Thermomechanical issues of displacement damaged tungsten PFCs

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Questions

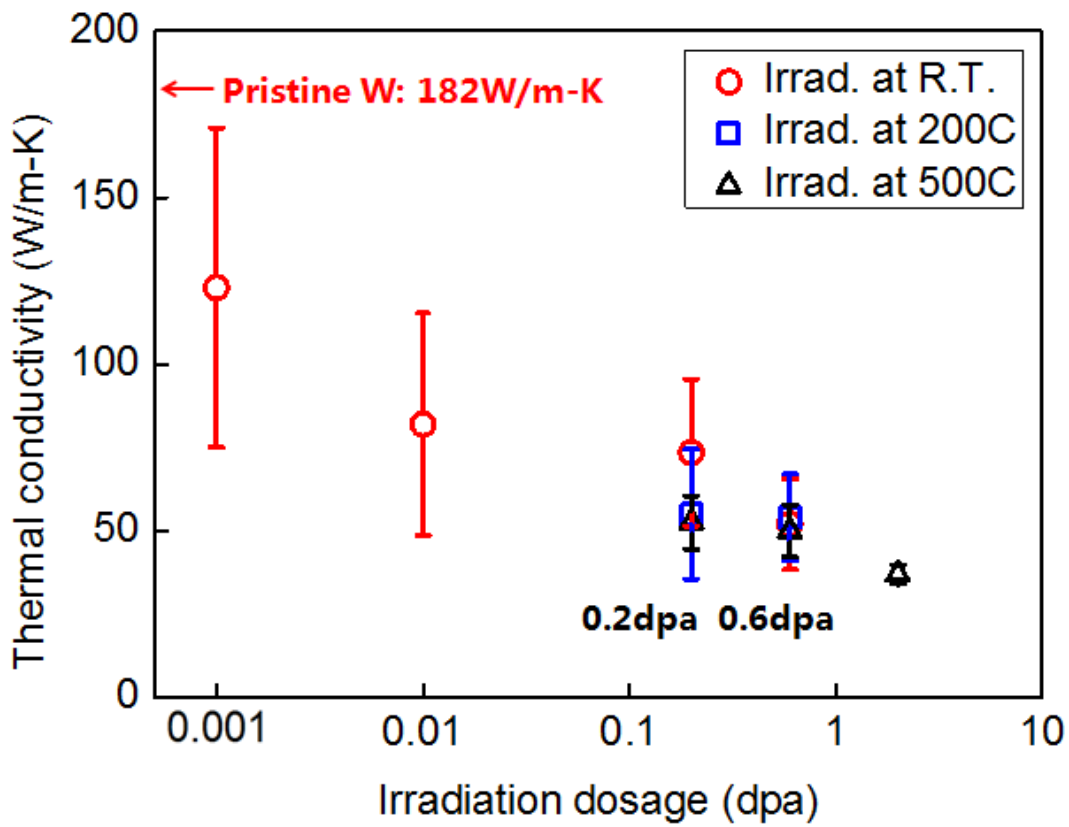
- How does thermal conductivity evolve under displacement damage? With H/D/He implantation?
- How does elastic modulus, hardness evolve?
- Thermal expansion coefficient?

GOAL: develop predictive model of FW/Divertor target response under plasma/irradiation conditions?

Experimental Approach

- Energetic (0.5-5 MeV) He, Cu, W Ion Beams to induce displacement damage; Control damaging temperature from 300-1200K
- 3ω thin-film thermal conductivity of damaged region
- Nanoindentation for Modulus & Hardness of damaged region

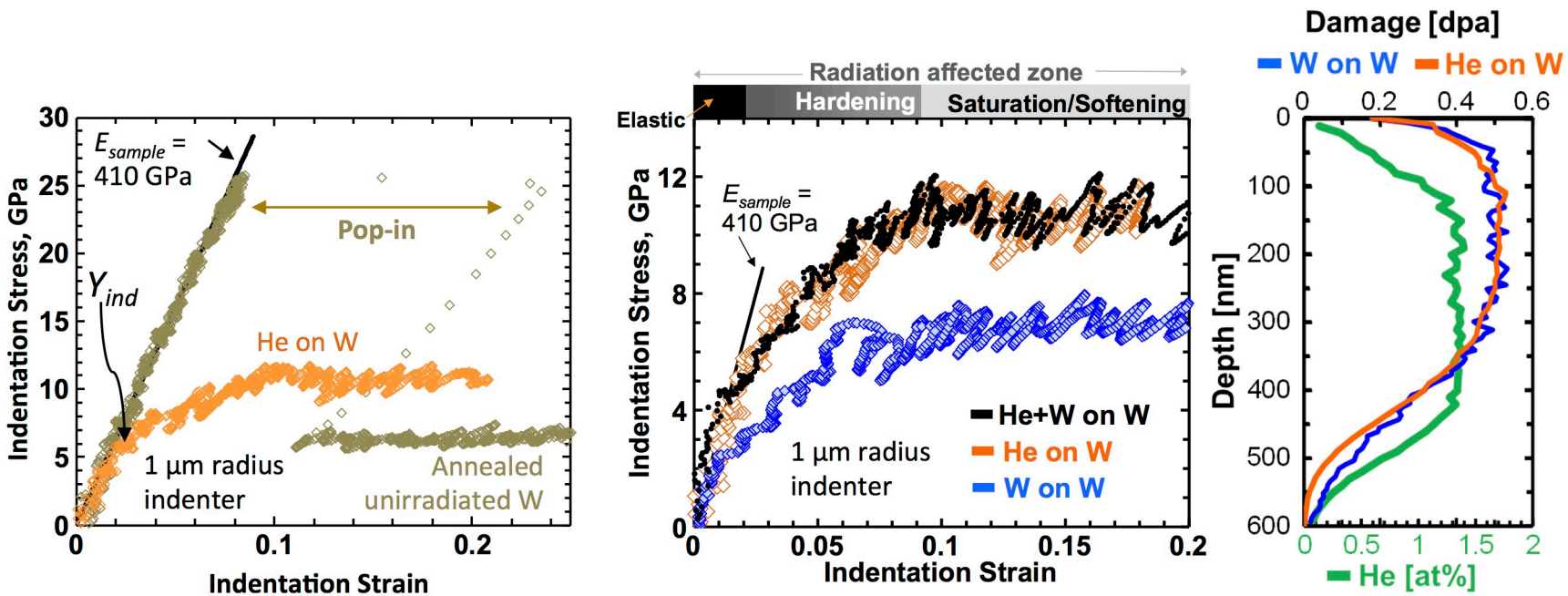
Reduced thermal conductivity seen across range of damaging temperatures



- Similar results seen in He-ion beam expts (Hofmann'15)
- Less pronounced reduction reported in neutron experiments (Peacock JNM'04)

S. Cui, R. Chen et al, in prep.

Modulus unchanged; few-x increase in hardness with 0.5 dpa He damage



Open Research Questions

NEAR TERM

- Why the difference in thermal conductivity ion-beam v. neutron damage?
  - Surface effect? Try deep (~10 micron) (H, D, He) beam studies
  - Repeat w/ neutron damaged materials
  - Is this important for HHFC design?
- How to relate these macro-changes to microstructural damage physics?
  - Need direct micro & macro measurements (of what?)
  - First principles modeling of damage & electron/phonon scattering

LONGER TERM

- Can thermomechanical changes be annealed out ?
- Mat'l mixing/transmutation effects?
- Thermal expansion coeff of damaged mat'l?
- Will grad-T_{surf} result in excessive mechanical stresses that result in failure?