

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

## RIAR current and future activities



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## 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 CO<sub>2</sub> 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

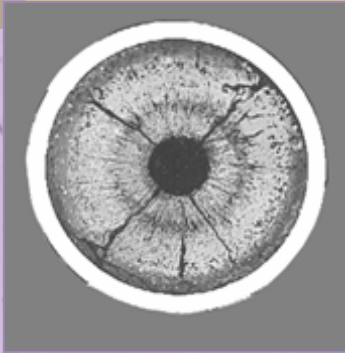
	Fuel production		Repro- cessing	P&T	Advan- ced	Cladd. Materials	Concept Studies	Funda- mental Studies
	MOX	other						
China	pellet/ vibro?	-	-	-	-	-	-	-
France	-	MA oxide	-	Am, Cm recovery	Pyro/ RTIL's	+ ?	FS	Cm
India	-	Met/Th? Carbide?	?	?	?	?	?	?
Japan	MOX vibro	-	MOX / nitrides?	MA/REE separ.	Pyro/ Fluorex/ MoO <sub>4</sub> <sup>2-</sup>	ODS	FS	MA
Korea	-	MA met. ?	Metalliz. / vibro- DUPLIC	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

- Dry technologies for MA fuel reprocessing and preparation
- Oxide fuel application as the most widely studied one
- Vibropacking automated technology of the fuel pin production
- Integrated 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<sub>2</sub> fuel, 19% burn-up

- ✓ Pyrochemical technology of adding Np into oxide fuel (5-20%) has been developed
- ✓ Performance of vi-pack (U,Np)O<sub>2</sub> 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<sub>2</sub> fuel pins with compared with UO<sub>2</sub> 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 UO<sub>2</sub> 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

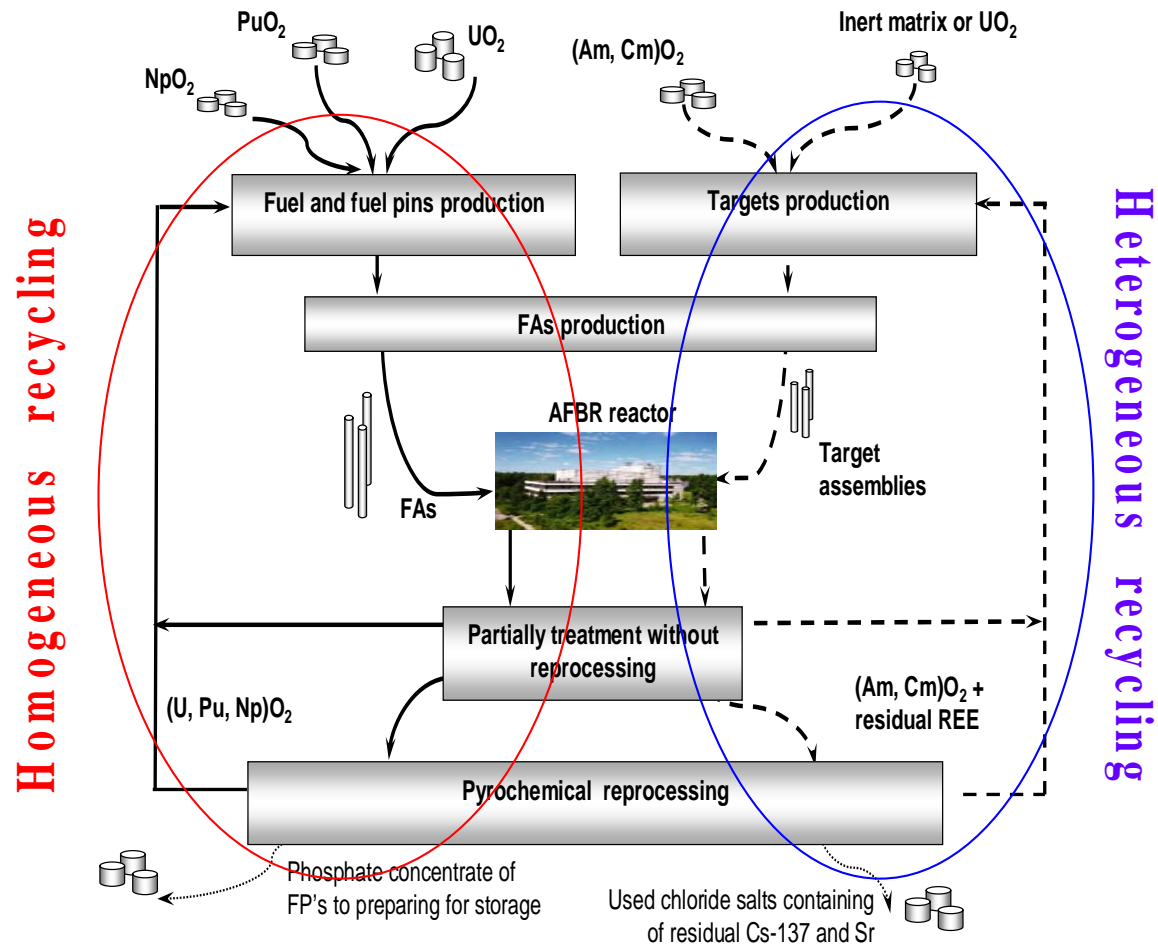
Pyrochemical partitioning

- # ISTC 279
- # ISTC 3231p
- # ISTC 3261

Targets with MA

- # ISTC 2680

## DOVITA fuel cycle



# 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.

# 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 cation

### 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

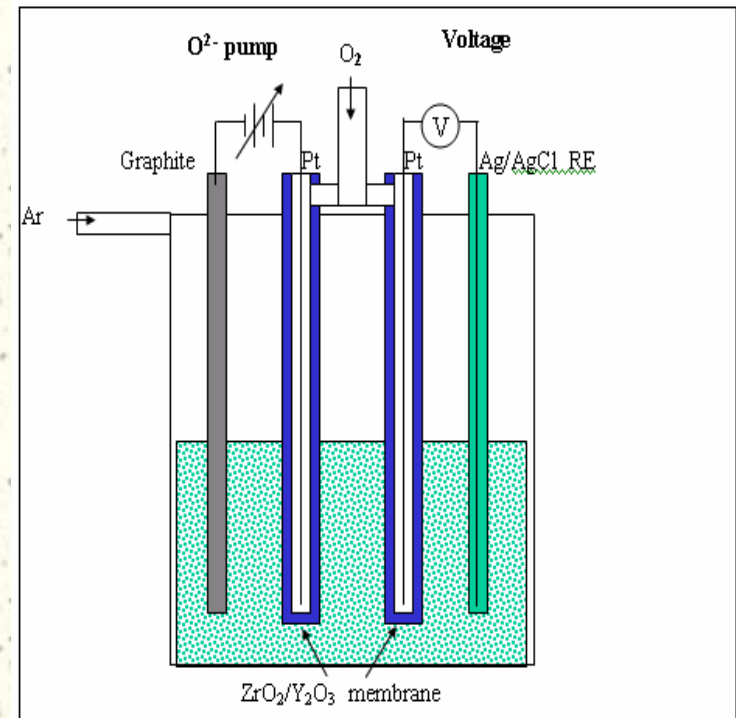
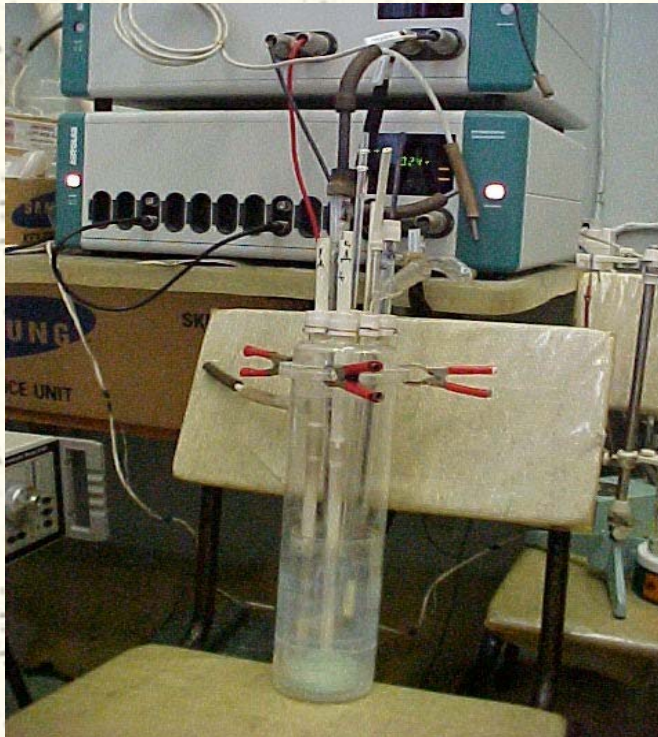
# ISTC Project # 3261

## Study of Cm thermodynamics in molten chlorides

### Investigation methods

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

Potentiometric titration with oxygen pump  
advantage - 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)

$(2 - 5) \cdot 10^{-1}$  mol/kg (EMF, Cyclic Voltammetry, Chrono-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 ( $\text{NO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{F}^-$ ,  $\text{CN}^-$ ) 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 Precipitation	Metallization
	Liquid cathodes	Solid cathodes	Anodic dissolution	E/Chem. oxide titration		
Chlorides	Cd, Bi, Ga	Al,	+	+	+	+
Fluorides	Bi, Ga, Al, Pb	-	+	+	+	-
Cl <sup>-</sup> /F <sup>-</sup>	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 ....