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 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
Deuterium, Helium and Heavy ions
Irradiation damage dependence of grain orientation

Deuterium irradiation:

F sample: Full recrystallized pure tungsten

Irradiation damage dependence of grain orientation

Helium irradiation:

Irradiation damage dependence of grain orientation

Heavy ions:

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Fabrication process

Reduction
WO$_2$\textsubscript{9} → W powder, 3 μm → Pressed W
H$_2$, 850-950°C/2h → Several minutes, ~15 MPa

Cold pressing

Stress relief annealing
SR-W

Medium-frequency induction sintering
Pre-sintering
H$_2$, 1573K/40min

Pressing

Pre-sintered W

Rolled W
H$_2$, 1373K/2h

Rolling

Sintered W

1773K

Rolled W

H$_2$, 2373K/2h

Sintered W
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• 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
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/m². Pulse duration: 5 ms

- Thermal shock resistance:
  Recrystallized > Rolled
  Large reduction > Small reduction
Rolling texture

- $\theta$ fiber, $\alpha$ fiber, $\gamma$ fiber and Goss texture
- Intensity increased with reduction
- $\theta$ fiber texture evolution
- $\gamma$ fiber texture evolution
- $\alpha$ fiber texture and Goss are stable
• 40%, 60%, 90% rolled tungsten displayed more $\gamma$ fiber texture

• 80% rolled tungsten exhibited more Goss texture and $\theta$ 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 $\gamma$ fiber texture while 80% rolled tungsten exhibited more Goss texture and $\theta$ fiber texture.

- 80% rolled tungsten may exhibit the best irradiation resistance.
Thanks for your attention!