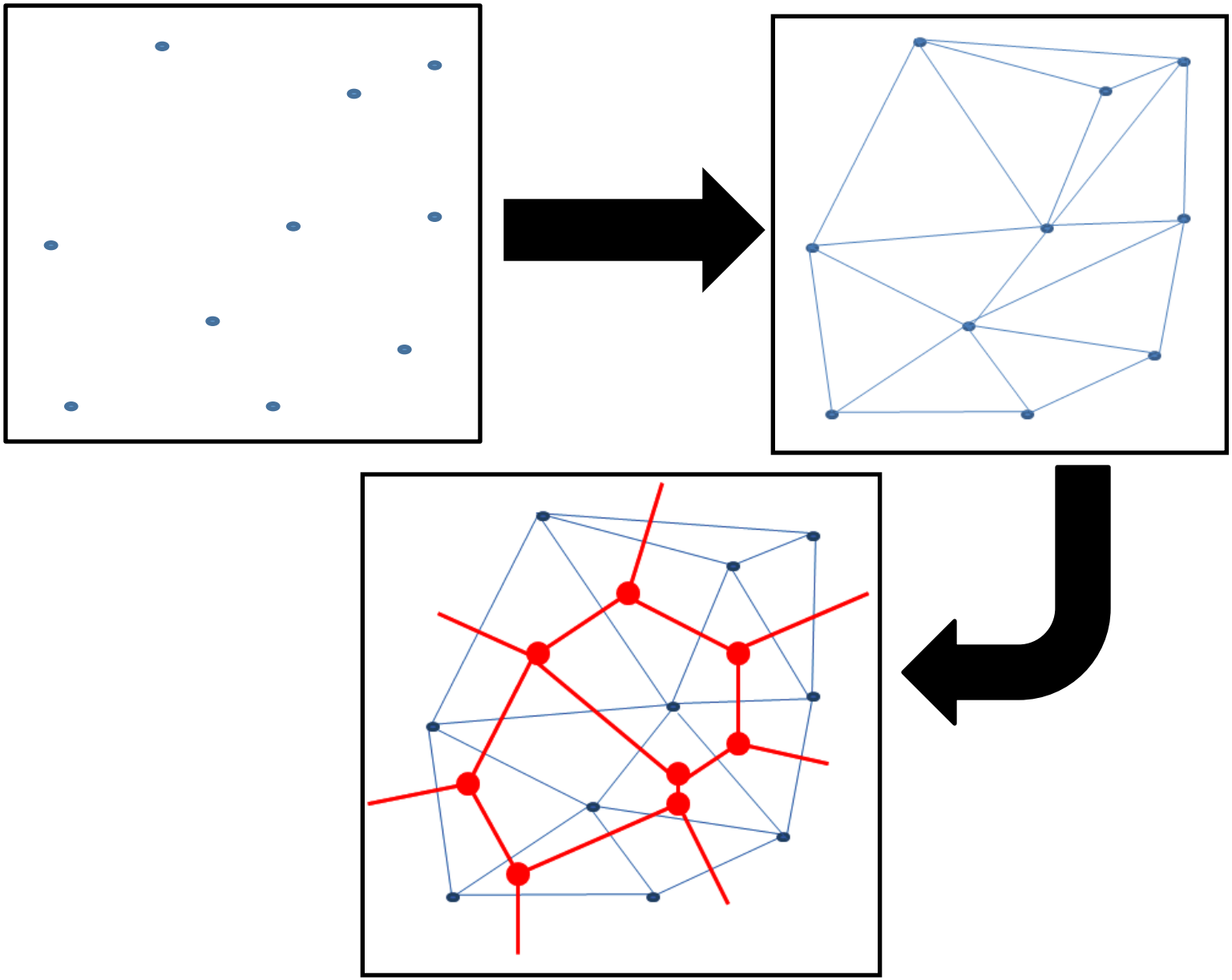
Reference: D. Das and P. P. Chattopadhyay, J. Mat. Sci., 44 (2009) 2957

Objective

Architecturing DP microstructure by Micro-mechanical modeling



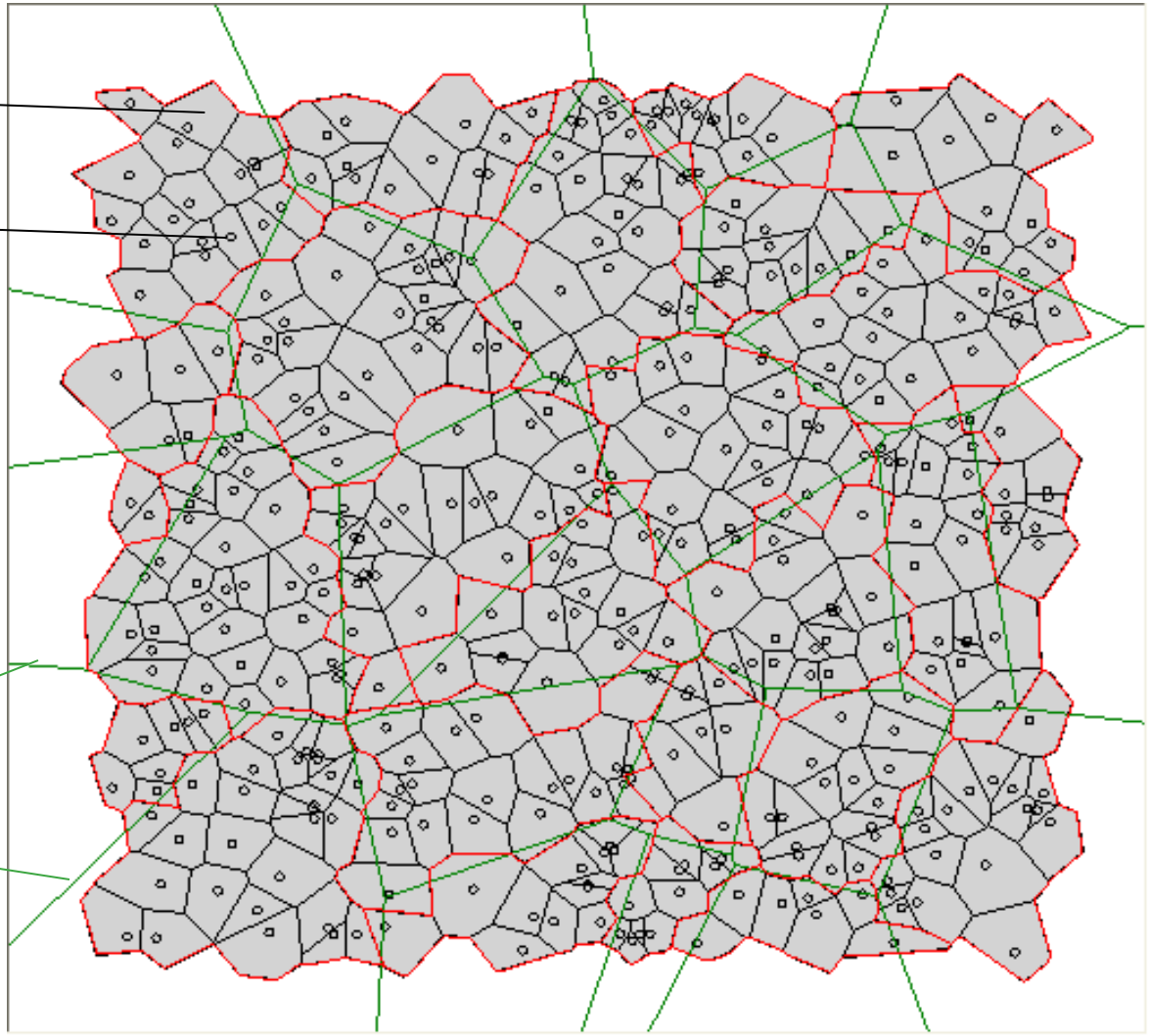
Voronoi Tessellation



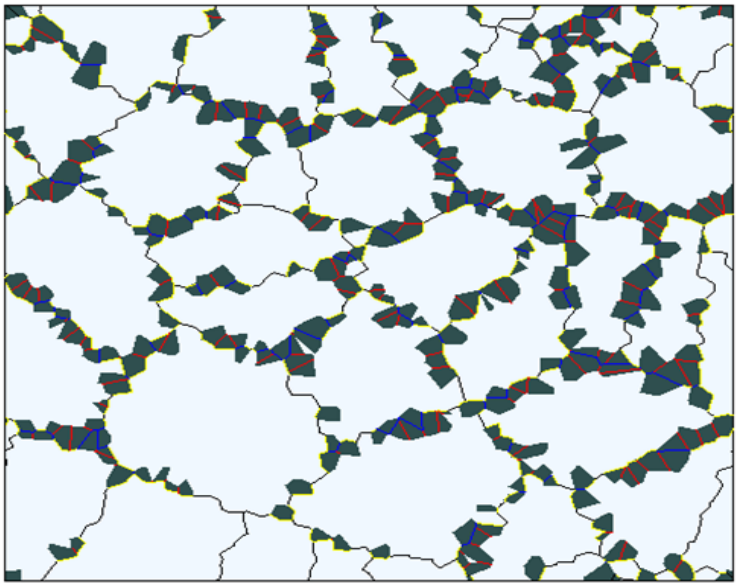
Multi level Voronoi principles of the new algorithm

First level: fine tessellation

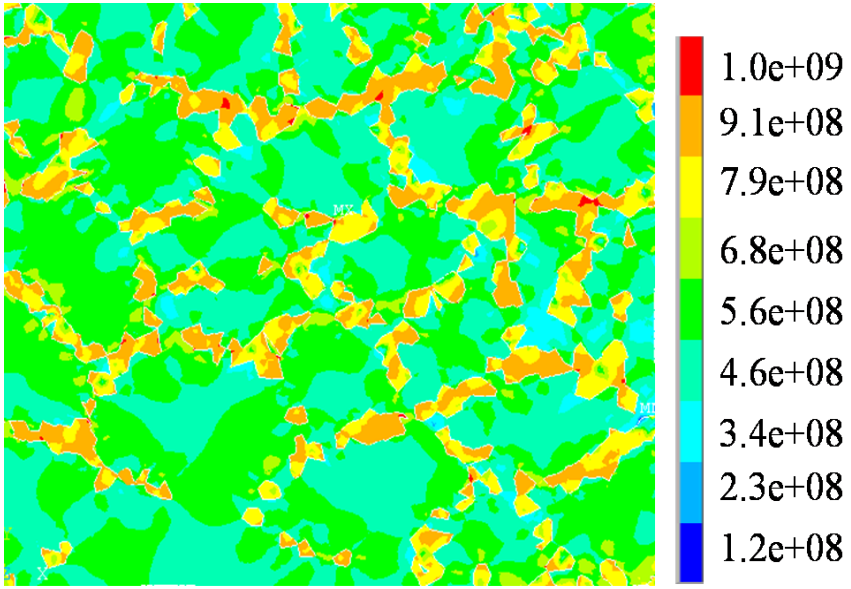
Second level: coarse master tessellation



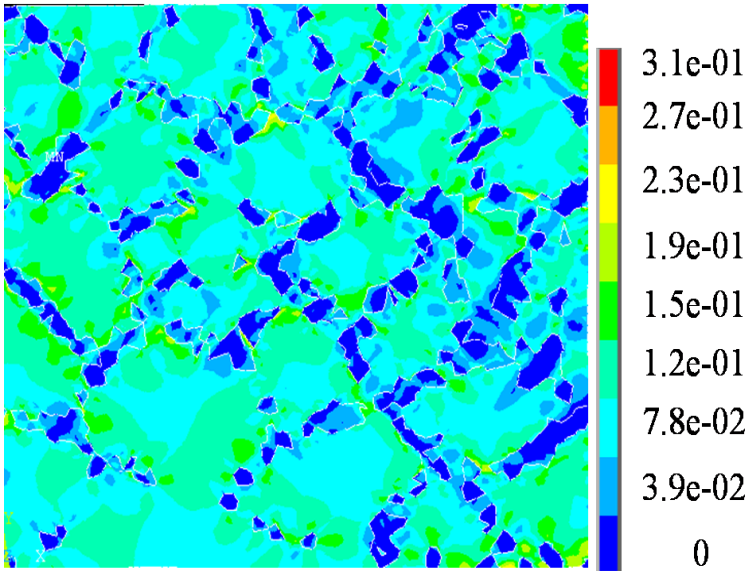
Ferrite contiguity parameter (FCP)= 0.31

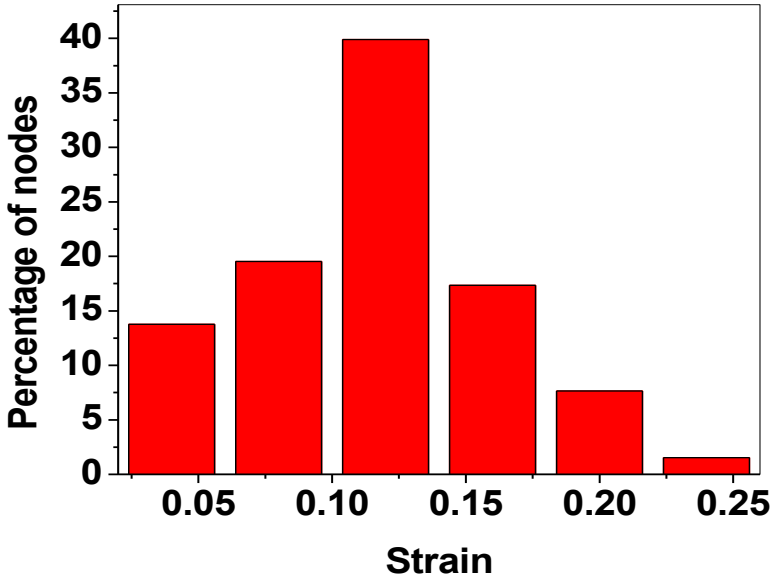


Von Mises stress (VMS) distribution

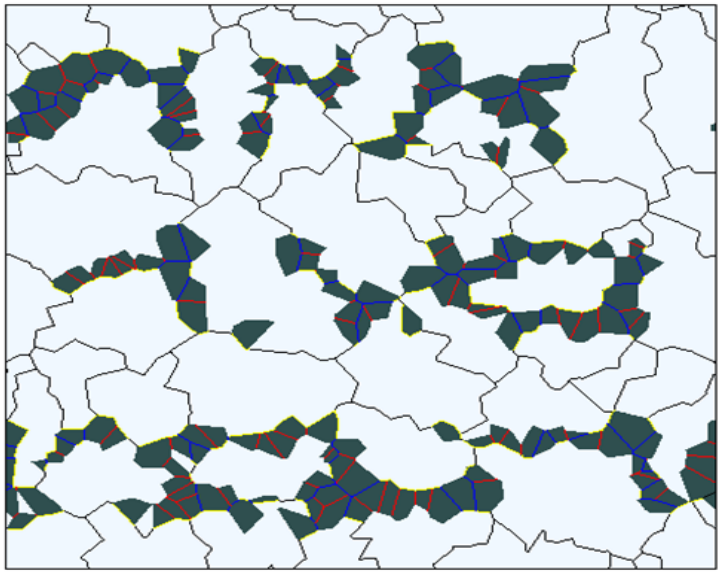


Equivalent plastic strain (EPS) distribution

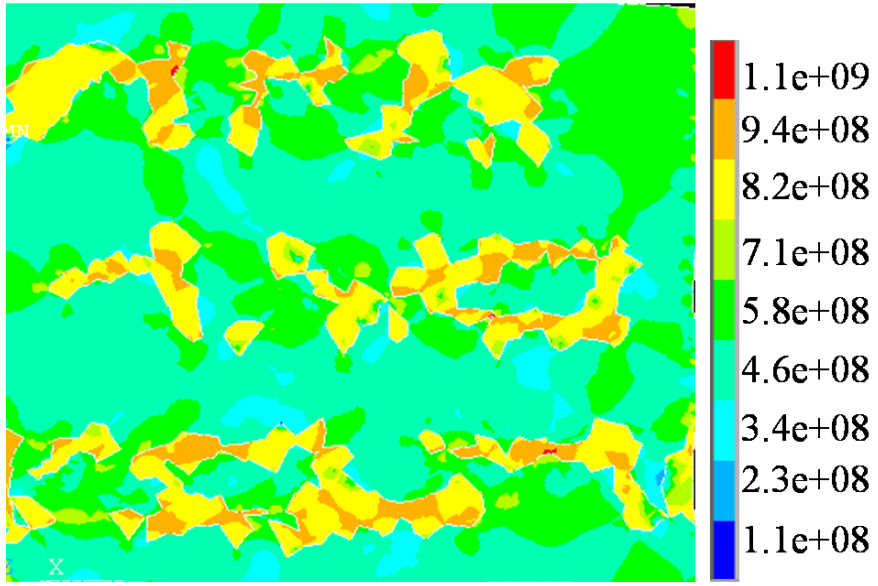




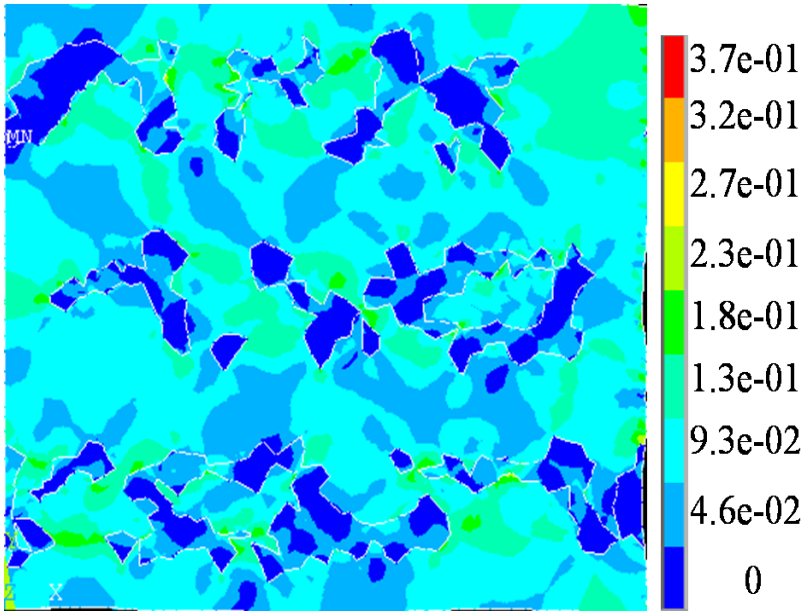
FCP=0.41

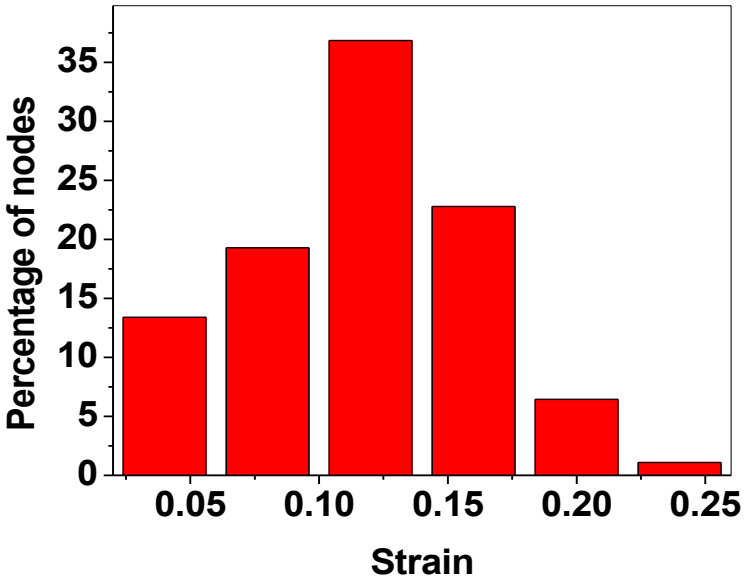


VMS distribution

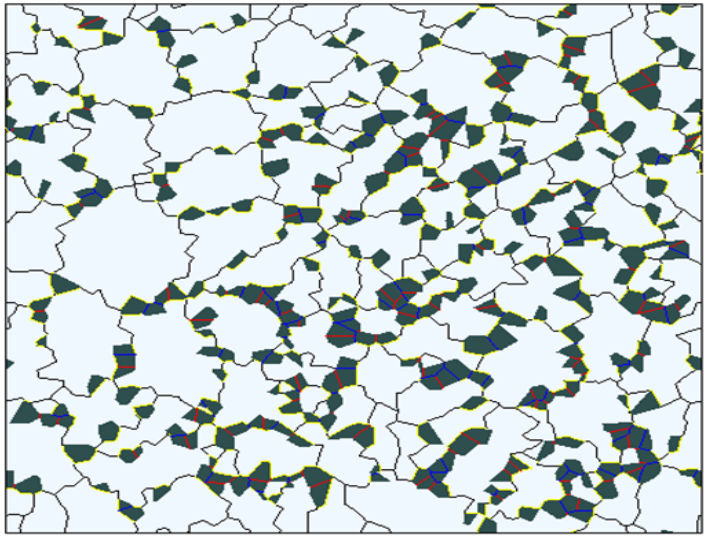


EPS distribution

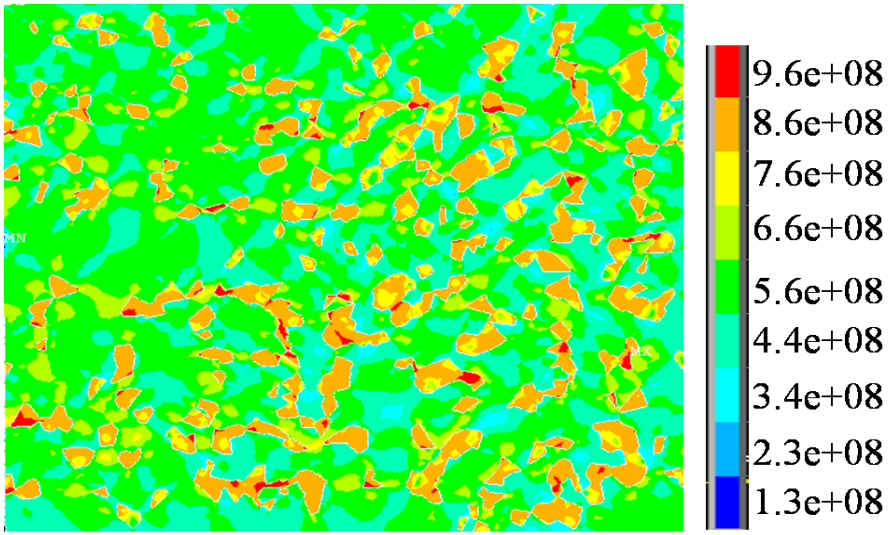




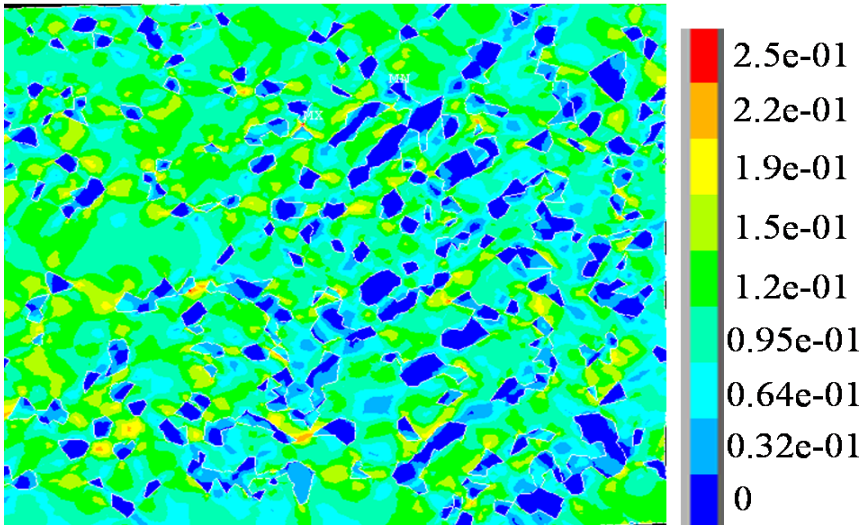
FCP= 0.52

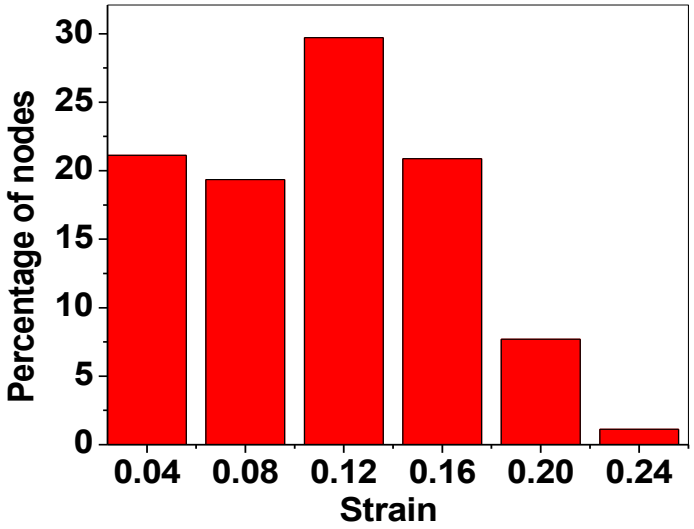


VMS distribution

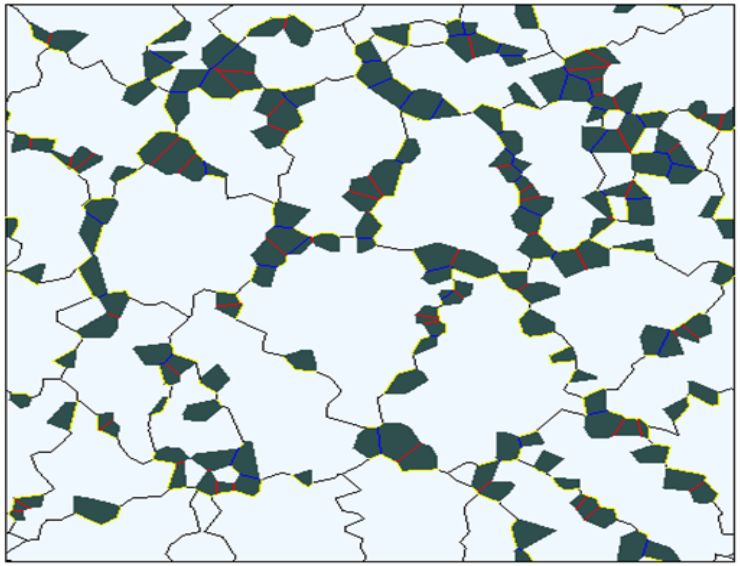


EPS distribution

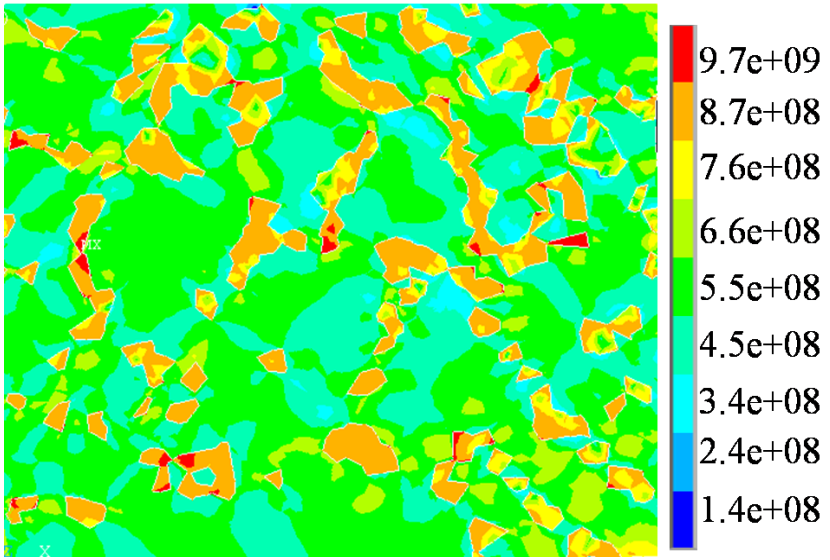




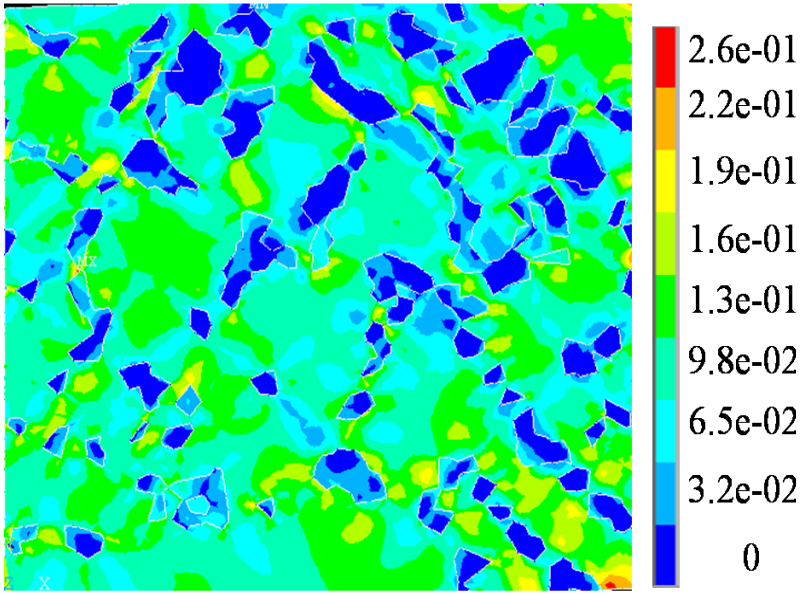
FCP=0.54

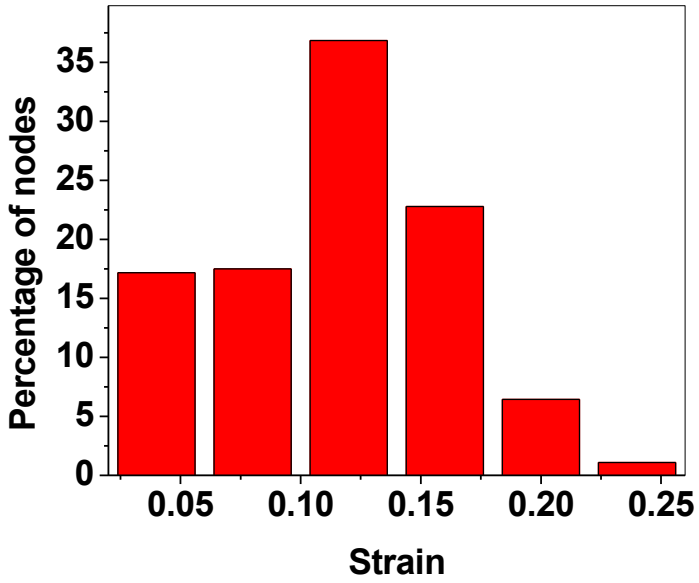


VMS distribution

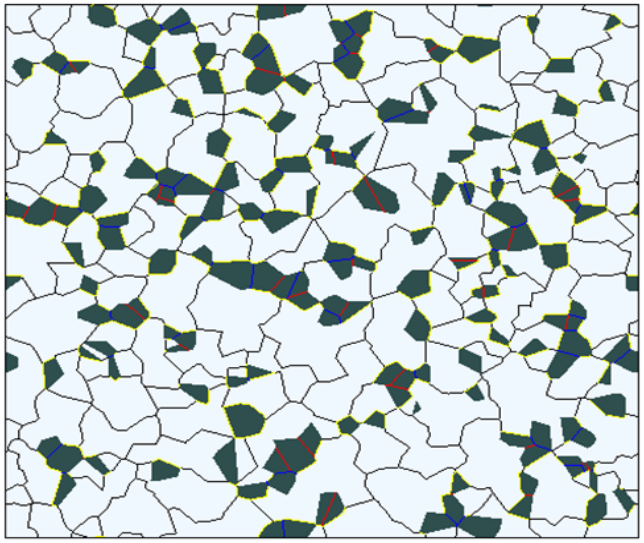


EPS distribution

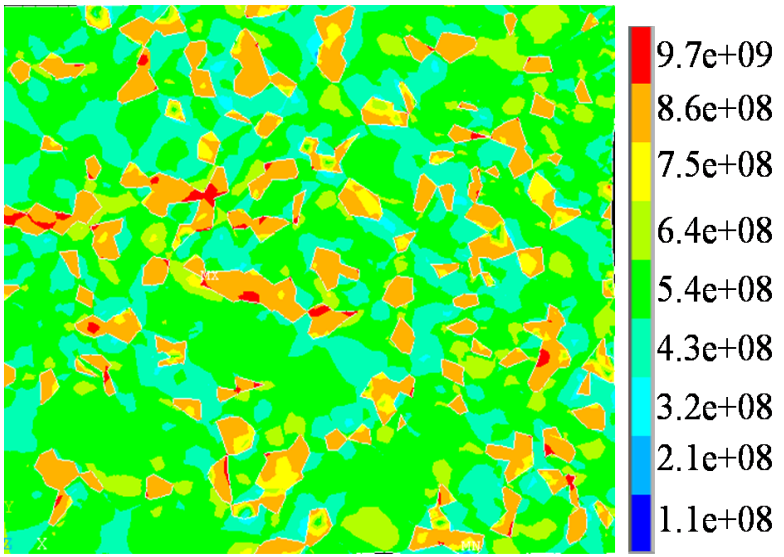




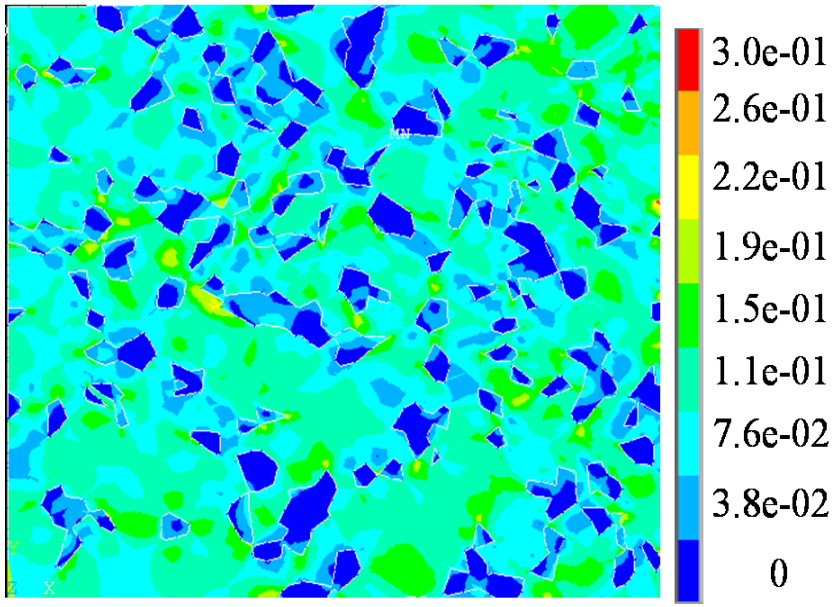
FCP=0.61

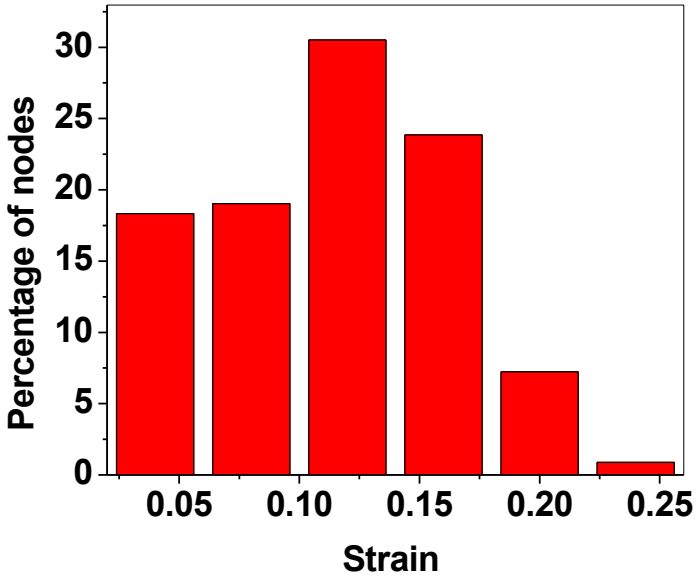


VMS distribution

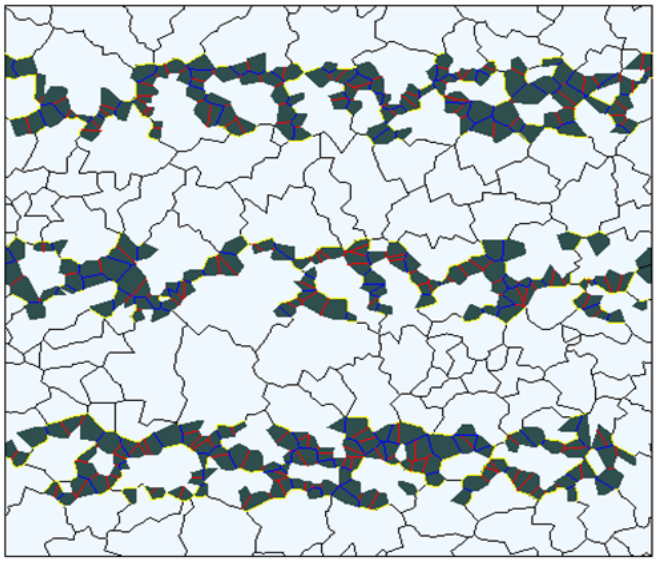


EPS distribution

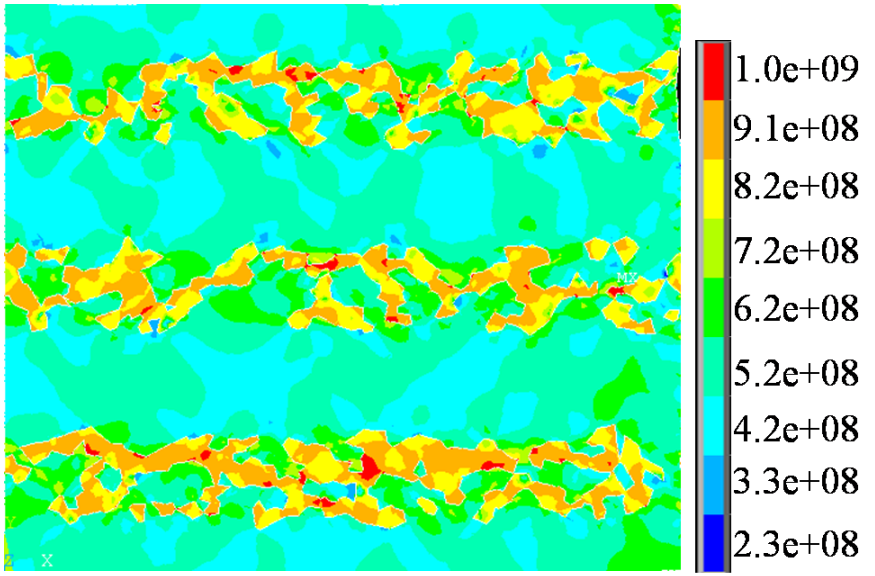




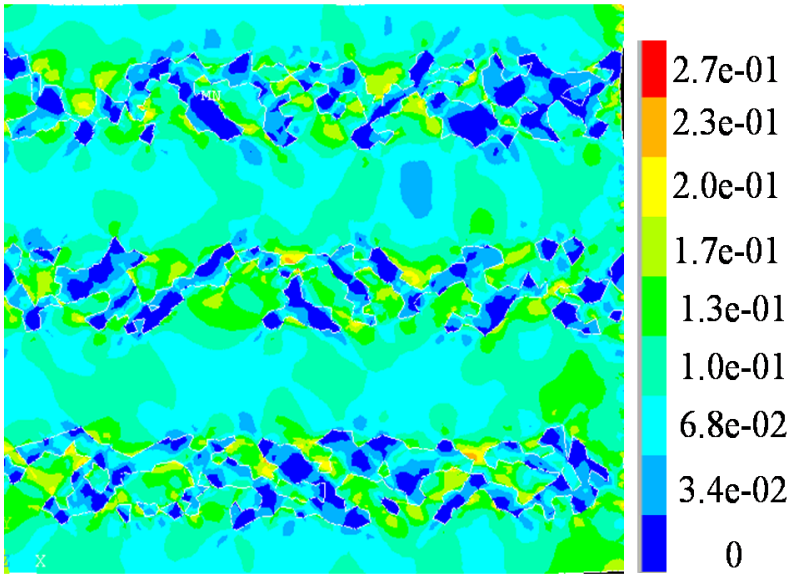
FCP=0.62

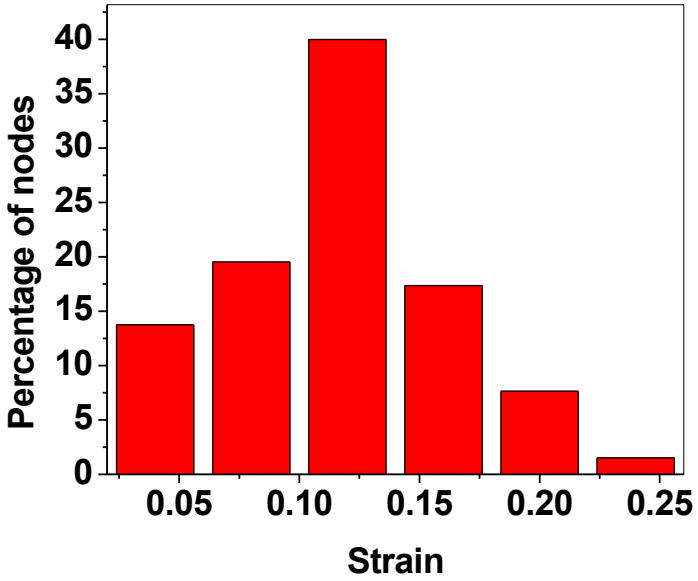


VMS distribution

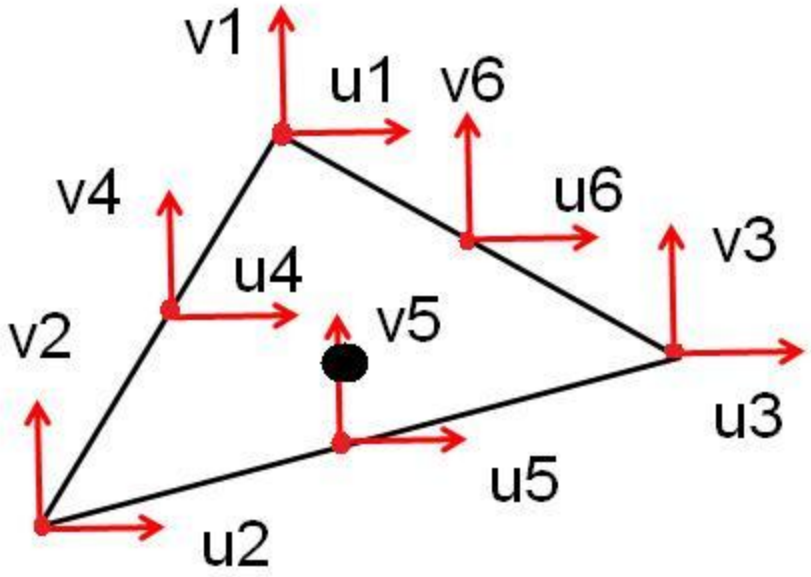


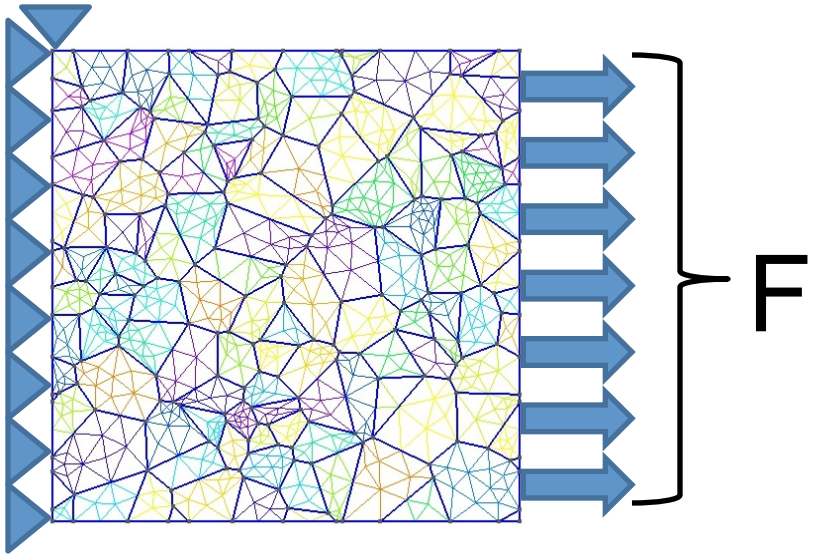
EPS distribution





Elasto-plastic Finite Element Formulation

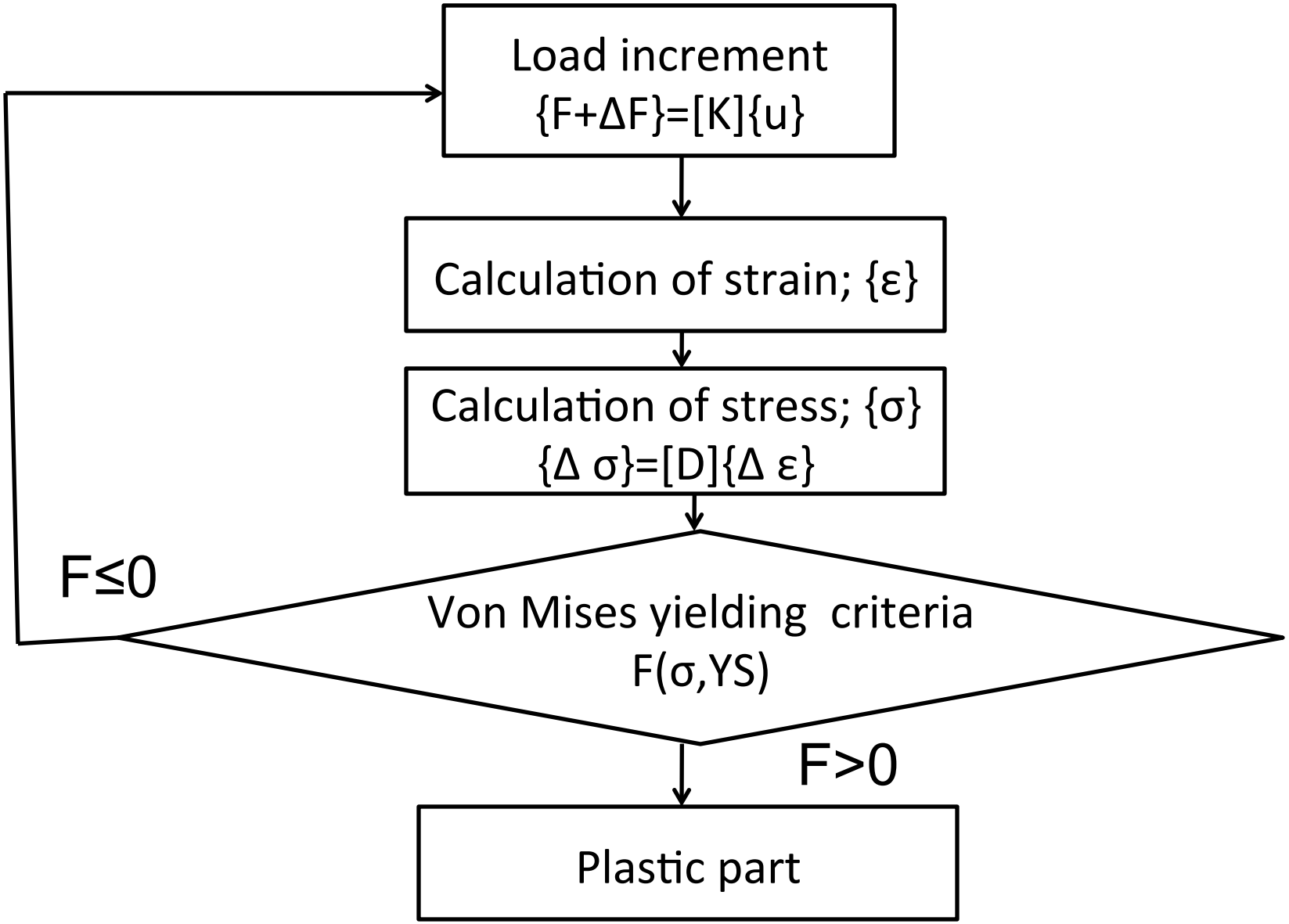




Assumptions:

1. Bilinear Material behavior.
2. Plane strain condition.
3. Stress and strain calculation at centroid of linear strain triangle.

Elasto-plastic Finite Element Formulation-Elastic part



Elasto-plastic Finite Element Formulation-Plastic regime

Proportional reduction

↓

Calculation of corrected stress and strain

$\sigma_C = \sigma_B + R.\ \Delta\sigma$

$\varepsilon_P = (1-R).\ \Delta\varepsilon$

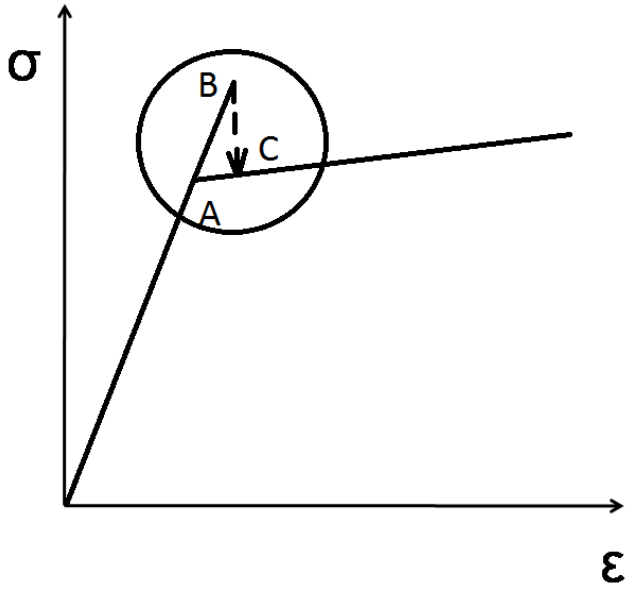
↓

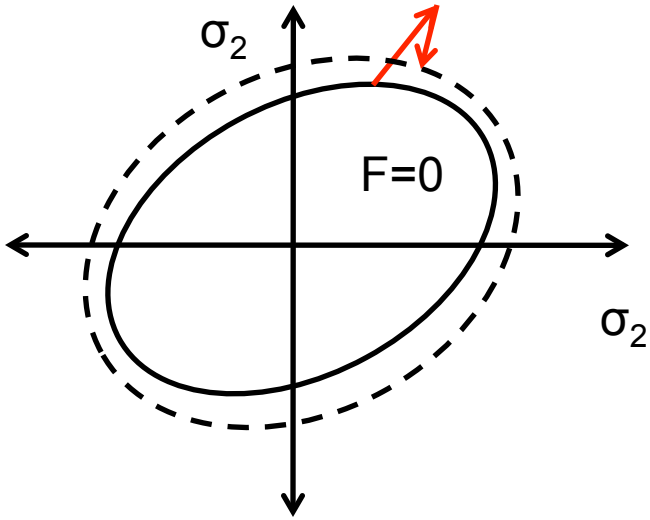
Stress by Euler forward sub-division

$\{\Delta\sigma\} = [D]\{\varepsilon_P / n\}$

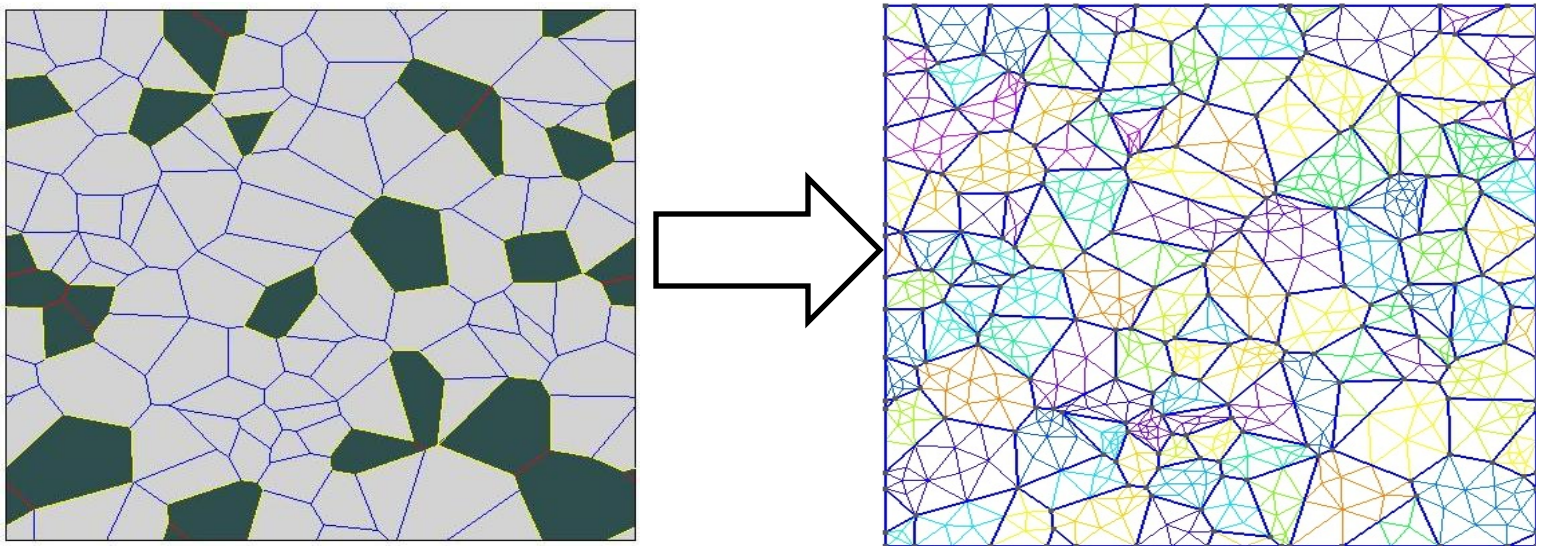
↓

Correction of yield surface drift

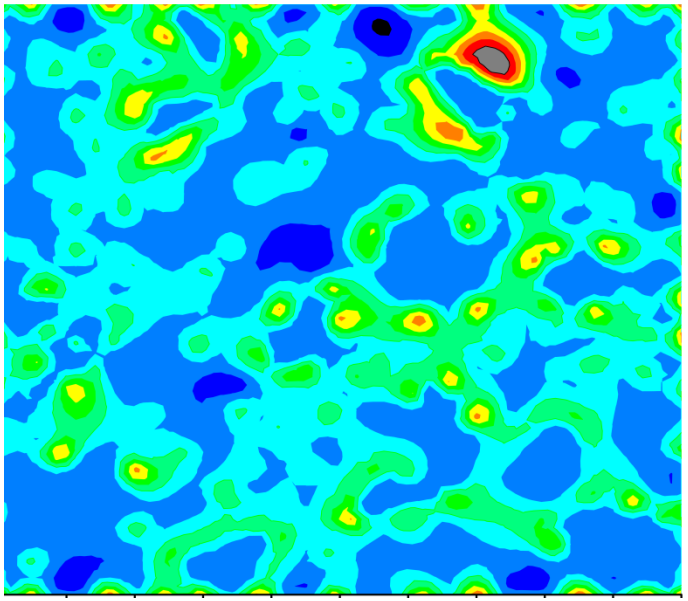




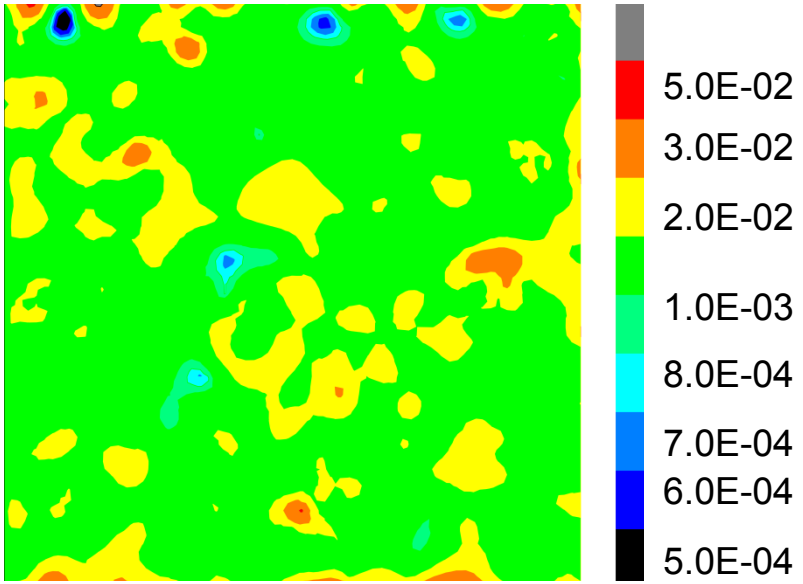
Test results



VMS distribution



EPS distribution



Conclusion

- Voronoi construction has been employed for development of architectured microstructure.
- Evolution of Von Mises stress and equivalent plastic strain has been estimated by micro-mechanical analysis.
- Suitable finite element code has been developed for its use as the objective function in the attempt of multi-objective optimization of microstructure.