Neutronic Behavior of SMART-ATFs Nuclear Fuel

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Outlines

1. Objective
2. Accident Tolerant Fuel (ATF)
3. SMART Reactor

Conclusion

Objective

Neutronic parameters of SMART modified core will be assessed using MCNP 6.1 code through:

- Criticality,
- Inventory and,
- Radioactivity.

Accident Tolerant Fuel (ATF)

- As commercial zirconium clad alloys under severe accident interacts with steam at high temperature; it could affect the nuclear fuel integrity.

$$Zr + 2H_2O \rightarrow ZrO_2 + 2H_2 +\ \text{Exothermic heat (Q = 190 kJ/mol)}$$

- After Fukushima Daiichi NPP accident, extensive research studies started of ATF performance behavior with the purpose to:
  - Improve fuel performance during normal operation and accident scenarios - LOCA or RIA-
  - Tolerate the loss of active cooling in a reactor core
  - Increase safety margin for nuclear fuel
  - Higher thermal conductivity, for dispersion fuels, (SiC matrix)
  - Reduce the oxidation and hydrogen generation.
  - Reduce the fuel cycle cost
  - Fuel stability with high burn up, (accommodation of fission products is high)

SMART

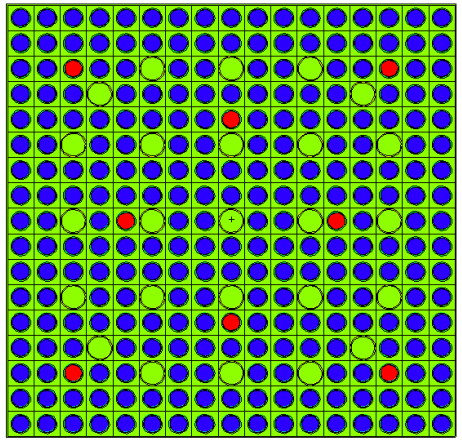
SMART (System-integrated Modular Advanced Reactor) is a small-sized advanced integral PWR with 330 MW_{th} and developed by **K**orea **A**tomic **E**nergy **R**esearch **I**nstitute “KAERI”.

SMART is a multi-purpose SMR used for process heat for industries and small isolated grids, district heating, sea water desalination and electricity production.

SMART has 57 fuel assemblies. Each fuel assembly is arranged in 17x17 square array, fuel rods contain a mixture of UO_2+Gd_2O_3 that known as IFBA. Its cycle length is 36 months, and the average discharge burnup is 36 MWd/kgU.

SMART- modified core

The modified core was loaded with MOX fuel (U+Pu) O_2 with 7% Pu- fissile content coated with Zr_2B as an IFBA with HANA-4 cladding.



8 IFBA in FA

		4 IFBA	8 IFBA	4 IFBA				
	8 IFBA	20 IFBA	24 IFBA	20 IFBA	8 IFBA			
8 IFBA	20 IFBA	12 IFBA	8 IFBA	12 IFBA	20 IFBA	8 IFBA		
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		8 IFBA	20 IFBA	24 IFBA	20 IFBA	8 IFBA		
			4 IFBA	8 IFBA	4 IFBA			

SMART Core Configuration

IFBA: Integral Fuel Burnable absorber
HANA cladding: **H**igh performance **A**lloy for **N**uclear **A**pplication

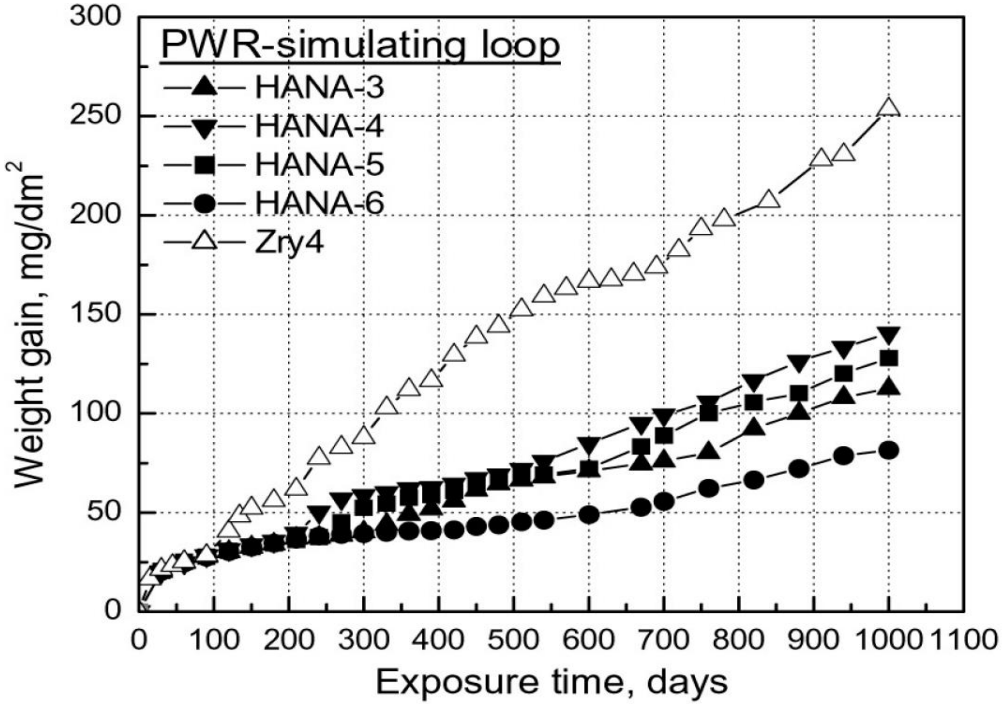
HANA Cladding

- HANA was developed by KAERI and KNFC. It was tested to sustain high discharge BU to more than 70GWd/MTU at Halden research reactor .
- The out-of-pile and in-pile properties were evaluated for the manufactured HANA claddings.

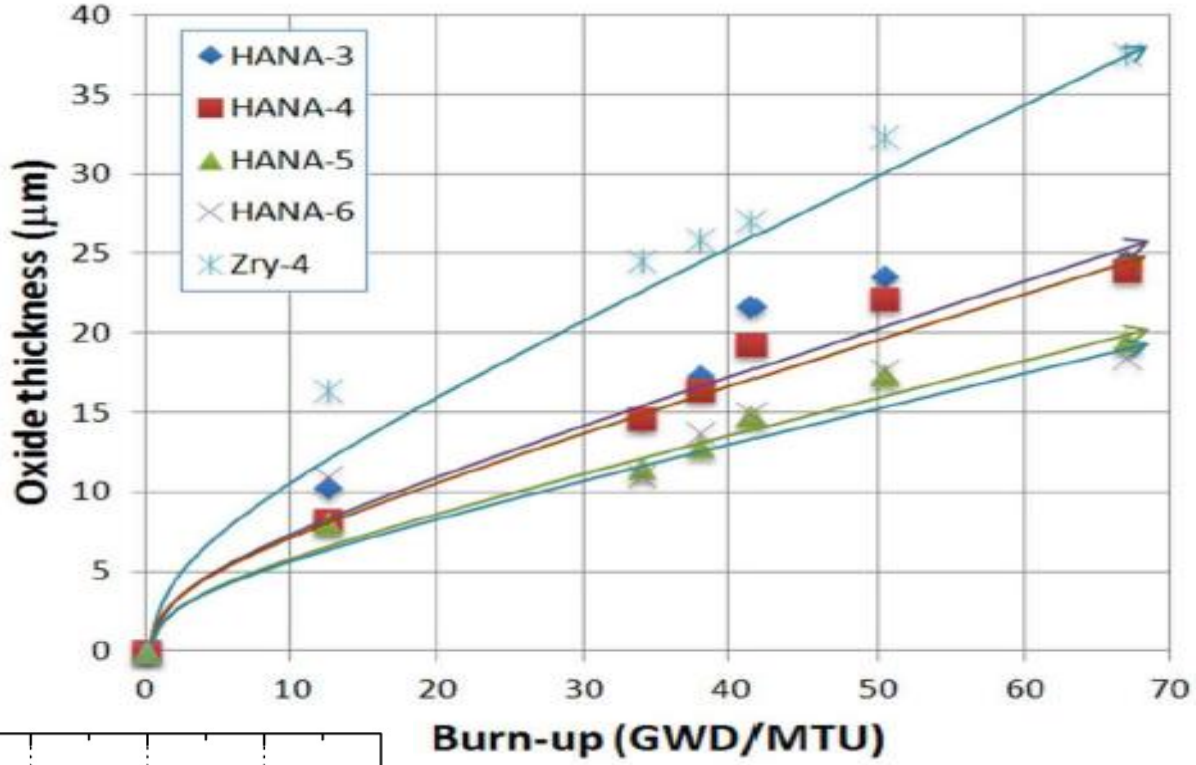
Alloy	**Chemical composition (wt.%)**
HANA-3	Zr-1.5Nb-0.4Sn-0.1Fe-0.1Cu
HANA-4	Zr-1.5Nb-0.4Sn-0.2Fe-0.1Cr
HANA-5	Zr-0.4Nb-0.8Sn-0.35Fe-0.15Cr-0.1Cu
HANA-6	Zr-1.1Nb-0.05Cu

KNFC: Korean **N**uclear **F**uel **C**ompany

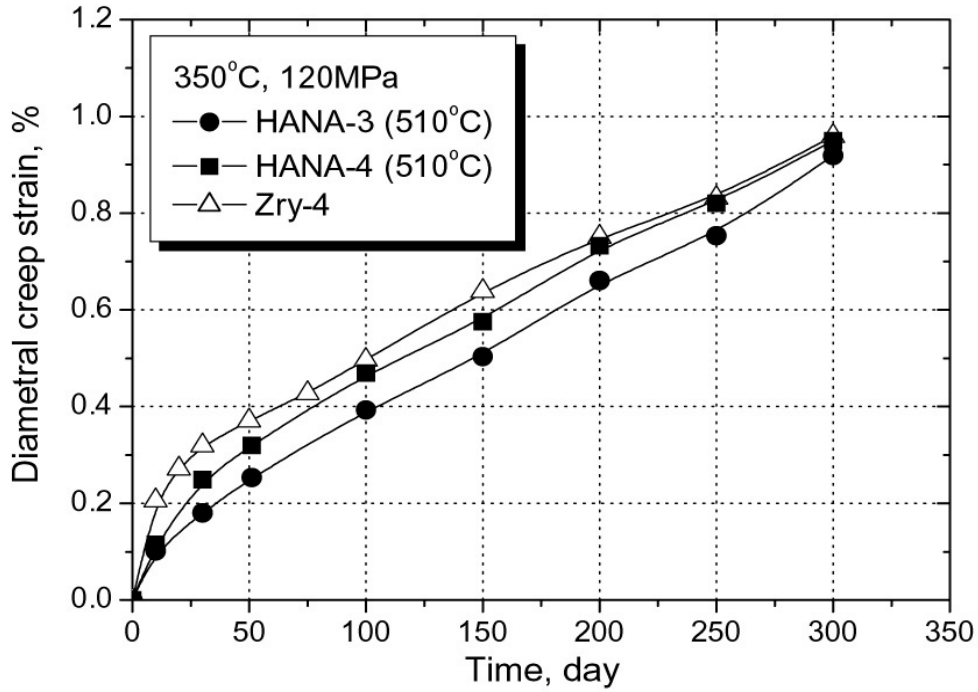
Corrosion Behavior

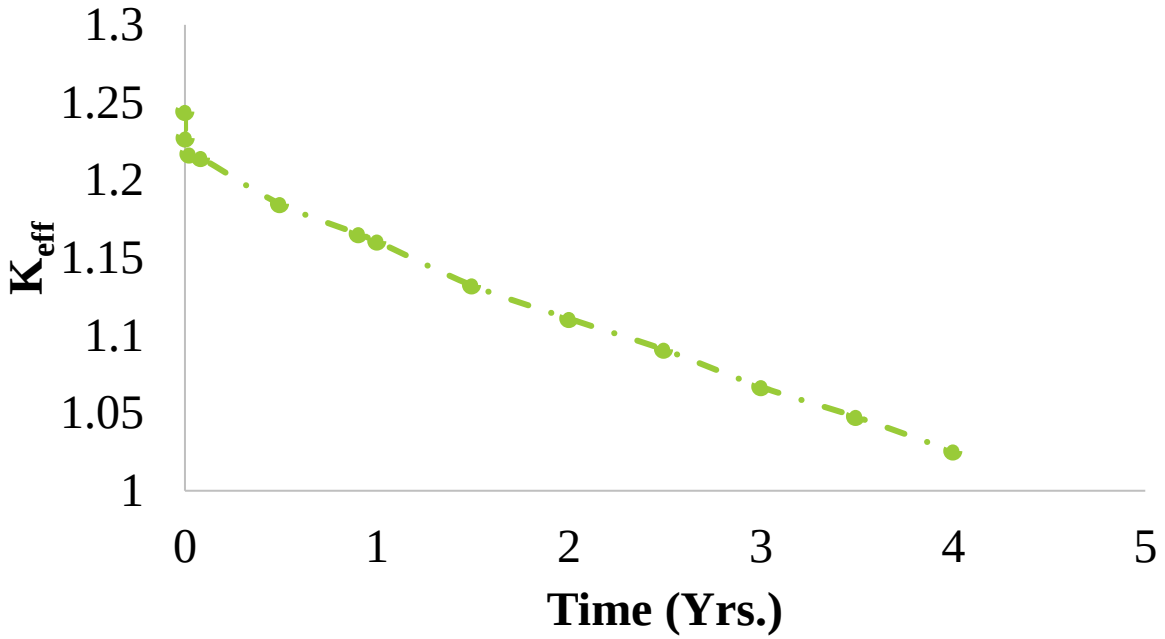


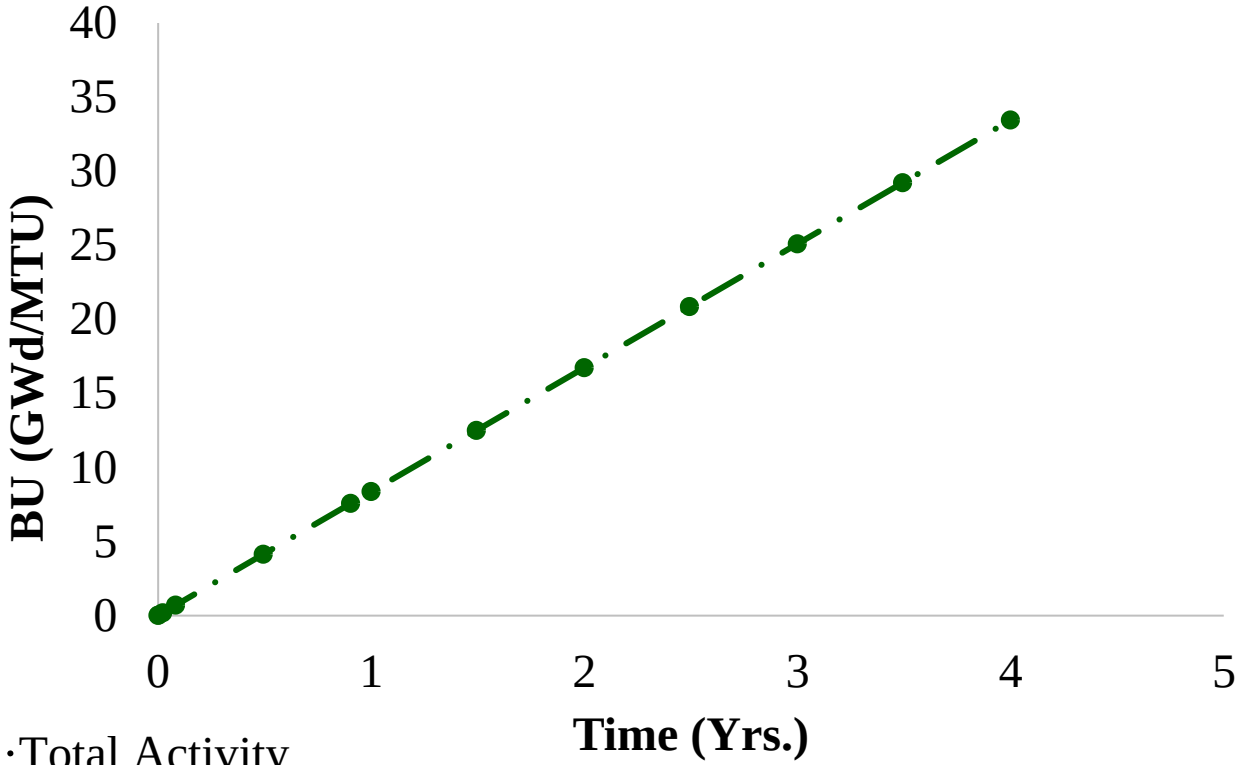
Oxidation Thickness

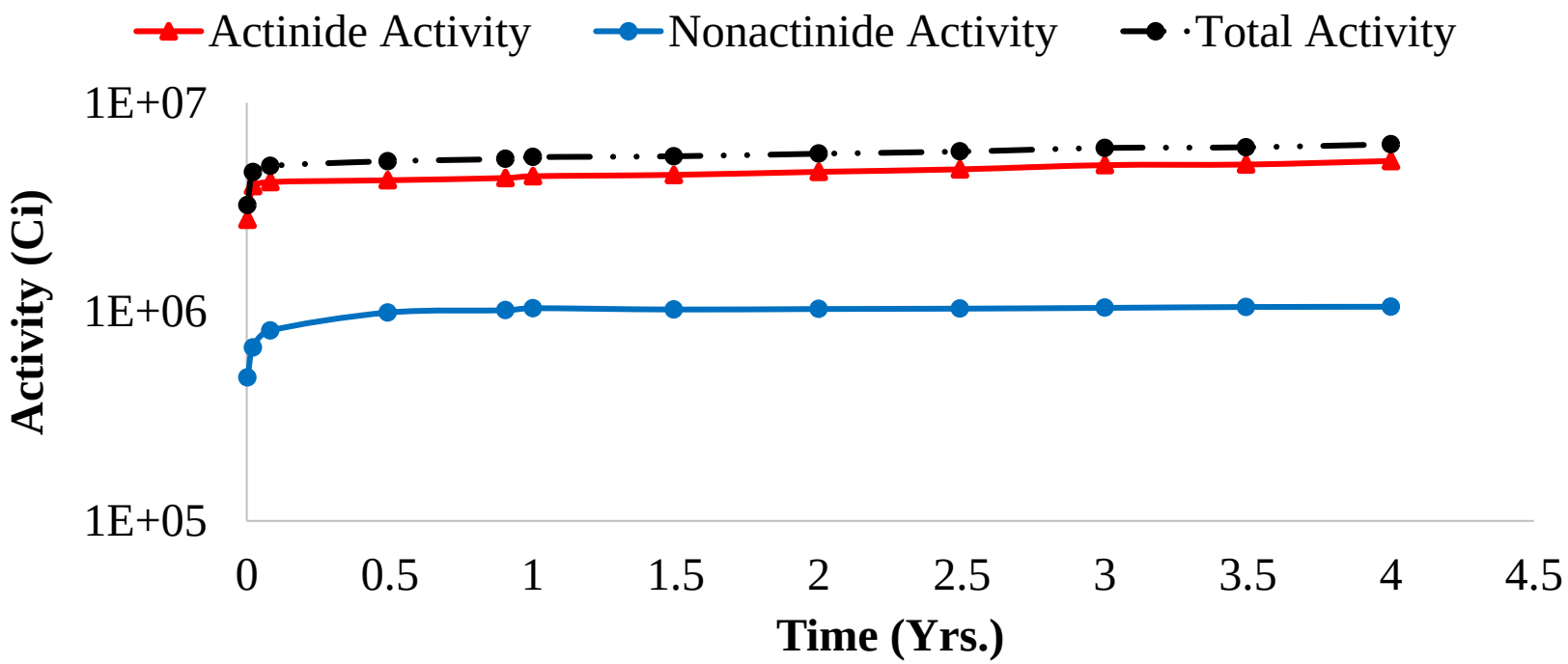


Creep Test

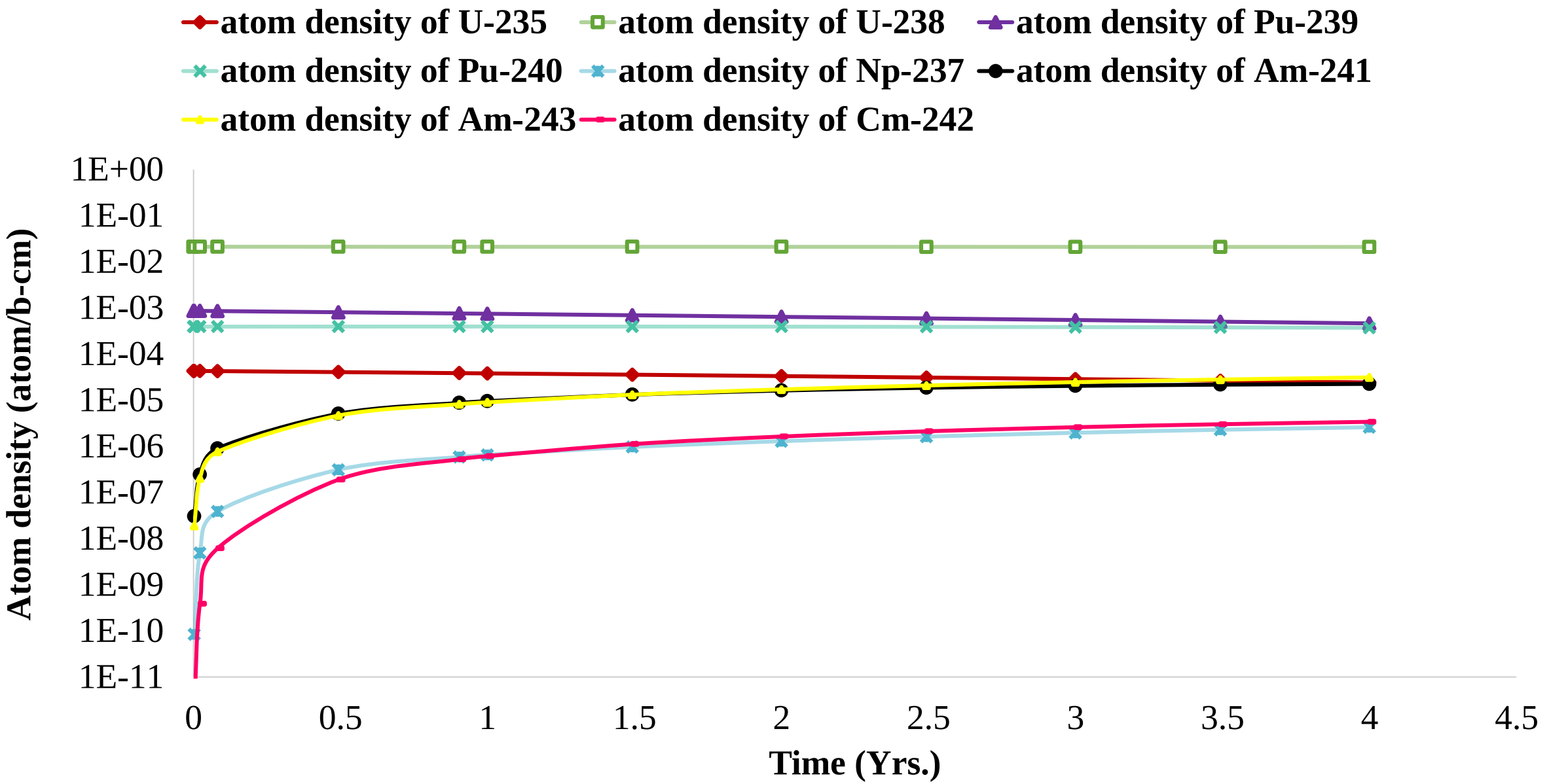








Safety parameters of MOX fuel assembly



Atom density of Fission Products per assembly

Conclusion

- SMART modified core provide a long-time irradiation and high burn up
  - Cycle length is 4Yrs.
  - BU per assembly is 33.5 GWD/MTU
  - Total activity of spent fuel assembly was 6.34E+06Ci
  - Plutonium inventory content was reduced from 1.26E-03 to 8.31E-04 atom/b-cm.
- The modification reduces the amount of high-level waste of fission products and the radiotoxicity amount.
- Promoting MOX as an ATFs with HANA cladding into the nuclear industry of GENIII+, the sustainability of clean nuclear power can be achieved.

Thank you