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Texture evolution and basic thermal-mechanical properties of pure tungsten under various rolling reductions

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Outline

- Introduction
  - Irradiation damage dependence of grain orientation
- Experimental
- Results
  - Microstructure
  - Basic thermal-mechanical properties
  - Rolling texture
- Summary

Spallation target

Advantages

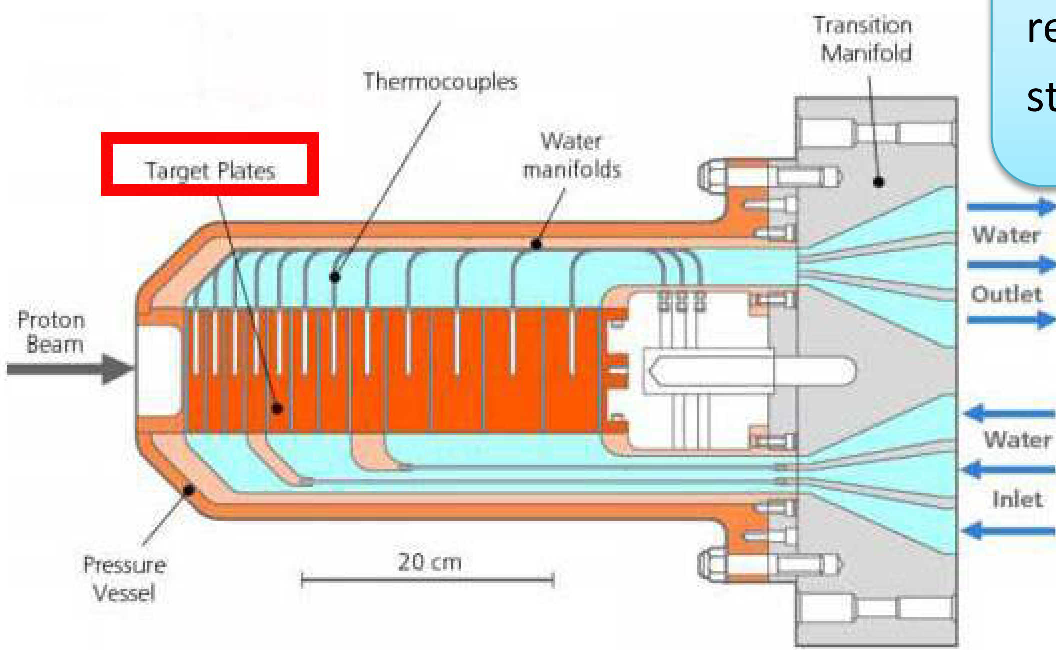
- High neutron yield
- High strength
- High thermal conductivity
- Moderate activation

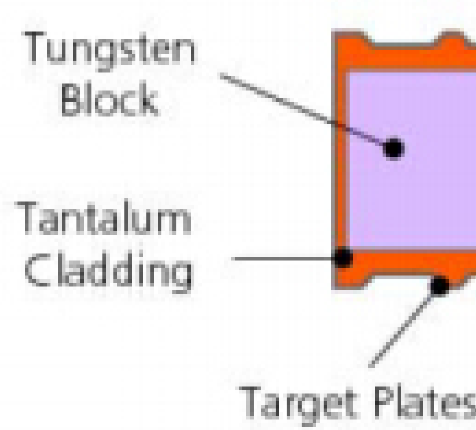
Disadvantages

- high-corrosion rate in water under radiation at high temperature

Cladding tungsten with a corrosion-resistant materials:

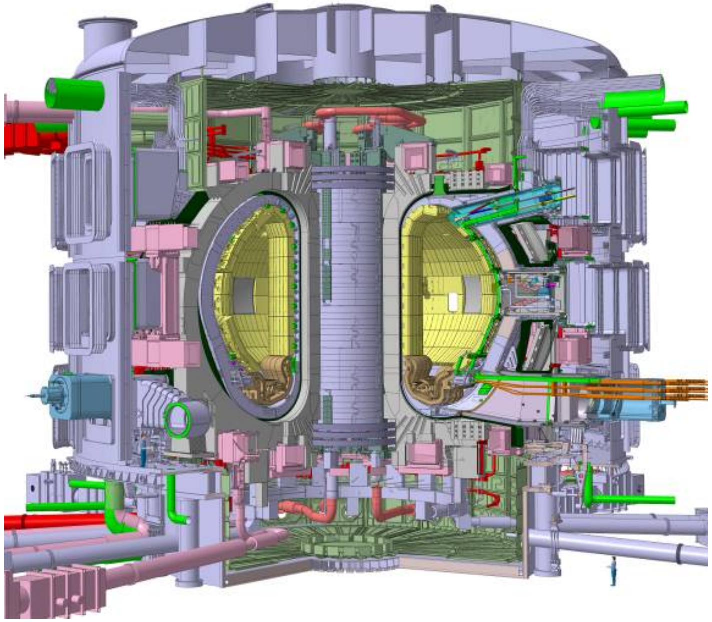
stainless steel, tantalum and so on

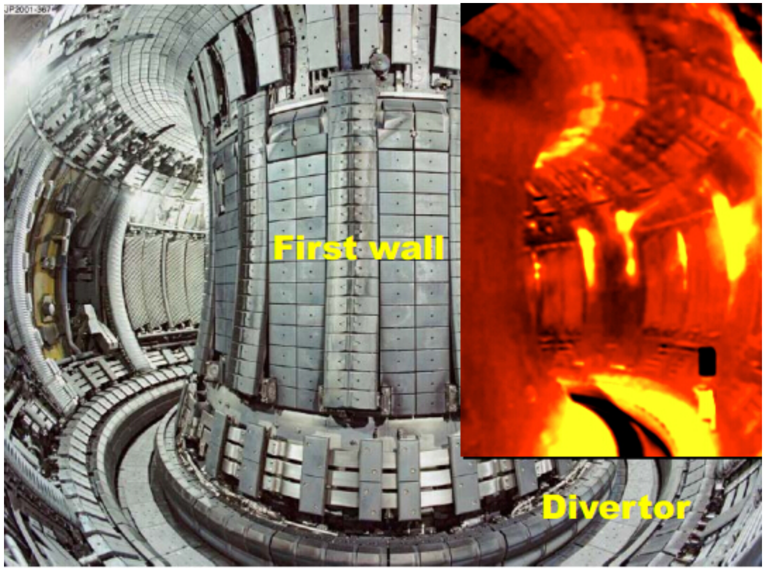




Cristian Bungau et al, Proceedings of IPAC2014, Dresden, Germany

Application in Fusion reactor





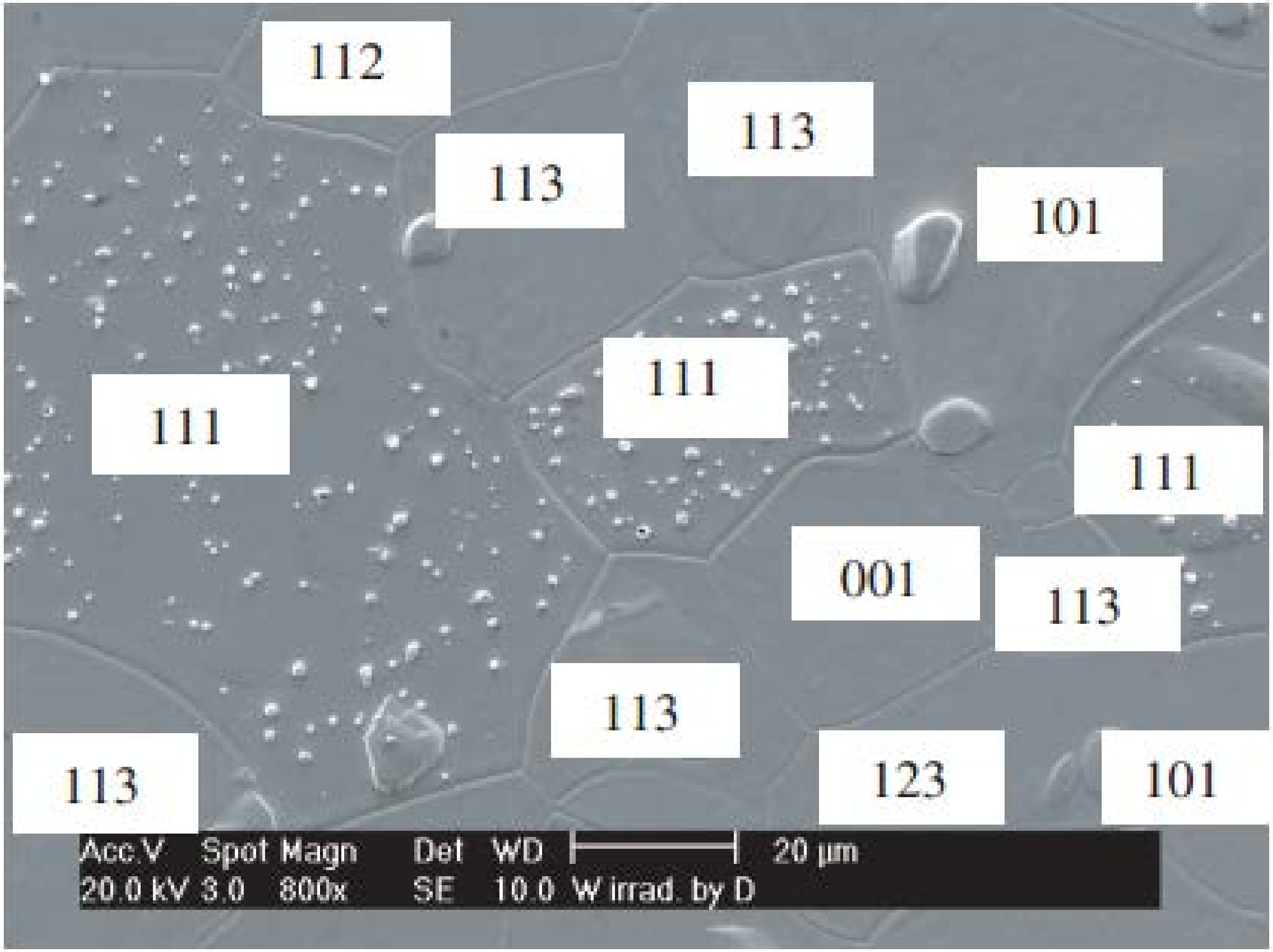
Deuterium, Tritium, Helium, Neutron, Electron bombardment

Irradiation damage dependence of grain orientation

<u>Deuterium, Helium and Heavy ions</u>

Irradiation damage dependence of grain orientation

Deuterium irradiation:

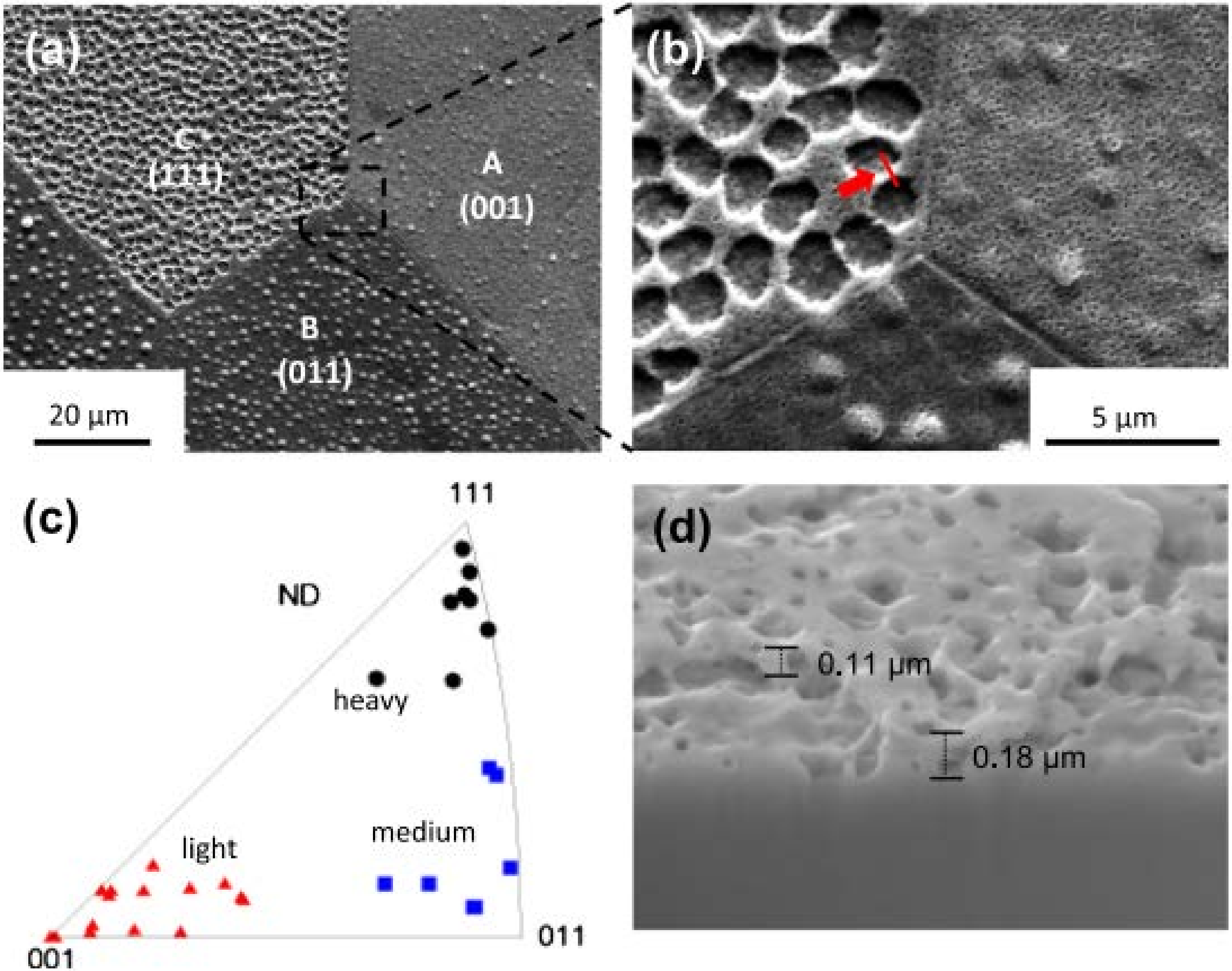


F sample: Full recrystallized pure tungsten

W M Shu et al, T128(2007) 96–99, PHYSICA SCRIPTA

Irradiation damage dependence of grain orientation

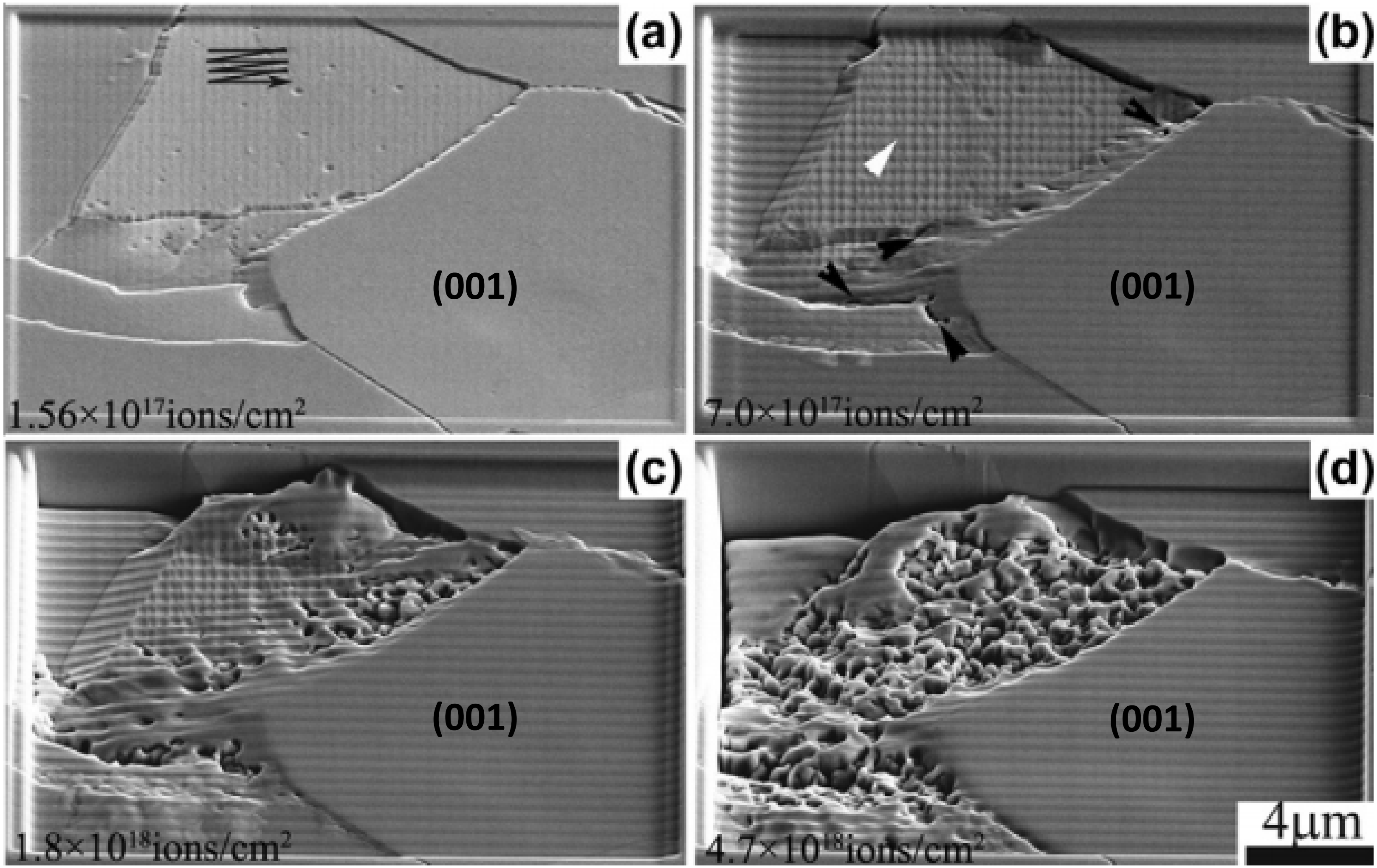
Helium irradiation:



W. Liu et al, 437 (2013) 297–302, Journal of Nuclear Materials

Irradiation damage dependence of grain orientation

Heavy ions:



Guang Ran, Lumin Wang et al, 289 (2012) 39–42
Nuclear Instruments and Methods in Physics Research B

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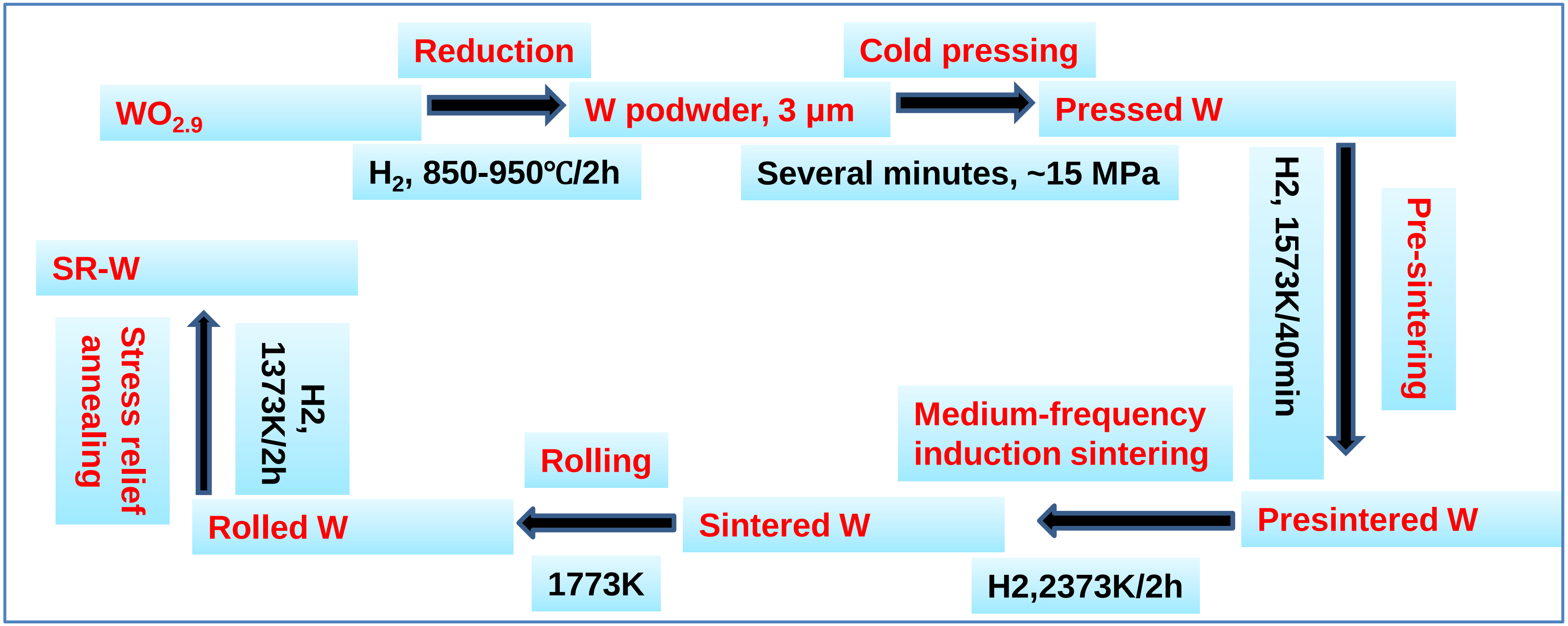
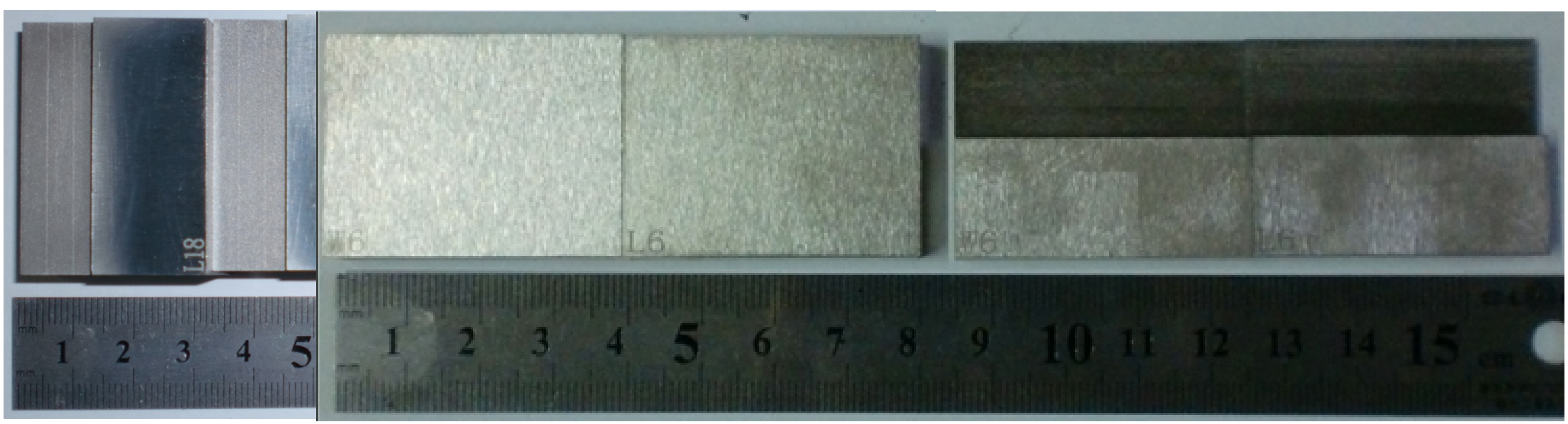
Fabrication process





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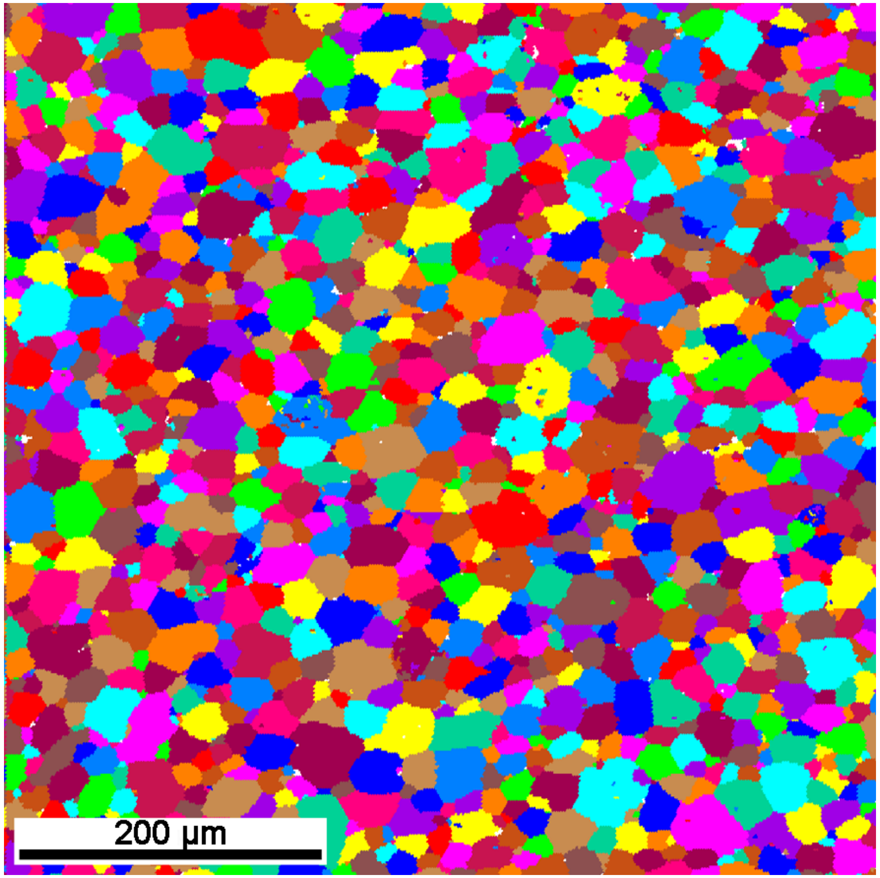
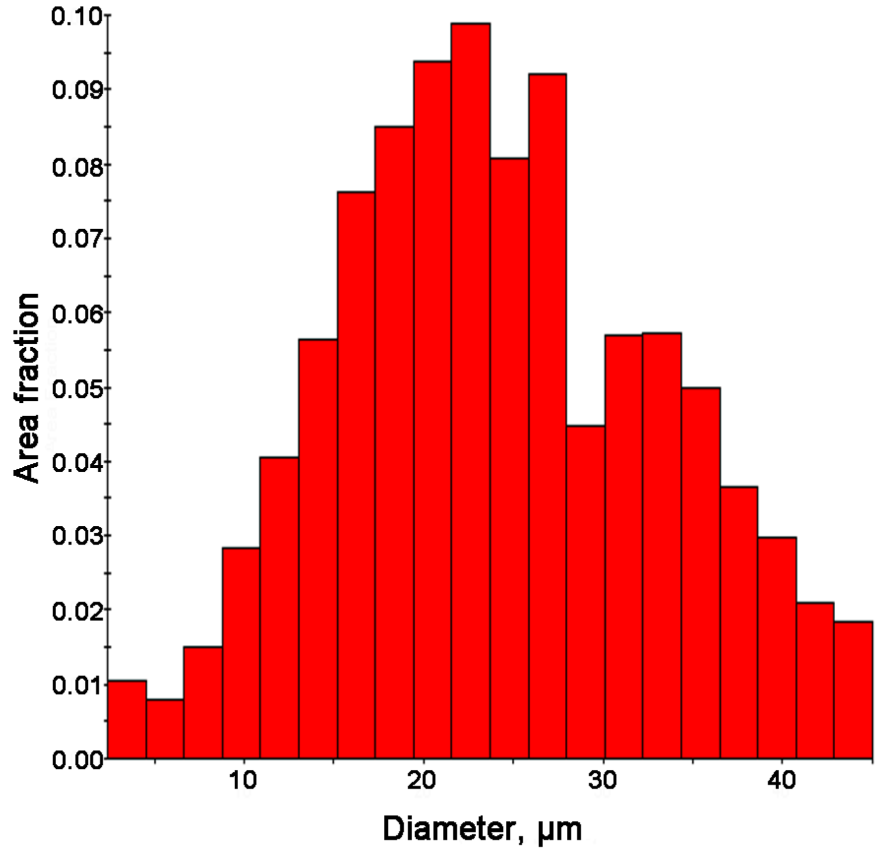
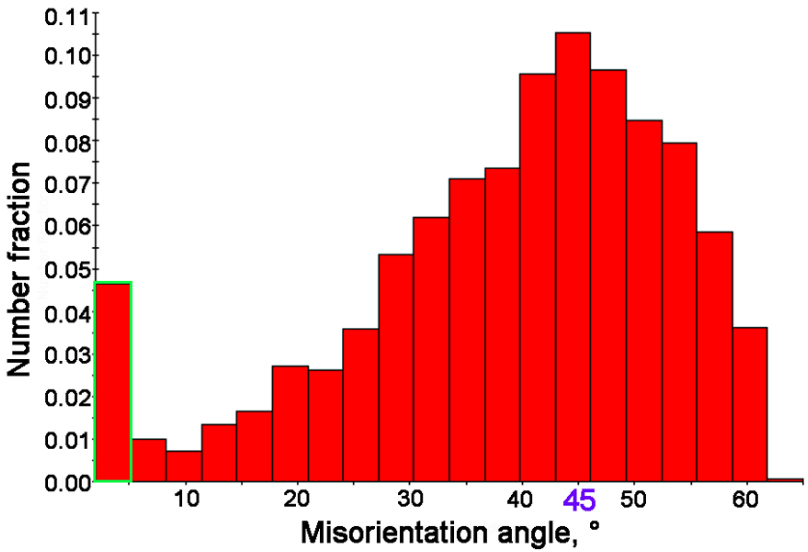
Microstructures





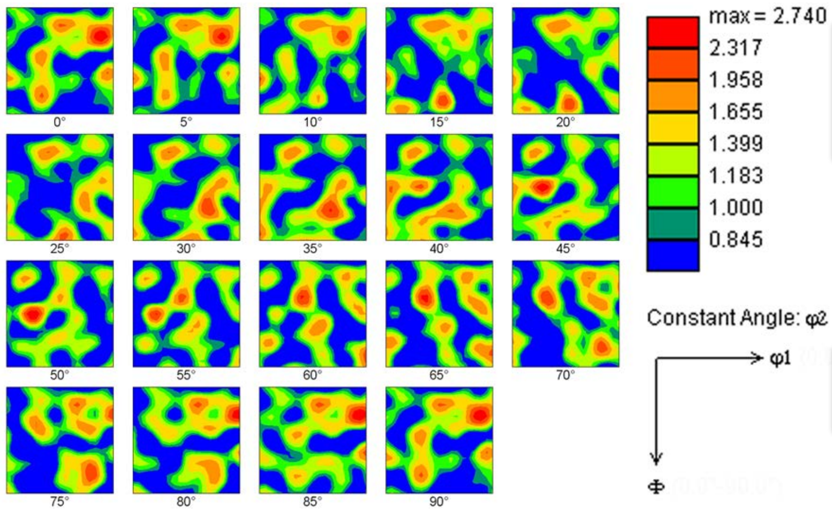
- Homogeneous microstructure with grain size of about 20 µm

Microstructures



- Misorientation angle: maximum and cutoff

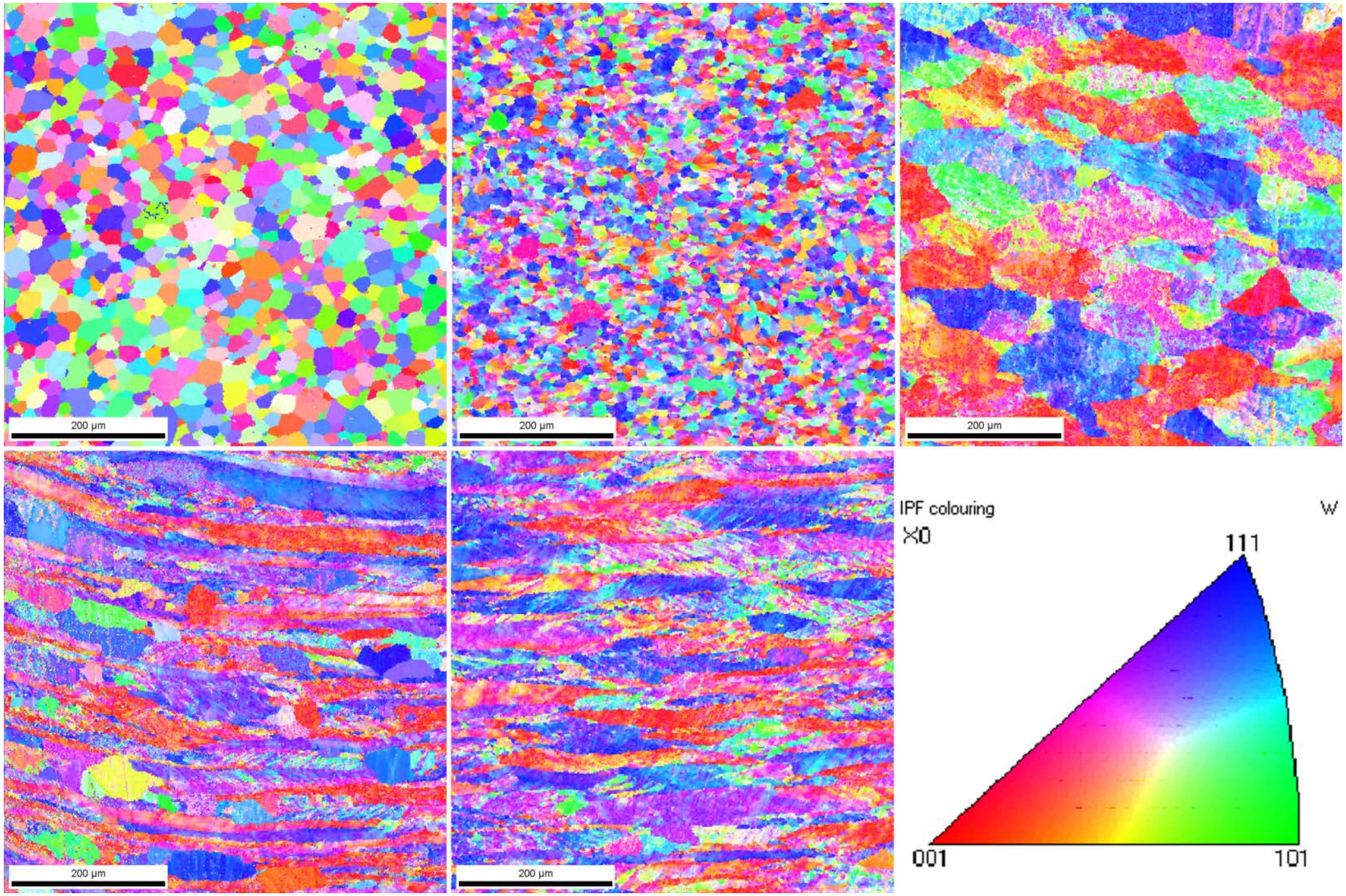
- Low misorientation angle: noise effect



- The maximum pole density: 2.7
- Too small to be neglected

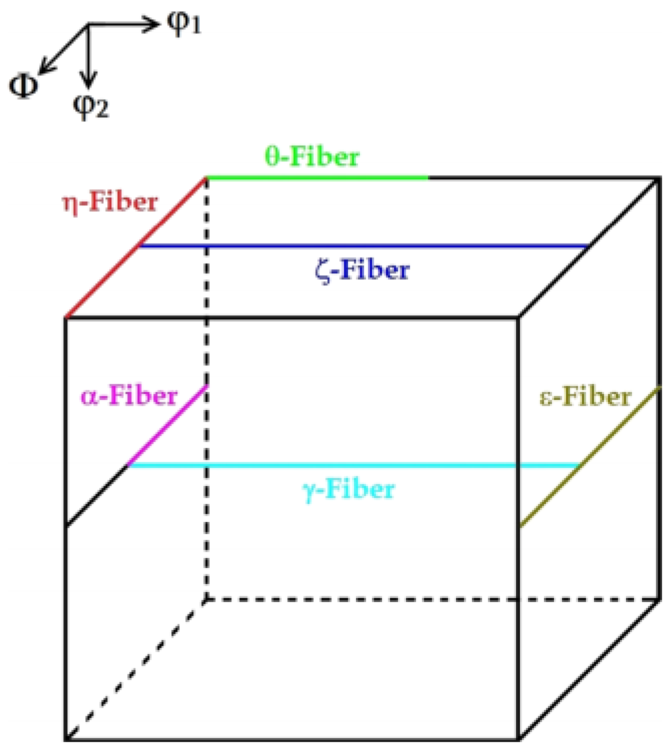
- Sintered tungsten: random orientation

Microstructures



- **Texture transformation occurred during rolling process**
- **80%,90% rolled tungsten: fiber structure**

Microstructures

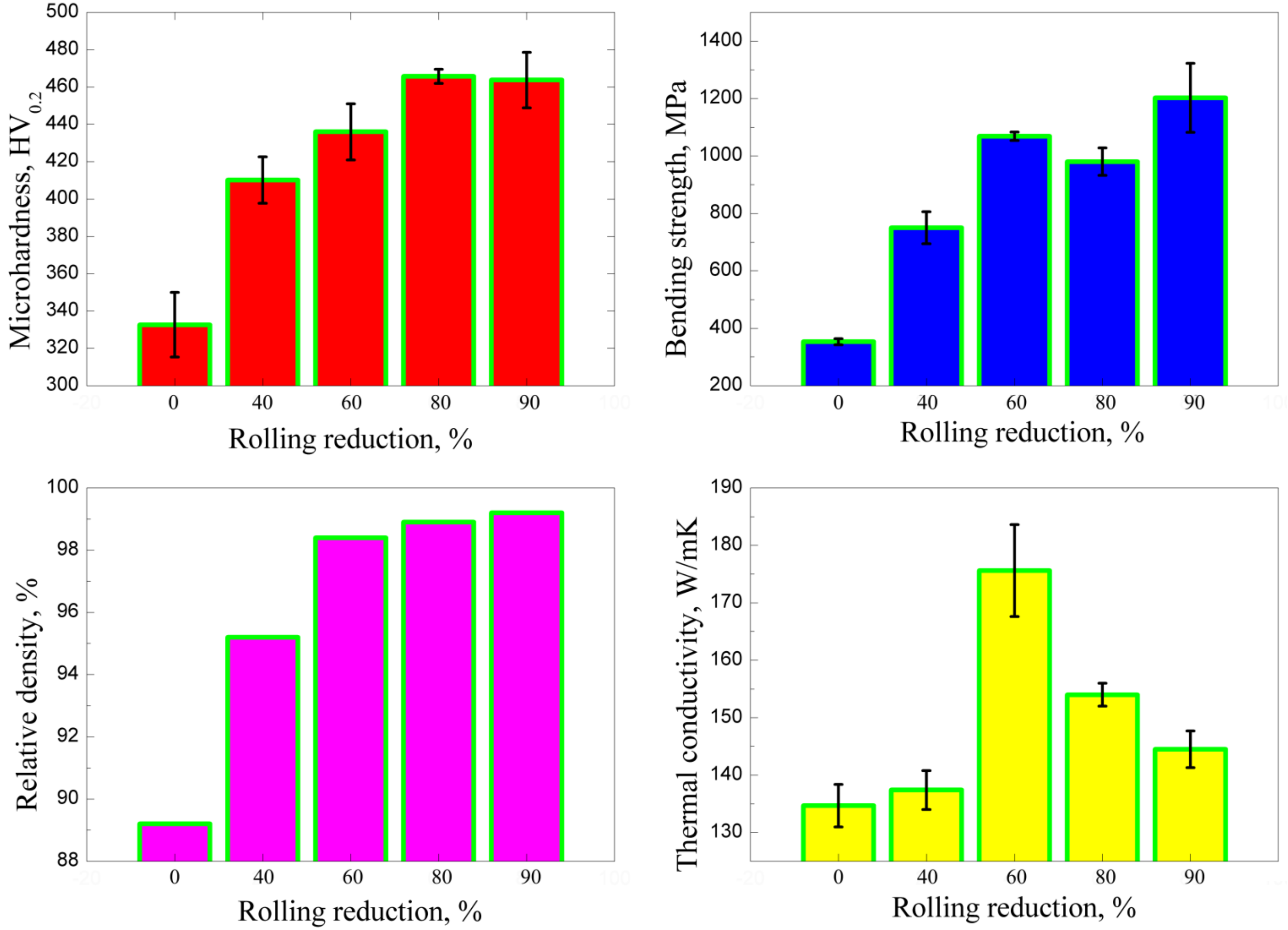


Euler angles and Miller indices for important texture components in the BCC materials.

Texture components	Euler angles			Fiber
	φ_1	Φ	φ_2	
{001}⟨100⟩	0	0	0	η/θ
{001}⟨110⟩	45	0	0	θ
{011}⟨100⟩	0	45	0	η/ζ
{011}⟨011⟩	90	45	0	ζ
{011}⟨211⟩	35	45	0	ζ
{011}⟨111⟩	55	45	0	ζ
{111}⟨112⟩	30	55	45	γ
{111}⟨110⟩	0	55	45	α/γ
{112}⟨110⟩	0	35	45	α

◆ **γ-fiber texture and θ-fiber texture formed on the rolled tungsten**

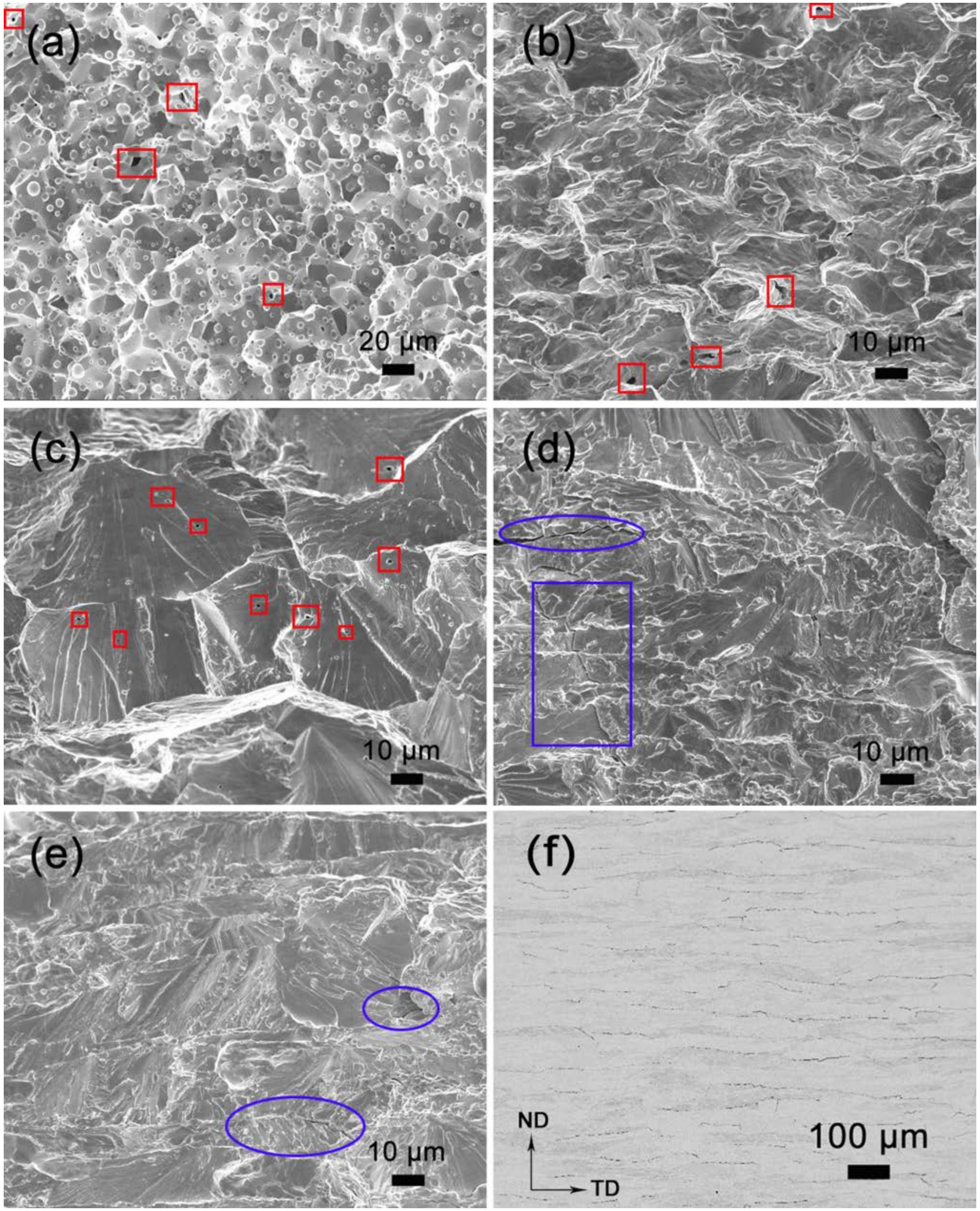
Basic thermal-mechanical properties



- Microhardness, bending strength, and relative density increased with rolling reduction
- 60% rolled tungsten exhibited the highest thermal conductivity

- **Pores and cracks**

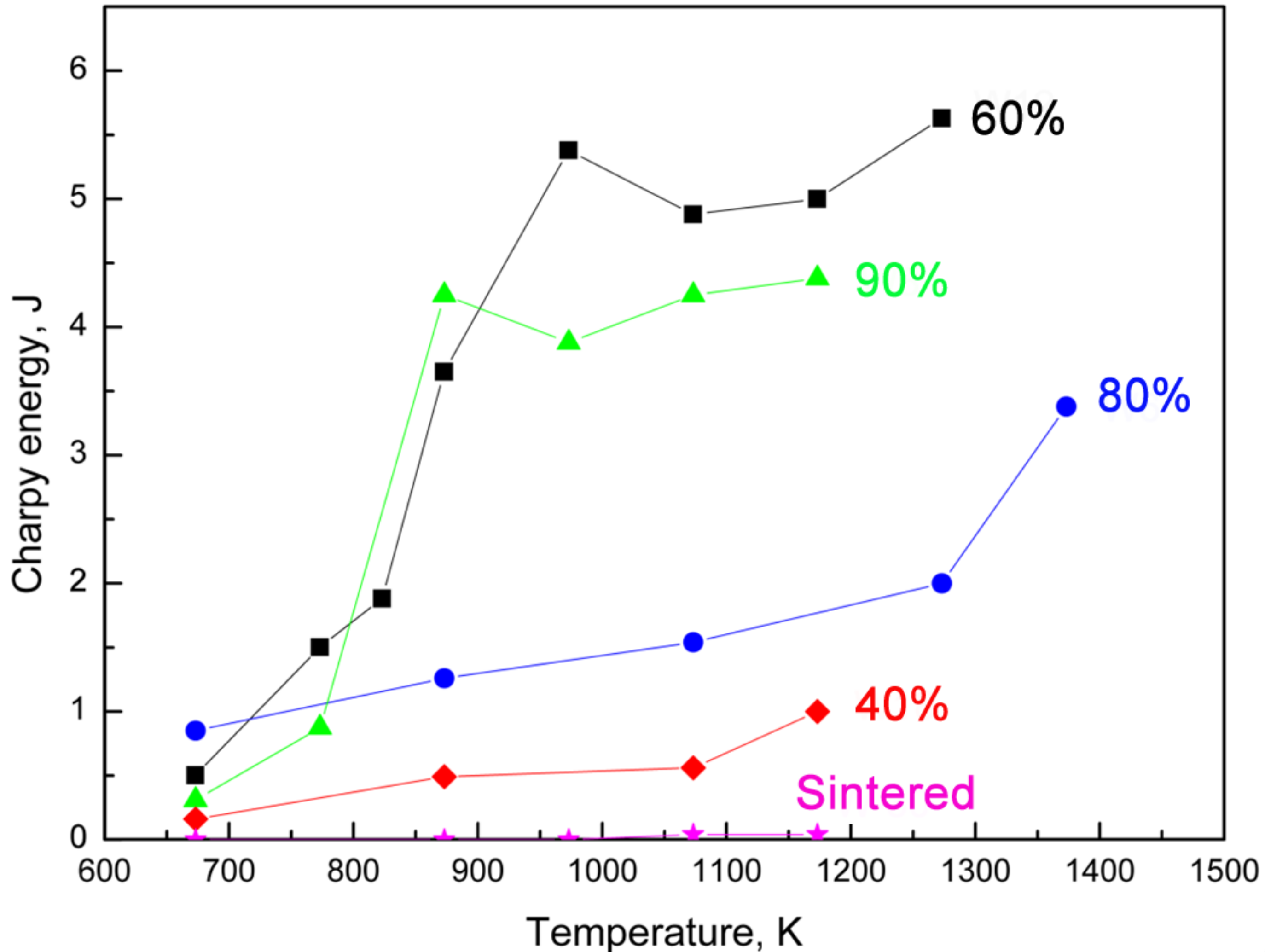
Basic thermal-mechanical properties



- Sintered and 40% rolled tungsten: **large pores**
- 80%, 90% rolled tungsten: **cracks**

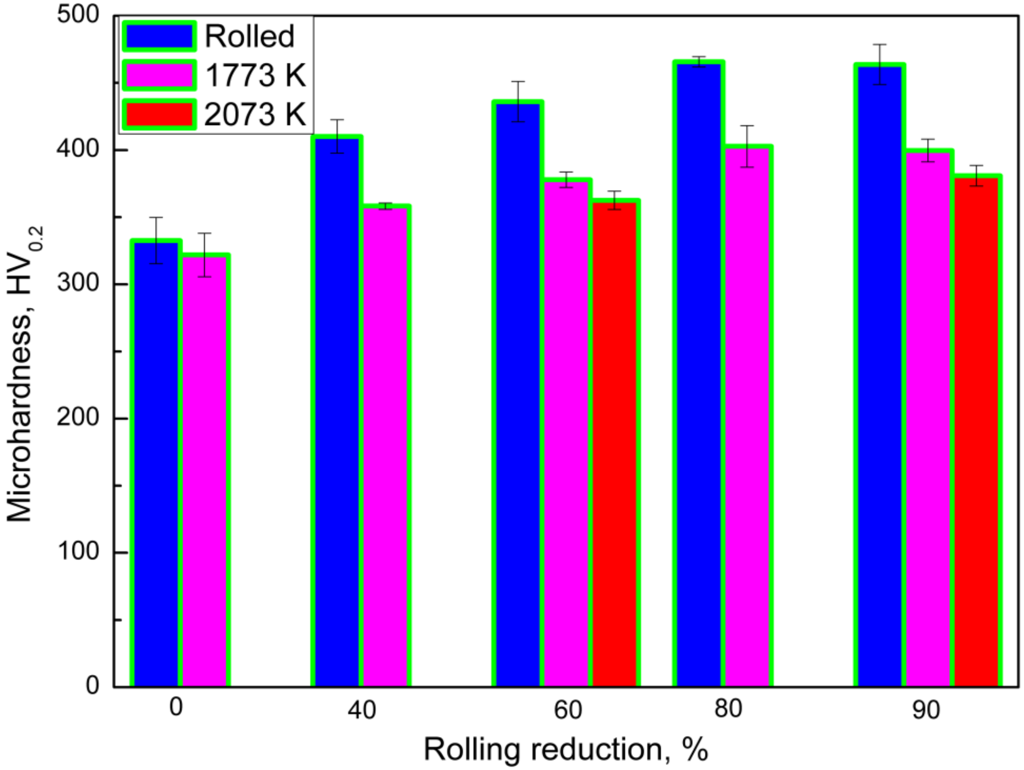
Weaken heat transfer ability

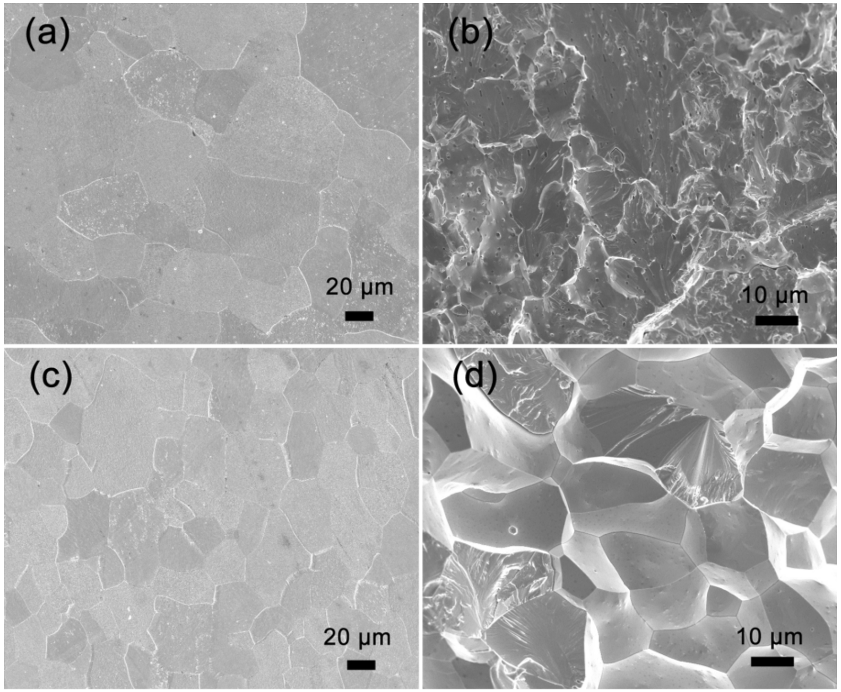
Basic thermal-mechanical properties-Chary performance



- 60% rolled tungsten: best Charpy impact performance
- Few pores and cracks

Basic thermal-mechanical properties-Recrystallization





- **Microhardness decreased:**

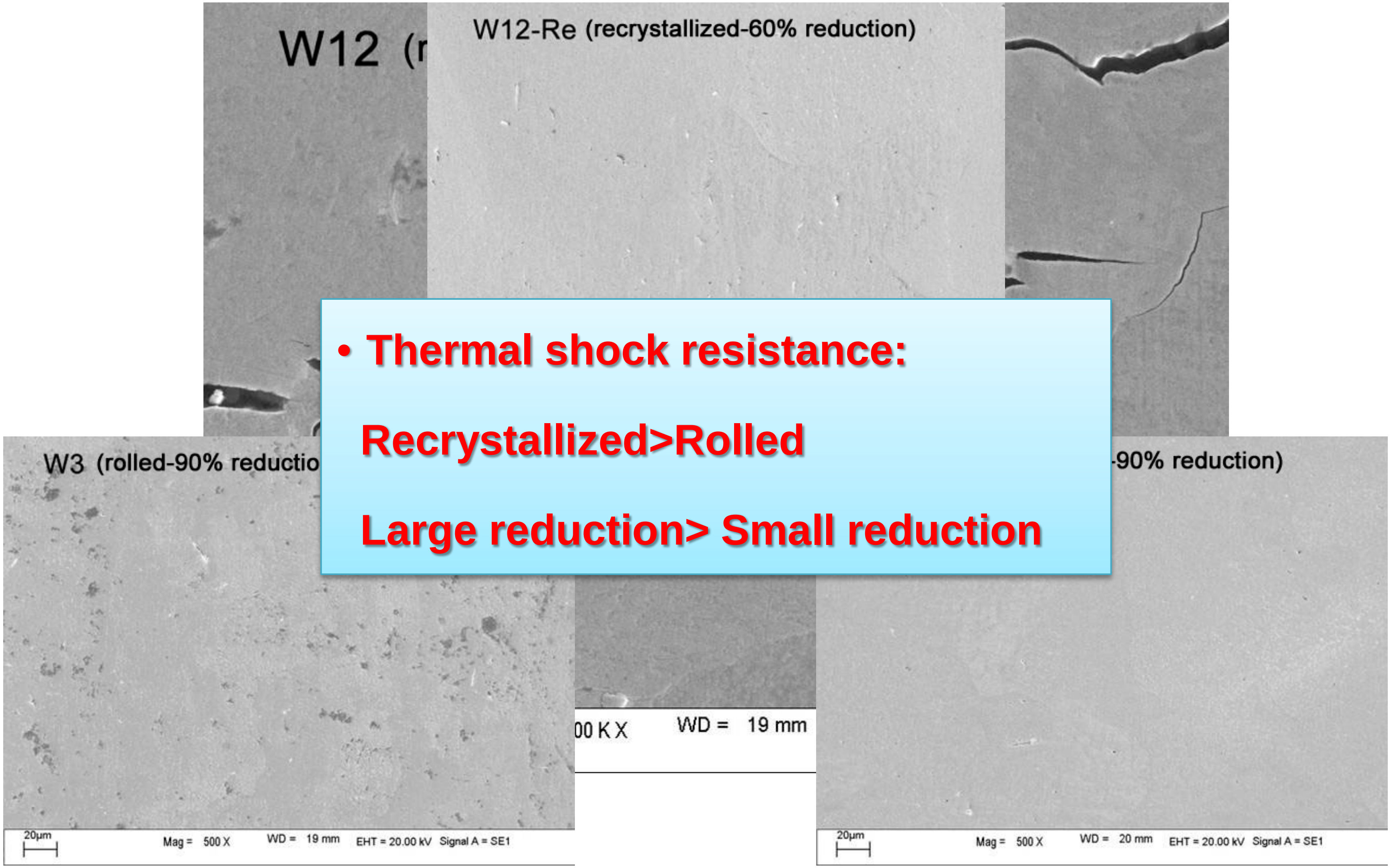
  significantly after annealing at 1773 K for 2 h

  slightly after annealing at 2073 K for 2 h

- **60%, 90% rolled tungsten: coarse grains after 2073 K annealing**
- **Full recrystallization: 2073 K/2 h annealing**

Basic thermal-mechanical properties-Thermal shock

Electron beam: 0.22 GW/m^2. Pulse duration: 5 ms

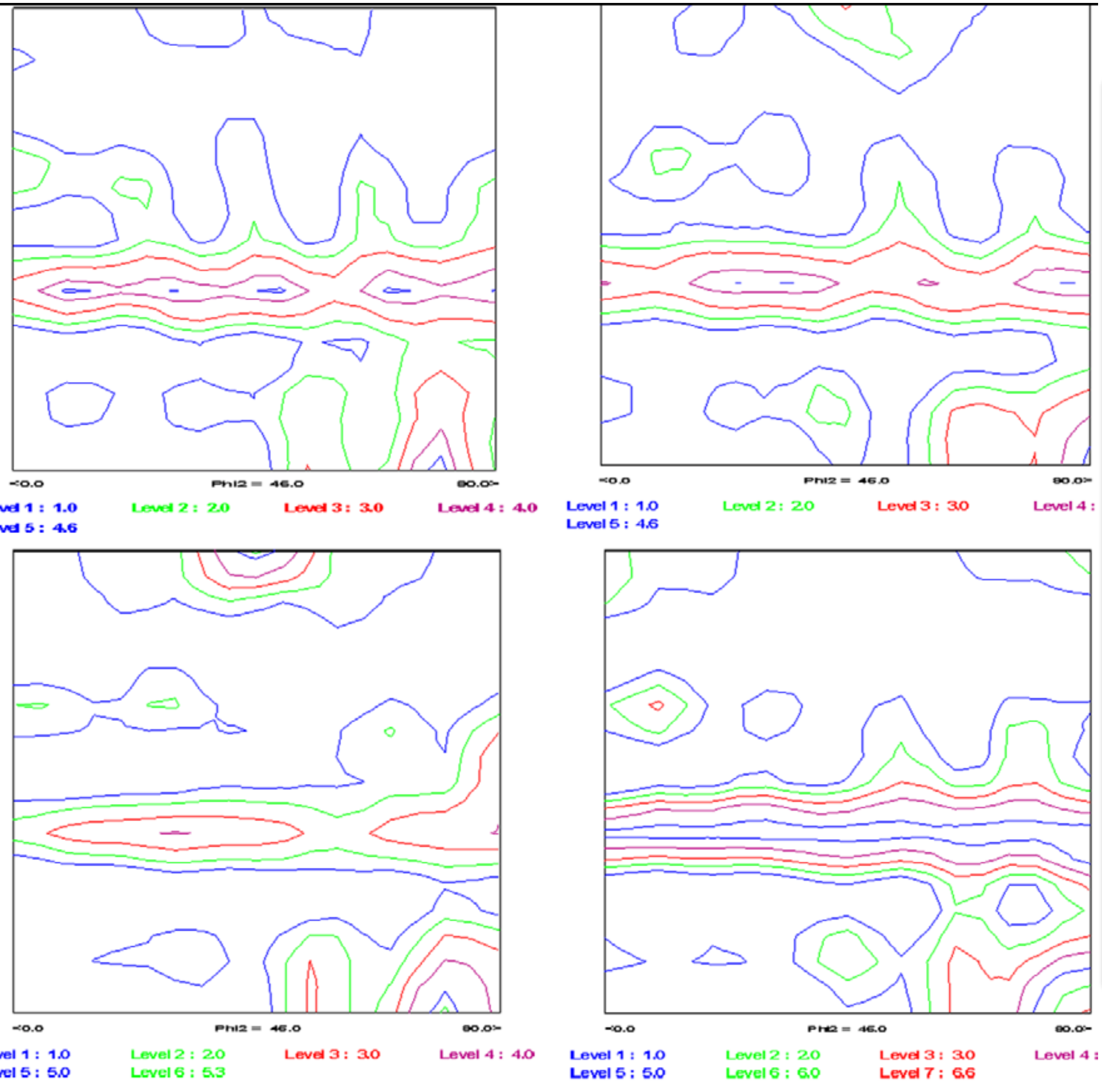


- **Thermal shock resistance:**

  Recrystallized>Rolled

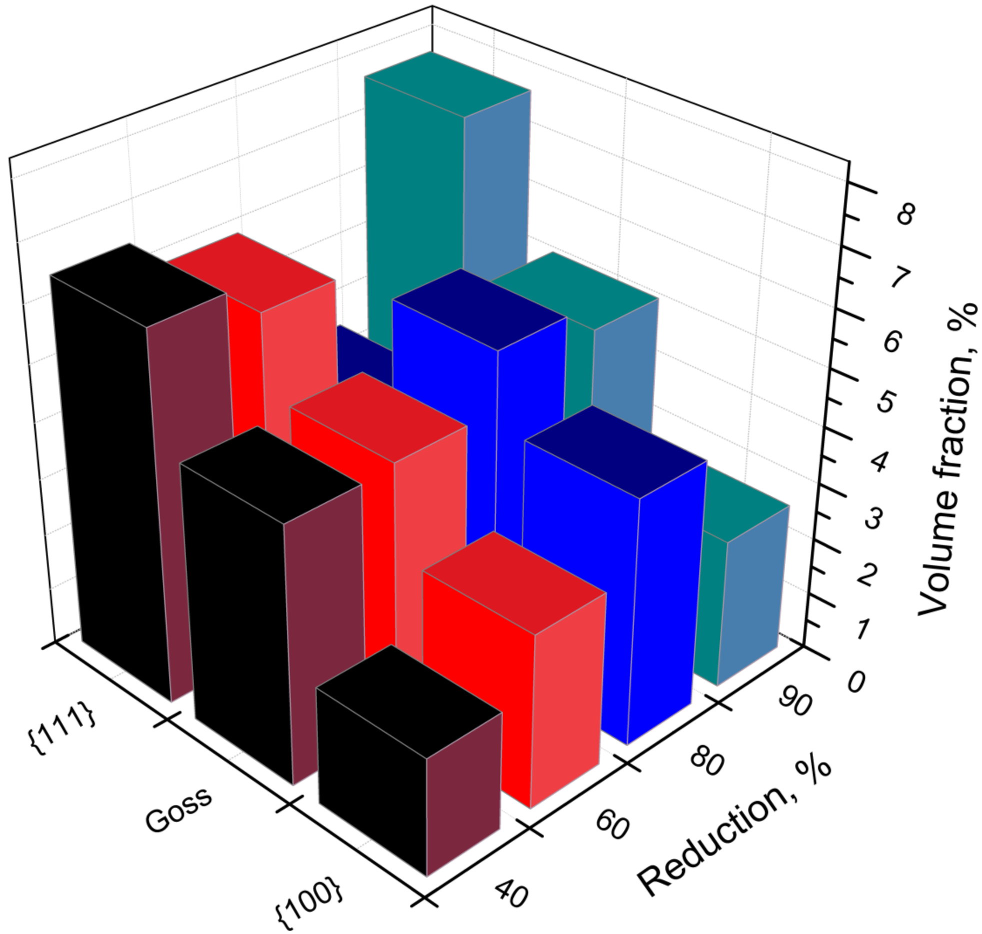
  Large reduction> Small reduction

Rolling texture



- θ fiber, α fiber, γ fiber and Goss texture
- Intensity increased with reduction
- θ fiber texture evolution
- γ fiber texture evolution
- α fiber texture and Goss are stable

Rolling texture



- 40%, 60%, 90% rolled tungsten displayed more γ fiber texture
- 80% rolled tungsten exhibited more Goss texture and θ fiber texture
- 80% rolled tungsten may exhibit the best irradiation resistance

Rolling texture

- Factors: deformation degree, rolling friction, deformation temperature

- For 40%, 60%, 80% rolled tungsten, small deformation degree, high deformation temperature

  dynamic recovery and dynamic recrystallization may restrict the development of γ fiber texture and promote the formation of θ fiber texture

- For 90% rolled tungsten, large deformation degree, low deformation temperature

  “Cold rolling” with large deformation degree may facilitate the formation of γ fiber texture

  Friction may also influence the texture evolution of the 90% rolled tungsten: 3 mm thickness

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- **60% rolled tungsten showed the highest thermal conductivity and the best Charpy impact performance**

- **Recrystallized tungsten or rolled tungsten with larger reduction may exhibit better thermal shock resistance**

- **40%, 60%, 90% rolled tungsten displayed more γ fiber texture while 80% rolled tungsten exhibited more Goss texture and θ fiber texture**

- **80% rolled tungsten may exhibit the best irradiation resistance**

Thanks for your attention!