Rhenium and Molybdenum Coatings for Dendritic Tungsten Armors of Plasma Facing Components: Concept, Problems, and Solutions

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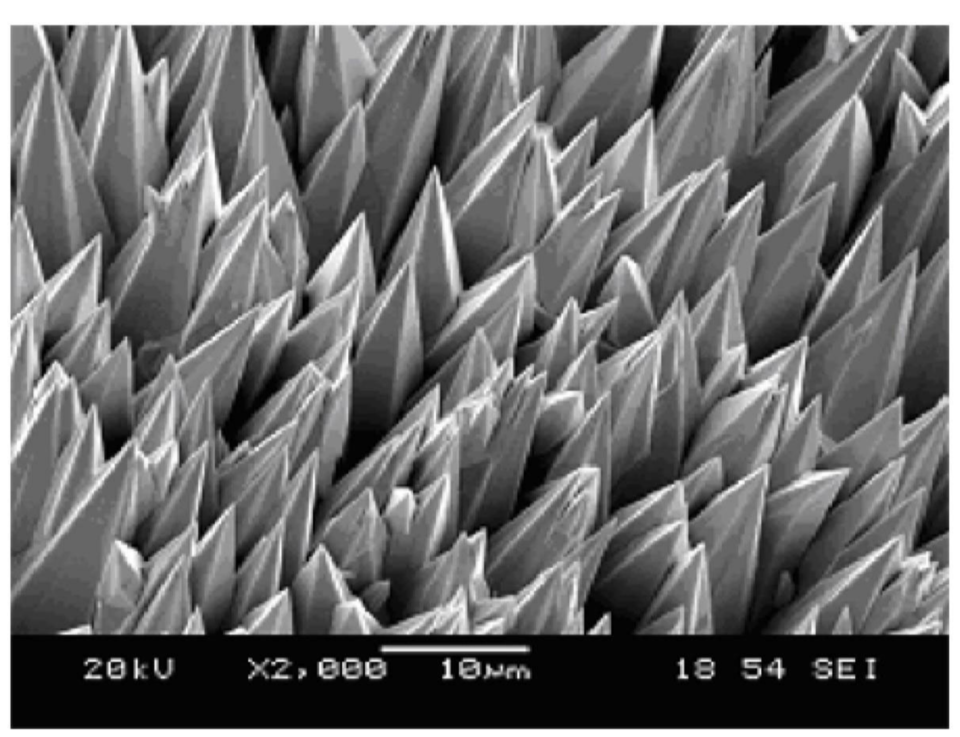
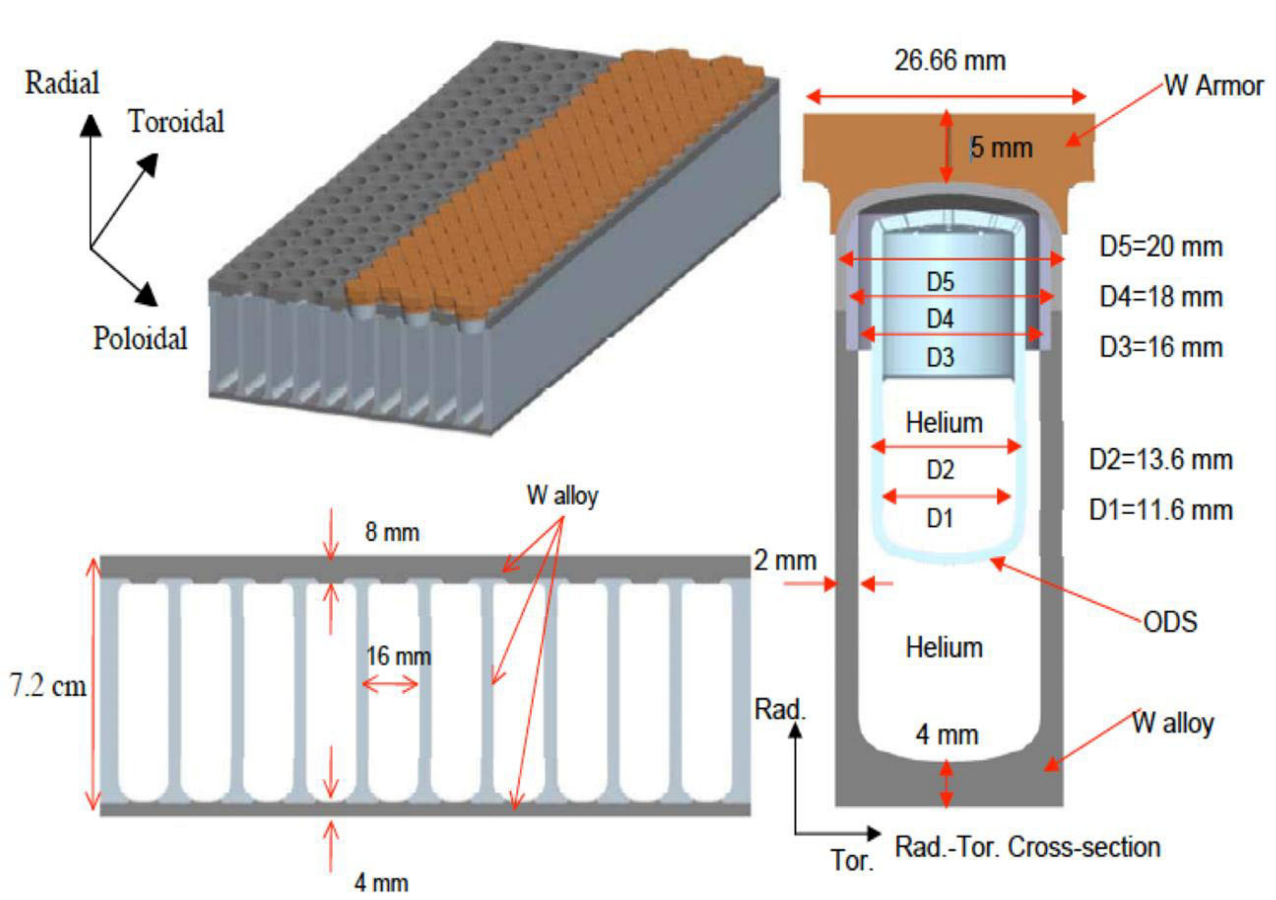
Introduction

- Tungsten (W) is low activation and high heat resistant material used for fusion applications
- Rhenium (Re) and molybdenum (Mo) are either impurities of W or additive alloying elements to increase structural integrity of W alloy
- Re and Mo deposited on dendritic W increases allowable heat flux and dimensional stability
- Waste management issues arise from transmutation of Re and Mo in 14 MeV neutron environment created by fusion reactions.
- Waste disposal rating (WDR) associated with activation of thin coatings of Re and Mo on ARIES-ACT W-based divertor is examined



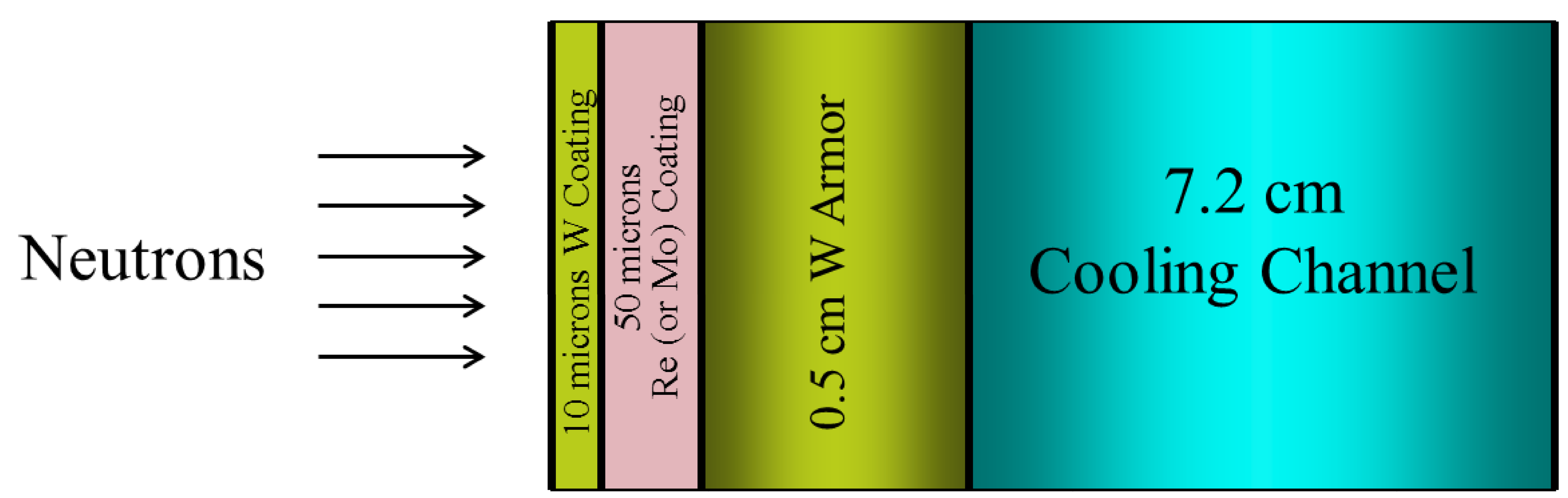
Re dendritic coating on W substrate



Several views of the original ARIES-ACT divertor with dimensions and without coatings.

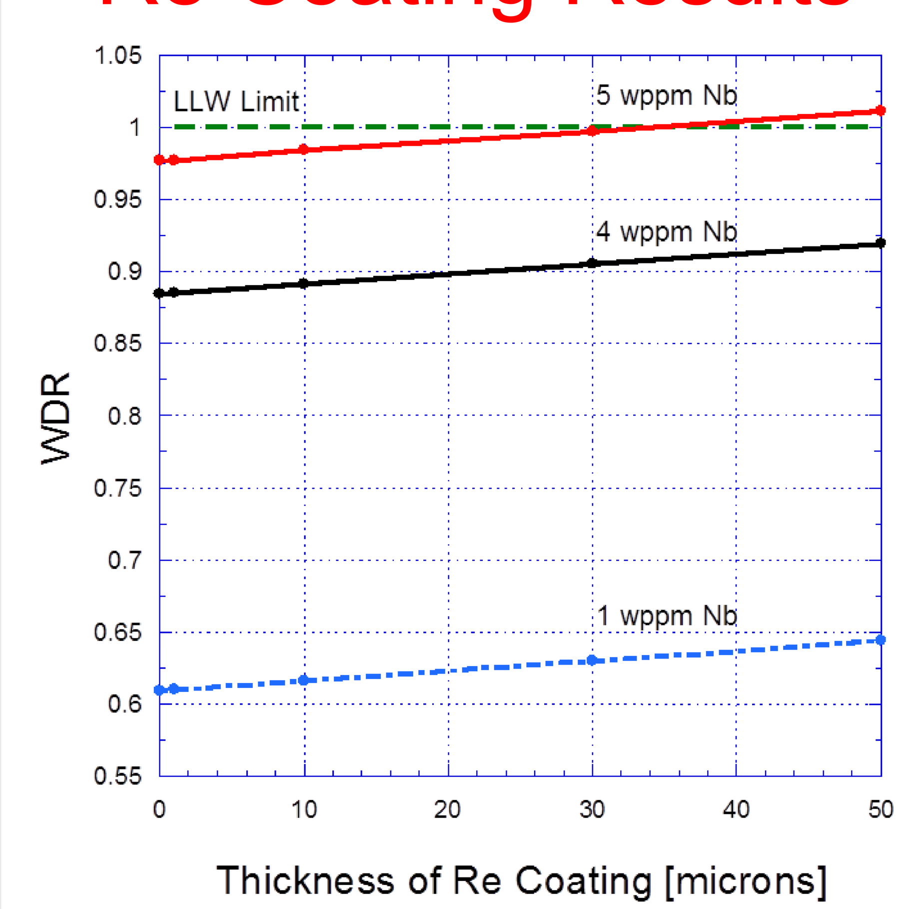
Methodology

- 1-D cylindrical model with 14 MeV neutrons from plasma impinging on divertor
- Neutron wall loading (NWL) of 1 MW/m^2 over divertor surface.
- Operation pulse schedule modeled for 85% availability and lifetime of 3.4 full power years (FPY), meaning 4 years of operation
- WDR calculated using compacted volume averages at 100 years after shutdown
- DANTSYS discrete ordinate neutral particle transport code and ALARA activation code with FENDL-2 data library



Radial build of divertor model for WDR calculations given Re and Mo coatings of thicknesses varying from one to 50 microns.

Re Coating Results



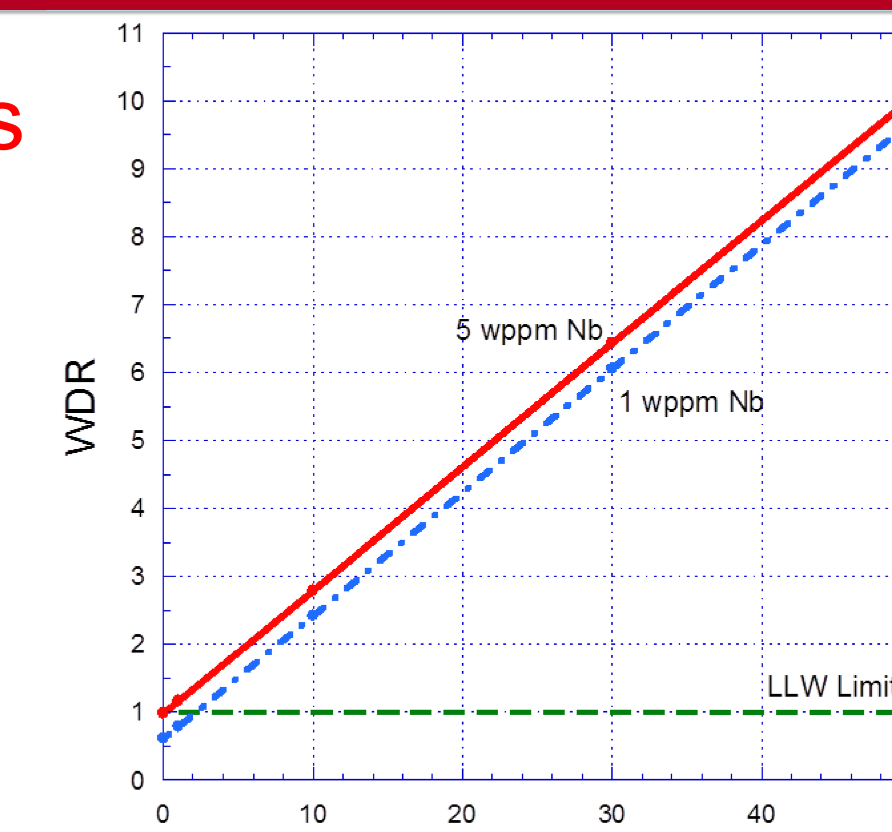
WDR as function of thickness for Re coating given tungsten Nb impurity content of 1, 4, and 5 wppm

- Dominant isotope is Re-186m
- Re-185 and Re-187 transmute to Re-186m via (n, gamma) and (n, 2n) reactions, respectively
- Re coating less than 30 microns classifies as LLW
- Controlling Nb impurity to 4 wppm allows for thicknesses greater than 50 microns

Reference
A. Jaber, L. El-Guebaly, A. Robinson, D. Henderson, and T. Renk, "Activation of W-Based Divertors with Thin Re and Mo Coatings for Fusion Applications," University of Wisconsin Fusion Technology Institute Report, UWFDM-1382 (March 2011). Available at: http://fti.neep.wisc.edu/pdf/fdm1382.pdf.

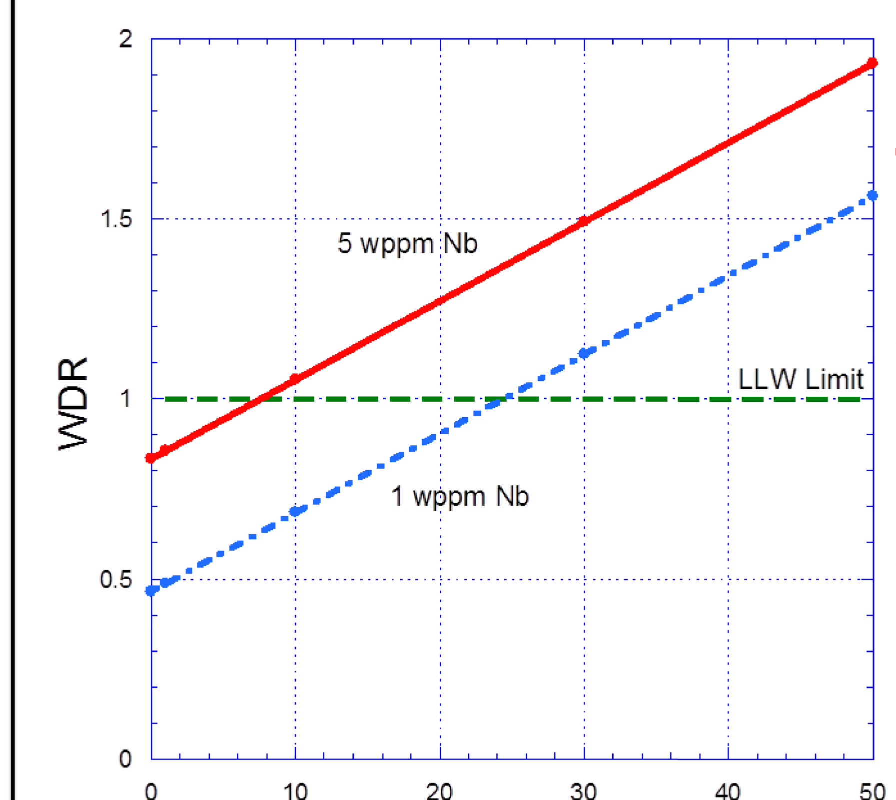
Mo Coating Results

- Dominant isotope is Tc-99
- Mo-98 and Mo-100 transmute to Mo-99 via (n, gamma) and (n, 2n) reactions, respectively, which then beta decays to Tc-99
- Mo coating less than a few microns classifies as LLW



WDR as function of thickness for Mo coating given tungsten Nb impurity content of 1 and 5 wppm.

Mo Isotopic Tailoring Results



WDR as function of thickness for tailored Mo coating given tungsten Nb impurity content of 1 and 5 wppm.

- Removed Mo-94, 98, 100 (~43% of natural isotopes)
- Tailored Mo coating less than 8 microns for 5 wppm Nb and 25 microns for 1 wppm Nb classifies as LLW

Conclusions

- Re does not appear to raise geological disposal concerns for plasma facing components if limited to 30 microns
- Mo should be avoided because of potential high level-waste generation unless Mo is tailored to remove Mo-94,98,100
- Isotopic tailoring helps alleviate Mo waste disposal problem, but currently this process has unknown efficiency and cost
- Controlling Nb impurity increases WDR margin for Re and tailored Mo coatings but has negligible effects on natural Mo coating