93 Juhid

(1) Advanced reactor systems can have different operating conditions compared to traditional LWRs. Many of them have high operating temperature. As a result, traditional structural materials, such as steel, might not be a feasible option since material properties of steel degrade at that point. Advanced reactors might also employ different types of coolants and moderators. So, the structural material needs to work well with those.

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(2) The considerations when optimizing the composition of F/M include precipitation, hardening, embrittlement, etc. For example, Cr can determine DBTT for the steels. The carbon content can determine the formation of $M_{23}C_6$ precipitates. The precipitates can determine hardening and embrittlement. The composition is tweaked ~~ttd~~ to get ~~a~~ overall better properties under irradiation.

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(3) Ferritic steels have bcc structure while austenitic steels have fcc. Also, the grains of ferritic steels are larger than that of ~~f~~ austenitic steels. The crystal structure itself along with larger grains makes it possible for the ferritic steels to swell less.

4/6

yes, but would like more...

depends

(4) Oxide particles in ODS steels harden and strengthen the steel. The oxide precipitates can inhibit the motion of point defects and dislocations. This increases the creep resistance of the steel as well. However, the dispersed oxides reduce the ductility of the material. This makes the fabrication process harder. So, the oxide particles provide great strength at the expense of ductility.

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⑤ The advantages of Ni alloy mainly derive from the fact that they can be used at higher temperatures compared to Fe-based alloys. Ni-based alloys have good strength even at 1000° C. The main issue with Ni-based alloys is that they are more expensive to fabricate. For structural materials, this can be a major concern. The strength of Ni-alloys can be improved by tweaking the amount of alloying elements.

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- main issue is He embrittlement from transmutation

Yes, but I would have liked more specificity

10/10

⑥ Research reactors operate at lower temperature but at high fission density. Unlike power reactors, research reactors don't need the distribution of energy to turbines. Therefore, research reactors need materials that can operate at low temperatures but at high irradiation. The fuel type is also different. Research reactors can use plate-type fuels that LWRs cannot.

⑦ Amorphization can change the microstructure of the material. So, the local properties or phases can be different at different places. This can lead to unintended behavior. Research reactors operate at high fission ~~ra~~ density. This makes amorphization of the materials almost inevitable. - not always, U-Mo does not

Amorphous materials can enable mobility of fission product and diffusion in general. Thus amorphous material can show more swelling. As a result, research reactors need to consider amorphization.

6/6

⑧ U-Al fuel has lower fuel density than U-Si fuel. The push towards U-Mo also comes from the goal to load more U in the fuel so that LEU can be used.

6/6

Compared to U-Al, U-Si fuels show more swelling. Old OM images did not show any ~~see~~ fission gas bubbles in U-Al, although there might be tiny bubbles in the material. U-Si shows considerable amount of swelling for both U_3Si and U_3Si_2.

⑨

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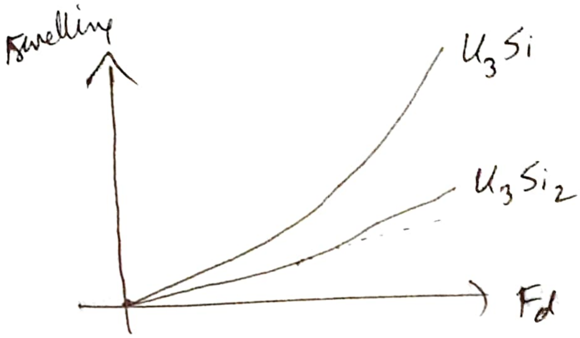

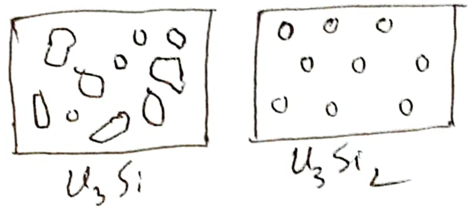

U_3Si shows significantly more swelling than U_3Si_2. The bubbles that form U_3Si are more irregular than U_3Si_2. U_3Si has more fuel density (6.6 g/cc) than U_3Si_2 (5.1) g/cc). So, U_3Si_2 has more space to retain the FPs. This leads to a more uniform bubble formation and subsequently less FGS swelling in U_3Si_2.

doesn't work this way

ΔV from crystal to amorphous

⑩

$$\gamma U\text{-}Mo \rightleftharpoons \alpha U + \gamma' U\text{-}Mo \ (U_2Mo)$$

7/7 The γU-Mo phase is the dominant phase due to irradiation. This phase starts to break down into αU and Mo-rich γ' U-Mo phase. The γ' phase is stoichiometric and crystalline. Irradiation knocks out the Mo from the γ' phases. This helps to keep the γ-phase the dominant one. The balance in this bidirectional reaction depends on the fission rate. Higher fission rate makes it easier to retain the γ phase.

- Sluggish transformation kinetics

(11) The solidus/liquidus gap determines the ~~tt~~ presence of Mo-rich regions and segregated U, or Mo-lean U-Mo regions. A bigger solidus/liquidus gap means the phases throughout the material will be uniform after the fabrication process. If the gap is too small, segregated regions can be present. → has to do w/ the slope

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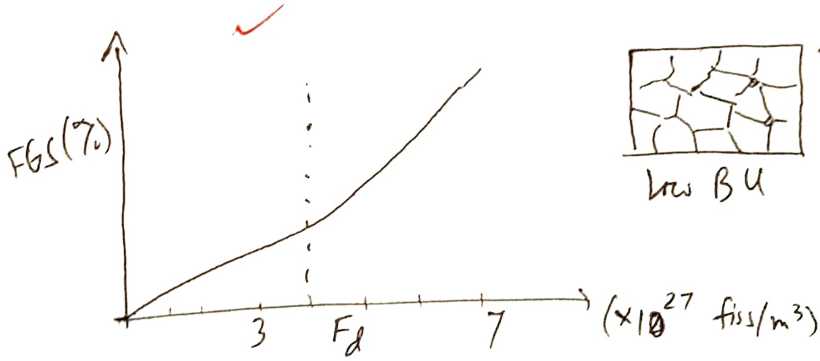
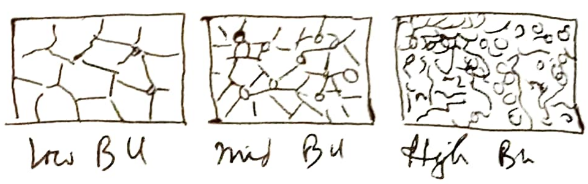
(12)

8/10





There are two distinct regimes of swelling behavior in U-Mo. Up to 3-4 $\times 10^{27}$ f/m^3, the fission gas swelling is slow. After that, fission gas bubbles form at an increasing rate. This is due to recrystallization or grain refinement. With increasing number of grain boundaries and nucleation sites, many gas bubbles form. They can even coalesce and form connected bubbles.

- fission gas superlattice
- grain refinement destroys this lattice

(13) The role of the Zr layer is to act as a barrier between U-Mo fuel and Al cladding. In the dispersion U-Mo fuel, formation of intermediate layer between the matrix Al and the fuel itself is observed.
6/6 This IL is also prone to the formation of voids and bubbles. Overall, breakaway swelling can occur in systems where Al is in contact with U-Mo. Including a Zr interdiffusion barrier gets rid of this problem.

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(14) In research reactor environments, the operating temperature is considerably less than in LWRs. In the operating range of research reactors, Al remains stable. Also, it's cheaper to use Al as cladding. Al is also machineable, weldable and has properties that make the fabrication process easier.