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Will Windes
ART Graphite Technical Lead
Idaho National Laboratory

Introduction to NEUP Graphite Research (FY21)

RC X-Y. Effects of Irradiation Induced Microstructure Change in Graphite

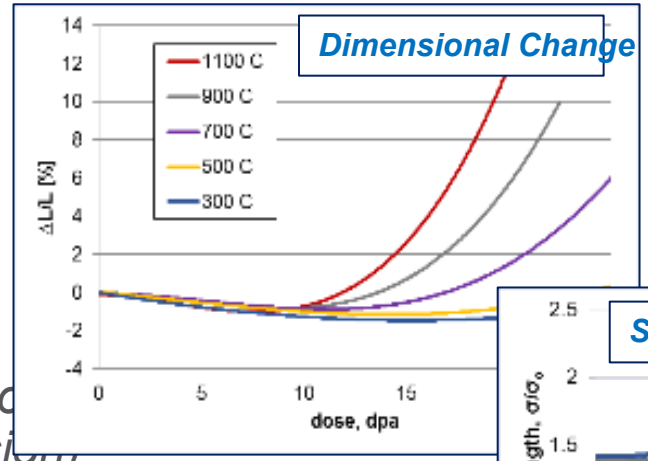
DOE ART Gas-Cooled Reactor (GCR) Reviw Meeting
Virtual Meeting
July 25 – 27, 2023

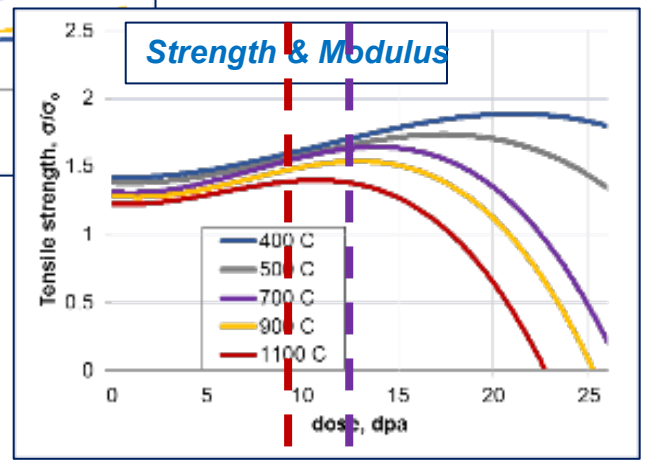
ART
Advanced Reactor Technologies

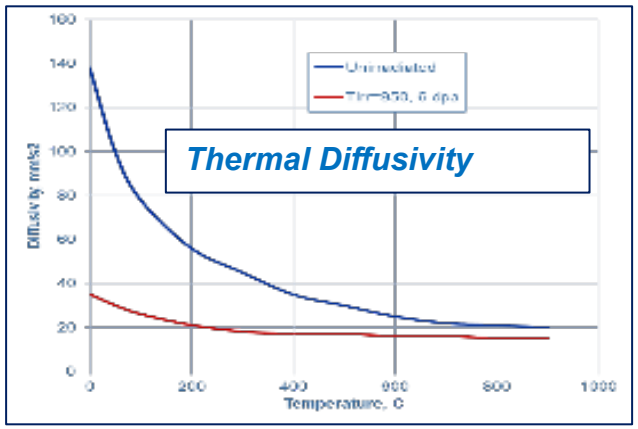
Irradiation Behavior

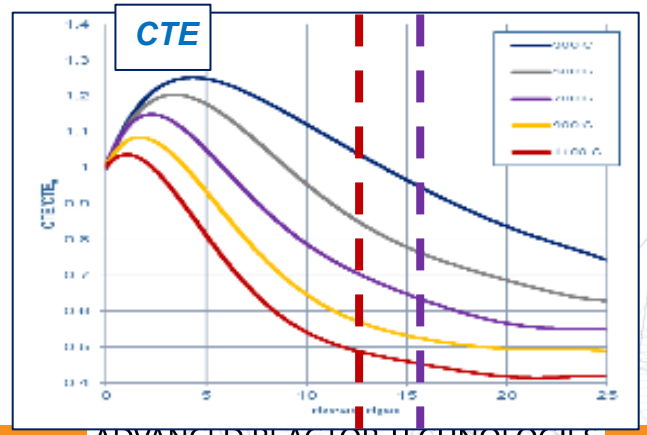
Significant changes occur during normal operation:

- Density - Densification
  - *Graphite gets denser with irradiation until Turnaround do*
  - *After Turnaround density decreases (volumetric expansion)*
  - *Formation of microcracks (molten salt consideration)*
- Dimensional change
  - *Turnaround dose is key parameter*
  - *Highly temperature dependent*
- Strength and modulus
  - *Graphite gets stronger with irradiation …*
  - *Until Turnaround. It then decreases*
- Coefficient of thermal expansion
  - *Initial increase but then reduces before Turnaround*
  - *CTE is why properties are so temperature dependent*
- Thermal conductivity
  - *Decreases almost immediately to ~30% of unirradiated values*
  - *At temperatures it is same as unirradiated conductivity*





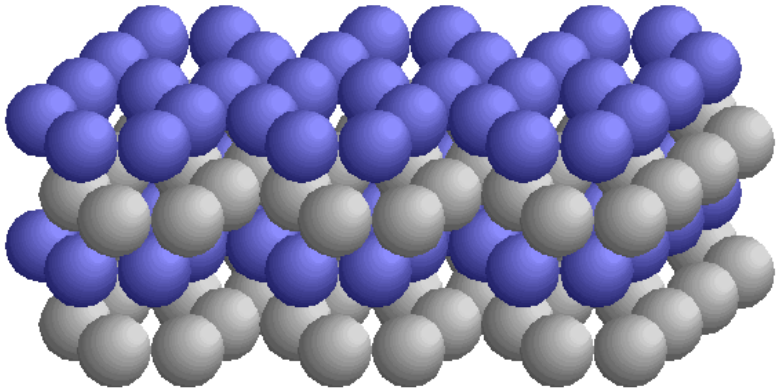




A closer look

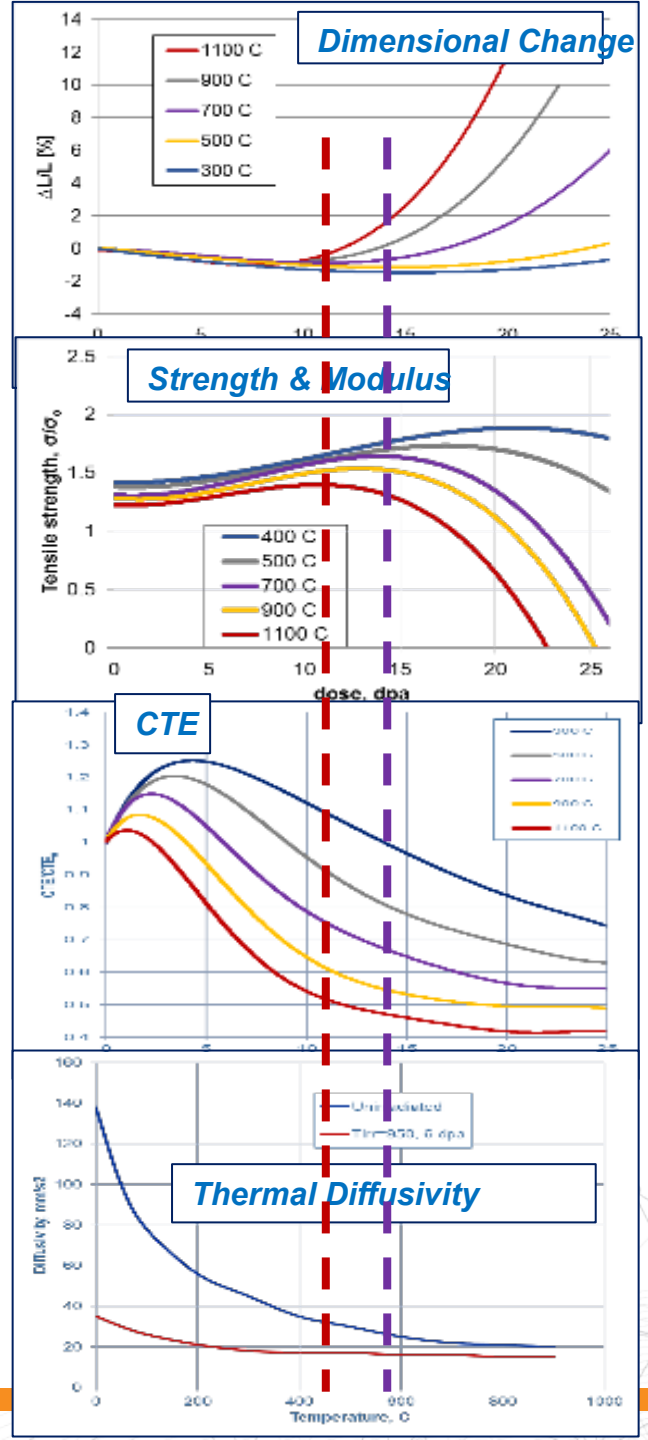
Why doesn't Dimensional Change affect thermal diffusivity?

- Thermal Diffusivity affected by atomic level damage
  - ***Point defects dominate thermal diffusivity***
- Changes at grain size or large pores doesn't affect thermal diffusivity



Why doesn't CTE match Strength/Modulus exactly?

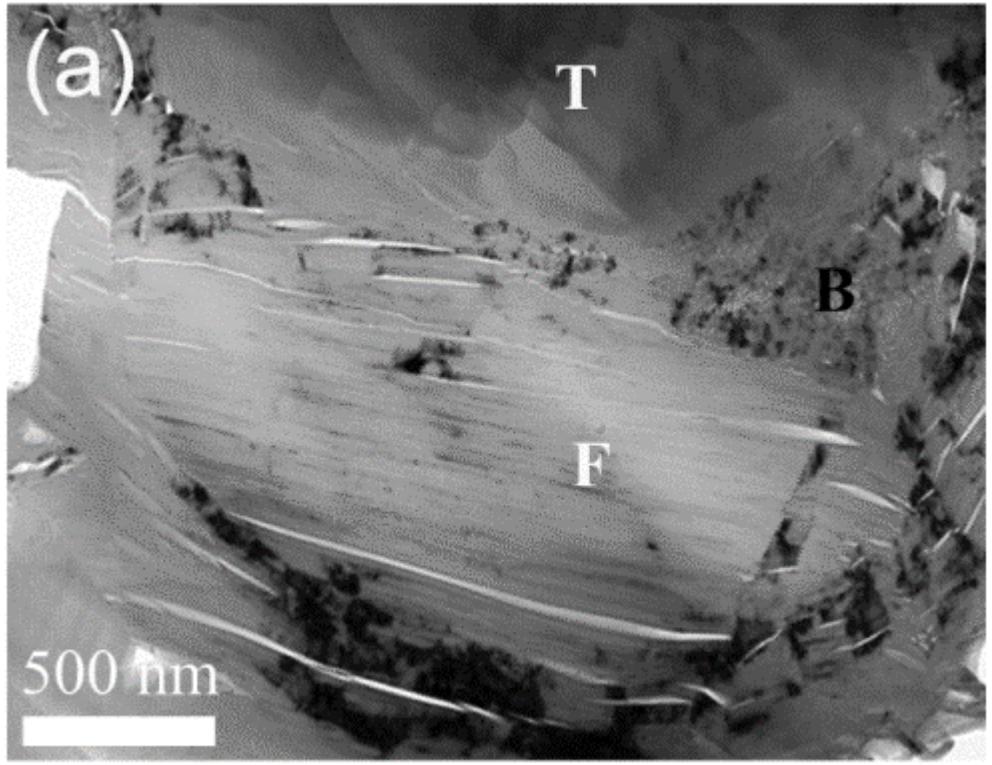
- Behavior may be from microstructure changes
  - ***Larger than crystal length-scale***
  - ***Smaller than grain size***

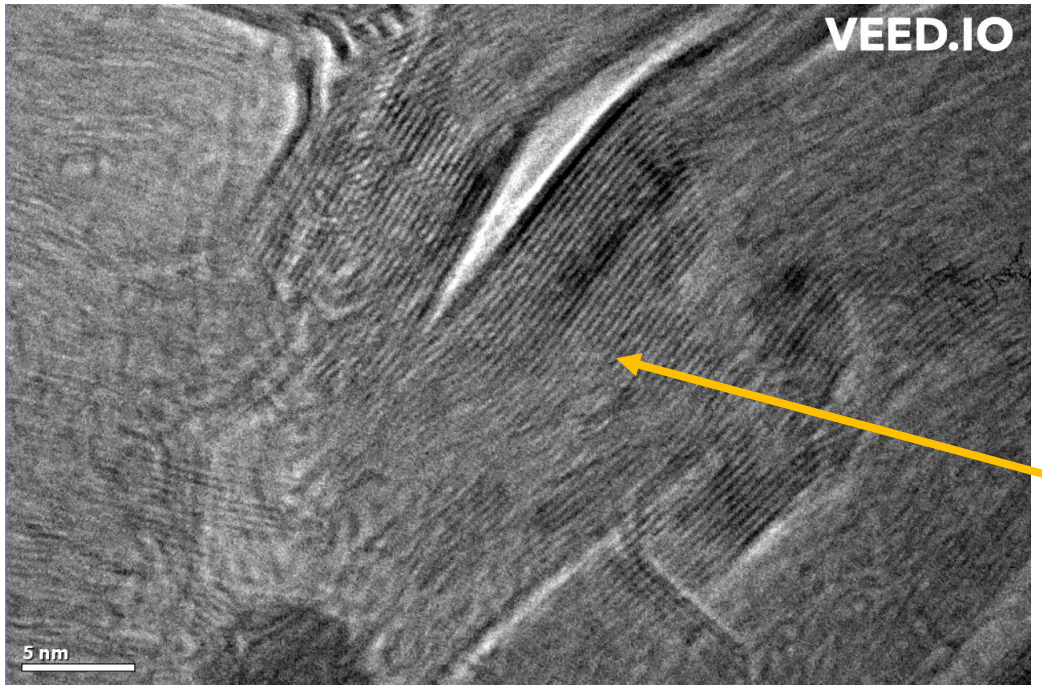


The problem

Pretty sure we know what goes on at the atomic and basal plane length scale

- ***Many studies in atomic damage models***





Crack closure under irradiation

Not so sure what is going on at submicron level.

- ***Very dependent upon graphite grade***
- ***Coke, binder, graphitization temperature, manufacturing, pores***

The research call

Advanced Reactor Component Materials Topics on High Temperature Reactors
FY21 NEUP Call

RC X-Y. Effects of Irradiation Induced Microstructure Change in Graphite

Irradiated graphite nuclear reactor core component behavior is the result of a combination of atomic and crystallographic changes caused by neutron ballistic damage accumulating within the bulk graphite microstructure. While significant progress at understanding and observing the crystallographic length-scale have been made recently, the effect on graphite behavior resulting from microstructural changes require more investigation. Research activities exploring the effect of **microstructural changes** (either irradiation, oxidation, and thermally induced) are sought to determine its **contribution to the overall material property changes** and graphite behavior. For this research, the focus should be on determining the underlying microstructural mechanisms responsible for the main mechanical graphite material property changes of interest; dimensional change-turnaround, strength, and elastic modulus. Thermal properties such as the coefficient of thermal expansion (CTE) and thermal conductivity are not of interest at this time.

NEUP: New graphite research

Advanced Reactor Component Materials Topics for FY21 NEUP Call

- RC X-Y. Effects of Irradiation Induced Microstructure Change in Graphite

1. Multiscale Effects of Irradiation Damage on Nuclear Graphite Properties
   - ***Aman Haque, Pennsylvania State University***

2. Quantifying the Dynamic and Static Porosity/Microstructure Characteristics of Irradiated Graphite through Multi-technique Experiments and Mesoscale Modeling
   - ***Jacob Eapen, North Carolina State University***