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# NE 795 - Exam 4

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1) Because current cladding materials will not be able to survive advanced reactor systems environments. They will operate at higher temperatures, higher pressures, use different coolants (salts, metals) and have different operational designs. Plus, degradation phenomena will be exacerbated due to the higher irradiation doses expected. As a result, corrosion, creep, swelling, structural decomposition, among other issues need to be investigated/resolved for the advancanced reactor systems.

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2) We must consider the balance between the ferritic and martensitic phases.
Addition of Cr is good for corrosion resistant but too much of it can be detrimental.
Adding Si will help form carbides but we also don't want too many of them.
Alloying elements must find an optimal concentration to prevent loss of ductility, embrittlement, irradiation enhanced swelling, creep, etc.

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3) Ferritic steels swell less than austenitic steels because their microstructure provides sinks to prevents defects (dislocations) to aggravate the swelling. Precipites and stable GB's help too. Voids and bubbles are more likely to form is austenitic than ferritic.

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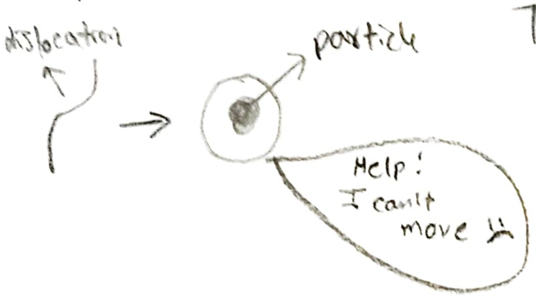
4) Oxide particles can prevent the gliding and climbing of dislocations. Thus, when a dislocation is traveling through the matrix of the material it will get trapped around the particle. They are important defect sinks.

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5) Ni alloys Advantage: 8/8

- Studied thanks to CANDU reactors
- Good corrosion resistant ✓
- Can be thermodinamically treated and alloyed to improve mechanical properties ✓

Disadvantage:

✓
- He formation is a problem. He embrittles the Ni alloys.
- Besides He bubbles, formation of voids can aggravate swelling. ✓

6) Inside research reactors:

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- Operate at lower temperatures ✓
- It's not for electricity production so no complicated loops ✓
- Main goal to produce neutrons ✓
- Now we want them to operate with low-enriched uranium fuel ✓
- Safer → no highly pressurized vessel, with LEU they'll be proliferation resistant ✓

7) Amorphization is a concern in RR because their fuel amorphizes at low doses. When the fuel is amorphized, the elements can more readily move. Thus, their diffusion across the matrix is easier. The movement of solid fission products and gasseous fission prodcts can result in unwanted consequences such as breakaway swelling and/or failure at the fuel/cladding interface.

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8) U-Si can accomodate a higher density of uranium than U-Al which is needed for LEU fuels.

6/6 The swelling in U-Si (specifically $U_3Si_2$) is stable.
U-Si is best qualified in performance and loading.
$U_3Si_2$ and Al cladding has been observed to be free of porosity formation. In U-Al with Al clad, interface many phases form.

The push for U-Mo is due to Mo being a strong gamma stabilizer.

-higher U density

9) $U_3Si$ vs. $U_3Si_2$ 4/4

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$U_3Si$ swelling shows breakaway swelling behavior. ✓
Both $U_3Si$ and $U_3Si_2$ amorphize under irradiation. ✓
$U_3Si_2$ swells but it is more stable than $U_3Si$. ✓
In $U_3Si$ the fission gas bubbles that produce the swelling can be vary a lot in size and be very large. Their distribution is also random and when in contact with the cladding the interaction layer grows and can lead to delamination of the fuel. For $U_3Si$ the bubbles are about the same size and more evenly distributed.

10) The gamma phase of U-Mo is the dominant phase in-reactor because the irradiation the fuel experiences disorders the α and γ' phases trying to form so the fuel remains in γ-phase. ✓

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- sluggish transformation kinetics

11) The solidus/liquidus gap affects the ability to evenly distribute Mo in the U-Mo fuel during fabrication. Thus, heat treatments are needed to disperse the element.

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12) Bubbles in U-Mo:

Gas Bubbles growth as a function of burnup. At first they form and grow slowly at low burnups. At higher burnup, the bubbles grow faster. This is driven by grain refinement. Thus at low BU the small bubbles are found at the grain boundaries. Their number density is large. As BU increases and the fuel amorphizes and the population of bubbles rises. The bubbles form at the new GB's. Thus increasing in size and density at high BU.

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- Fission gas superlattice & intragranular bubbles

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13) The Zr layer in U-Mo monolithic fuel serves as a interdiffusion barrier between the fuel foil and the Al cladding.

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14) Al is abundant, cheap, machineable, has good enough water corrosion resistance.
Al is ductile and light. It can be strenghtened. It has a stable fcc structure.
Although it has a low melting temperature, it is good enough for RRs.

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