


“Investigation of Irradiation Induced Phase Formation at Ferroboron and SS 304L Clad Material Interface”

A red arrow graphic pointing to the right, positioned to the left of the author names.

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Date- 10/09/2019

Outline

In-vessel shielding in FBR

Test irradiation of FeB capsule in FBTR

Post Irradiation Examination

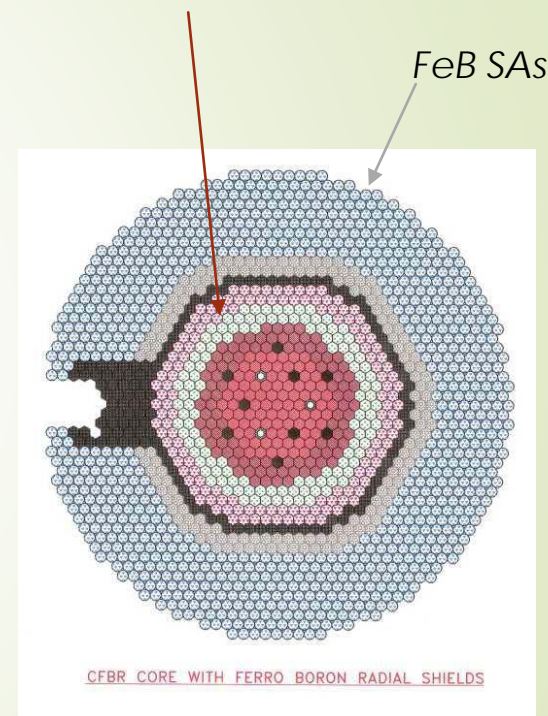
Microstructure & Phase investigation

Conclusion

In vessel Shielding in Fast Reactors

- In pool type fast reactors, Intermediate Heat Exchangers (IHX) are immersed in the pool of liquid sodium within the reactor vessel.
- Without adequate neutron shielding around the core secondary sodium passing through IHXs gets activated leading to unacceptable dose in the steam generator building.
- Fuel and blankets are surrounded by a large quantity of shield materials, to the extent of 60-70% of the core volume in fast reactors.
- Hence improved shield configurations with advanced shield materials with an objective of reducing shield volumes and improved economics are important.

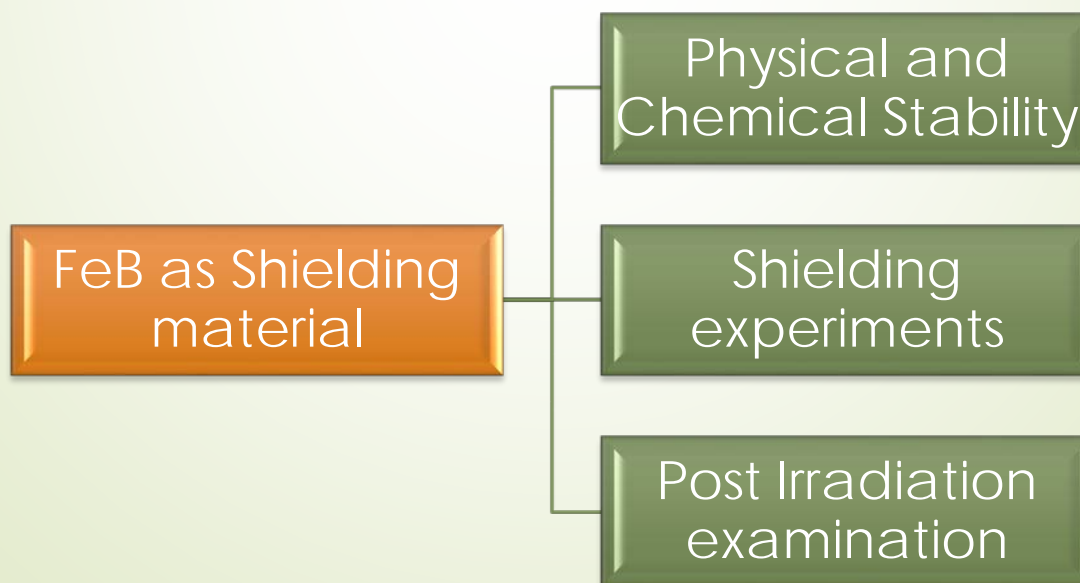
Fuels and reflectors SAs



FBR core with 881(8 rows) FeB shielding SAs

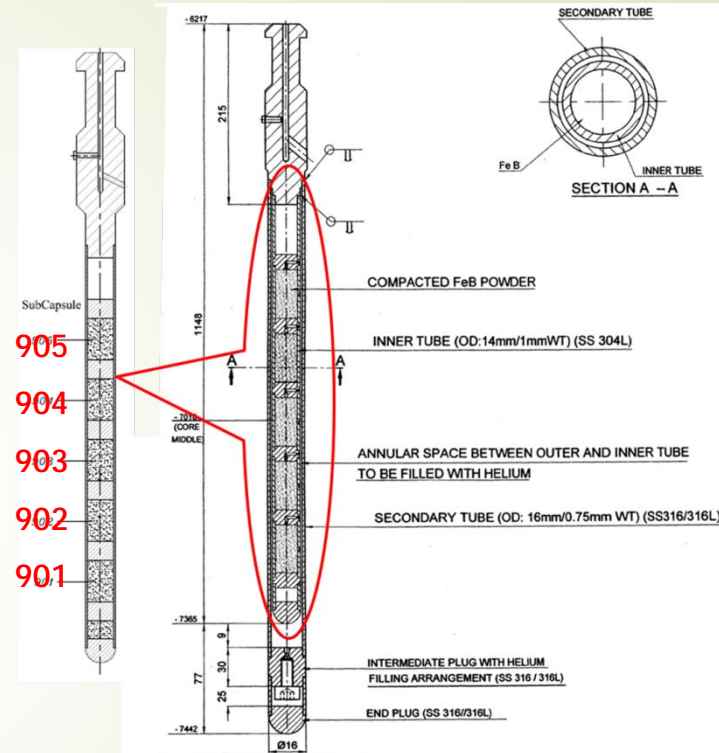
In vessel Shielding...

- Toward this, feasibility of using commercial grade FeB alloy as a shielding material in future fast reactors is investigated.
- Commercial grade FeB provides adequate neutron and gamma shielding and can reduce the core volume.
- Out-of-pile characterization have established its neutron shielding property and long-term compatibility with 304L SS clad under sodium at the operating temperatures.



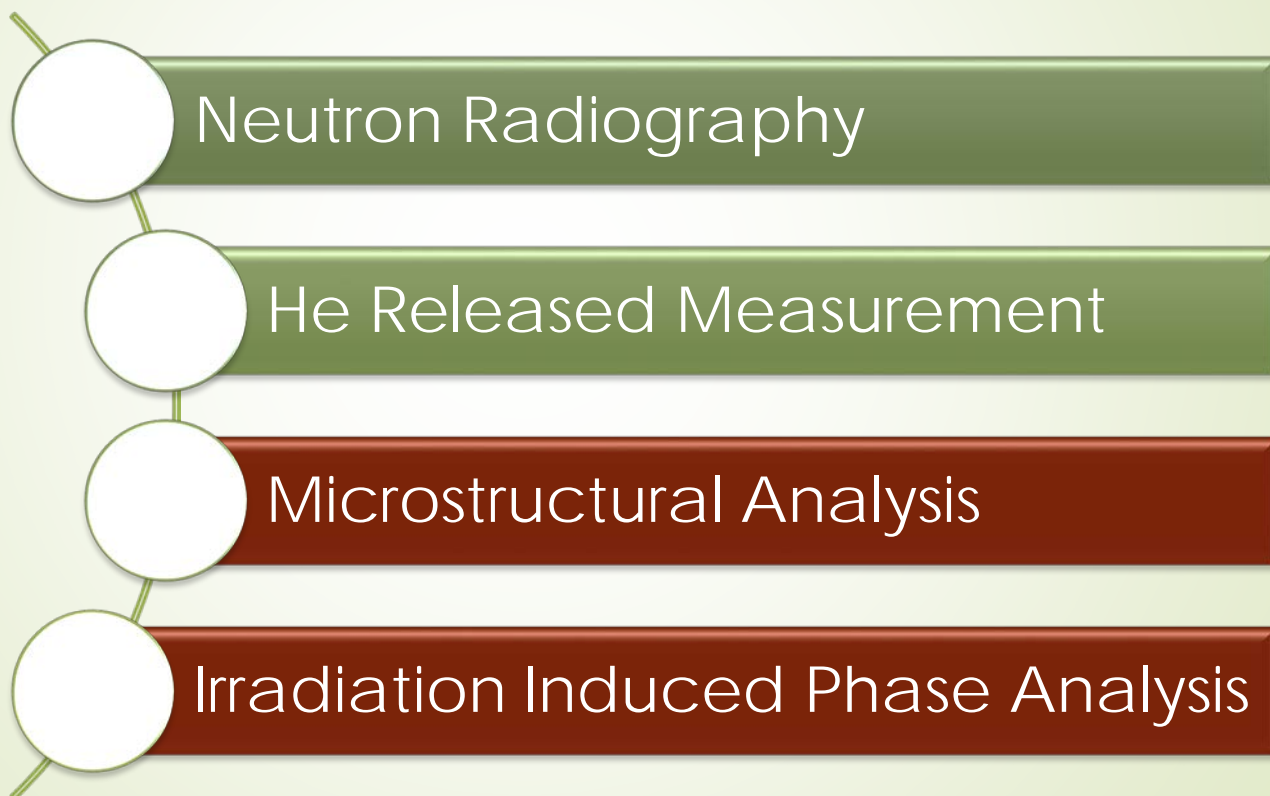
Test irradiation of FeB capsule in FBTR

- An accelerated irradiation experiment has been carried in FBTR in an experimental subassembly on FeB as shielding material for a duration equivalent to the target life-time of 60 years in a commercial FBR.
- ESA contain an irradiation capsule consisting of two concentric SS tubes with the inner tube having five compartments, each of 100 mm height called sub-capsules.
- FeB powder is packed in the sub-capsules to a density of 4.2g/cc under Ar atmosphere.
- The capsule was irradiated in FBTR with displacement damage in the five sub-capsules varying in the range of 0.50-2.96 dpa. 2.96 dpa corresponds to the life time fluence of 60 years undergone in a commercial FBRs.



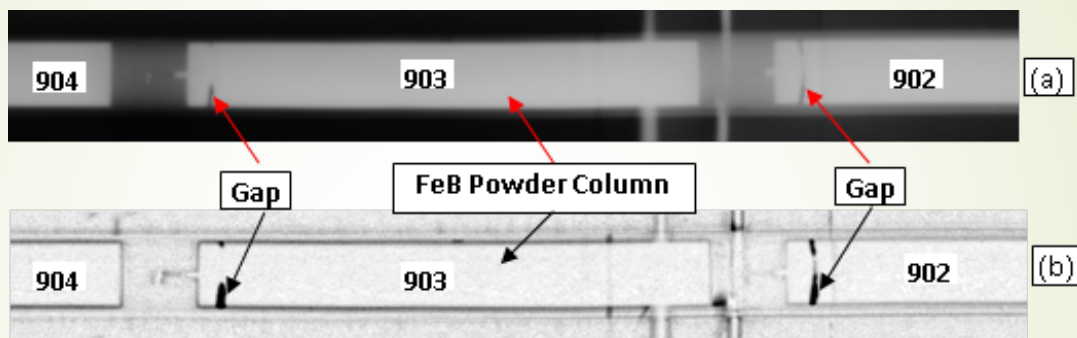
Element Wt %	Boron	Silicon	Aluminium	Carbon	Sulphur	Phosphorus	Iron
	15.42	0.89	0.169	0.29	0.0061	0.0046	Bal.
Phases present	FeB & Fe ₂ B						

Post Irradiation Examination of FeB



Post Irradiation...

Neutron Radiography Analysis



Slumping of the FeB stack is found to be limited to a maximum of 0.5 mm in a 100 mm pre irradiation stack height using neutron radiography.

He Release Measurement

Maximum pressure due to **He** release from (n, α) reaction was measured to be 0.16 Mpa.

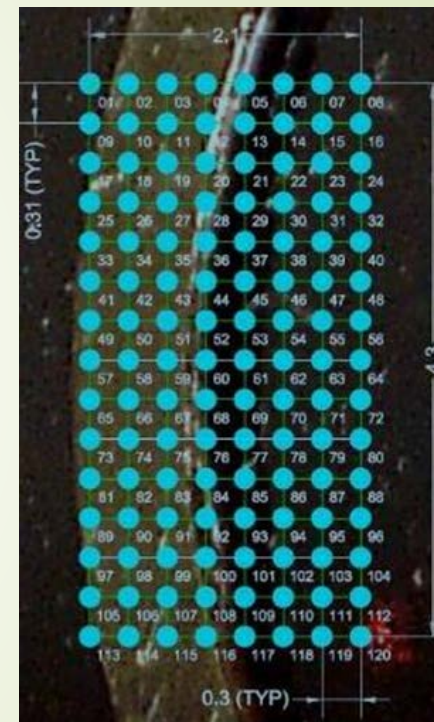
Microstructure and Interface Analysis

Metallographic preparation of clad section from different sub-capsule

In-cell Optical Microscopy

SEM study at maximum damage region

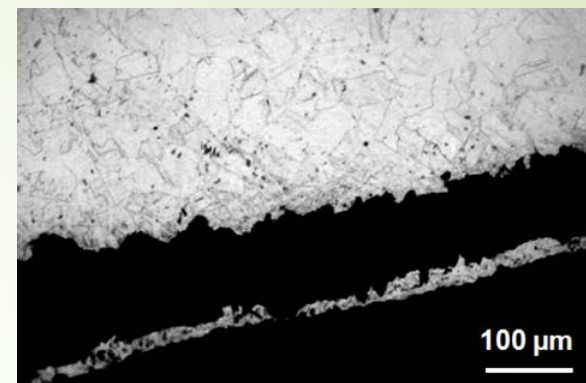
XRD scan at the FeB & Clad interface



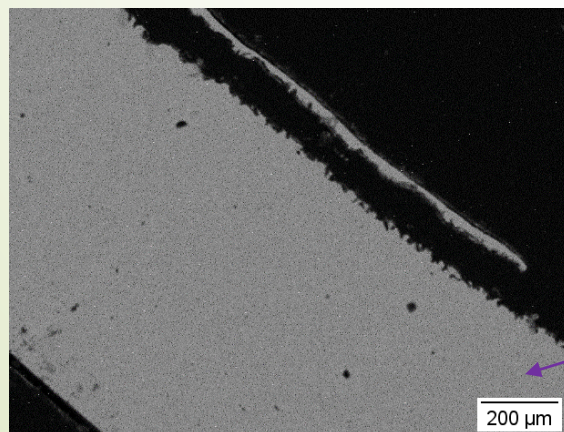
XRD scan spots on the FeB clad sector

Microstructure of FeB clad

- Reduction in wall thickness in the central sub-capsule (#903) of FeB clad which has seen the peak displacement damage.
- Maximum clad wall thickness reduction measured using optical microscopy was around 200 μm .
- SEM examination confirms the FeB clad attack leading to formation of discontinuous interaction phases with varying thickness at the FeB clad interface.

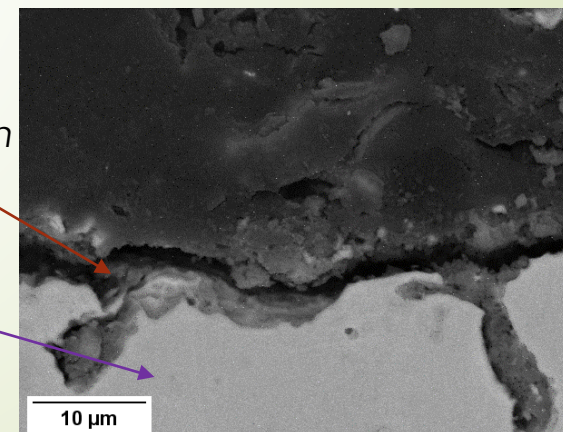


Microstructure of the SS 304L clad



damaged region

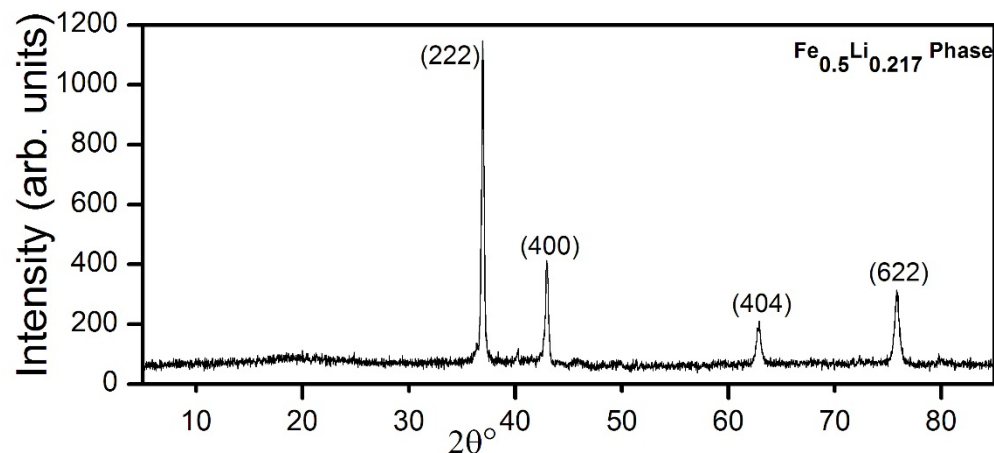
SS 304L clad



SEM micrographs indicating chemical interaction between FeB and SS 304L

Phase investigation

- Towards the inner side of the clad, a Lithium rich secondary phase formed due to chemical interaction between the clad and FeB.
- Extent of interaction zone measured from XRD was in agreement with SEM analysis.
- XRD analysis clearly indicated presence of $\text{Fe}_{0.5}\text{Li}_{0.217}$ phase.
- Nascent "Li" atom, being small enough and having affinity to Fe diffuses easily into the clad material at the inner surface and forms the $\text{Fe}_{0.5}\text{Li}_{0.217}$ phase along the circumference.



XRD pattern at the interface region at scan point 12

Conclusion

- ▶ Nascent Li produced from the transmutation of Boron caused chemical attack on SS 304L clad inner surface.
- ▶ Interaction region is discontinuous and non-uniform
- ▶ The maximum thickness reduction is ~20% (200 micron) of the clad wall initial thickness.
- ▶ Irradiation induced phase formed was found to be $\text{Fe}_{0.5}\text{Li}_{0.217}$ using X-ray diffraction analysis.
- ▶ Further investigation is required for clear understanding of the kinetics of Li attack on SS 304L.



Thank You
For your attention

