Potential Coatings for Li/V System: Nuclear Performance and Design Issues

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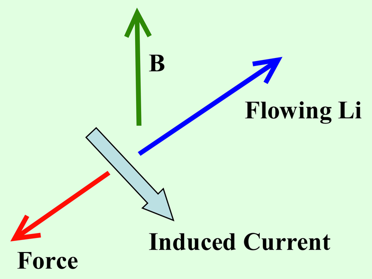
MHD Coatings, Design Problems, and Potential Solutions

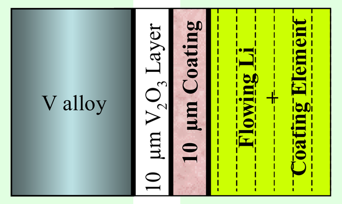
- MHD force inhibits flow of Li, causing load to pumping system and significant pressure drop.



- V coating decouples Li and V, preventing MHD-generated current
  ⇒ no influence of magnetic field on Li.

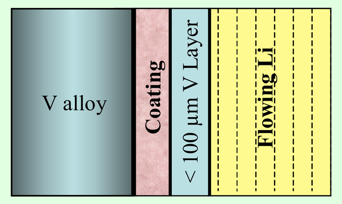
- **Coating requirements**:
  - Thin (1-10 μm)
  - High electrical resistivity
  - High corrosion resistance
  - Good thermal expansion match with V
  - High stability during thermal cycling
  - Compatibility with Li at high temperatures
  - High radiation damage resistance
  - Acceptable degradation to T breeding
  - Attractive safety and environmental features
- **Candidate coatings**:
  - Oxides: CaO, Y_2O_3, Er_2O_3, $CaZrO_3$, Sc_2O_3, $YScO_3$, BeO, MgO, $MgAl_2O_4$
  - Nitrides: AlN, Si_3N_4, BN
- Concentration of coating elements in Li is unknown.

Coating Approaches



In-situ self-healing approach

Coating elements added to Li flow for self-healing of micro-cracks developed during operation
Concerns:
- Coating dissolution at elevated temperature
- Impact on T breeding.

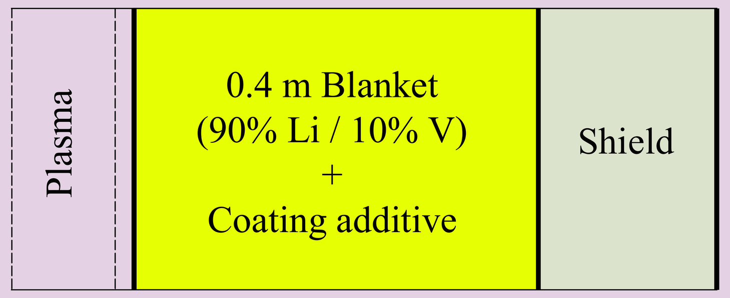


Multilayer approach

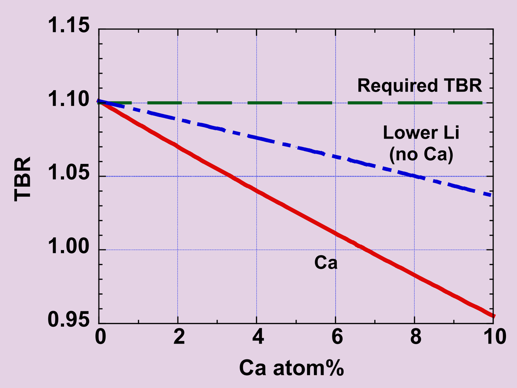
More durable system where coating sandwiched between main V structure and thin V layer facing Li flow.
No major effect on breeding.
Concerns:
- Fabrication of multilayer system.

Breeding Analysis & Results

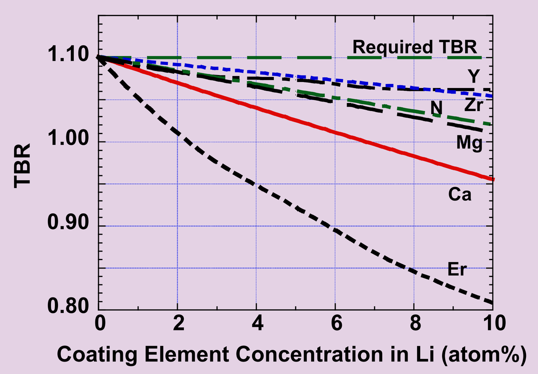
- Simple cylindrical model developed to estimate degradation in breeding due to coating additives.



- 0.4 m blanket provides TBR of 1.1 and assures T self-sufficiency.
- 1-10 atom% of coating concentration considered (coating atoms replaces Li atoms).



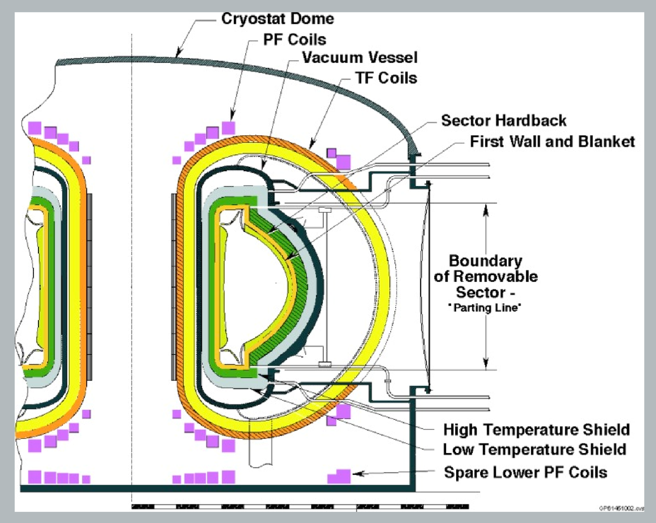
Sensitivity of TBR to Li reduction and Ca addition



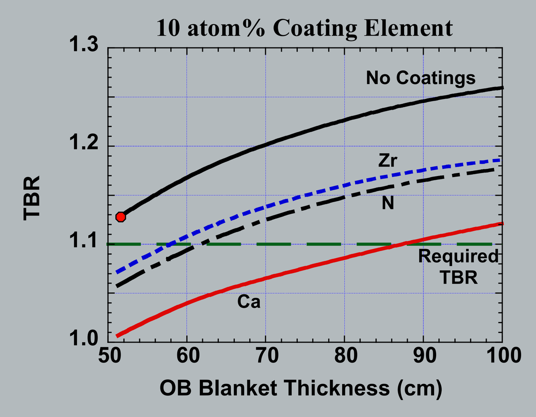
Relative effect of coating materials on breeding

- Y and Zr exhibit superior nuclear performance.
- Al behaves similarly to N.
- Er results in dramatic reduction in breeding.

Impact of Coatings on ARIES-RS-type Blanket



- Practical means to compensate for breeding losses involves thicker blanket.



Variation of TBR with ARIES-RS-type OB blanket thickness

- 50 cm thick blanket of ARIES-RS could accommodate:
  - 0.5 atom% Er
  - 2 atom% Ca
  - 4 atom% N, Mg, or Al
  - 5 atom% Zr or Y.
- 10 atom% coatings call for thicker OB blanket (60-90 cm).
- 3-4 atom% Er requires major changes: doubling OB blanket size and/or adding Be multiplier.

Conclusions

- Self-healing approach poses unique breeding challenges.
- While some coatings exhibit moderate effect on breeding, blanket must be substantially modified to accommodate other coatings.
- From breeding perspective, Y and Zr are best coatings, followed by N, Al, Mg, and Ca.
- Erbium causes far more degradation to breeding.
- Potential solutions that mitigate effect Er coating include doubling blanket thickness and/or adding beryllium multiplier to Li/V blanket.
- Economic and safety implications of such major modifications must be evaluated for ARIES-RS design and the like.

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