Vibropac MOX-Fuel For Fast Reactors – Experience and Prospects

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Main tasks

- In the USSR the activity in the field of vibropac fuel development and production started in late 60-s of the previous century as a logic end of Closed Fuel Cycle for Fast Reactors together with “dry” reprocessing
  - Power-generating plutonium as a first stage of Closed Fuel Cycle for Fast Reactors creation

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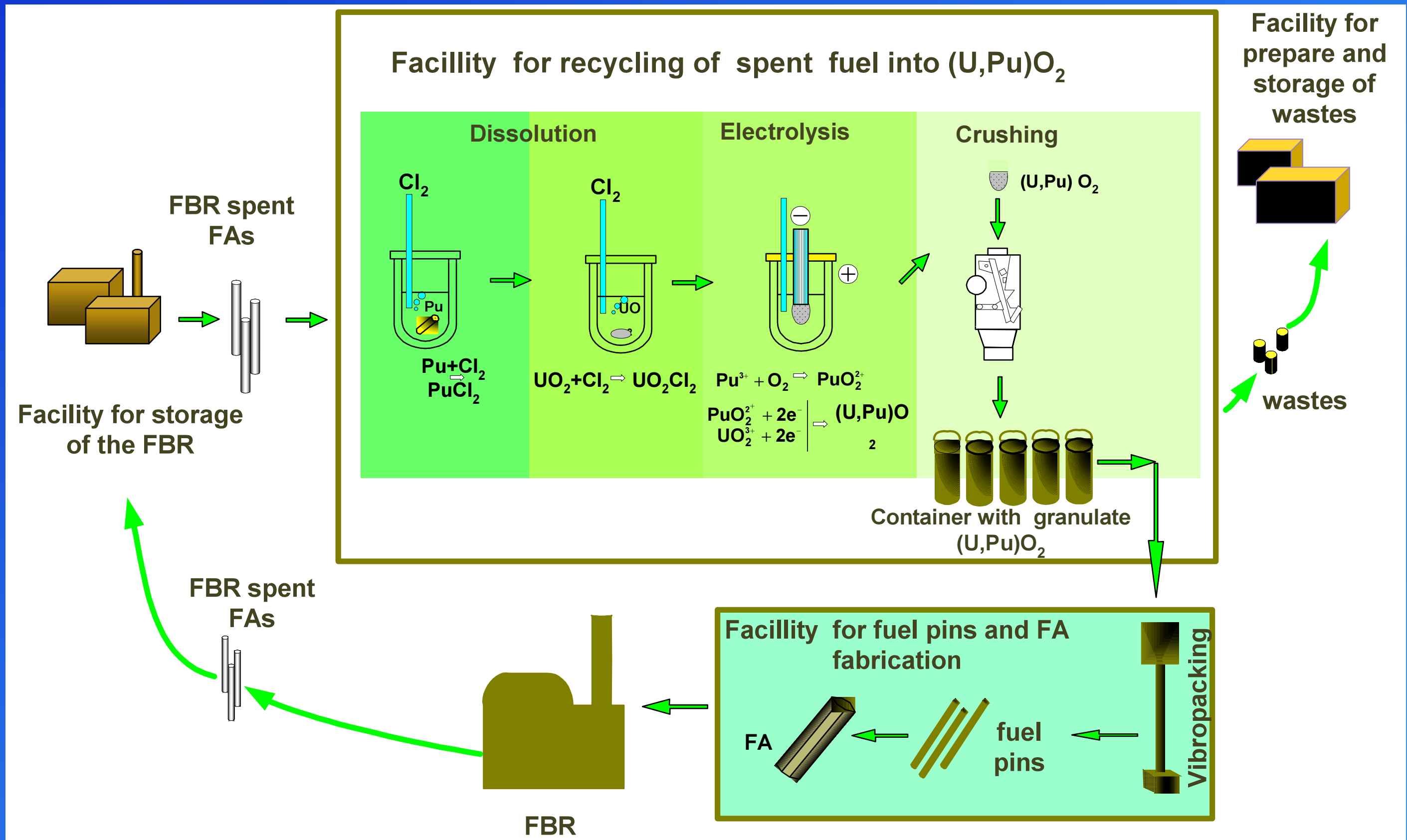
Fuel Cycle for Fast Reactors



First steps, 70-s

- Laboratory facilities for granulated fuel production and fuel pins manufacturing
- Requirements for fuel pins formalization
- Irradiation tests of vibropac fuel in different reactors
- Start of the OREL facility construction for BOR-60 fuel production

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History, 70-s...80-s

- OREL facility: start-up;
- Vibropac fuel is a standard fuel for the BOR-60 reactor;
- Vibropac fuel irradiation in the BN-350 reactor;
- Substantiation of vibropac MOX-fuel for fast reactors is completed.

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Vibropac fuel in BOR-60

- Problems of fuel pins serviceability during the initial period:
  - intercrystalline corrosion of the cladding
  - lower smear density
  - insufficient reliability of the welded joint "cladding –upper endplug‟
- Solution of problems
  - Getter additives in the form of metal U particles- 5-10 wt. %
  - Granulated fuel improvement
  - special preparation of cladding and granulated fuel

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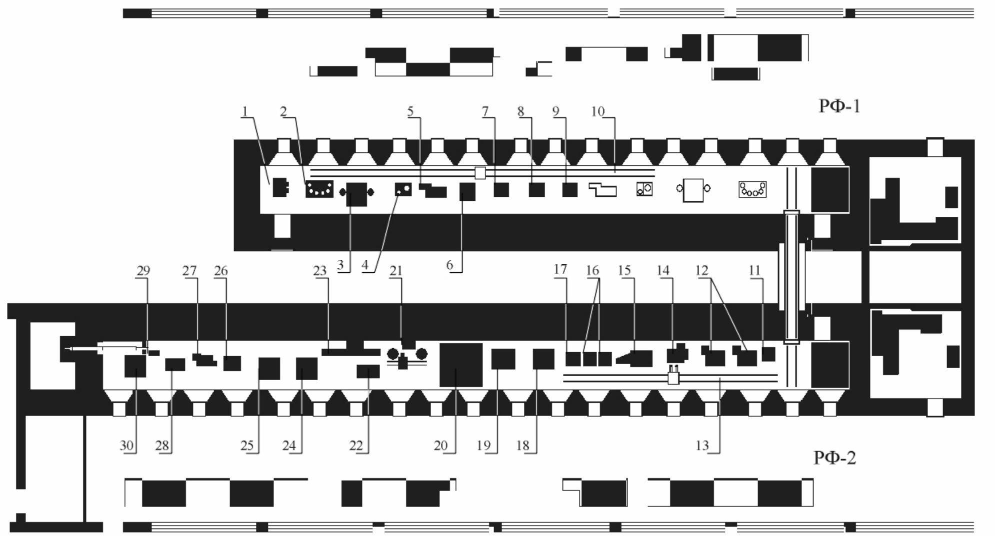
OREL facility



. Схема расположения оборудования для изготовления твэлов и ТВС в условиях защитных камер РФ-1 и РФ-2
1- бокс разделки твэлов; 2- подготовка гранулята; 3- виброуплотнение гранулята;
4- загрузка экрана; 5- загрузка верхней заглушки; 6- герметизация твэла;
7, 8, 9, 11, 16, 17, 18, 19, 20- хранение твэлов; 10, 13- транспортная система твэлов;
12- контроль герметичности твэлов; 14- контроль распределения компонентов топливного сердечника твэлов; 15- контроль геометрических размеров твэлов и их визуальный осмотр; 21- сборка ТВС; 22- сварка ТВС; 23- кантование ТВС;
24- контроль герметичности твэлов в составе ТВС; 25- измерение гидравлических характеристик ТВС; 26- контроль сварного шва; 27- визуальный осмотр ТВС;
28- радиографический контроль сварного шва; 29- сварка контровочной гайки;
30- хранилище ТВС.

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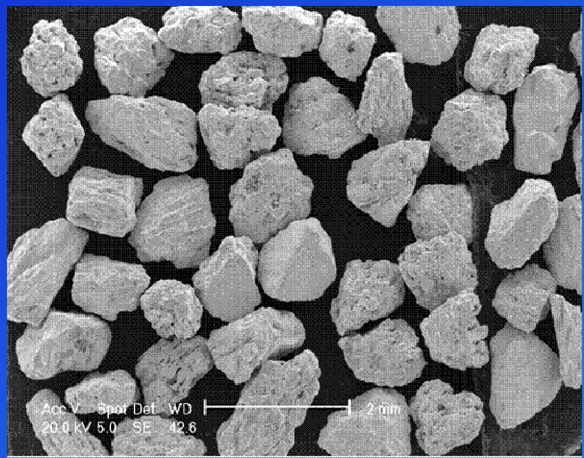
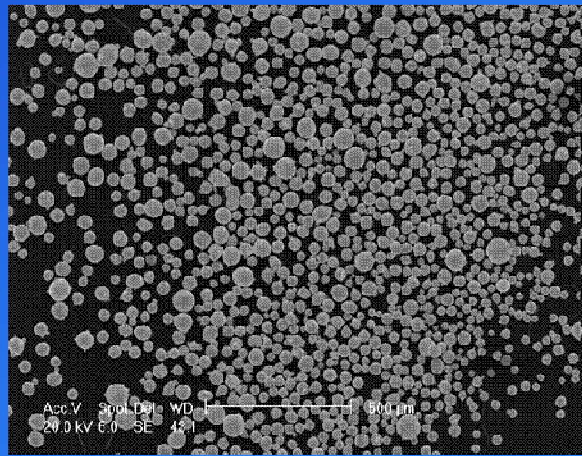
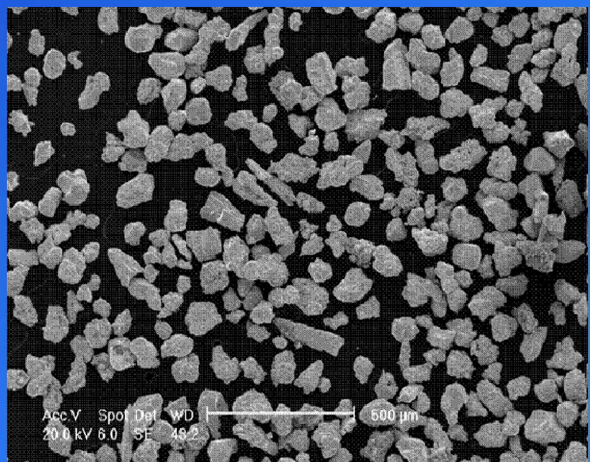
Granulated MOX-fuel







Metal content, %	87,75
Pycnometric density, g/cm^3	
O/M ratio	$2.00^{\pm 0.01}$
Impurities, %	
-chlorine-ion	0.005
-Carbon	0.015

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BOR-60 Vibropac fuel

- About 1000 standard and experimental FA irradiated
- Different cladding and wrapper materials used
- Different types of vibropac fuel
  - UO_2, $UPuO_2$, UO_2+PuO_2,
  - MOX-fuel with 45 PuO_2 %,
  - Fuel with 5 % of NpO_2,
  - Recycled fuel with 8 % of FP

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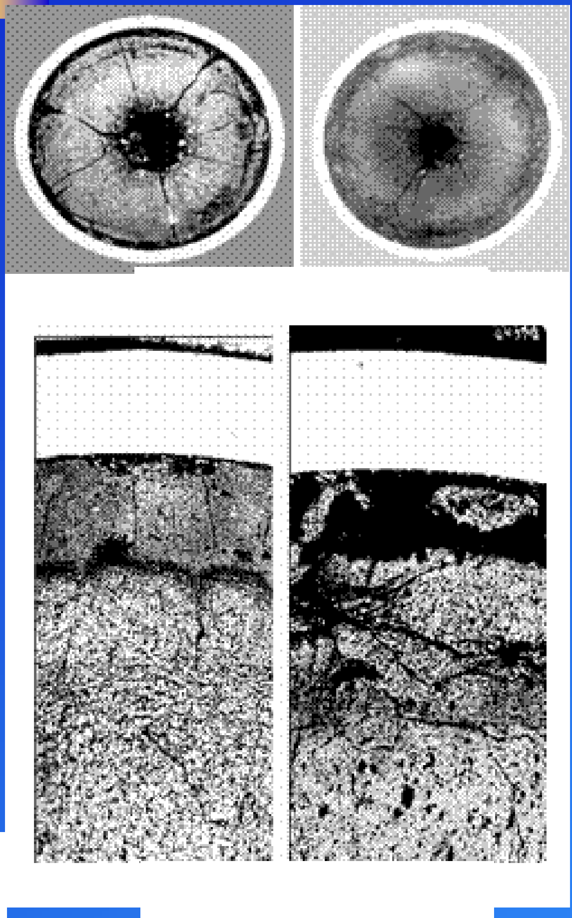
BOR-60 experimental fuel



Macro- and microstructure of cross section of high-temperature part of fuel rod at a burnup of 32 % h.a.:

fuel 95 % UO_2 + 5 % PuO_2

fuel 78 % UO_2 + 22 % PuO_2

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BOR-60 vibropac fuel

- Maximum parameters
  - Cladding temperature – 722℃
  - Linear power – 502 W/cm
  - Burnup – 32 % h.a.
- No corrosion internal surface of cladding. No limit burnup. Limit of lifetime – damage doze for structural material

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History, 80-s

- Optimization of fuel pins design and fabrication technology;
- Reconstruction of the OREL facility and creation of Semi Industrial Complex (SIC);
- Start of vibropac fuel irradiation

  in the BN-600 reactor.

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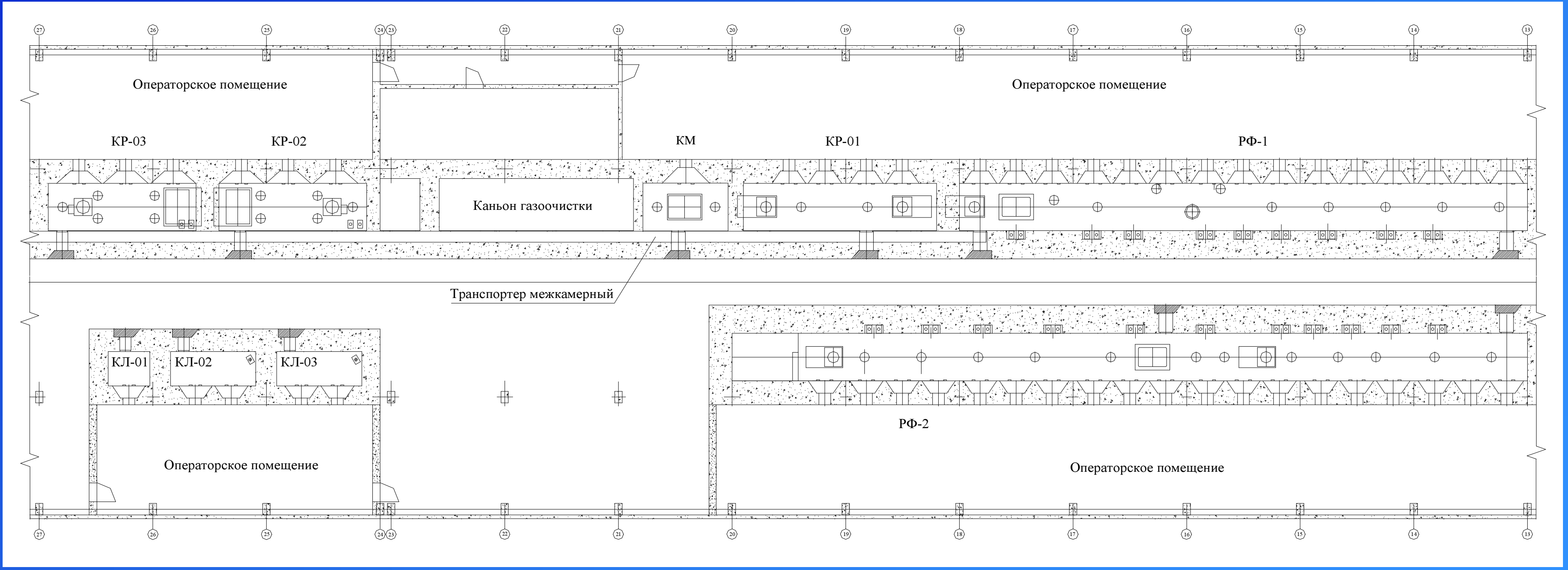
Semi Industrial Complex



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Vibropac MOX-fuel in BN-600 First stage.

Serial number of FA	NF0187	NF0287	NF03…NF06
Year of production	1987		1989…1990
Getter content, %	10		
Plutonium content, %	22…28		~30
Effective density, g/cм^3	8,9…9,1		8,8…9,2
Cladding material	Steel EP-172		Steel ChS-68
Wrapper material	08Cr16Ni11Mo3Ti		05Cr12Ni2Mo
Linear heat rate, kW/м	41		47
Cladding temperature, °C	670		680…698
Damage dose, dpa	52,3	77	64…70
Burnup, % h.a.	6,8	9,6	9,0…9,8

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Vibropac MOX-fuel in BN-600 Second stage.

Serial number of FA	01.99… 03.99	04.02… 06.02	07.03… 09.03	10.05… 12.05	01.05… 12.06
Year of production	1999	2002	2003	2005	2006…2007
Getter content, %	7				
Plutonium content, %	23…25				
Effective density, g/см³	8.9…9.2				
Cladding material	ChS-68				
Cladding size, mm	6,6				6,9
Wrapper material	05Cr12Ni2 Mo	EP-450			
Linear heat rate, kW/м	31,8…42,5	35,3…45,3	30,9…33,9	38,0…38,9	28,8…42,0
Cladding temperature, °C	661…705	643..694	613…659	647…694	660…700
Damage dose, dpa	73,6…77	60,3…61,7	71,8…77,1	75,5…76,1	59,4…81,4
Burnup, % h.a.	10,1…10,5	8,7…9,0	9,9…10,6	10,1…10,2	7,1…9,8

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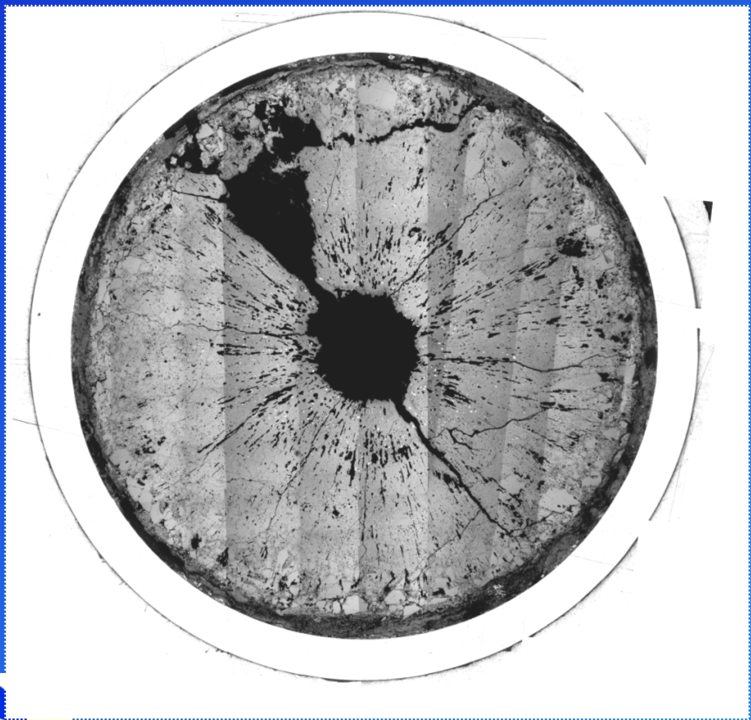
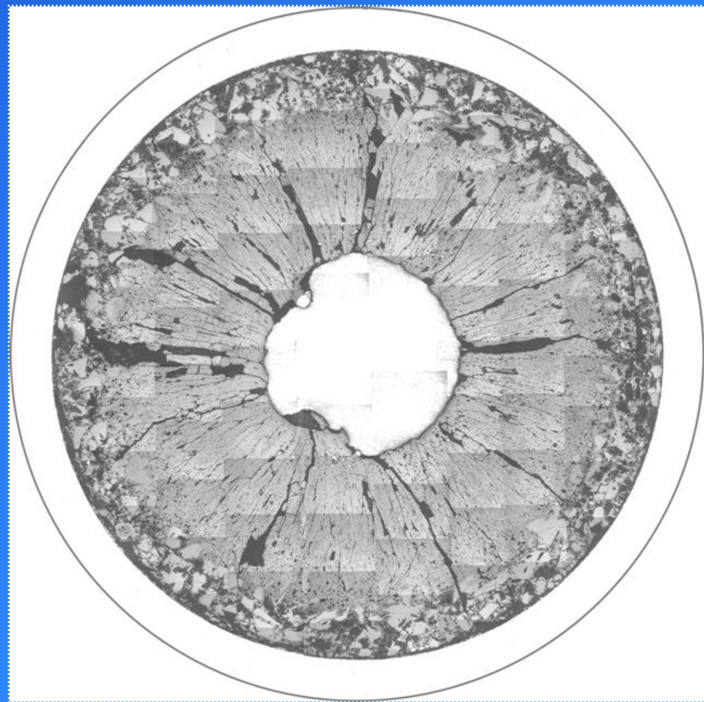
Vibropac fuel in BN-600





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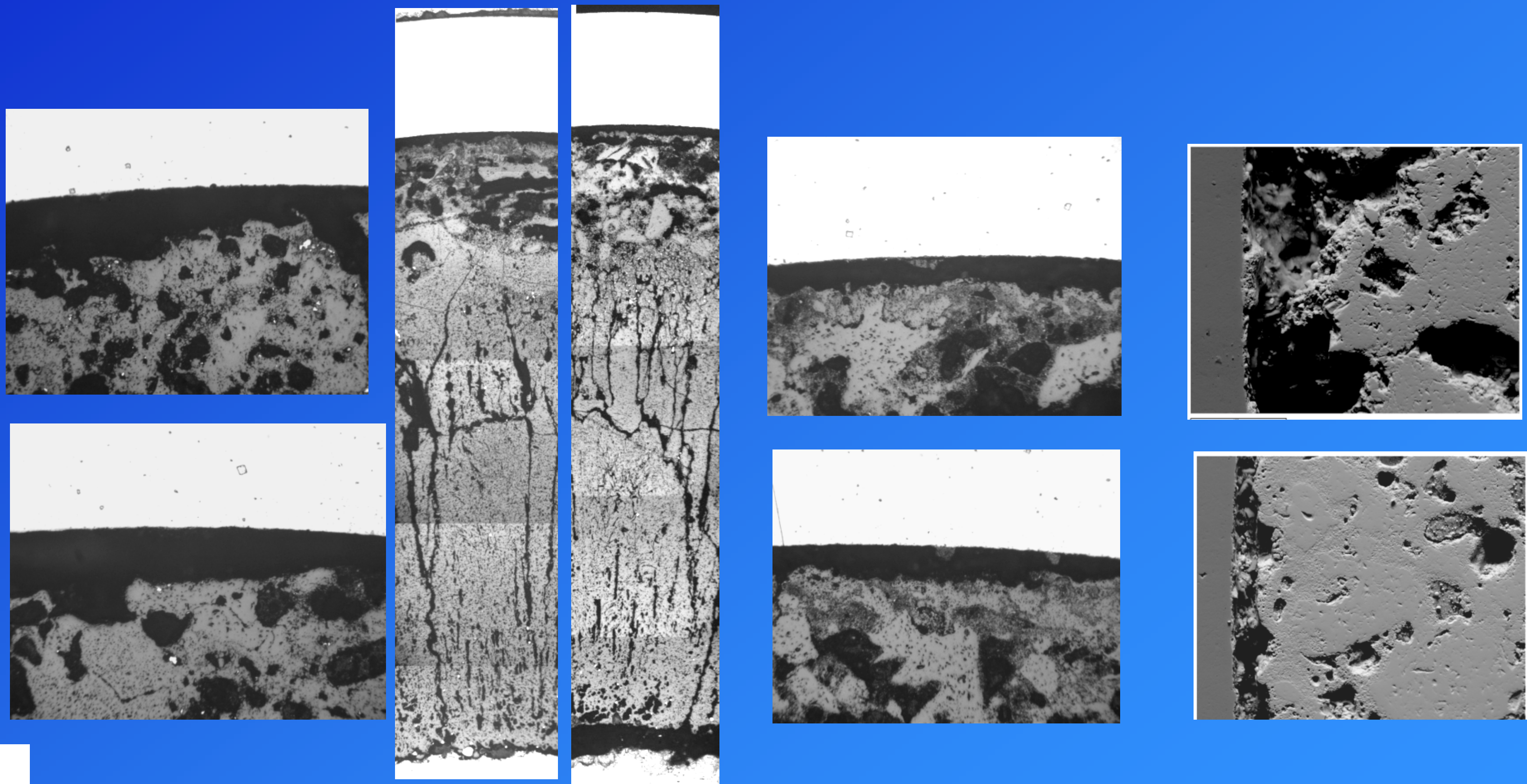
Vibropac fuel in BN-600



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Vibropac fuel in BN-600

- No specific differences in radiation-thermal effects in fuel pins and FA tested in BOR-60, BN-350 and BN-600 were observed;
  - More detailed information about second stage of vibpaced MOX-fuel irradiation is provided in another paper for this conference (IAEA-CN-176-07-16P)

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Current Status

- Fuel pin design, technologies for granulated fuel production and fuel pins fabrication are ready for industrial application;
- RIAR technologies are main technologies for BN-800 fuel supply
  - Start of modernization of technological complex

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