Study of dislocation dynamics under cycle fatigue : acoustic emission and microstructural characterizations

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State-of-the-art

« mild »

Crystalline plasticity

Dislocations motions

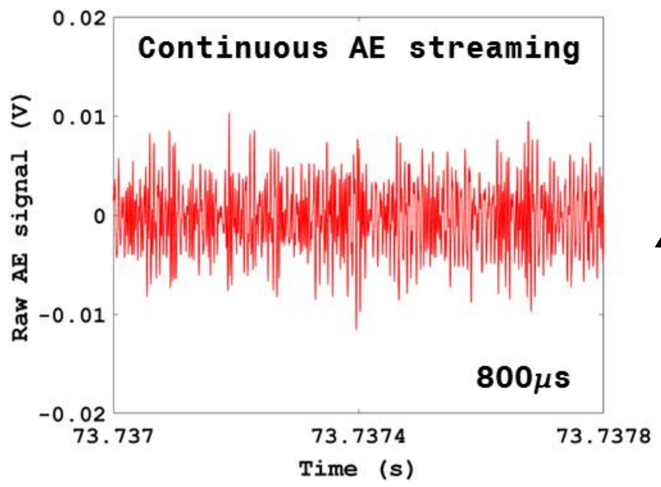
« wild »

« Classical »
Homogeneous deformation in time and space

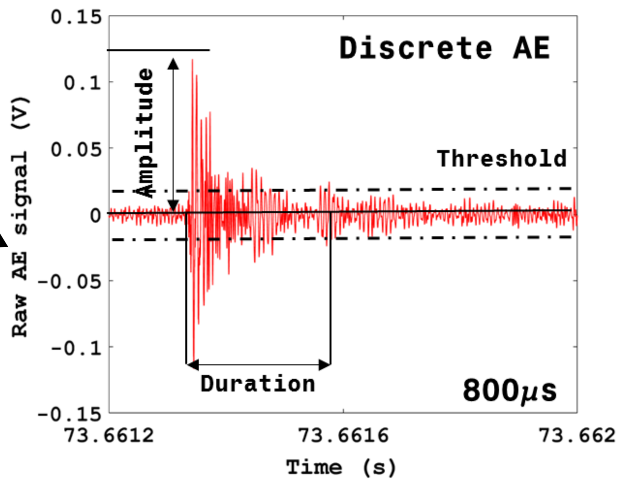
Numerous, smalls and uncorrelated motions of dislocations

« Intermittent »
Heterogeneous deformation : dislocations avalanches

Collective dislocation dynamics



Acoustic Emission (AE)
A tool for exploring dislocation dynamics.



- **Continuous** : linked to the background noise of the signal (sampling rate : 1KHz)
- **Discrete** :Define above a threshold

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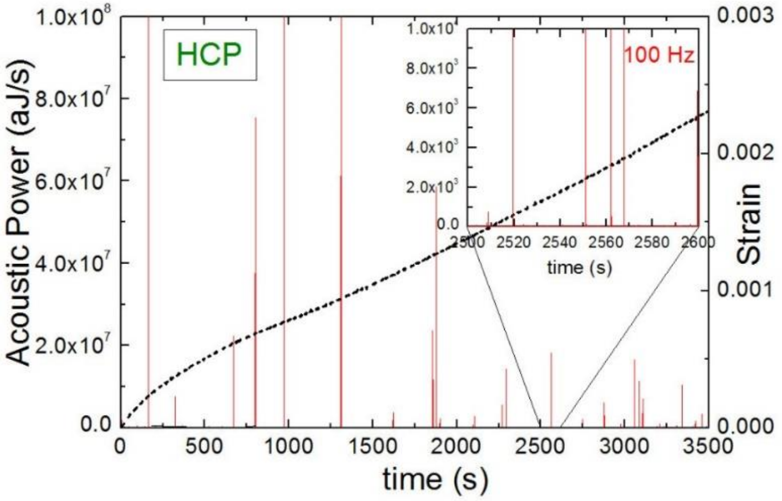
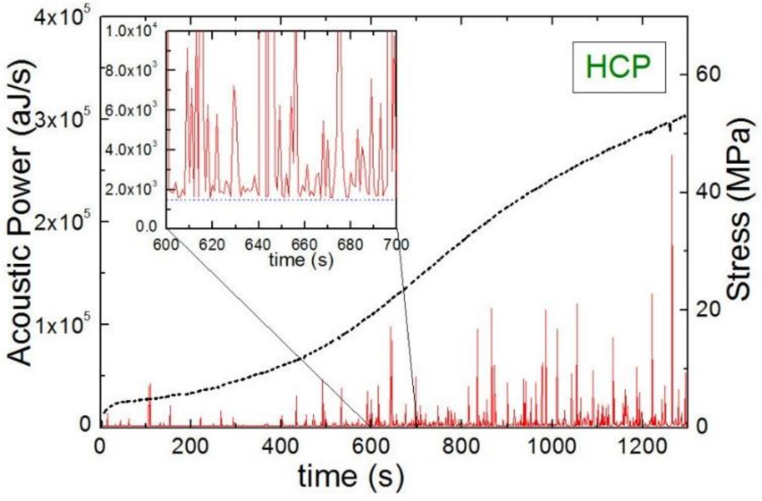
Ice

~ 100%



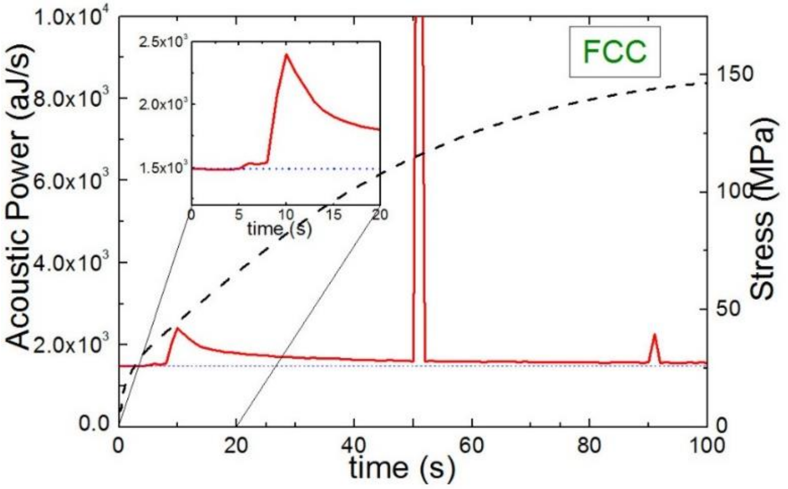
Cadmium

98/100%



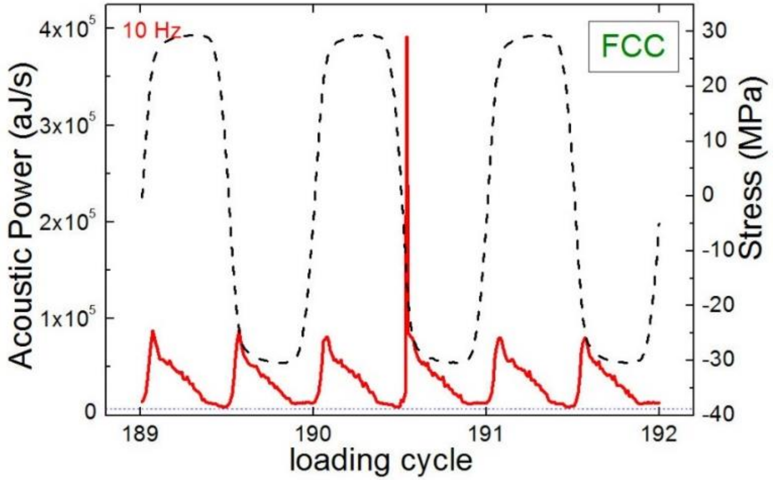
Copper

10/50%



Aluminum

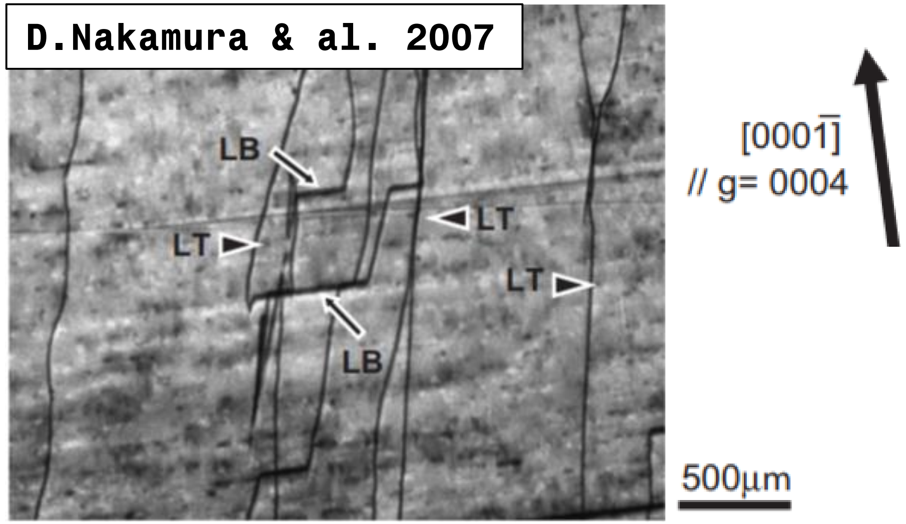
<2%



Hexagonal (H/HC)

- Anisotropic glide (single slip)
- Long-range interactions between dislocations

D.Nakamura & al. 2007

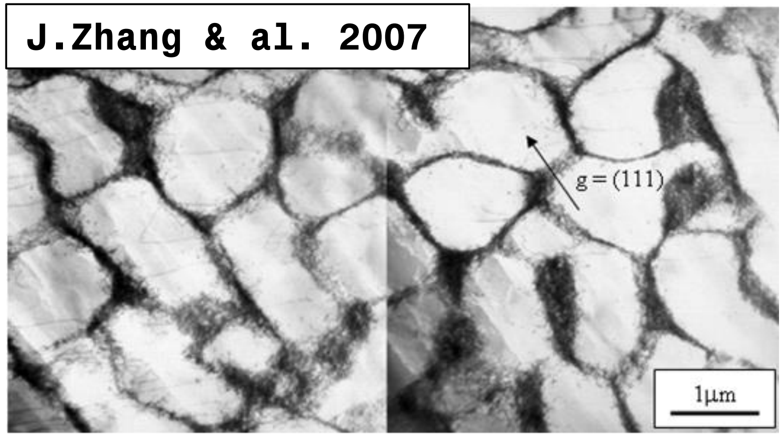


Dislocation avalanches favoured

Face Centered Cubic (FCC)

- Isotropic glide (multiple-slip)
- Short-range interactions between dislocations
- Pattern formation

J.Zhang & al. 2007



Mild plasticity favored & avalanches hindered

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Dislocation dynamics of Cu single crystals under stress imposed fatigue test

« Mild » vs « Wild »

Dislocations structure

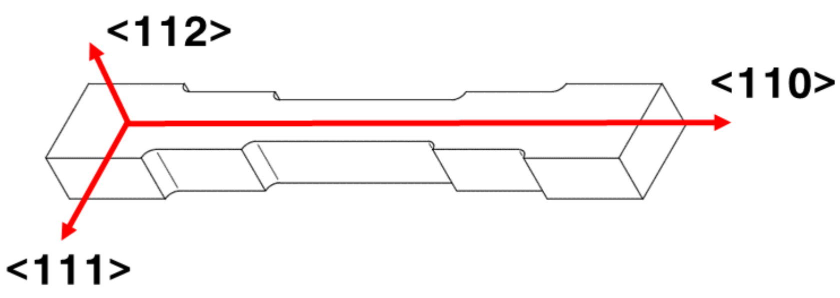
In situ Acoustic Emission (AE)

Post fatigue cycle Electron Channeling Contrast Imaging (ECCI)

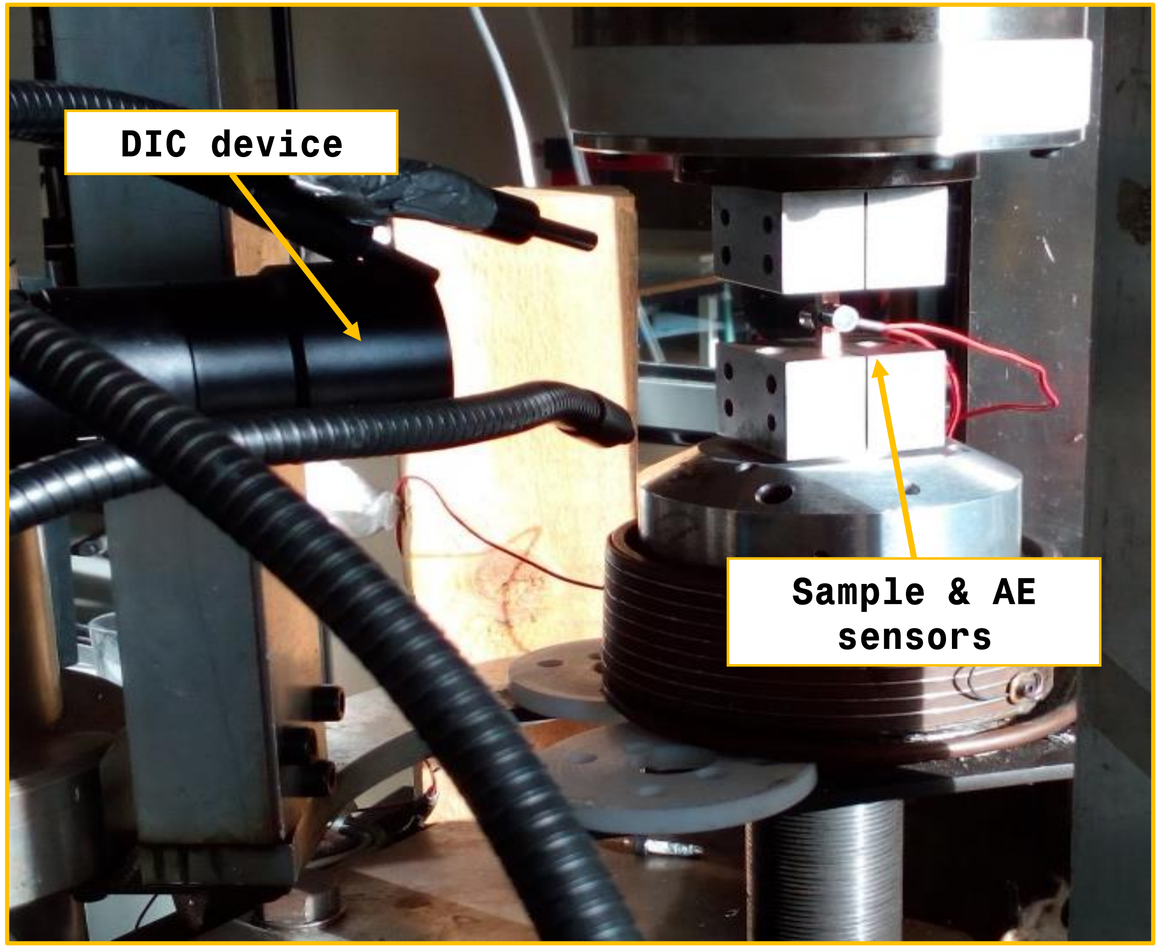
- Effect of crystallographic **orientation** on the dislocation dynamics.
- Comparison between **monotone** and **cyclic** experiment.

Copper single crystal (multiple slip)

(From P.Courtois (ILL, Grenoble))



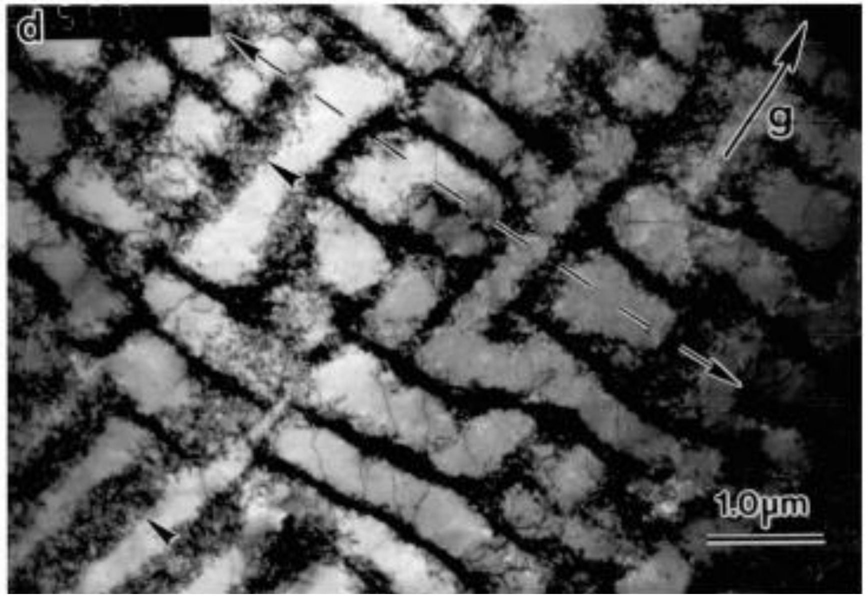
Fatigue machine	Frequency (Hz)	Loading mode
	0,1	Stress imposed
EA / DIC	**Sampling frequency (KHz)**	**Coupling**
	1	Silicone



Cyclic fatigue machine

Transmission Electron Microscope (TEM)

H.L.Huang, 2003



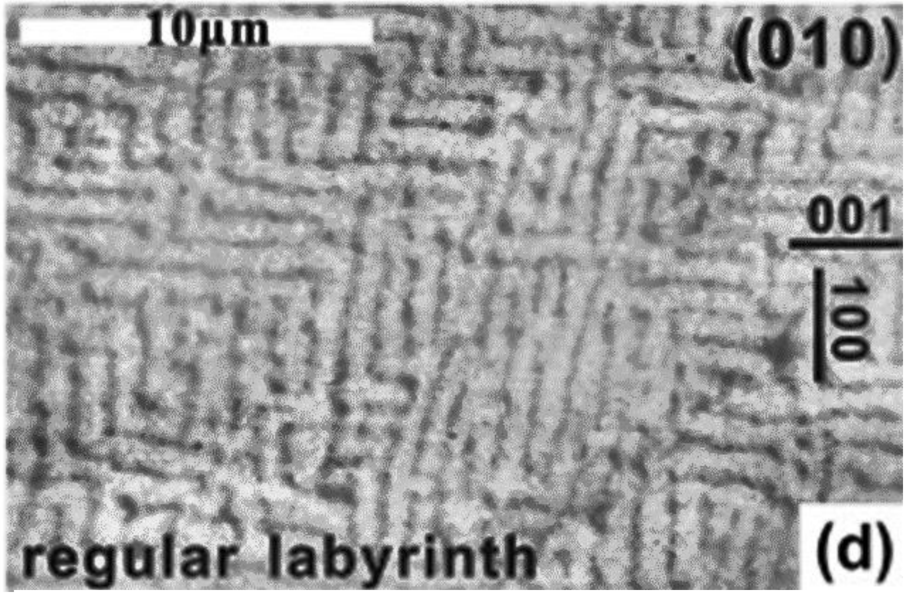
Labyrinth structure in polycrystalline Cu

Thin foil samples

- Tedious preparation
- Good resolution

Scanning Electron Microscope (SEM)

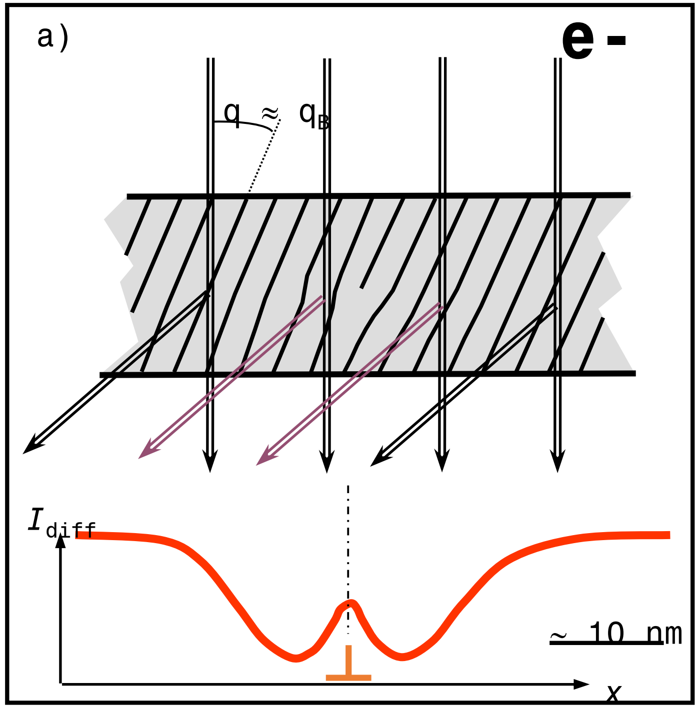
P.Li & al, 2011

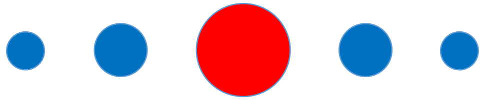


Labyrinth structure in [001] Cu

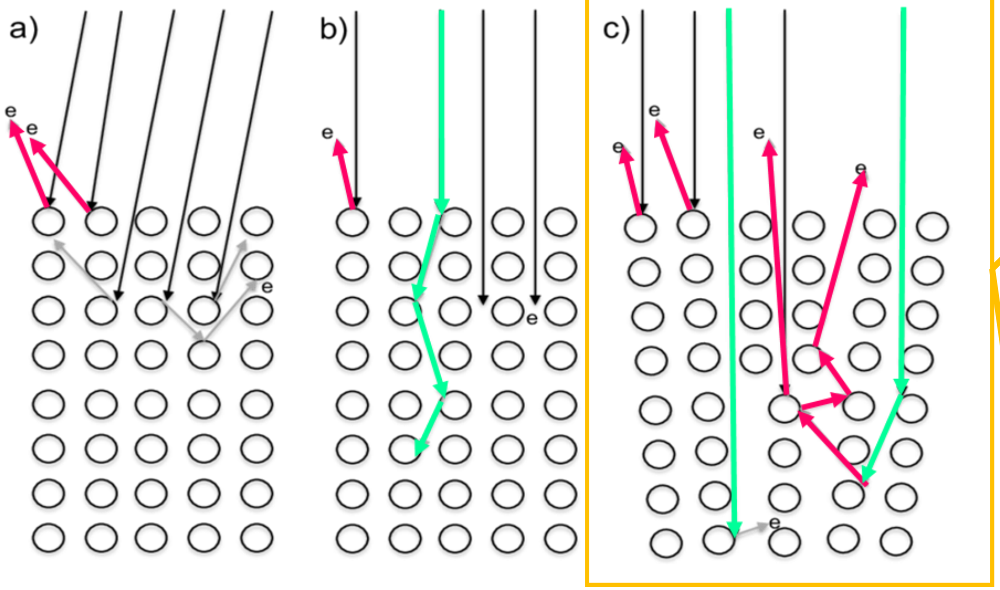
Applied on bulk materials

- No destructive preparation
- Recent technique



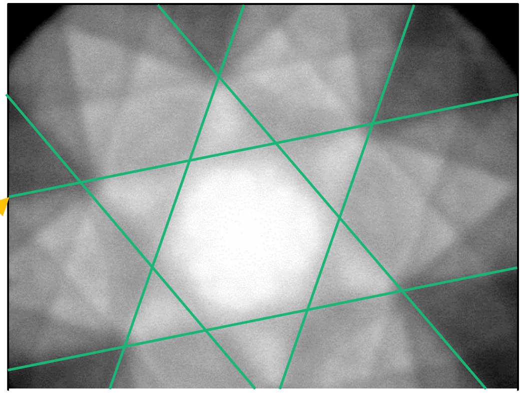


J.Saarimäki, 2015



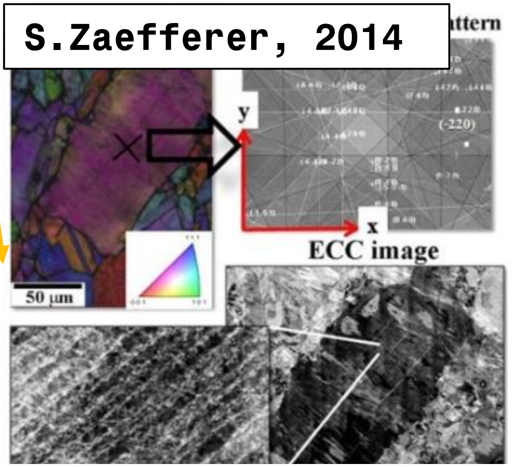
Channeling condition of electrons

- Hard to achieves
  - high precision needed (0.1 – 1°)
- Do not easily allows polycristal observation



Electron Channeling Pattern

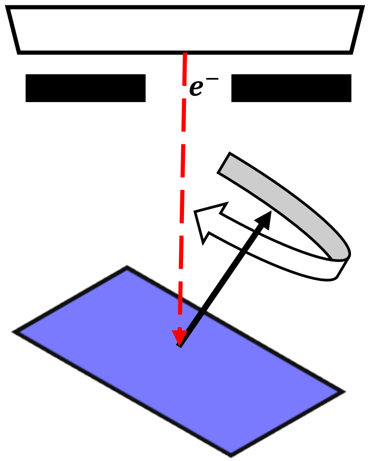
S.Zaefferer, 2014

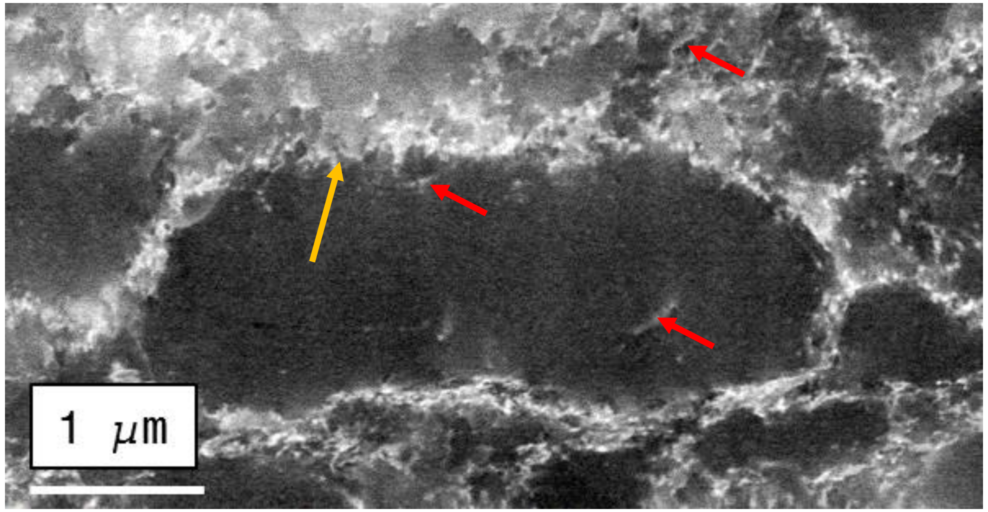


cECCI via EBSD

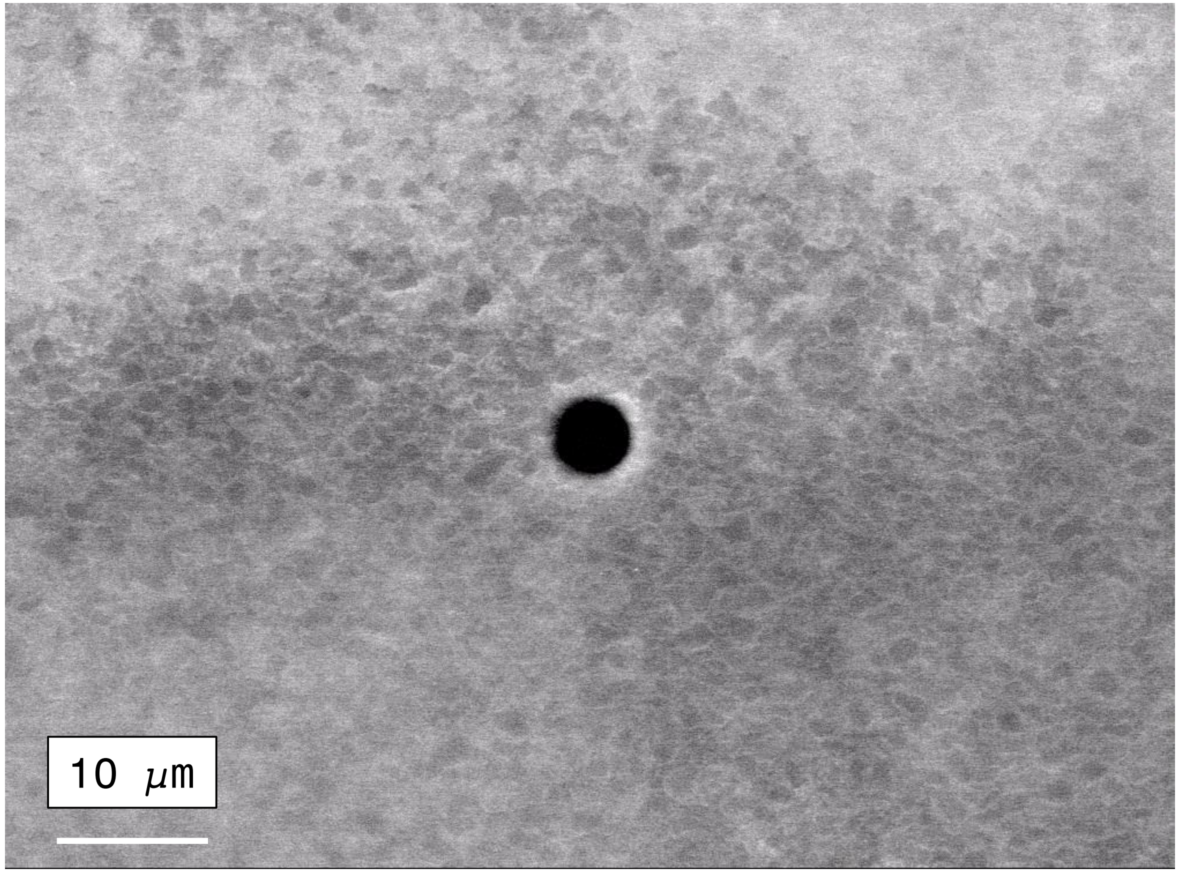
In rotation ECCI

- The idea : Tilt/ rotate & acquire images until dislocations become visible





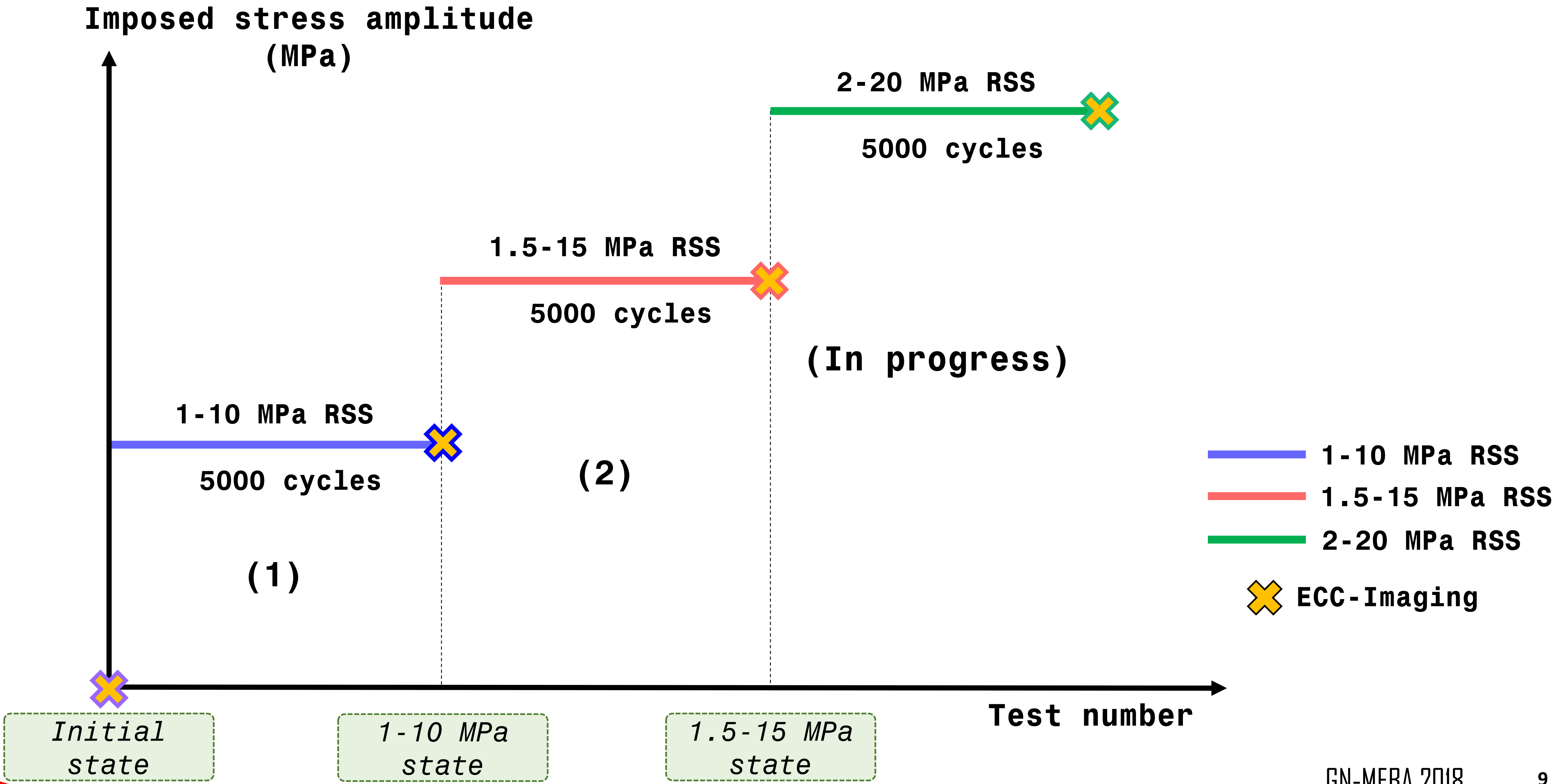
Dislocations cell in Cu single crystal



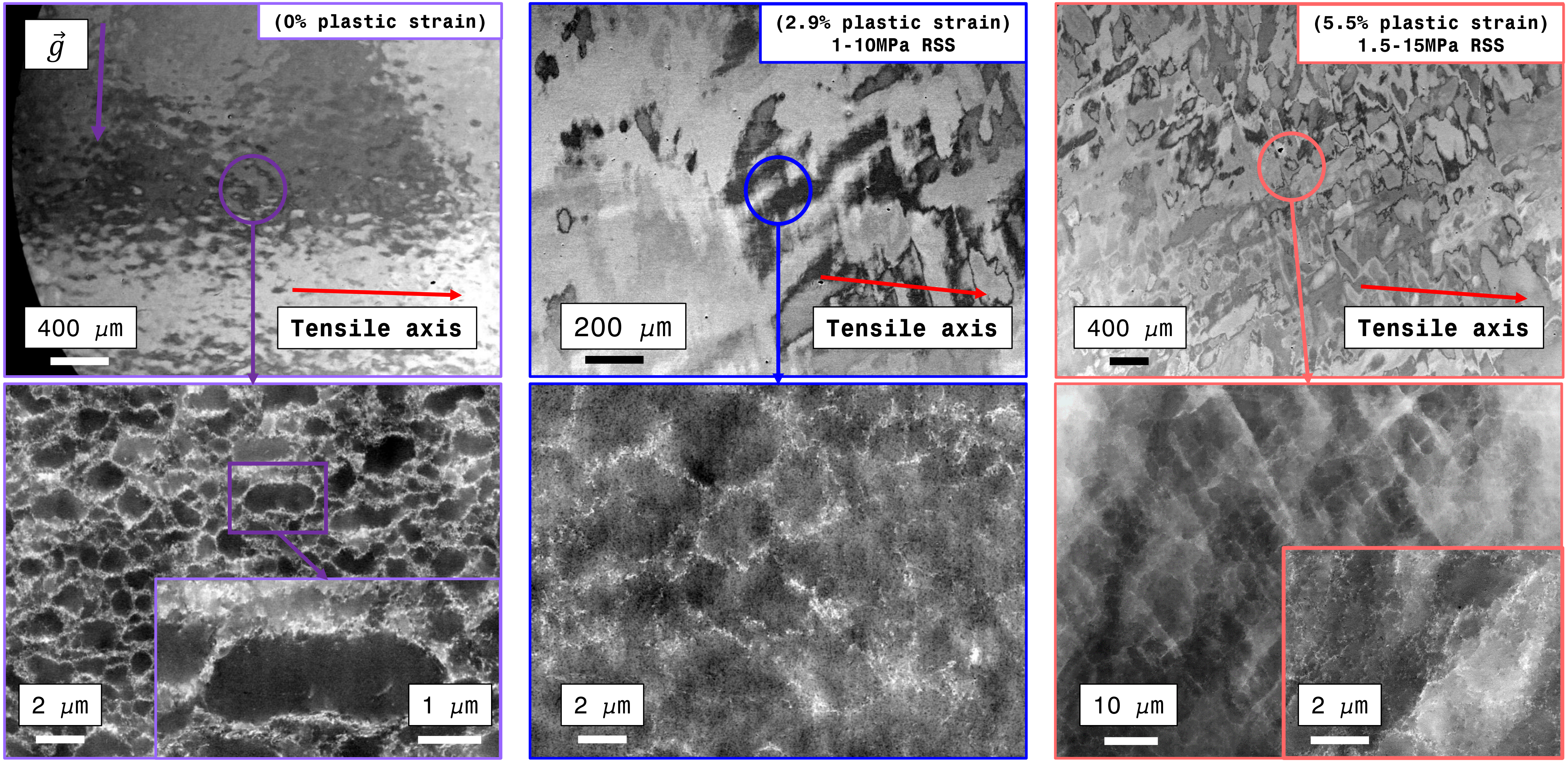
15° of rotation (1° step) – Cu single crystal <110>

C.Langois & al., 2015 / C.Lafond & al., 2018

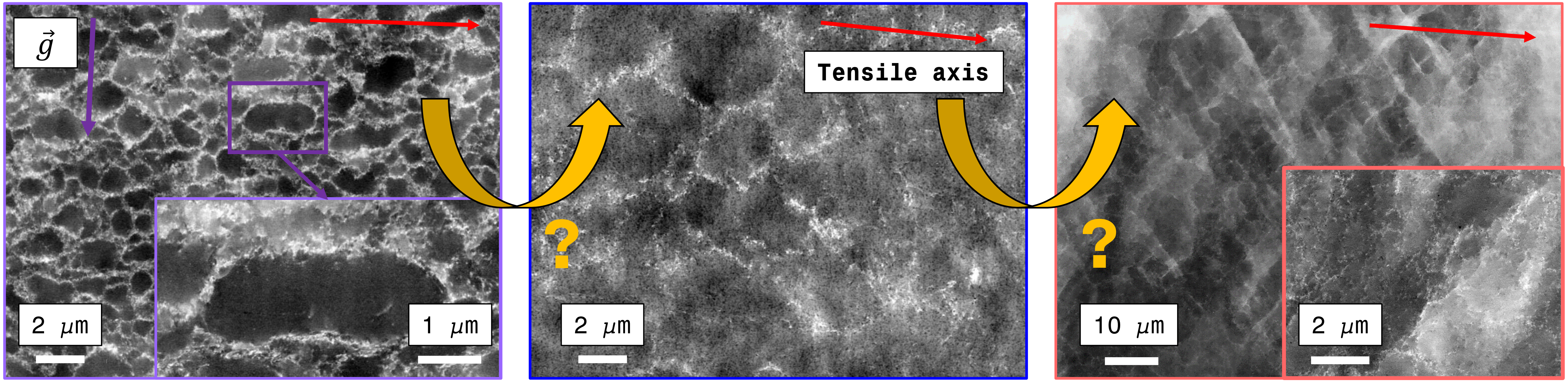
Experimental protocole

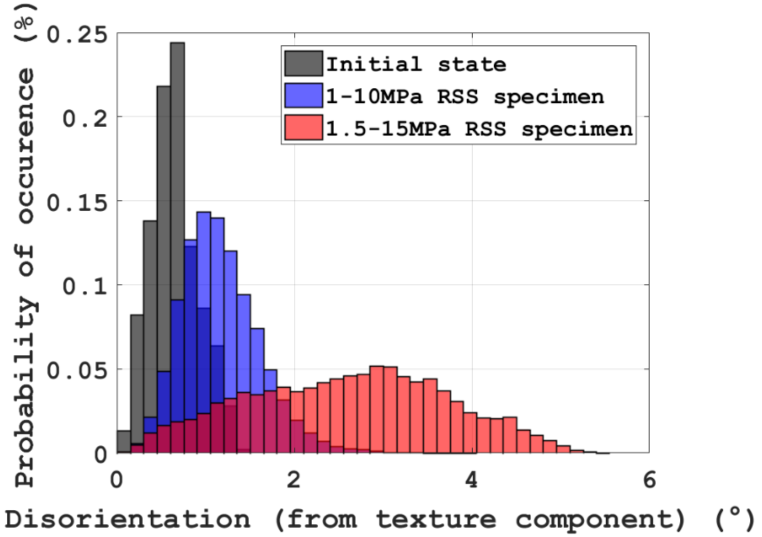


Dislocations structures



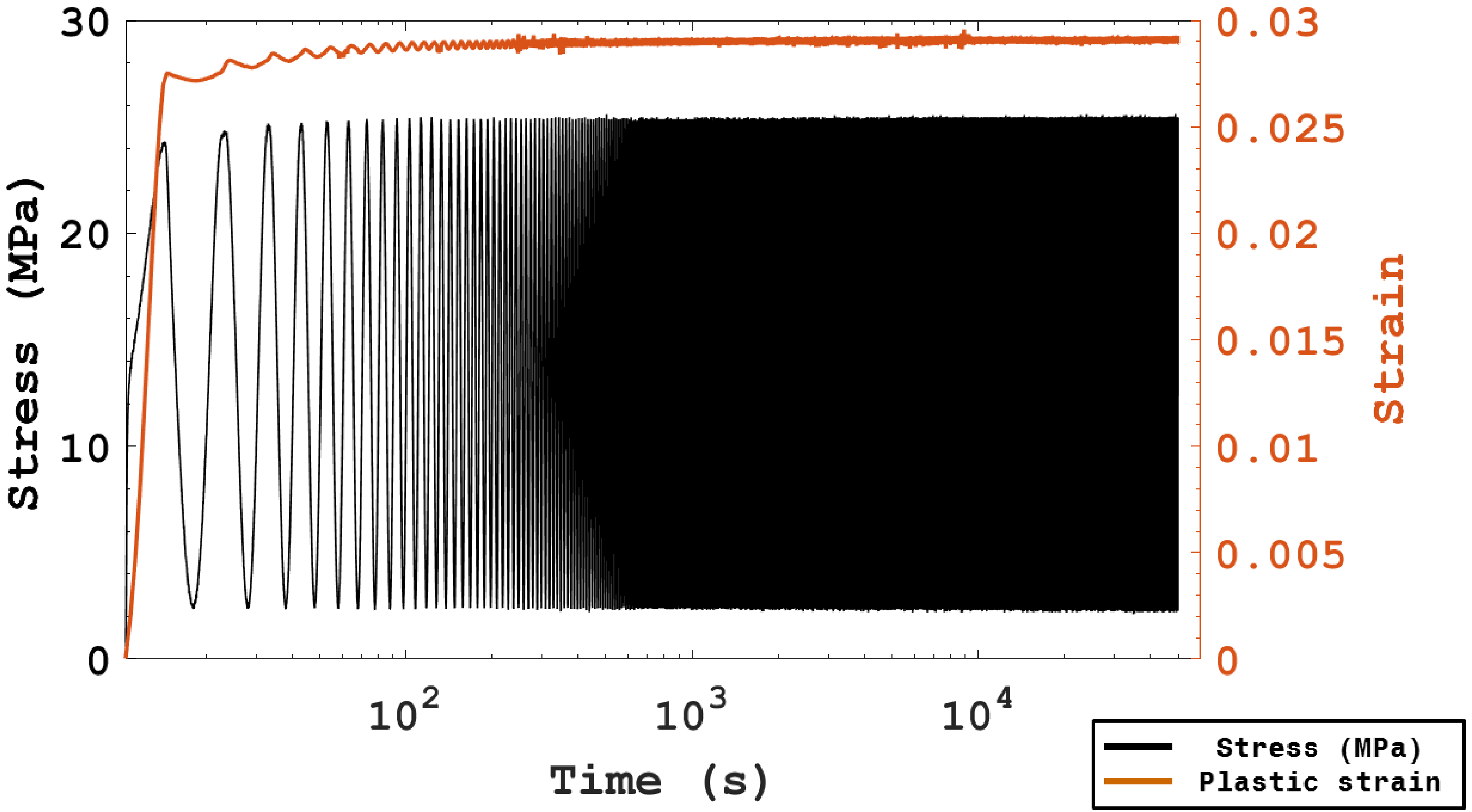
Dislocations structures



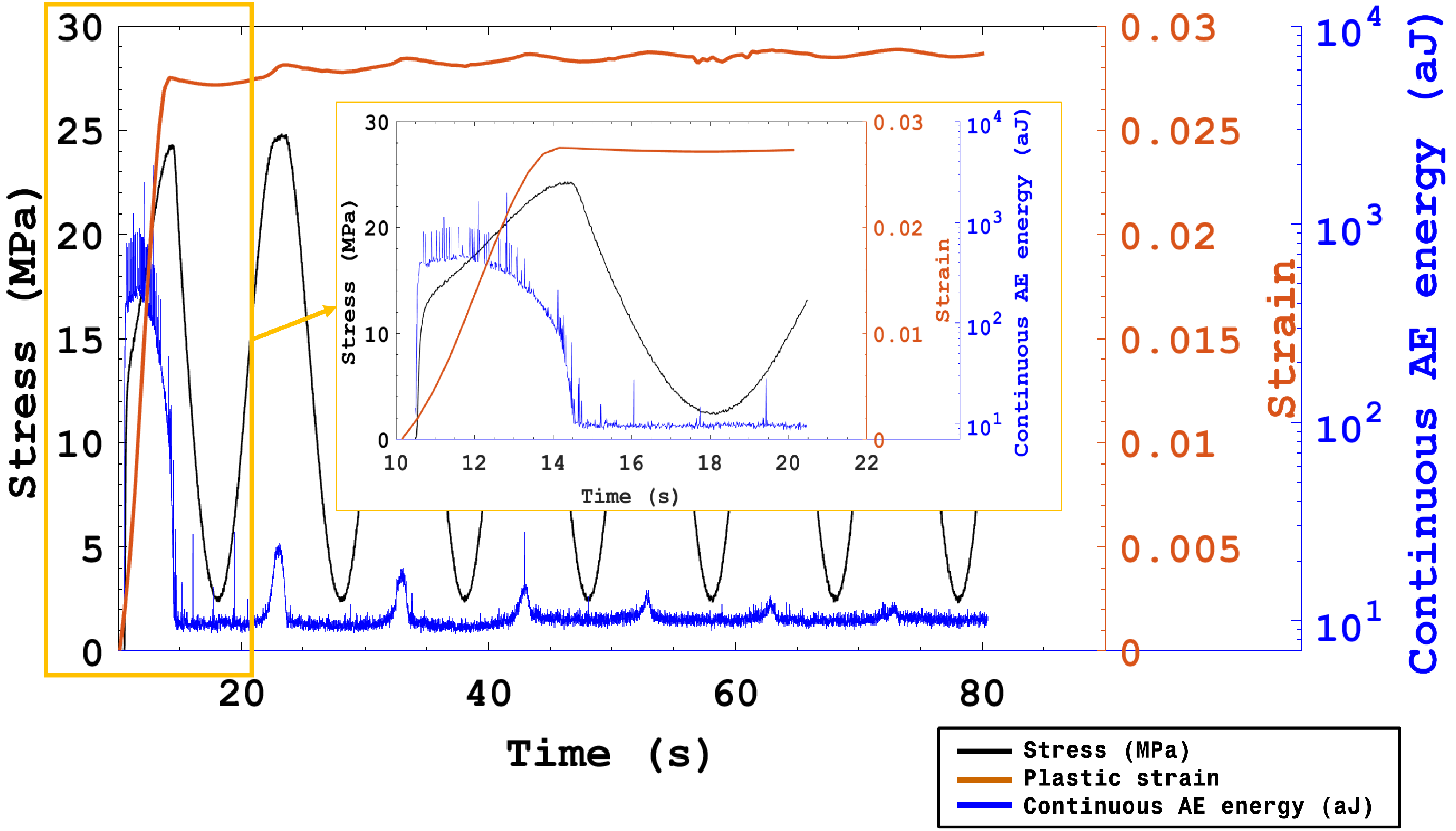


Dislocations structure	Cells Width(µm)	Cells size(µm)	Walls Width(µm)	Walls spacing(µm)
Initial state	0,16 ± 0,09	0,87 ± 0,43	/	/
1-10	0,36 ± 0,14	1,85 ± 0,71	/	/
1.5-15MPa	0.15 ± 0.05	1.95 ± 0.72	0,51 ± 0,10	4.27 ±1.71

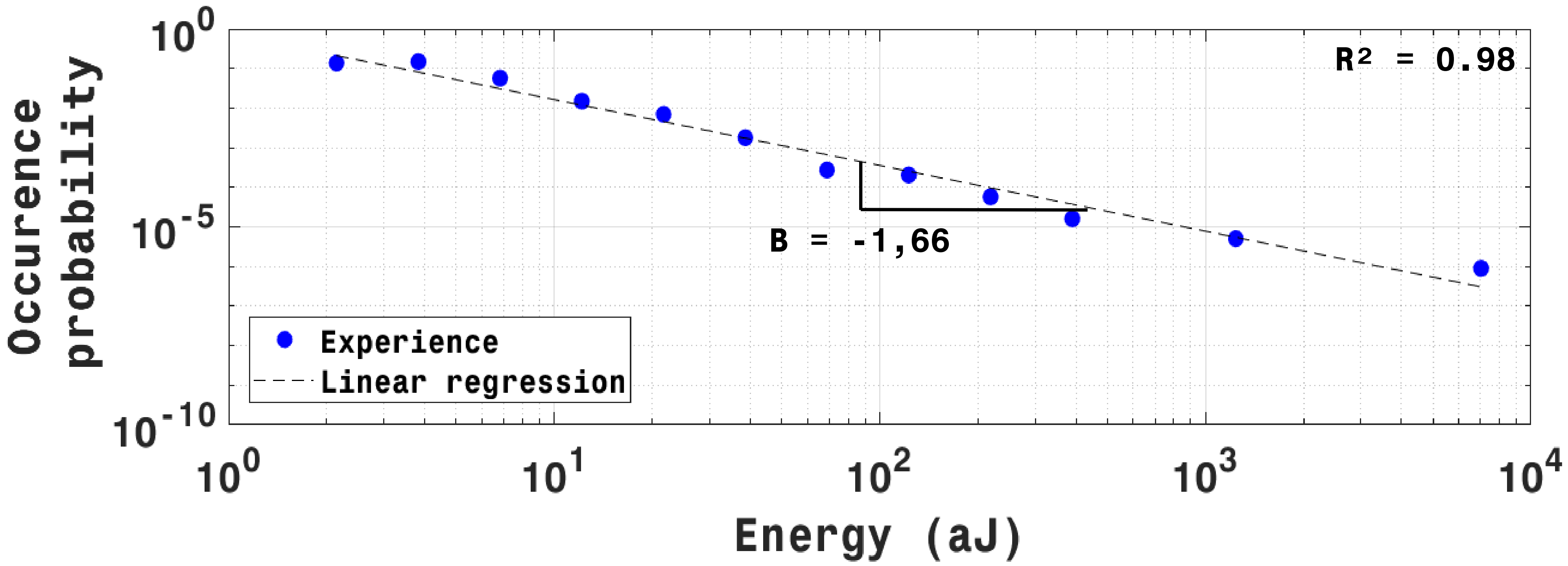
First cycle test : 1-10 MPa RSS



First cycle test : 1-10 MPa RSS



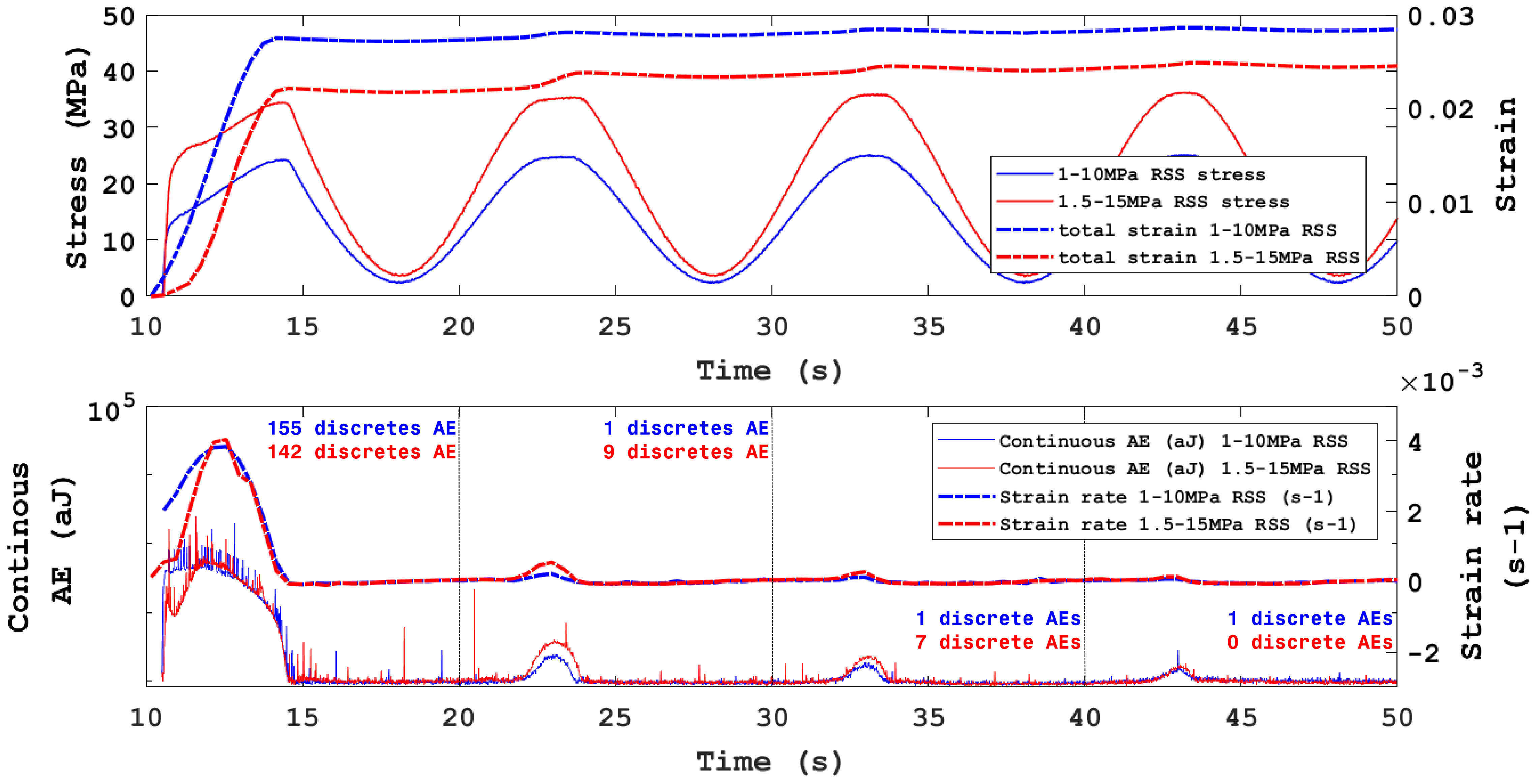
First cycle test : 1-10 MPa RSS



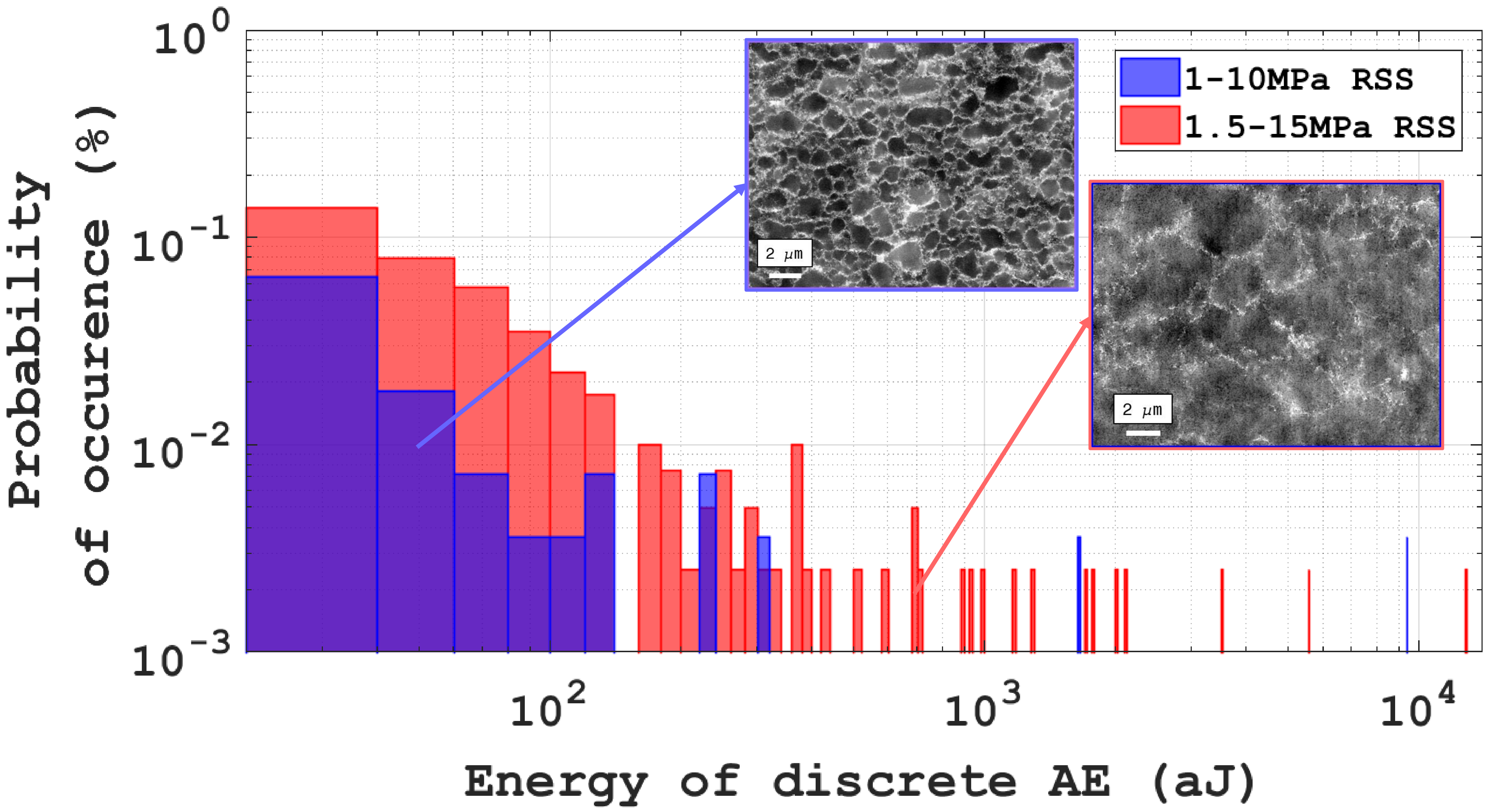
Power-law distribution of discrete AE during the all cycle test

- Power-law distribution
  - exponent in agreement with dislocation avalanches processes (W.Ben.Rhouma,2013)
  - Dislocations avalanches processes

1-10 MPa RSS vs 1,5-15 MPa RSS



1-10 MPa RSS vs 1,5-15 MPa RSS



Conclusion and perspectives

- Link between AE and dislocation structure is possible.
  - Dislocation avalanches monitored.
  - Initial dislocation structure impact the global dynamics of avalanches.
- « Rotation ECCI » : An easy way for observing dislocations.

- Stress imposed fatigue test.
  - Evolution of the structure and the AE ?
- Influence of crystallographic orientation
  - Multiple slip / Single slip
- Improve the « Rotation ECCI » apparatus
  - Determine the diffraction vector $\vec{g}$

Thanks for your attention

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