

## Radiation Damage - Zr

( See D. O. Northwood, Atomic Energy Review, Vol. 15, No. 4, p. 547, 1977)

• *Note that the operating temperature for Zircaloy in LWR's is 100 - 350 °C but mainly 300 to 350 °C*

• *Most typical damage structure is a high density of dislocation loops ( 20 - 100 Å in diameter)*

### Neutron Fluence Effects on Zircaloy - II

1.) no damage observed below  $2 \times 10^{19}$  n cm<sup>-2</sup> ( E > 1 MeV)

2.) Density of loops decreases with increasing n fluence

3.) Loop size increases with increasing fluence

4.) Saturation in visible defects at  $\approx 1 \times 10^{21}$  n cm<sup>-2</sup> ( E > 1 MeV)

(Figure 7-23)

### Temperature Effects

• Above  $\approx 500$  °C, no visible damage found

- At  $T > 400$  °C, mainly vacancy loops
- At  $T < 400$  °C, mainly interstitial loops
- Voids only found in ion bombarded samples when gas atoms are preinjected

### Alloying

Increasing alloying elements in solid solution, decreases loop size and increases loop density

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*For the effects of microstructure and stress, see Northwood*  
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**Recent Information From Dr. Ron B.  
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- Performance to date of BWR and PWR fuel

@ 40,000 MWd/MT ( $8 \times 10^{21}$  n/cm<sup>2</sup>, E>1 MeV)

only 1 failure in 100,000 rods

- The use of Zr sleeves has solved the PCI prob. (10 years ago the major mode

**of fuel failure was Pellet Clad Interaction (PCI))**

- **Crud Induced Localized Corrosion (CILC) definitely linked to Cu in BWR water. Many utilities have replaced copper based condenser tubes with stainless steel or Ti tubes.**
  - **Near term goal for BWR's and PWR's**
    - **45,000 MWd/MT for BWR's**
    - **60,000 MWd/MT for PWR's**
    - **only 1 failure in 1,000,000 rods**
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- **Irradiation makes  $Zr(Cr,Fe)_2$  precipitates amorphous by  $1 \times 10^{21}$  n/cm<sup>2</sup>**
  - **Radiation Effects**
    - **Fatigue (Fig)**
    - **Growth (Fig)**
    - **Creep (Fig)**

**GE Method to Reduce FCI in LWR's - After Adamson**

Patent # 4,894,203

