Dislocation loops in proton irradiated Zr and Zry-4
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Introduction
In service, neutron irradiation knocks atoms out of lattice, creating vacancies and self-interstitial atoms (SIA). Point defects may annihilate or form clusters, which then collapse into dislocation loops. Macroscopically, Zr crystals elongates in <a> and shrinks in <c>, i.e., irradiation-induced growth (IIG). We proton irradiate Zr and Zry-4 to mechanistically study these effects.

Key findings
1. Point defect mobility higher in pure Zr than in Zircaloy-4. After same irradiation, pure Zr has fewer, larger dislocation loops than Zircaloy-4.
2. Using bright field STEM, we can characterize the nature of <a>-loops larger than ~20 μm.
3. At higher dose (4 dpa) where <a>-loops are observed, <a>-loops align along <10-10> family of directions. Is <a>-loop alignment related to <->loop formation?
4. <->loops in alignment are of similar sizes, and of the same nature (identical Burgers vector)
5. At low proton dose (~0.15 dpa at 60% proton penetration depth), depth-dependence of dislocation density agrees with SRIM dose profile!
6. XRD satellite peaks may contain loop nature information, and may be orientation-dependent.
7. At high dose (~4 dpa at 60% penetration depth), damage profile does not show a Bragg peak as predicted by SRIM.
8. In general, SRIM (Quick Kinching-Pease, E_{kin}=40eV, amorphous) slightly overestimates proton penetration depth in Zr.

<a>-loops, alignment & nature

(S)XRD line profile analysis

I_{measured} = I_{strain} * I_{size} * I_{PlatonicDefects} * I_{Instrument} + BG

Bragg peaks
- Broadening ⇒ strain; loop density p
- Tail shape ⇒ dipole factor; loop size

Asymmetric satellites
- Lower d-spacing ⇒ interstitial
- Higher d-spacing ⇒ vacancy
- hkl dependent

During long irradiations, Bragg peak damage disappears due to diffusion of defects over time!

References

Acknowledgements

Sponsors

Damage v. irradiation depth

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<th>Peak broadening: depth-dependent in low dose only</th>
<th>During long irradiations, Bragg peak damage disappears due to diffusion of defects over time!</th>
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<td>Synchrotron X-ray diffraction; high energy; focused beam; transmission; depth sequence.</td>
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