**Plasma Facing Material Alternatives to Tungsten**

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**High-Z plasma facing material alternatives to tungsten**

**Motivation:**
We are very dependent on tungsten working for ITER, DEMO etc., plasma facing components (PFCs). (One issue is D-T and He induced "tandem surface formation"). We need alternatives, i.e., an "insurance policy".

**Goal:**
Identify and evaluate alternative high-Z materials, from three standpoints:

A) **Activation, waste disposal, recycling** (ARIES-ACT-1 divertor; PARTISAN transport code [6] and ALARA activation code analysis, with FENDL cross-section libraries. The entire divertor was modeled in poloidal, cylindrical geometry, with a typical average neutron wall loading of 1 MW/m²).

B) **Sputter erosion/redeposition** (REDEP/WBC code package analysis of simulated DEMO divertor. C-MOD geometry, w/ simulated DEMO plasma parameters).

C) **Plasma transient response** (HEIGHTS code package analysis of ELMs, disruptions, VDE's, runaway electrons; with tungsten and alternative materials).

- **Focus is on comparisons to tungsten.**

**ARIES-ACT-1 Design and Divertor**

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**Activation Analysis**

**W and Mo comparison; simulated DEMO tokamak conditions. Divertor peak net sputtering erosion. REDEP/WBC code package analysis.**

**Transient response analysis** for the alternating materials. Focus on disruption, which is the most important event in first wall design, with primary concern to disruption event, and secondary concern to disruption event (SDE) and off-axis disruptions. A higher disruption event, with 20 TW, can be thought of as disruption event = 10TW, 1TW a lower failure point, head of reprocessing, and thermal conductivity.

- Mo has some advantages over tungsten in terms of tritium retention, with a higher disruption event, and higher head of reprocessing, and lower thermal conductivity.

**Erosion/redeposition analysis**

- Analysis performed for a simulated DEMO-type tokamak divertor subject to high power loading. REDEP/WBC/PCMC modeling, c-MOD code designed with actual plasma conditions, or X1 divertor.

- Pure metals analysis, <1.5 mm thick structure/cooling. (There may be significant differences for metastable, O1 containing, and existing tritium surface).

- Zr and Nb sputtering and transport parameters: higher density, lower density, lower density, etc. (Found to be reasonably similar to Zr: Cheesewright & Ta similar to W—therefore compare Mo to W for some analyses).

- Three plasma edge cases examined. (All cases D-T plasma with 5% EHe.)
  1. low temperature, 15 eV at strike point
  2. low temperature with 5% Argon radiating impurity
  3. "high temperature", 30 eV at strike point

**Conclusions**

- The identification and initial analysis of alternative high-Z plasma facing materials is encouraging showing:
  - Environmentally attractive activation, and minimal or no waste disposal, for a commercial power plant divertor surface, using advanced recycling equipment; and
  - Acceptable sputtering erosion/redeposition performance, similar to a tungsten divertor. (Initial thin-wall surface material analysis has similar conclusions)

- Concerns about the transient response of the alternative materials but not fundamentally different than concerns for tungsten.

- This potentially expands the list of candidate solid high-Z facing materials from basically one (tungsten) to six, and could therefore provide a major design margin for future fusion reactors, against failure of any one material.

- This study is just beginning. Considerable work is needed to advance the qualification of these alternative materials (age for tungsten, and first wall surfaces). Required work includes testing, design, and supporting experiments for:
  a) PFC sputtering and transient response for materials/cooling redeposited material; and
  b) surface temperature operating windows; and
  c) possible disruption effects; and
  d) PFCs and related thermo-mechanical issues; and
  e) dust, and f) plasma edge solution variation effects on overall performance.

- We encourage fusion community interest in further studying these candidate materials.