Target Activation and Radiological Response of ARIES-IFE Dry Wall Chamber

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Objectives

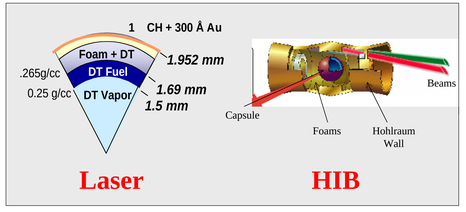
Identify waste management issues and concerns for dry walls plated with target debris

Recommend list of target coatings and hohlraums that generate low level waste

Main Issues and Concerns

- **Target debris become radioactive after interacting with source neutrons**
- **Debris condense on solid walls of chambers filled with low density buffer gases**
- **Condensed materials get re-irradiated during subsequent shots and become more radioactive**
- **At end of service life, low-activation FW structure covered with highly activated target debris may not qualify as low level waste, violating ARIES top-level requirements for power plant designs**

Laser and Heavy Ion Beam Target Designs



Candidate Coating and Hohlraum Wall Materials

Laser	
Gold (ref.)	$_{79}$Au
Tungsten	$_{74}$W
Lead	$_{82}$Pb
Platinum	$_{78}$Pt
Palladium	$_{46}$Pd
Silver	$_{47}$Ag

HIB	
Gold/Gadolinium (ref.)	$_{79}$Au/$_{64}$Gd
Gold	$_{79}$Au
Tungsten	$_{74}$W
Lead	$_{82}$Pb
Mercury	$_{80}$Hg
Tantalum	$_{73}$Ta
Pb/Ta/$_{55}$Cs	
Hg/W/Cs	
Pb/$_{72}$Hf	

ARIES-IFE Operating Conditions

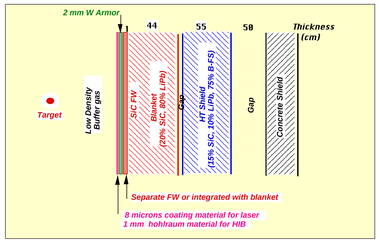
Fusion Yield	160 MJ
FW Radius	4 m
Neutron Wall Loading	3.5 MW/m^2
SiC/SiC FW Lifetime	6 FPY
FW EOL Fluence	21 MWy/m^2
Rep Rate	6 Hz
# of Shots	190 million/y
Availability	85%

Target Coating/Hohlraum Parameters

	Laser	HIB
Outer Radius	1.95 mm	~5 mm
Thickness	300 Å	15 μm
Mass per year	5 kg - Au	20 tons - Au/Gd
Δ on FW @ 6 FPY	8 μm	5 cm*
Δ Sticking on FW	8 μm	~1 mm

* Front layer will be melted by x-rays

FW Will be Plated with Coating/Hohlraum Materials



Sequence of Activation Process

Laser

- During burn, coating gets activated by intense source neutrons
- After burn, coating materials condense on FW and get reactivated during subsequent shots with lower FW flux for ≤ 6 FPY
- Coating materials accumulate on FW, reaching 8 μm @ 6 FPY
- Main activation concern is WDR of FW/B plated with 8 μm coating materials

HIB

- During burn, hohlraum gets activated by intense source neutrons
- After burn, hohlraum wall materials condense on FW and get reactivated during subsequent shots with lower FW flux for ≤ 6 FPY
- In 2-3 wks, ~1 mm thick hohlraum materials accumulate on FW if T<1000 °C
- X-rays will melt additional layers
- Molten hohlraum wall materials run down and get collected at bottom of chamber for recycling
- Main activation concern is WDR of FW/B coated with 1 mm hohlraum wall materials

Computational Tools and Model for Pulsed Activation Analysis

- **Spherical model**
- **Neutron and gamma transport analysis:**
  - **DANTSYS discrete ordinate code**
  - **175 neutron and 42 gamma group structure**
  - **P_3-S_8 approximation**
- **Activation analysis:**
  - **ALARA code**
  - **Exact modeling of pulse sequence**
  - **175 neutron group structure**
- **Nuclear Data:**
  - **FENDL-2 IAEA cross section library**

Waste Disposal Criteria

- **WDR < 1 means component qualifies as low level waste (LLW)**
- **All components should meet BOTH Fetter's and NRC-10CFR61 WD limits for Class C (or A) waste**
- **Reported WDR are for:**
  - **Highly pure coating/hohlraum/armor materials (no impurities)**
  - **Compacted solid waste (void excluded)**
  - **100 years after shutdown (end of institutional control at disposal site)**
  - **Fetter's limit (more restrictive than NRC's for materials considered)**
  - **Volumetric average over :**
    - **Coating (or hohlraum) materials only**
    - **W armor and FW plated with Coating (or hohlraum) materials (C/A/FW)**
    - **W armor, FW, and blanket plated with Coating (or hohlraum) materials (C/A/FW/B)**

Waste Disposal Rating (Laser)

Coating Material*			C/A/FW	C/A/FW/B
	---		0.24	0.04
Au	0.87	(^{194}Hg)	0.24	0.04
W	1.03	(^{186m}Re)	0.24	0.04
Pb	3.6	(^{208}Bi)	0.24	0.04
Pt	169	(^{192n}Ir)	0.35	0.05
Pd	4.6 x 10^3	(^{108m}Ag)	3.3	0.4
Ag	1.7 x 10^5	(^{108m}Ag)	114	12.4

FW and blanket should be disposed of as single unit if palladium is preferred coating

Silver causes waste disposal problem if thickness on FW exceeds 1 μm

* 8 microns sticking on FW

Waste Disposal Rating (HIB)

Hohlraum Materials#			H/A/FW	H/A/FW/B
	---		0.24	0.04
Au/Gd (50:50)*	1.2 x 10^4	(^{158}Tb)	924	107
Au	0.87	(^{194}Hg)	0.28	0.043
Pb	3.6	(^{208}Bi)	0.5	0.068
Hg	0.4	(^{194}Hg)	0.25	0.04
Ta	0.06	(^{182}Hf)	0.22	0.04
W	1.03	(^{186m}Re)	0.3	0.045
Pb/Ta/Cs (45:20:35)	1.5	(^{208}Bi)	0.34	0.05
Hg/W/Cs (45:20:35)	0.26	(^{194}Hg,^{186m}Re)	0.24	0.04
Pb/Hf (70:30)	2.9	(^{208}Bi)	0.44	0.06

Gadolinium causes waste disposal problem if thickness on FW exceeds 10 μm

* atom %
\# Assuming 1 mm sticking on FW

Conclusions

- **Exclude Silver and Gadolinium from the list for generating high level waste**
- **No waste disposal problem identified for:**
  - **Au, W, Pb, and Pt for Laser target coatings**
  - **Au, W, Pb, Hg, Ta, Hf, and Cs for HIB hohlraum walls**
- **Palladium coating can be used for laser target if FW and blanket are disposed of as single unit to meet LLW requirement**
- **Considerations other than activation (e.g., target performance, fabrication, dose during accidents, etc) may further limit materials choice**
- **Cost penalty (≤ 5% change in COE) associated with exclusion of material(s) should be evaluated**