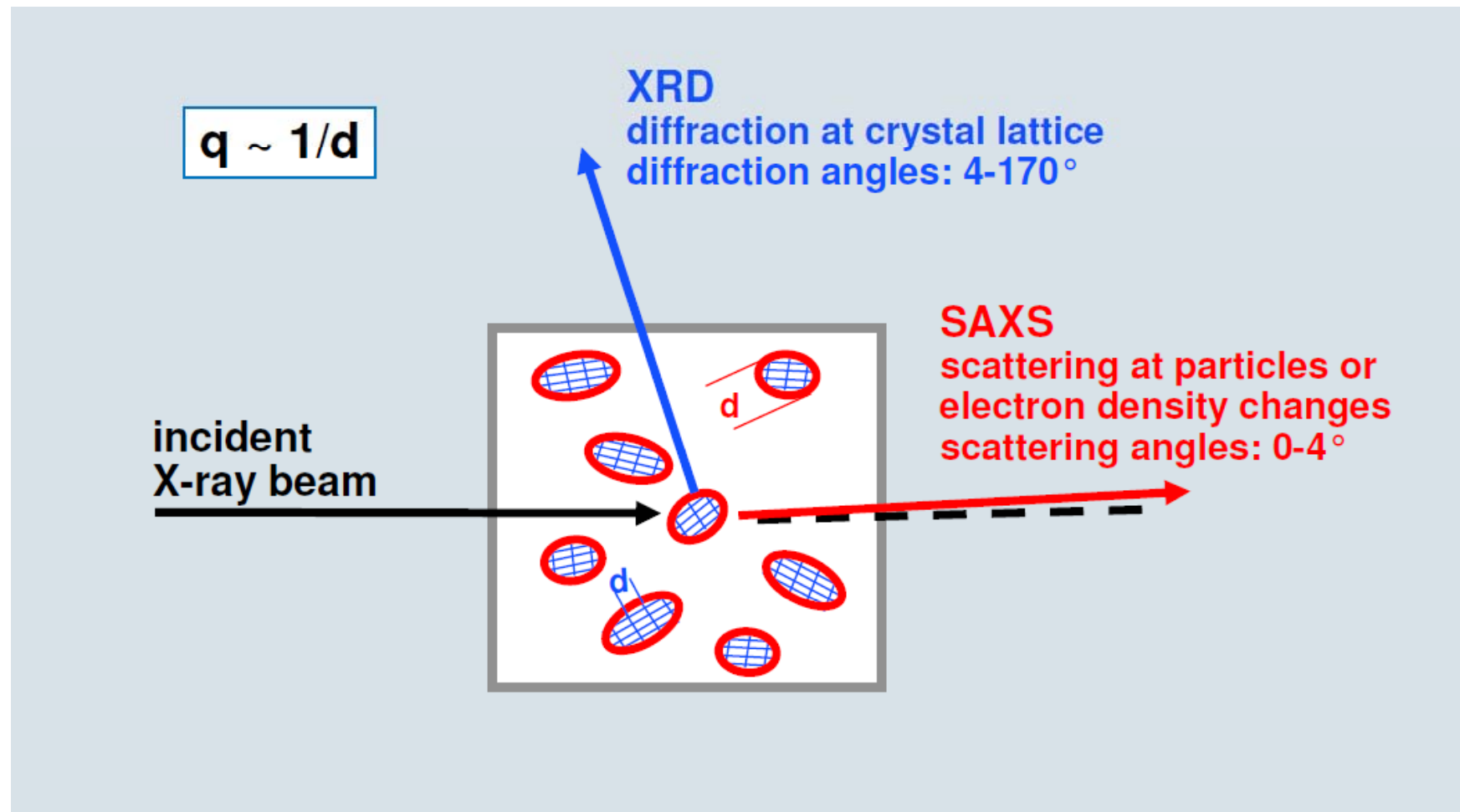


Group meeting (June 2, 2011)

Stephen Chou 周鴻昇

- 
- SAXS
 - Shear band stability

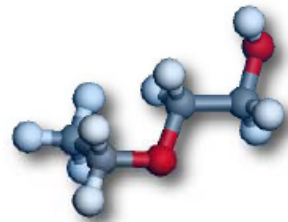
XRD/SAXS



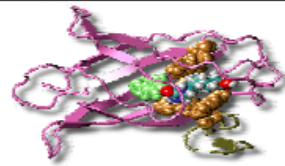
Crystallography

Microstructure

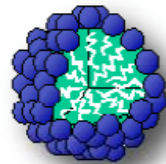
Structure



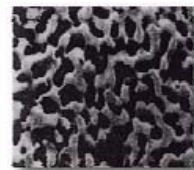
Atomic Structures



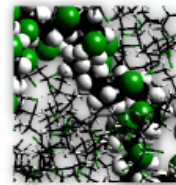
Proteins



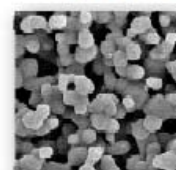
Micelles



Porous Media



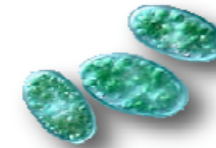
Polymers



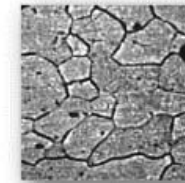
Precipitates



Viruses



Bacteria



Grain Structures

DIFFRACTION

X-ray, n, e

SANS/SAXS

10-1000 Å

DLS

TEM

USANS

Optical microscopy

Light scattering

10^{-11} m

10^{-9} m

10^{-7} m

10^{-5} m

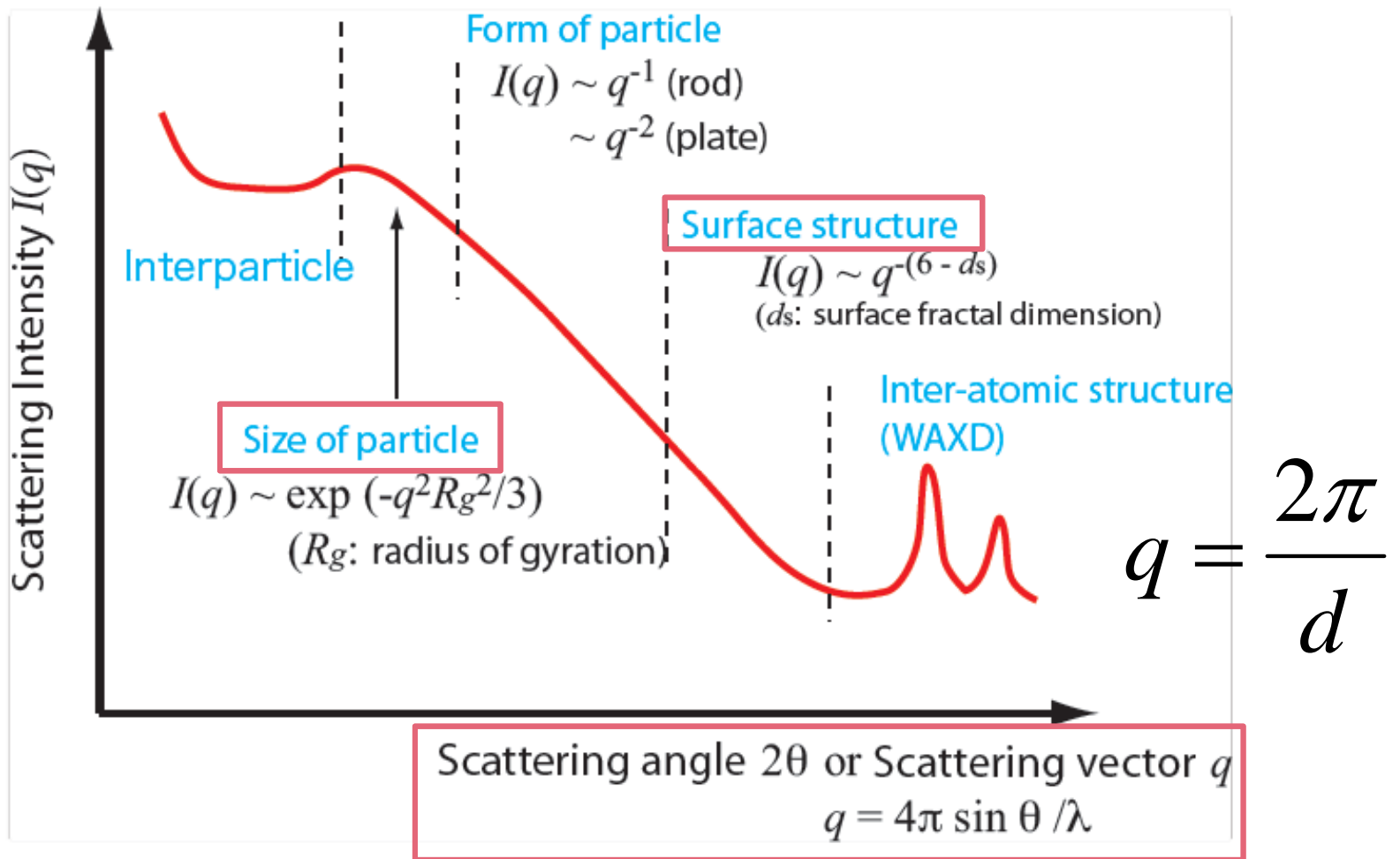
10^{-3} m

Intensity of SAXS

- The signals in crystals are attributed to diffraction. Contrarily, the intensity of scattering from anything else.
- **Basic principle**
 - **Form factor**-particle shape
 - **Structure factor**-inter-particle distances (interference)

$$I(q) = \phi V_{\text{particle}} \underline{S(q)} \underline{F(q)}$$

Structure Factor Form Factor



Measurement

- In-lab X-ray source-**electron density**
- High-energy X-ray (Synchrotron)-**electron density**
- Neutron-**scattering length**

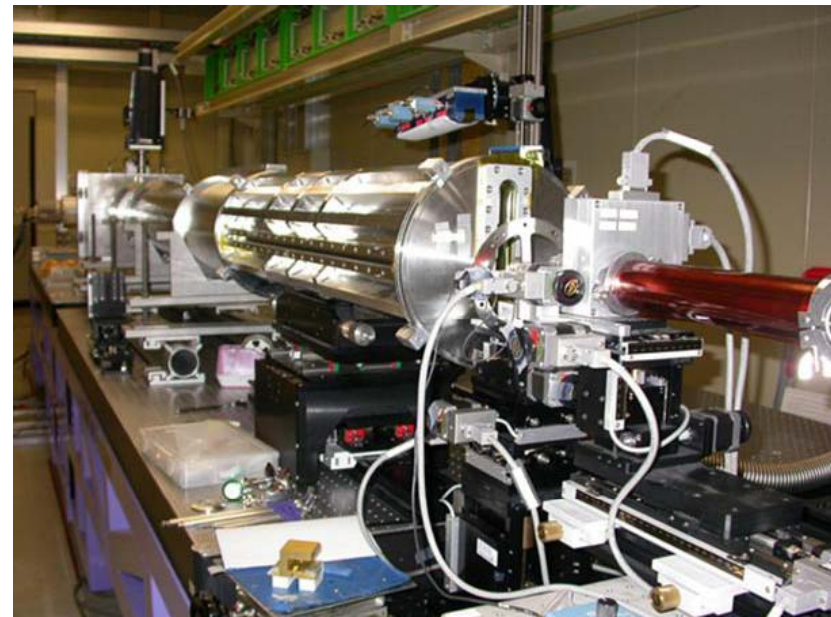
Facilities of small angle scattering analysis

- **In-lab instrument**

- Low background (in vacuum)
- Low intensity

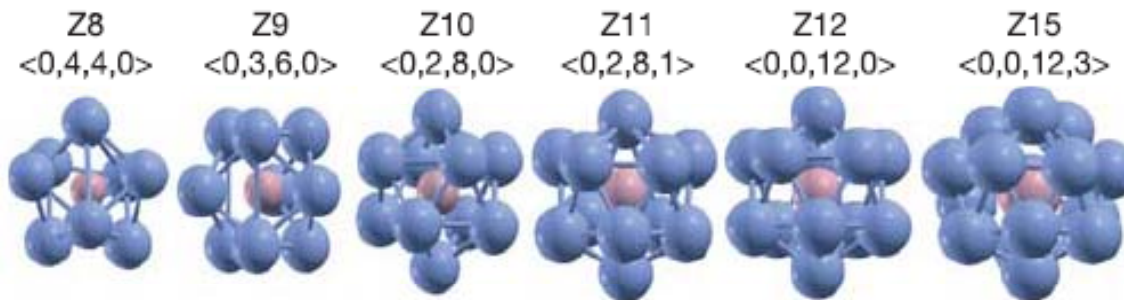
- **Synchrotron/neutron instrument**

- High background (in air)
- Ultra high intensity

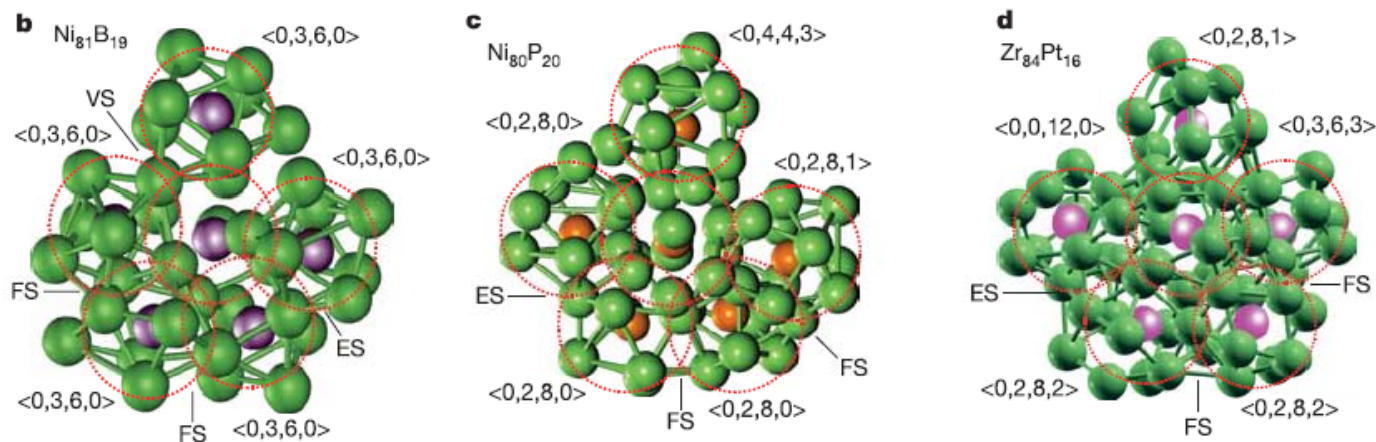


Atomic structure of amorphous alloys

Short-range ordering cluster



Medium-range ordering cluster



Spindonal decomposition of NiNbY amorphous alloys

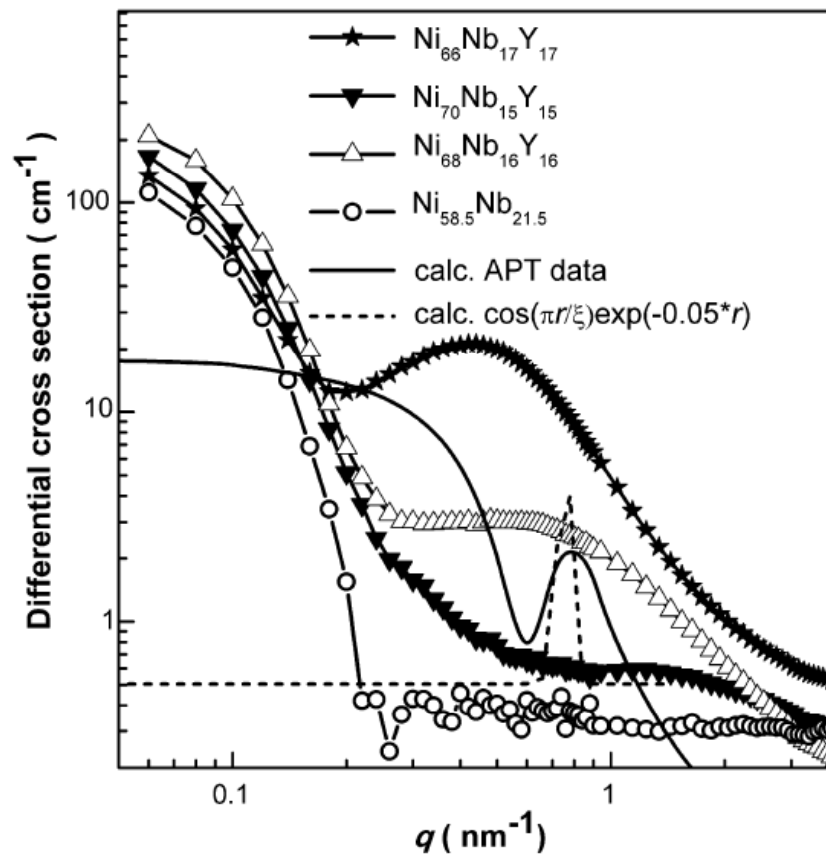


Fig. 5. SAXS curves $d\sigma/d\Omega(q)$ of glassy Ni-Nb-Y alloys and calculated data.

SAXS technique in amorphous alloys

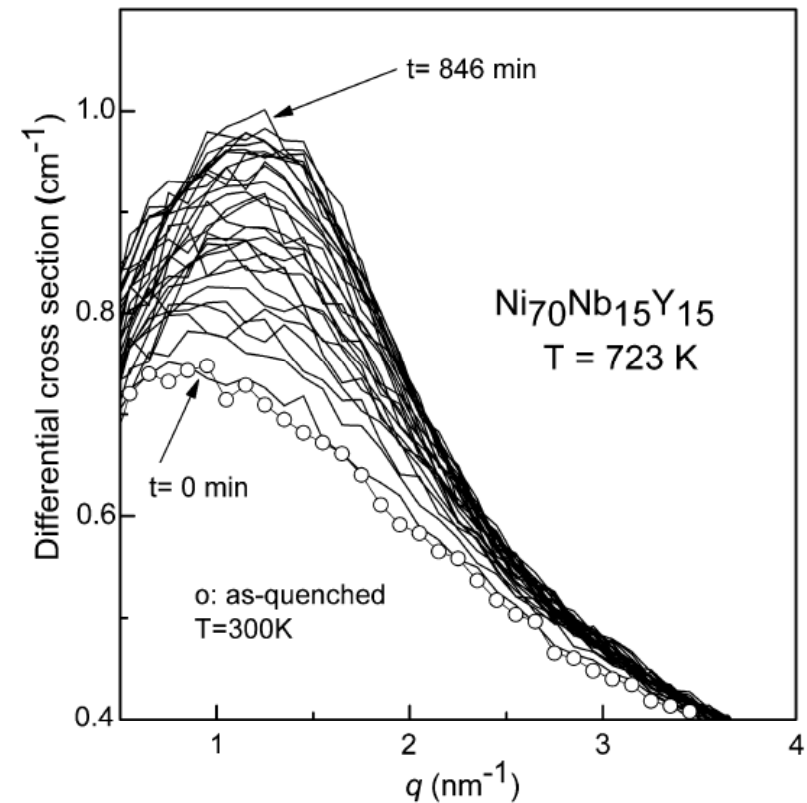
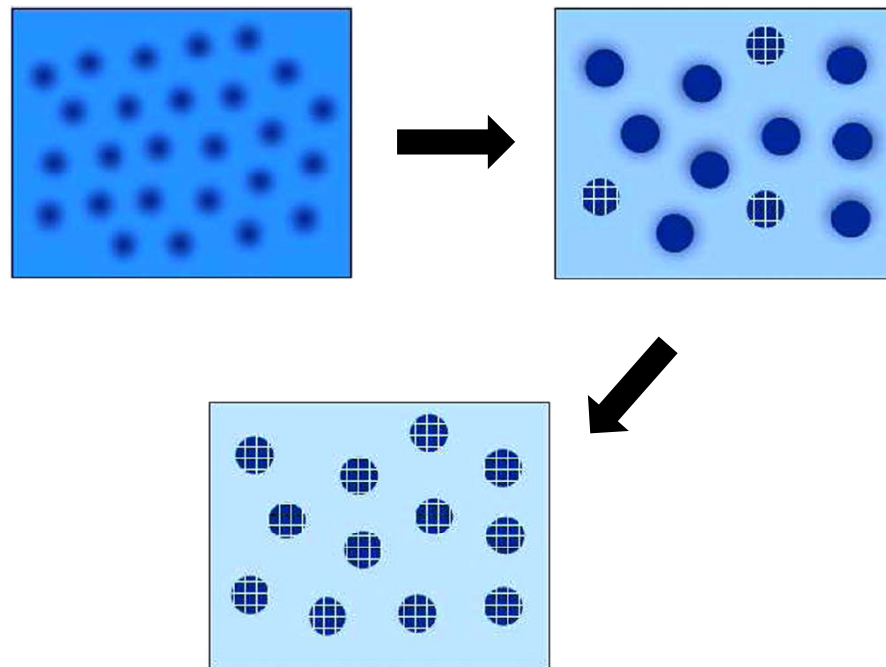
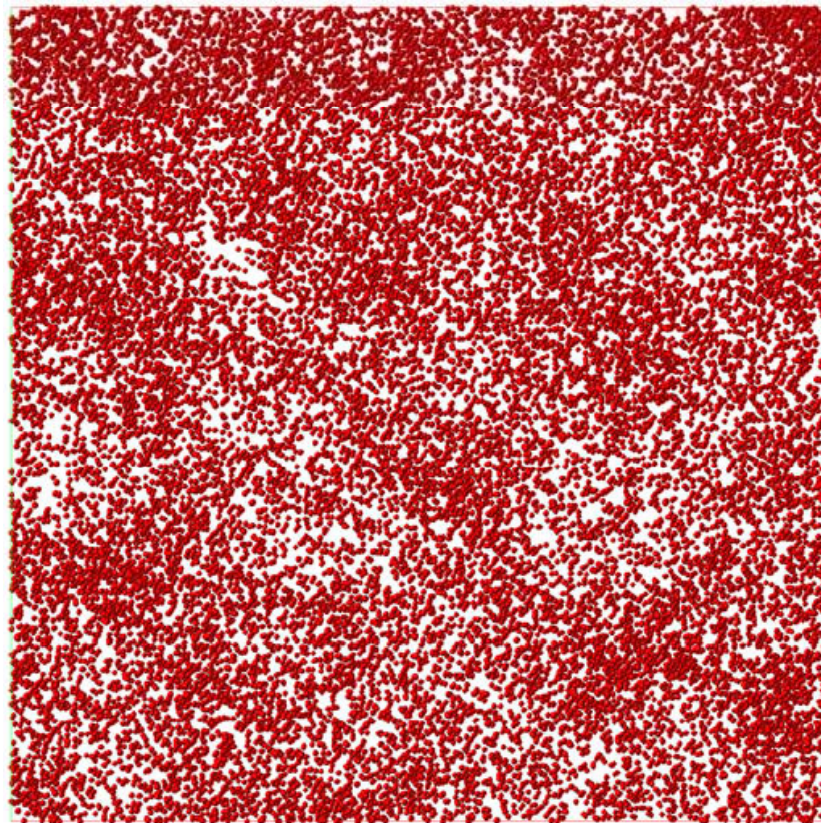


Fig. 7. In situ SAXS $d\sigma/d\Omega(q)$ of $\text{Ni}_{70}\text{Nb}_{15}\text{Y}_{15}$ glass after different times at $T = 723 \text{ K}$.

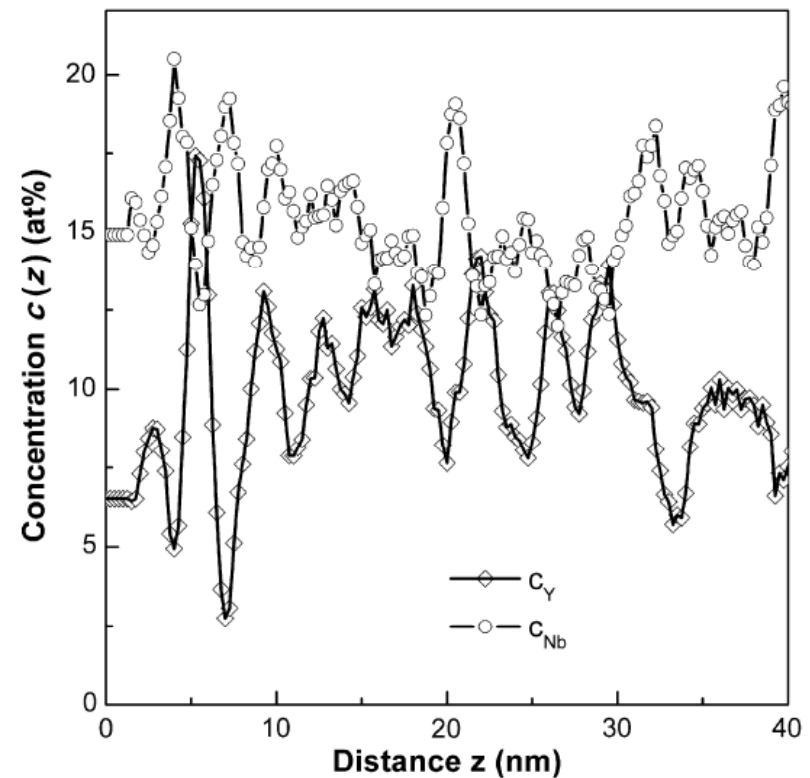
J. Antonowicz, M. Kedzierski, E. Jezierska, J. Latuch, A. R. Yavari, L. Greer, P. Panine, M. Sztucki, *J. Alloys Compd* **483** (2009) 116

N. Mattern, G. Goerigk, U. Vainio, M.K. Miller, T. Gemming, J. Eckert, *Acta Mater.* **57** (2009) 903

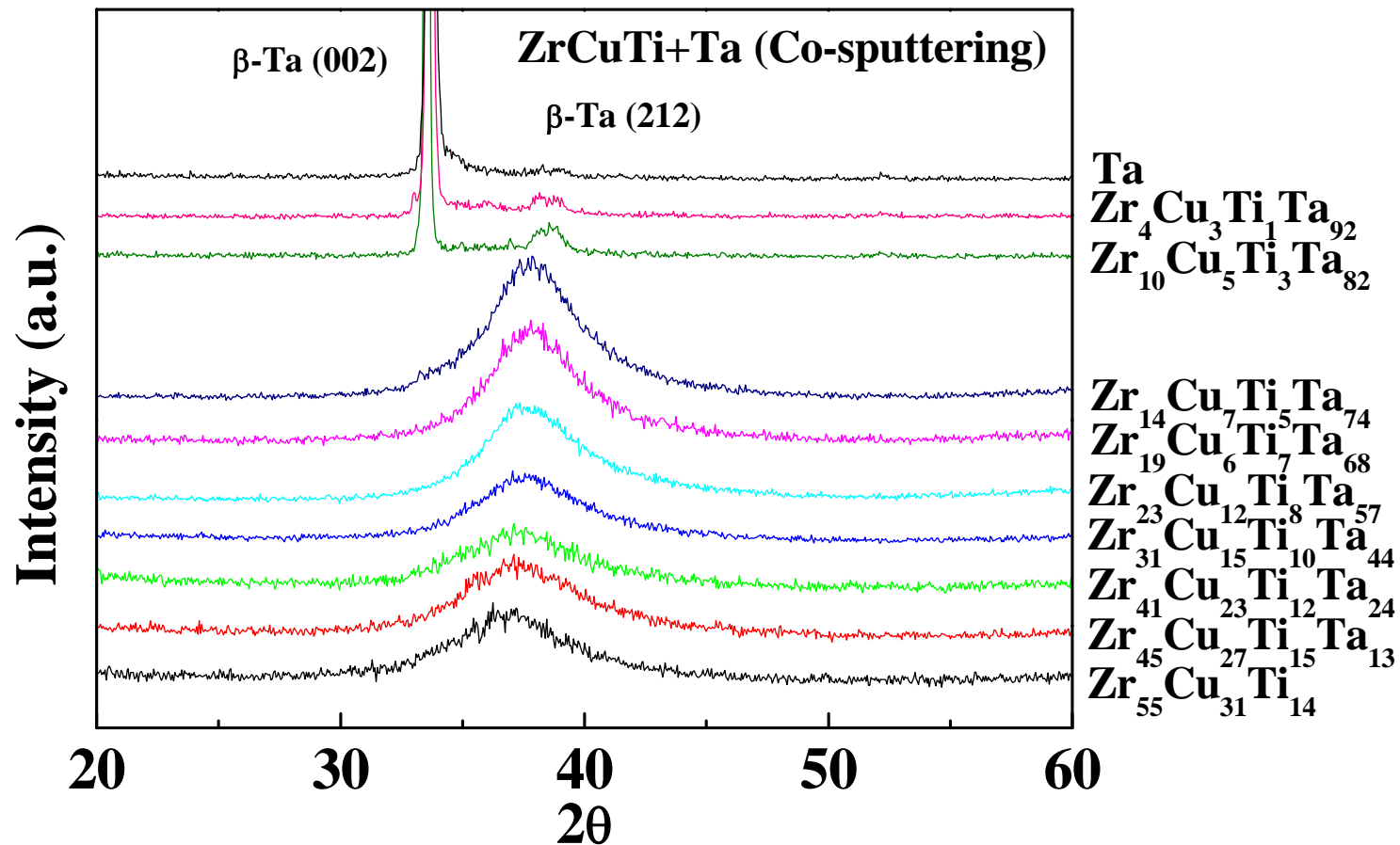
Atom probe of rapid-quenched NiNbY amorphous alloys



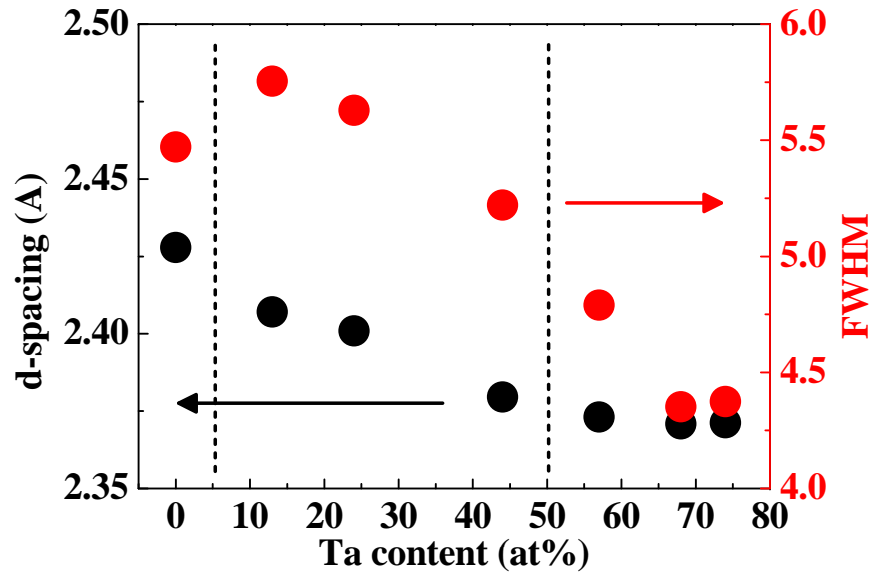
Mapping of Y element



X-ray diffraction patterns with addition of tantalum



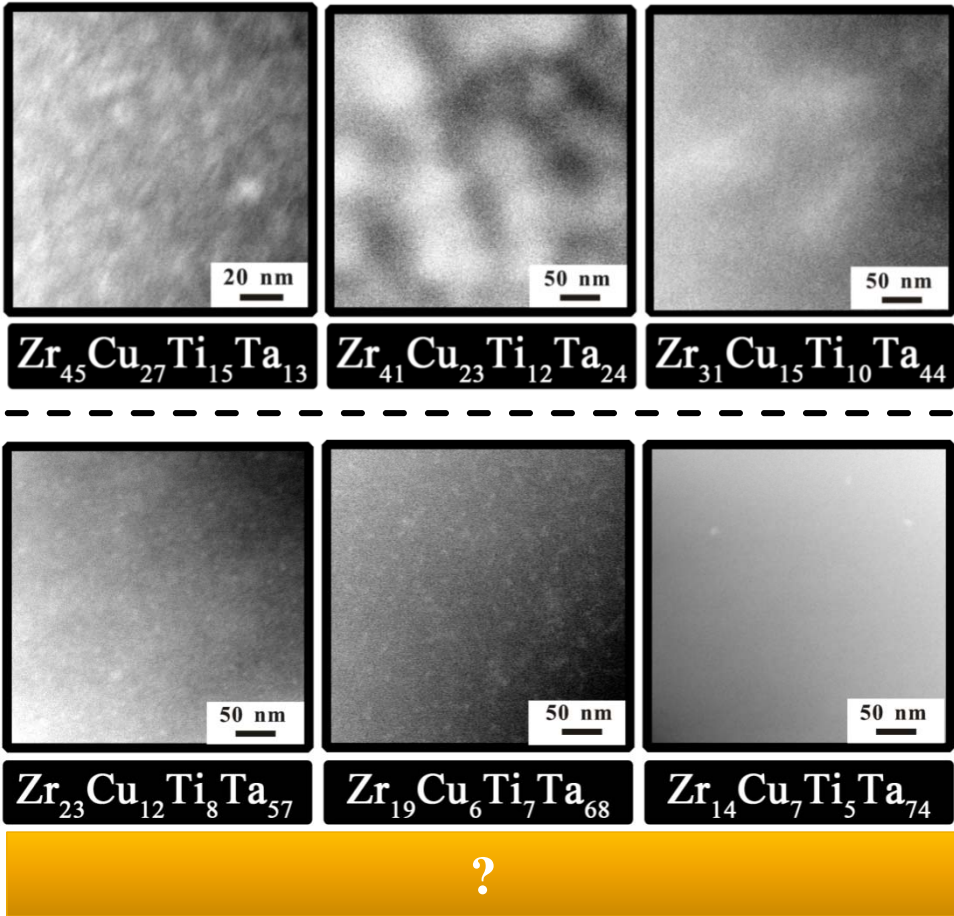
HAADF images of ZrCuTiTa TFMGs



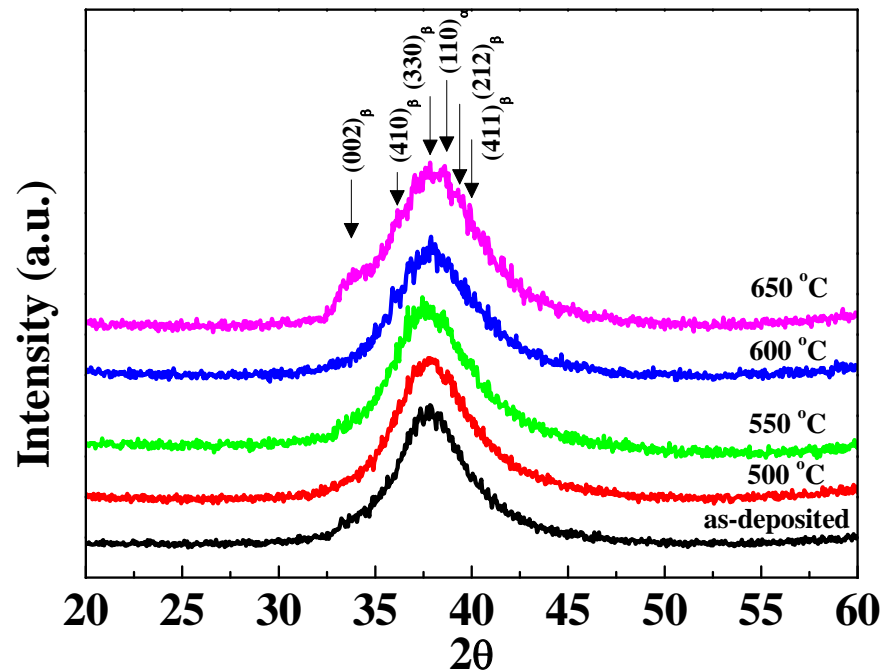
FWHM ↓

The distribution of the bonding length is more uniform.

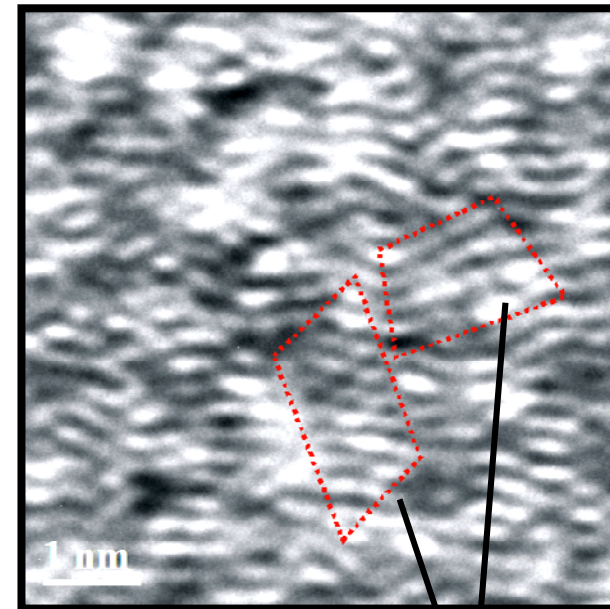
Composition fluctuation



Phase transformation of $Zr_{14}Cu_7Ti_5Ta_{74}$ through annealing

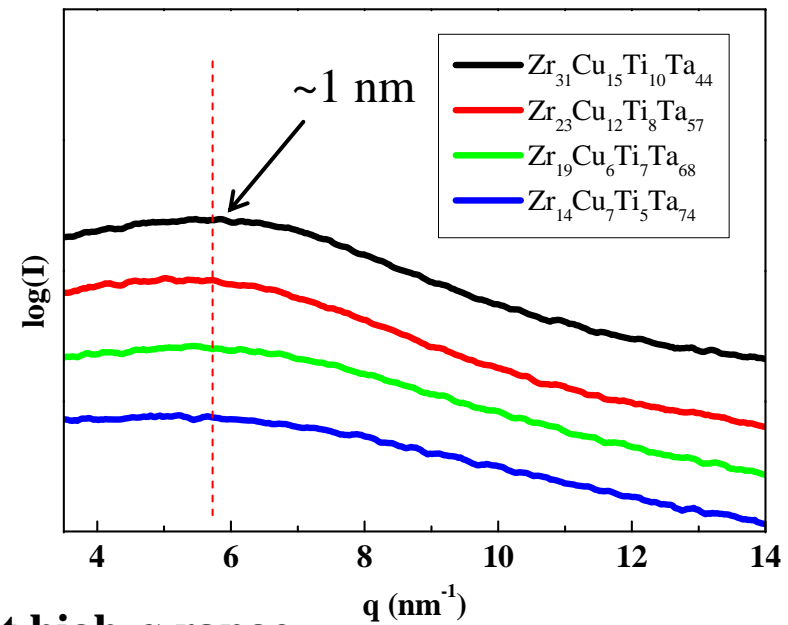
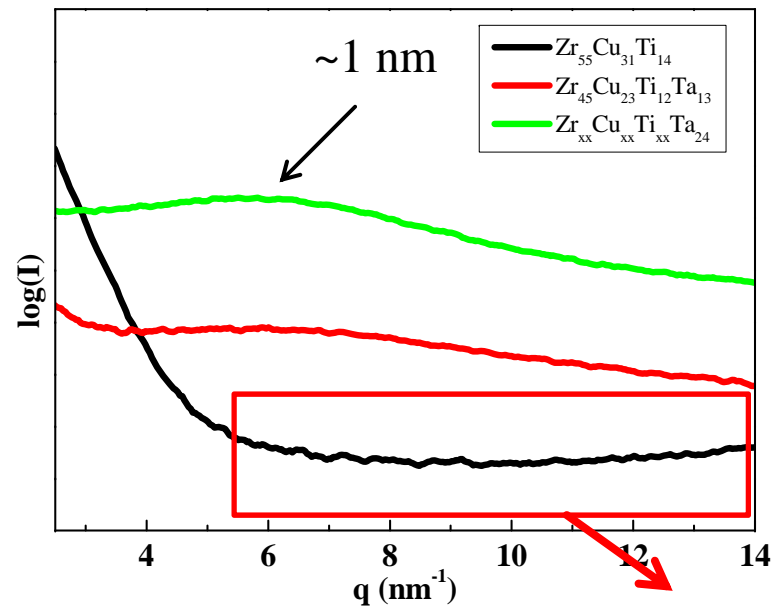


As-deposited $Zr_{14}Cu_7Ti_5Ta_{74}$

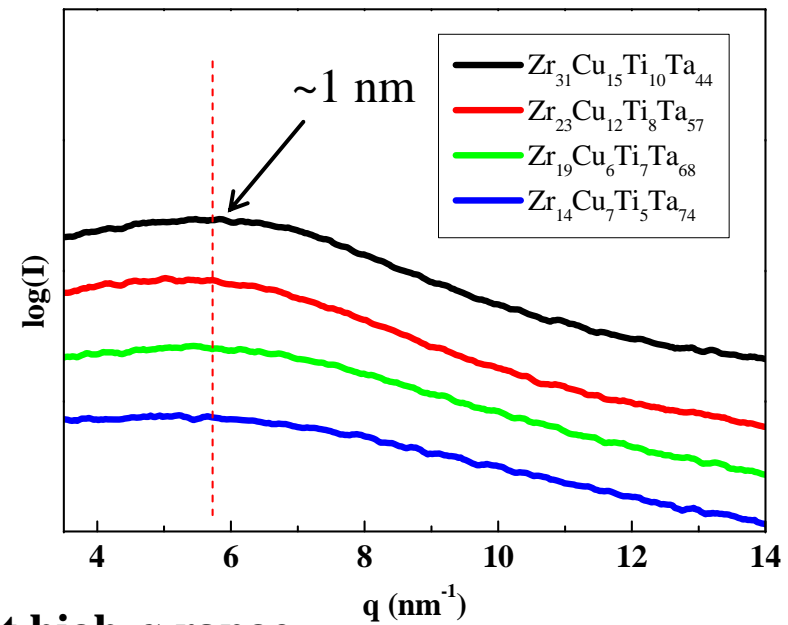
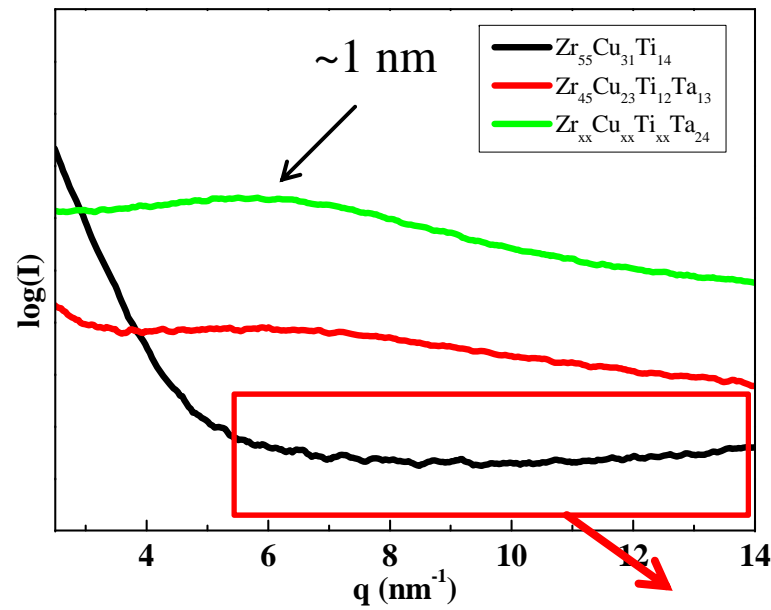


Ta-Ta clusters

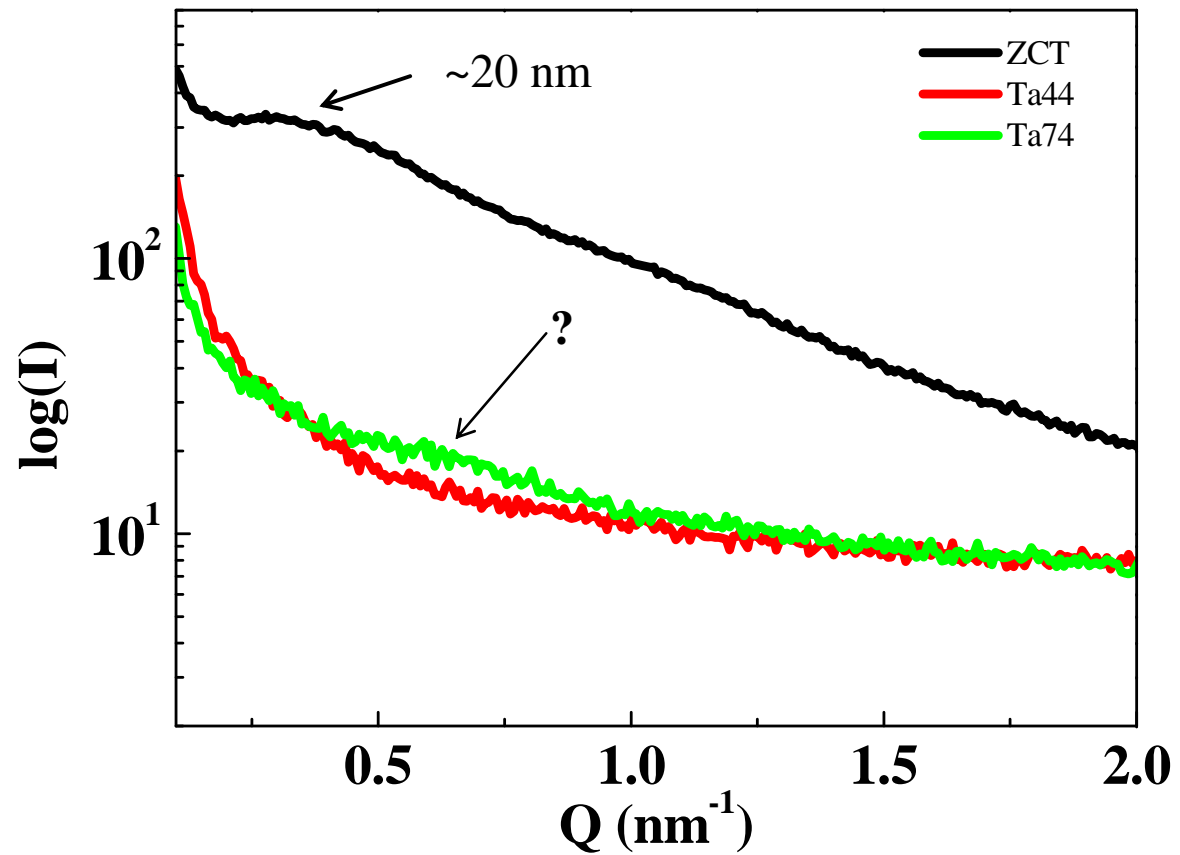
WAXS from 3-20°



WAXS from 3-20°

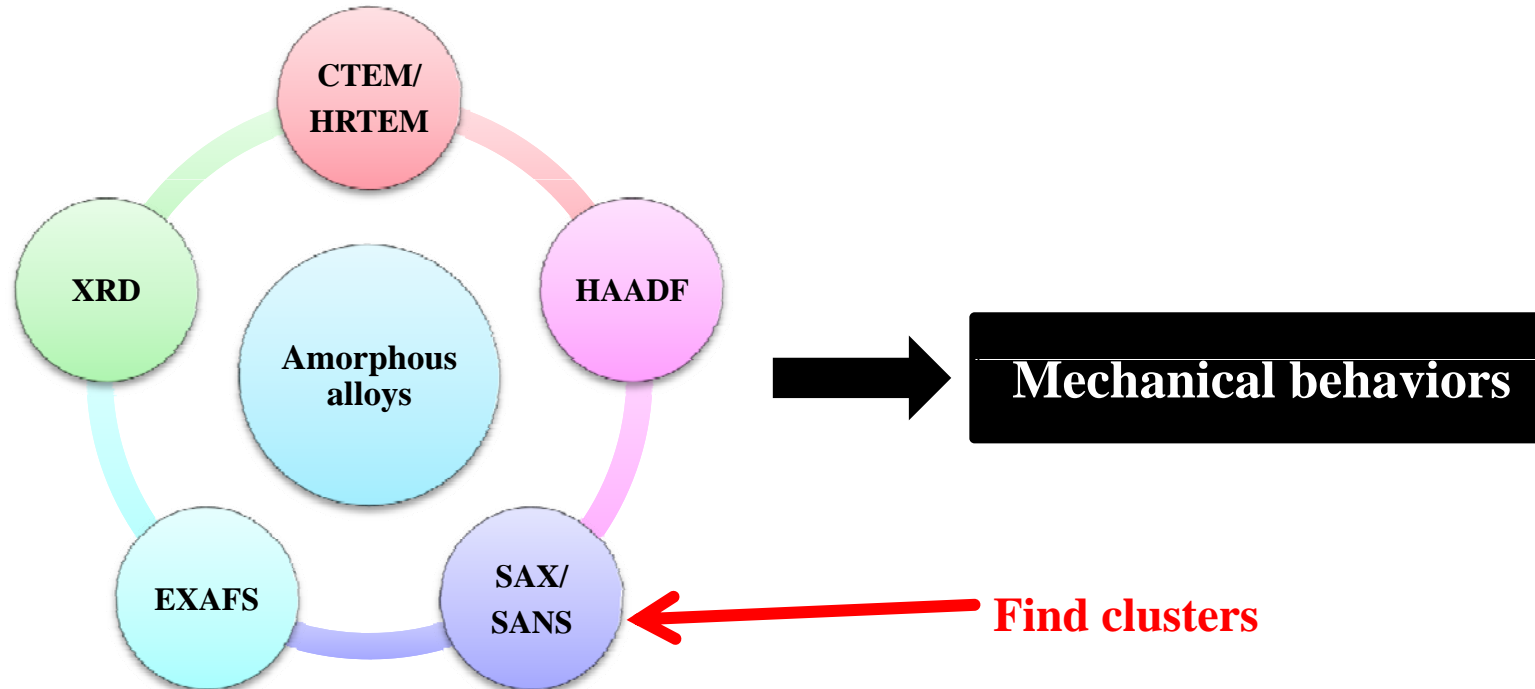


SAXS from 0.1-3°



Interesting topics

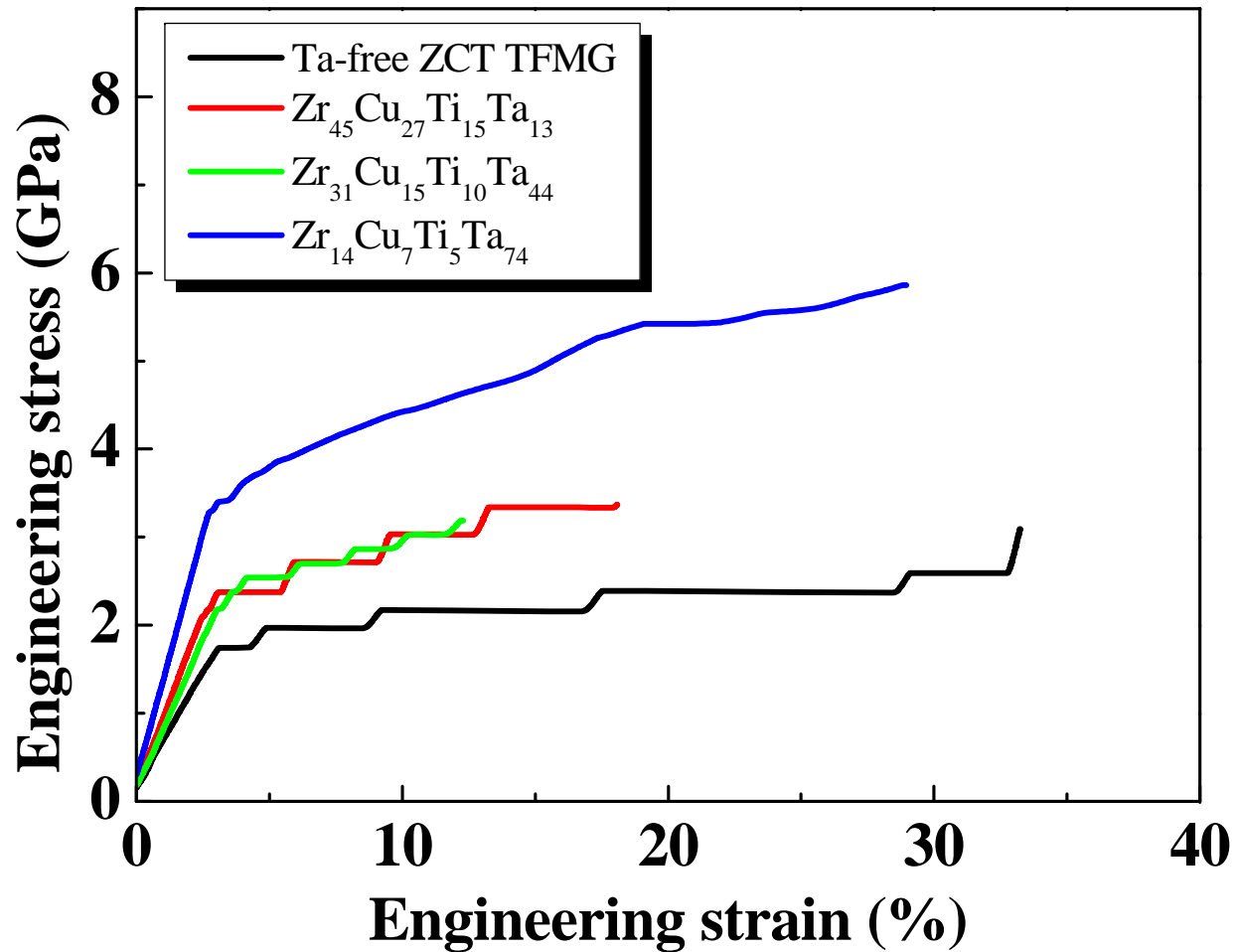
- Interaction between pre-existed Ta-Ta clusters and STZ cluster
- Analysis of the amorphous structure by combining among conventional X-ray diffraction, conventional TEM, HAADF, HRTEM, SAX/SANS.



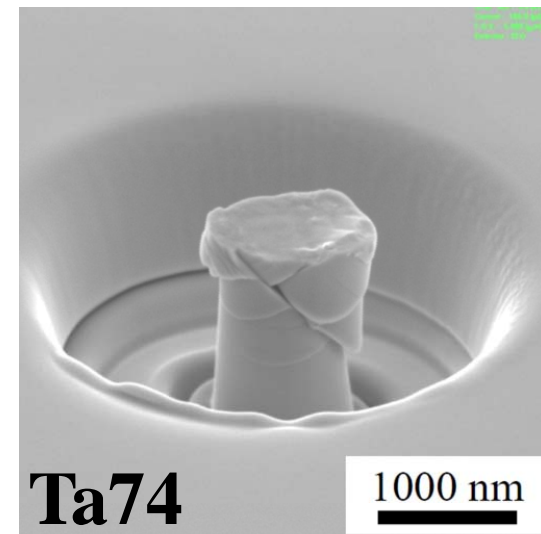
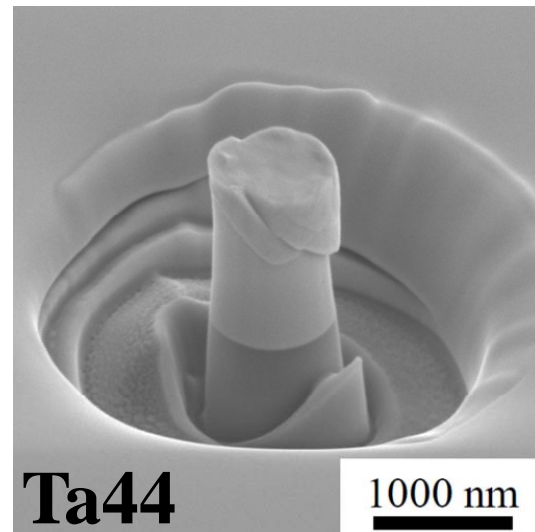
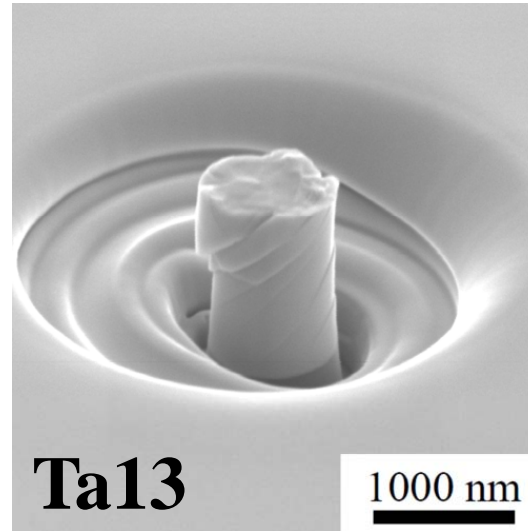
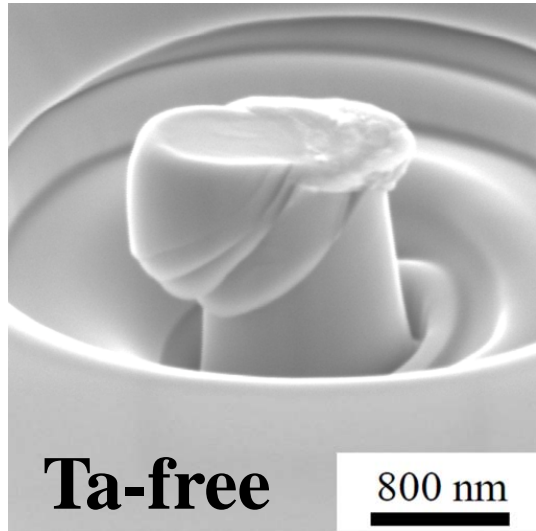
Critical issues for SAXS/SANS measurement

- Sample size
 - SAXS:
 - The measurement area \gg spot size (~ 1 mm in diameter)
 - SANS:
 - A **LARGE** sample (>20 mm in diameter)

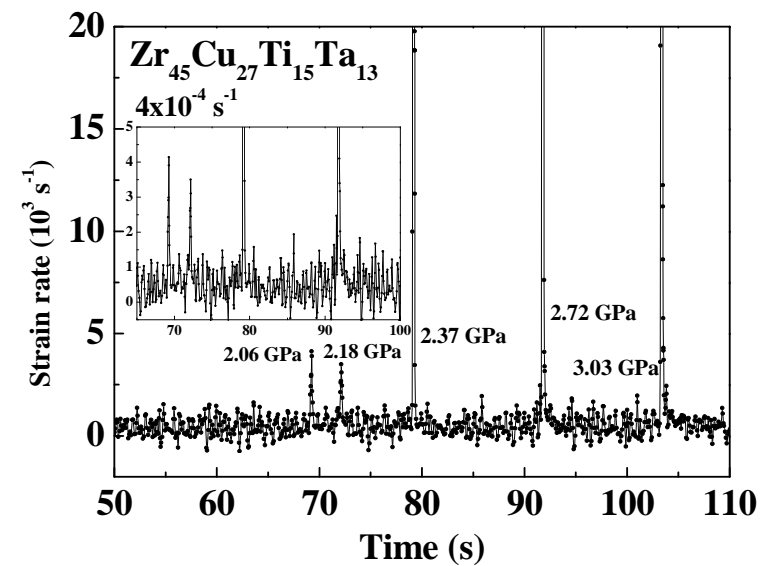
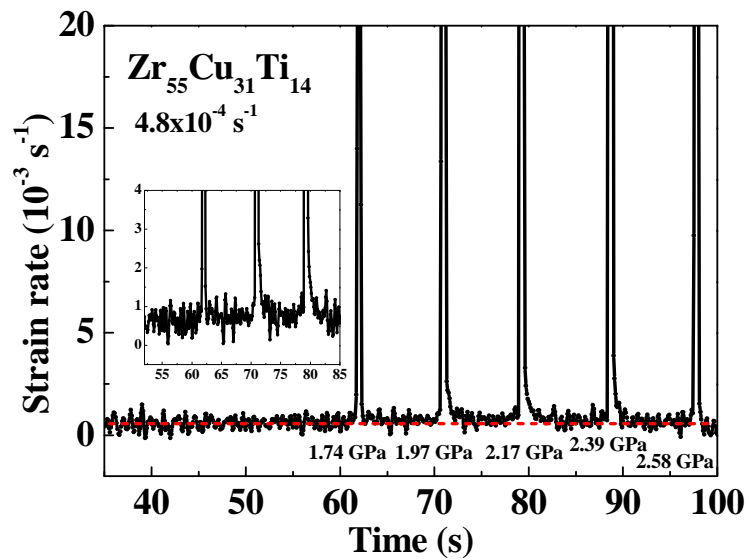
Mechanical properties of ZrCuTiTa micropillars



Deformed ZrCuTiTa micropillars

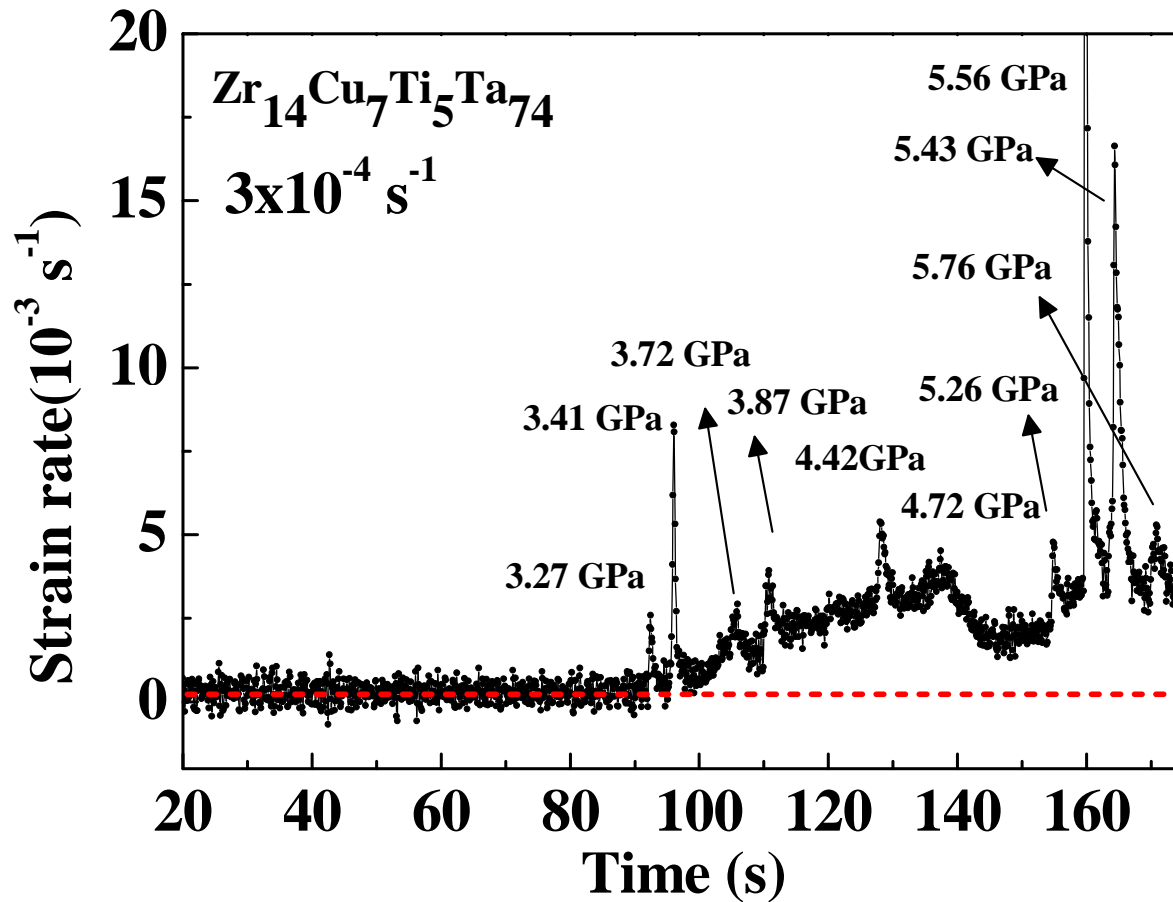


Shear band stability



**Rapid shear band
propagation**

Shear band stability



Slow shear band propagation

Shear band stability

Activation volume

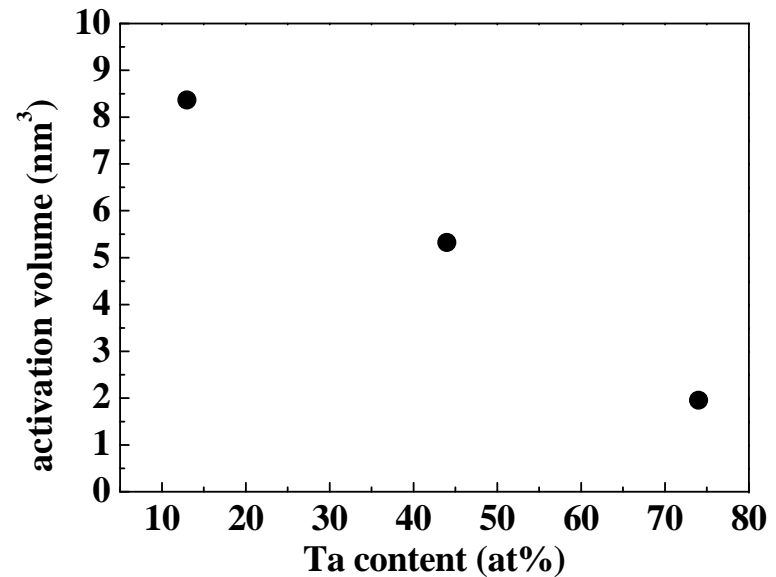
$$\Omega_s = \frac{kT}{C' mH}$$

Free enthalpy of shear band propagation

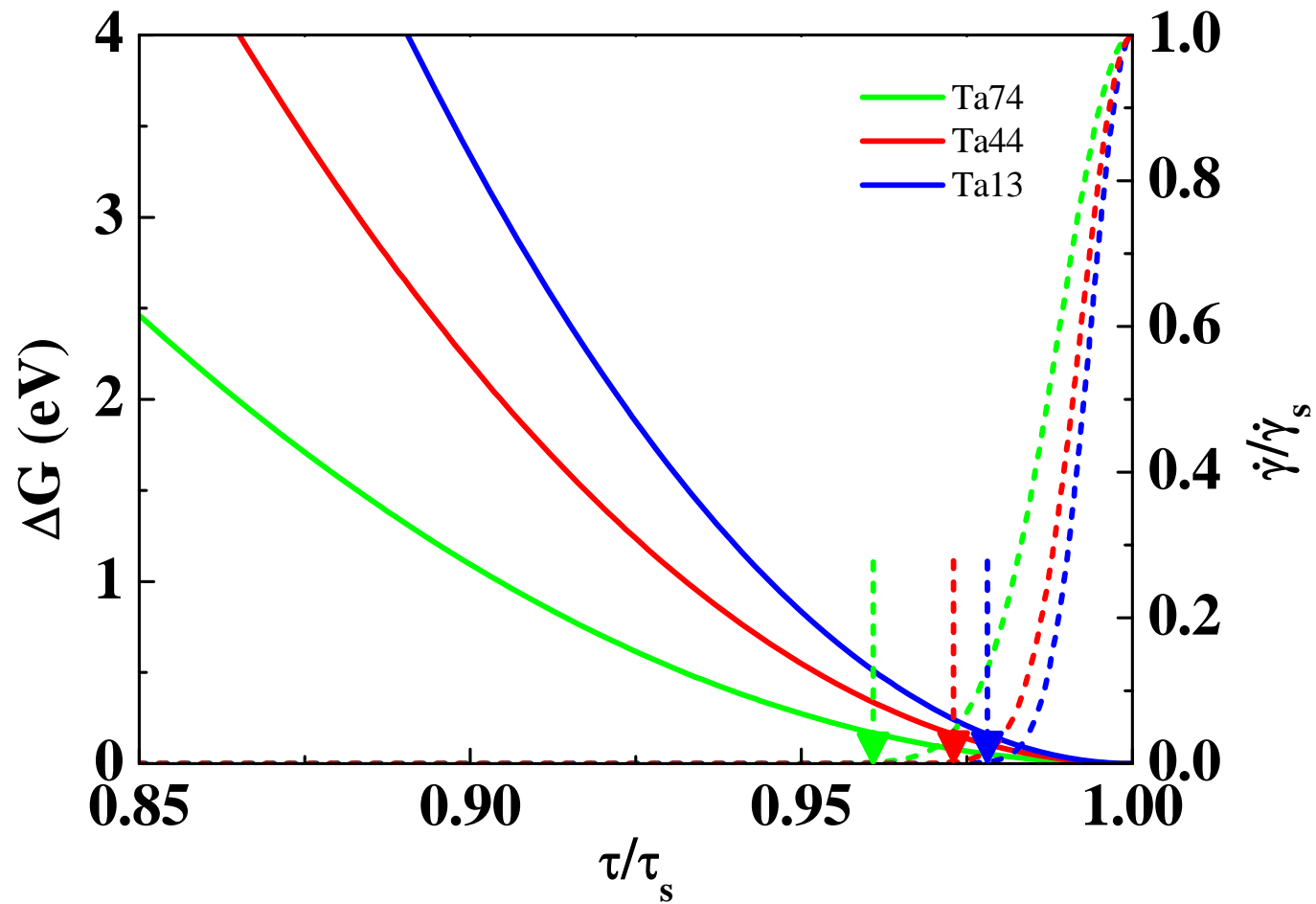
$$\Delta G_s = C_s \Omega_s \tau_s \left(1 - \frac{\tau}{\tau_s}\right)^2$$

Shear strain rate of shear bands

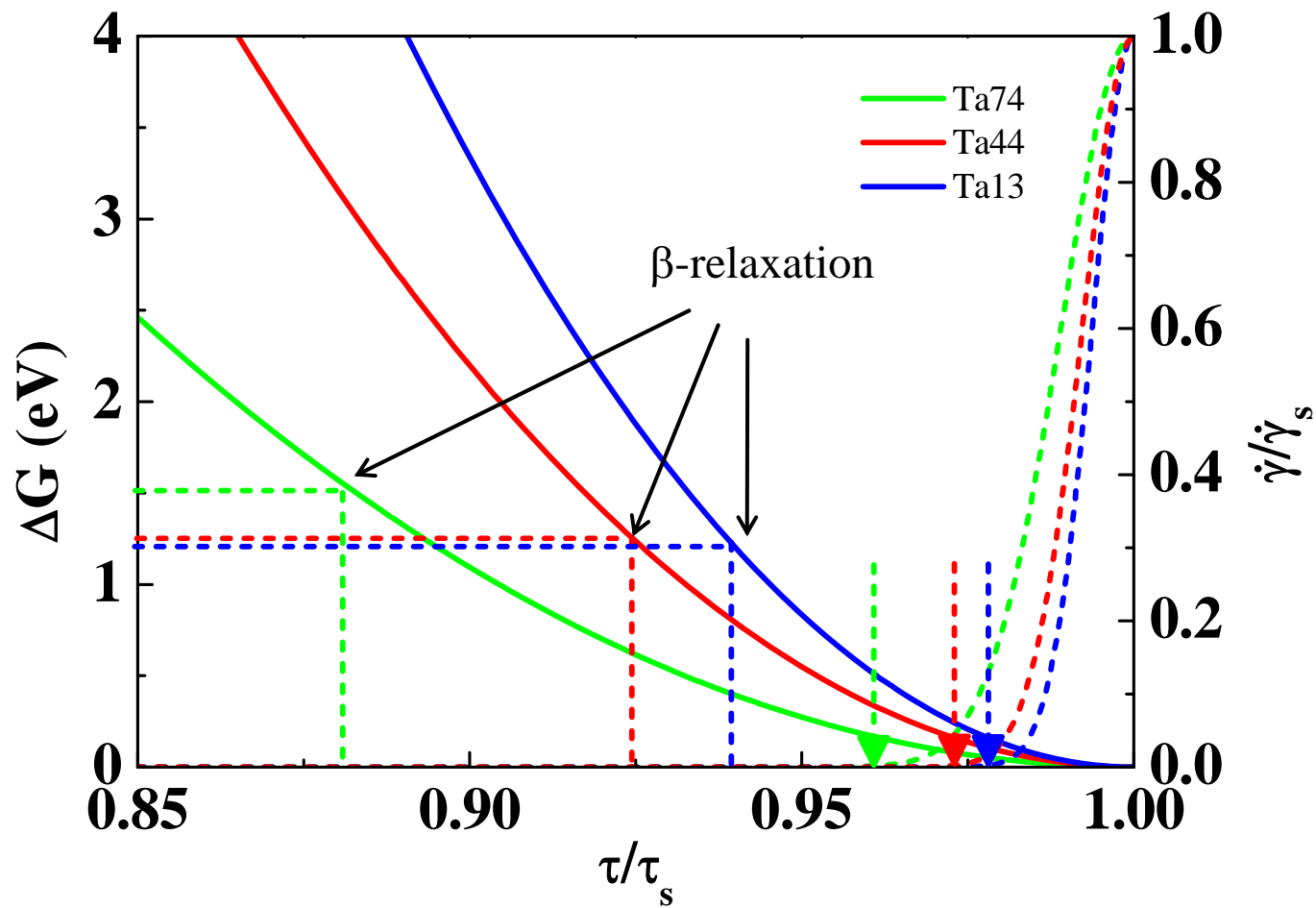
$$\dot{\gamma} = \dot{\gamma}_s \exp\left(\frac{\Delta G_s}{kT}\right)$$



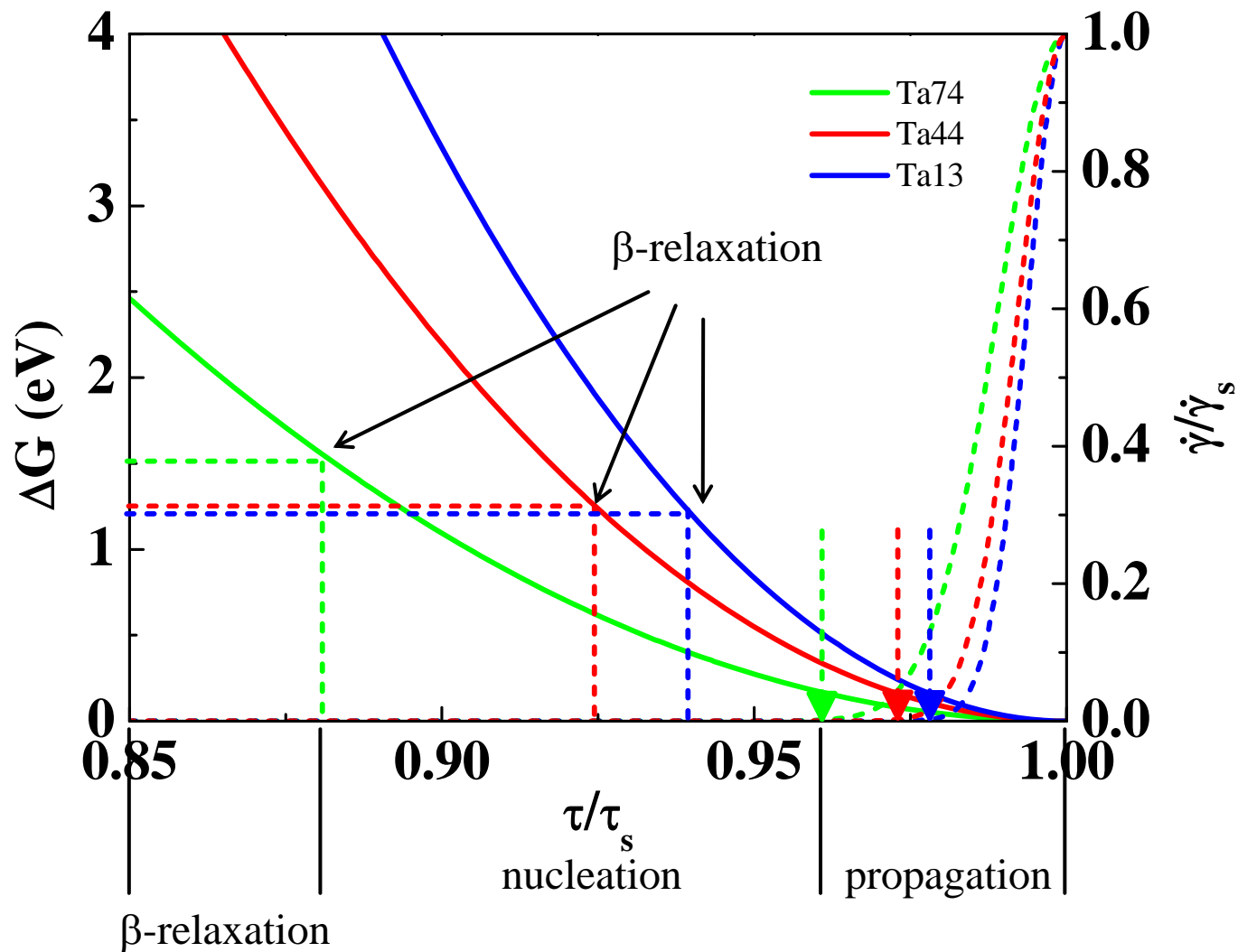
Shear band stability



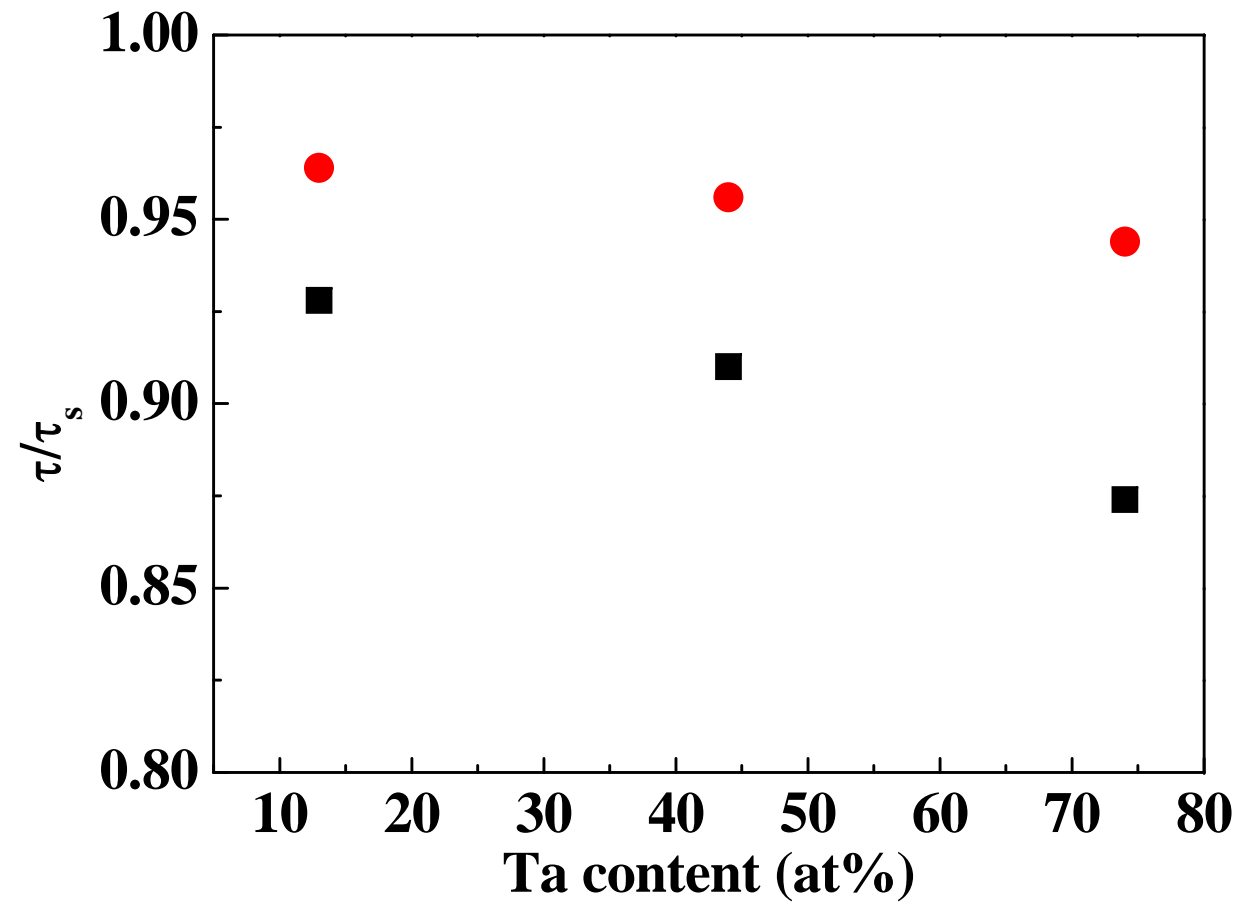
Shear band stability



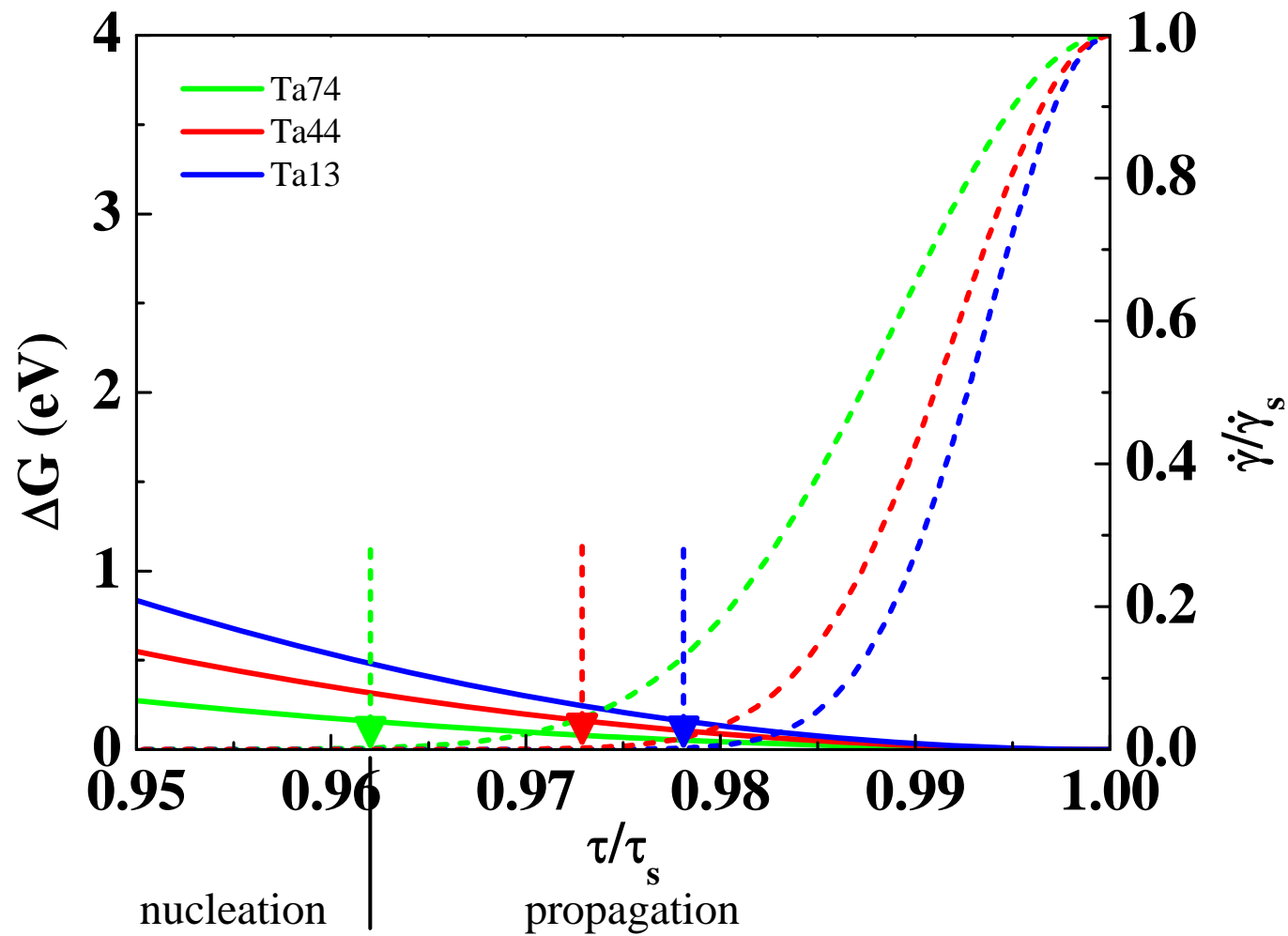
Shear band stability



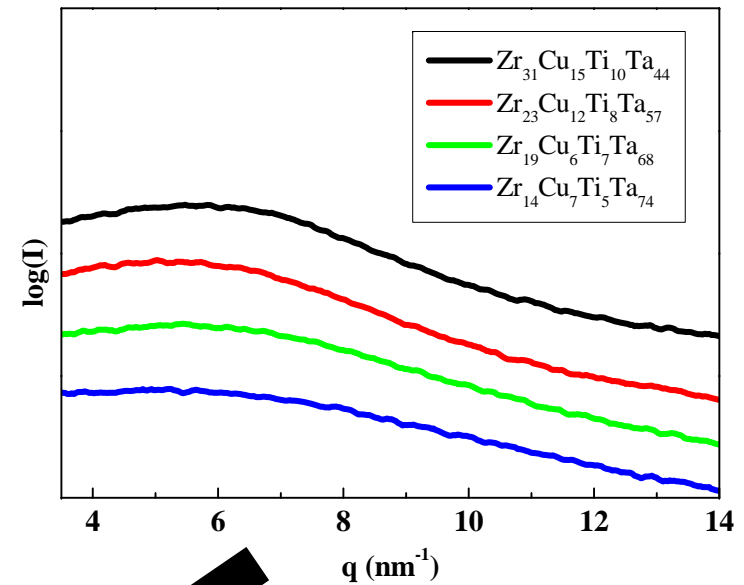
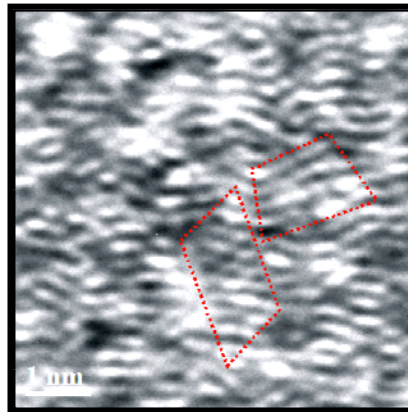
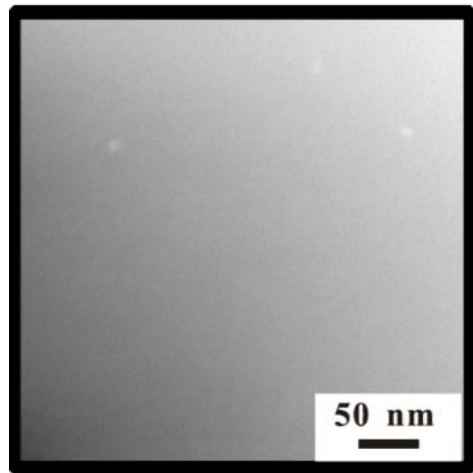
Shear band stability



Shear band stability

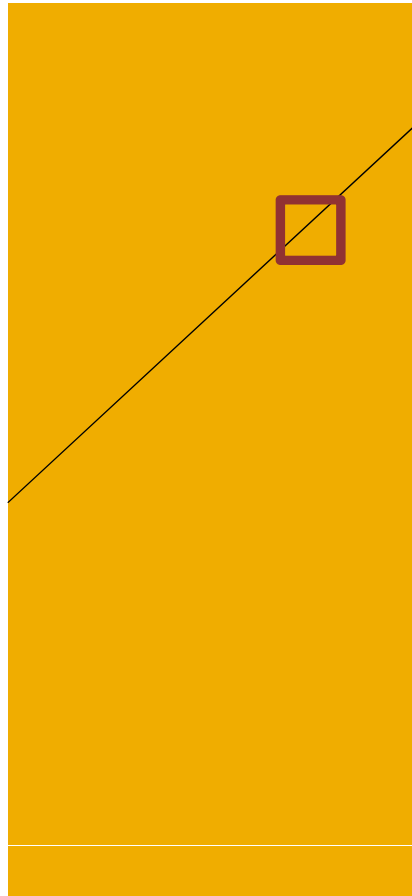


Shear band stability



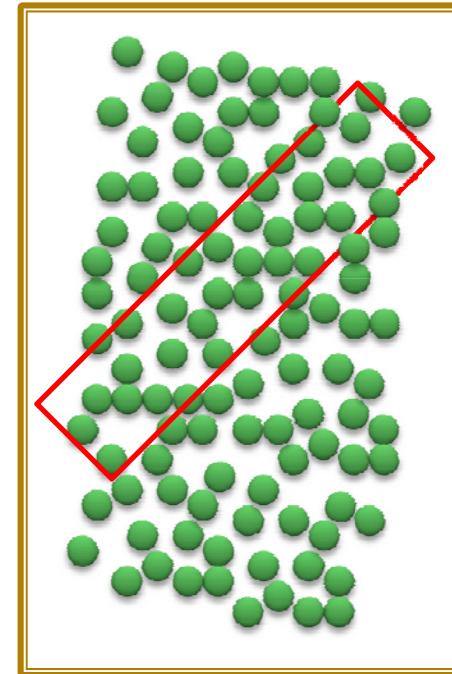
Ta-Ta clusters (**not crystalline particles**) indeed exist in Ta74 TFMGs.

Shear band stability



Thickness of shear band
=10-20 nm
Diameter of Ta-Ta clusters
≈1 nm

Ta-Ta clusters → Tough clusters



Friction of clusters would exhaust the kinetic energy of shear bands.

Thanks for your attention

