Partitioning of Fissile Materials and Radiotoxic Materials from Spent Nuclear Fuel.

RIAR current and future activities

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9th IEM on Actinide and Fission Products Partitioning and Transmutation

Nimes, France, 25-29 September 2006

Russian programs on partitioning (some history)

In 1980-s – partitioning of Np from SNF was implemented into MAYAK Plant, separation of Am+Cm/REE and extraction of Cs+Sr were tested on real HLW

1993-2001 – Minatom Program "RECYCLE":

Participants: MAYAK Reprocessing Plant, Bochvar Institute, Kurchatov Institute, **RIAR**, IPPE, Moscow Institute of Physical Chemistry of RAS

- **Main tasks**
  - Separation and collecting of **I, Tc, Am**
  - Development of reactor conceptions of FP and MA incineration (transmutation)

1999 (until now) – FS and R&D of advanced RT-2 Reprocessing Plant Concepts and following Concepts for future LWR reprocessing plant

- Technologies
  - Advanced (or extended) PUREX, Fluoride Volatility technology, **DDP**, supercritical CO2 extraction, others

Russian programs on partitioning (some history)

2003-2006 – Preparation of new Russian Program "Construction of the BN-800 FR with CFC demonstration"

Start of Pu fuel cycle in Russia (MOX fuel) and utilization of accumulated "power grade" Pu

- Possible technologies for MOX fuel production
  - RIAR – pyrochemical + vi-packing with Am burning
  - Bochvar Institute – codeposition GRANAT technology and pelletizing
- Possible technologies for MOX fuel reprocessing demonstration
  - RIAR – pyrochemical reprocessing with MA partitioning and vi-packing
  - Bochvar Inst. – simplified PUREX, GRANAT and pelletizing (no partitioning)

- Russian State Duma supported this Program as innovative Program

2000 (until now) – Program of BREST fast reactor

- Main approaches to BREST fuel cycle
  - So-called "on-site" closed fuel cycle (i.e. location of fuel cycle facility on the same site with reactor unit) Pyrochemical reprocessing
  - Homogeneous recycle of MA in frame of BREST close fuel cycle

Russian programs on partitioning

2006

Partitioning will be included into new integrated conception:

NEW TECHNOLOGICAL PLATFORM

Commercial Fast Reactors with Closed Fuel Cycle (included P&T)

Comments:
New look on Advanced Fuel Cycle Concepts

- PARTITIONING is most important component of FC
- not Spent Fuel REPROCESSING,
- **but Spent Fuel PARTITIONING**,
- i.e. P&T Nuclear Fuel Cycle
- It include: CLOSING, PARTITIONING, RECYCLING, IRRADIATION/TRANSMUTATION and WASTES TREATMENT
- In such approach the REACTOR units are only one of peer components of Fuel Cycle

International cooperation in the field of advanced FC. Russian research needs. RIAR view

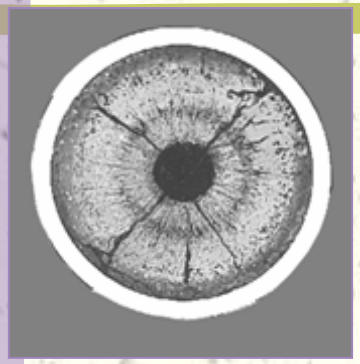
	Fuel production		Repro-cessing	P&T	Advan-ced	Cladd. Materials	Concept Studies	Funda-mental Studies
	MOX	other						
China	pellet/ vibro?	-	-	-	-	-	-	-
France	-	MA oxide	-	Am,Cm recovery	Pyro/ RTIL's	+ ?	FS	Cm
India	-	Met/Th? Carbide?	?	?	?	?	?	?
Japan	MOX vibro	-	MOX / nitrides?	MA/REE separ.	Pyro/ Fluorex/ $MoO4^{2-}$	ODS	FS	MA
Korea	-	MA met. ?	Metalliz. / vibro-DUPIC	MA/REE separ.	Pyro	+ ?	-	-
US	Vibro?		-	-	-	-	-	RTIL's
EU	-	MA nitride	-	-	MSR fuel	-	-	Cm

Blue – current and past activities, **red – planning, discussing and desired**, black – without RIAR, *but in any case – in all topics and cases RIAR is ready to participate*

Since 1992 RIAR has been performing the R&D DOVITA program

- **D**ry technologies for MA fuel reprocessing and preparation
- **O**xide fuel application as the most widely studied one
- **V**ibropacking automated technology of the fuel pin production
- **I**ntegrated disposition of fuel reprocessing and fuel element refabrication facilities on the same site with the reactor
- **TA** The whole complex of approaches will permit a creation of the compact plant for Transmutation of Actinides

RIAR DOVITA experience in adding of minor actinides in fuel compositions



Microstructure and macrostructure of irradiated (U, Np)O_2 fuel, 19% burn-up

- ✓ Pyrochemical technology of adding Np into oxide fuel (5-20%) has been developed
- ✓ Performance of vi-pack (U,Np)O_2 fuel has been validated experimentally to a burn-up of ~20% in BOR-60
- ✓ No evidence of significant difference in performance of (U,Np)O_2 fuel pins with compared with UO_2 or MOX fuel has been noticed
- ✓ Pyrochemical process of Am codeposition with MOX fuel (2-5%) has been developed
- ✓ Methods of Am/REE separation in melts has been tested (AMBOINE-1)
- ✓ Special vi-pack targets containing Am oxide with UO2 or inert matrix have been developed (AMBOINE-1)
- ✓ Transmutation of Np, Am, Cm is being studied in BOR-60

Oxides with MA. AMBOINE-1 Program in collaboration with CEA

The Program has started in December 2001.

- Study of Am recycling and separation from RRE by pyrochemistry
- Development and fabrication of BOR-60 fuel pins with $(UAm)O_2$ in core and with $UAmO_2$+MgO in axial blankets.

The Program is completed.

- The BOR-60 experimental fuel pin has been fabricated.
- Investigations on Am/REE separation by selective oxide precipitation in molten salts have been carried out.

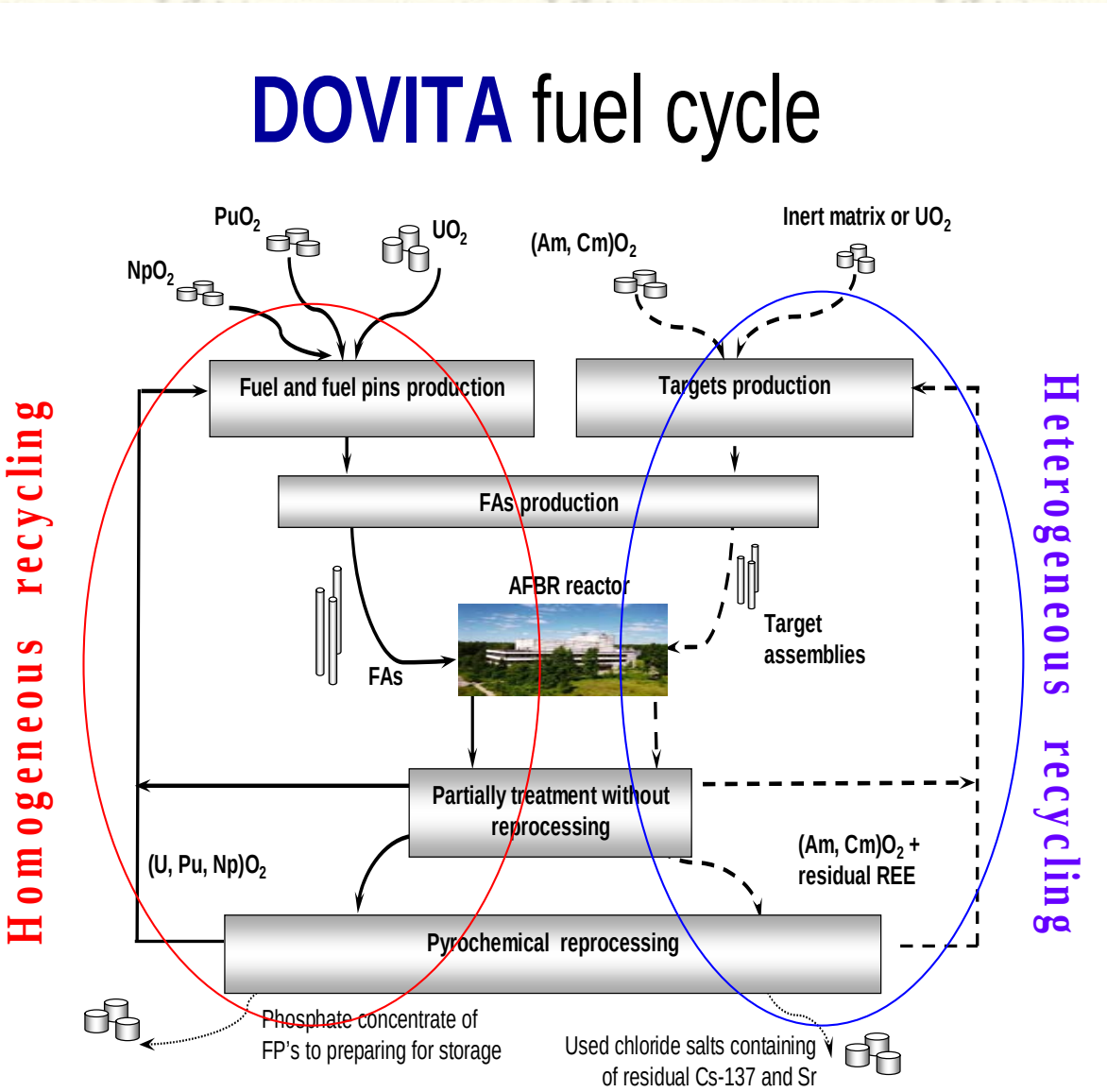
The possibility of the Program continuation – AMBOINE-2 - including comparative study of different fabrication techniques (vi-pack, sol-gel, GRANAT) and further irradiation in the BOR-60 reactor is under discussion.

Main part of RIAR activities related to P&T are carrying out in frame of ISTC

Integrated projects
- ISTC 17
- ISTC 272

Pyrochemical partitioning
- ISTC 279
- ISTC 3231p
- ISTC 3261

Targets with MA
- ISTC 2680



Nitrides with MA. "MATINE: Study of MA Transmutation in Nitrides: modeling and measurements of out-of-pile properties". ISTC Project#2680

- On May 2004 the Project has started.
  - Participants - IPPE, Bochvar Institute, RIAR.
  - Collaborators - CEA (France) and KTH (Sweden).
- Objectives
  - performance modeling of (Pu,Am,Cm,Zr)N (with ZrN=55-65%, Pu/Am/Cm=40/50/10) fuel under irradiation in ADS fast spectrum up to high burn-up in order to compare relative performance of helium, sodium and lead-bismuth bonded pins.
    - Two different fuel forms (pellet and vibropacked).
    - Experimental study of PuZrN properties .
- The Program continuation – ISTC Project #3608 MATINE-2 - including in particular the fabrication of (Pu,Am,Cm,Zr)N micro-targets (containing about 1 g of Cm-244) by vi-pack technique and further irradiation in the BOR-60 reactor - is under preparation.

ISTC Project # 3261

Study of Cm thermodynamics in molten chlorides

Objectives

Reactions of formation for oxygen Cm compounds

- equilibrium constants for reactions of Cm oxygen compounds formation versus temperature;
- equilibrium constants for reactions of Cm oxygen compounds formation versus the inverse effective radius of solvent cathion

Reactions of formation for oxygen-free Cm compounds

- standard potential for redox pair versus temperature;
- standard potential for redox pair versus the inverse effective radius of solvent cation

Simulation of Cm behavior in molten chlorides

Pourbaix diagrams

ISTC Project # 3261

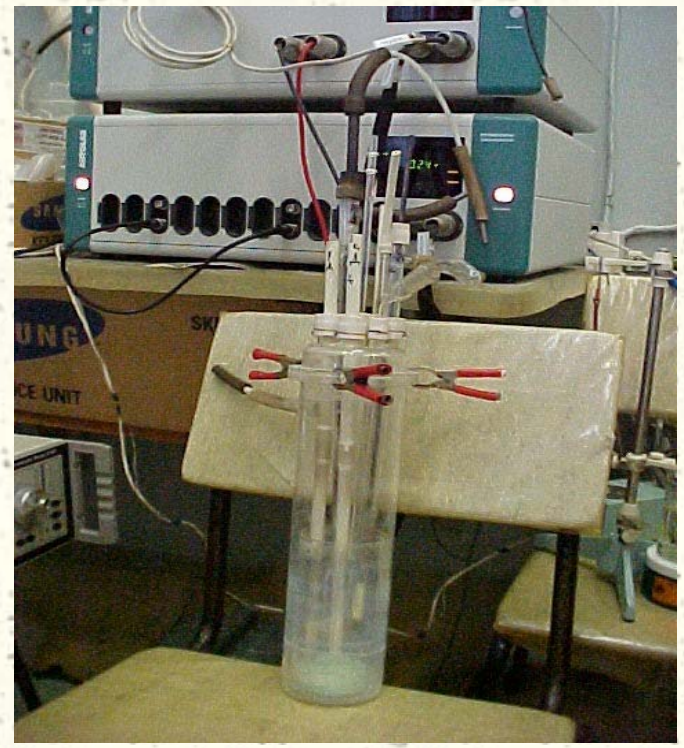
Study of Cm thermodynamics in molten chlorides

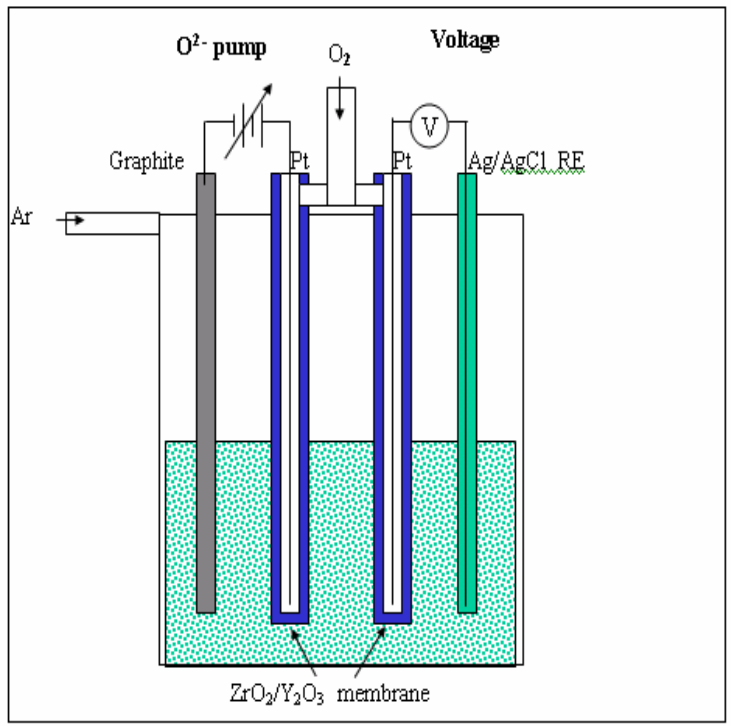
Investigation methods

- **Thermodynamics of formation for oxygen Cm compounds**

Potentiometric titration with oxygen pump

<u>advantage</u> - small concentration of Cm in melt





ISTC Project # 3261

Study of Cm thermodynamics in molten chlorides

Investigation methods

- Thermodynamics of formation of oxygen-free Cm compounds

Method of EMF

Cyclic Voltammetry

Chroho Potentiometry

necessary request - Cm concentration in melt must be more than 3%wt
(interaction of Cm with melt is negligible)

- Simulation of Cm behavior in molten chlorides

ISTC Project # 3261

Study of Cm thermodynamics in molten chlorides

Conditions

Molten salts
LiCl-KCl, NaCl-CsCl, NaCl-KCl

- Temperature range
450°C - 850°C

- Cm content
10^{-4} - 10^{-2} mol/kg (Potentiometric titration)
(2 - 5)*10^{-1} mol/kg (EMF, Cyclic Voltammetry, Chroho-Potentiometry)

Collaborators – ITU, CIEMAT, KTH, (CEA)

ISTC Partner Project # 3231 (RIAR-KAERI)

Separation of MA from REE on a liquid metallic cathode in molten chlorides

Objectives:

- Task 1: Polarization curves on electrodeposition of actinides and lanthanides on bismuth and cadmium cathodes
- Task 2. Electrodeposition tests for effective separation of actinides and lanthanides on liquid-metal cathodes
- Task 3. Effect of uranium content in molten salt to electrodeposition and separation of actinides and lanthanides on liquid metallic cathode

-Actinides - U, Np, Am, Cm,

-REE - Nd, La, Ce

-Systems: - Bi / LiCl-KCl and Cd / LiCl-KCl

Future ISTC proposals for studies

Continuation of recently investigated subjects:

Molten Salt chemistry of Am and Cm for fluorides

- Phase II for ISTC 3261

Partitioning of MA/REE in molten fluorides

with liquid cathodes

Application of Room Temperature Ionic Liquids for Separation of TPE and REE

RIAR proposal for ISTC project

The R&D program includes the following stages:

- selection of the RTIL with a rather wide electrochemical window, study of its properties,
- study of solubility of the TPEs and REEs salts with different anions (NO^{3-}, Cl^-, F^-, CN^-) in the chosen RTILs
- study of composition of the complexes and electrochemical behavior of the TPEs and REEs in the chosen RTILs
- study of TPE and REE cathodic deposition in the alloy form with transient metals (Zn, Cu, Ni, Al and others) and/or on a liquid metallic cathodes (Ga, Hg)
- study of separation Al and actinides from Al-An-alloys by Al electrorefining process

ISTC Project proposals from RIAR: Preparation of monographs related to P&T and advanced fuel cycle

- V.Nickolaev, E.Karelin, R.Kuznetsov, Yu.Toporov. Technology of Transplutonium Elements – second edition and translation to English and publishing
- V.Radchenko, M.Ryabinin, etc. Physical Metallurgy of Transplutonium Elements – preparation of Russian and English editions
- A.Mayorshin Fuel elements with vibropacked oxide fuel – preparation of Russian and English editions
- O.Skiba, A.Bychkov, V.Ivanov. Pyroelectrochemical process in nuclear fuel cycle – preparation of Russian and English editions

Research area of pyrochemical (non-aqueous) methods for MA/FP partitioning development

Melts/ media	Electrochemical methods				Oxides Precipi-tation	Metalli-zation
	Liquid cathodes	Solid cathodes	Anodic dissolu-tion	E/Chem. oxide titration		
Chlorides	Cd, Bi, Ga	Al,	+	+	+	+
Fluorides	Bi, Ga, Al, Pb	-	+	+	+	-
Cl^- /F^-	Cd, Bi, Ga, Al, Pb	Al	+	+	+	-
Molibdates	-	+	-	-	+	-
RTIL	Ga, Hg	Zn, Cu, Ni, Al, …	+	-	-	-

+ Methods of Volatility of Fluorides and /or Chlorides

New Russian Initiative P&T Group

Main objective

- To establish New Russian National R&D P&T Program

Form of coordination and cooperation

- Multi-lateral Frame Agreement between different Russian R&D Institutes and Organization

Initiative Participants

- RIAR (Dimitrovgrad)
- Kurchatov Institute (Moscow)
- IPPE (Obninsk)
- JINR (Dubna)
- Chlopin Institute (Petersburg)
- …
- List is open ….