Overview of China Nuclear Waste Vitrification

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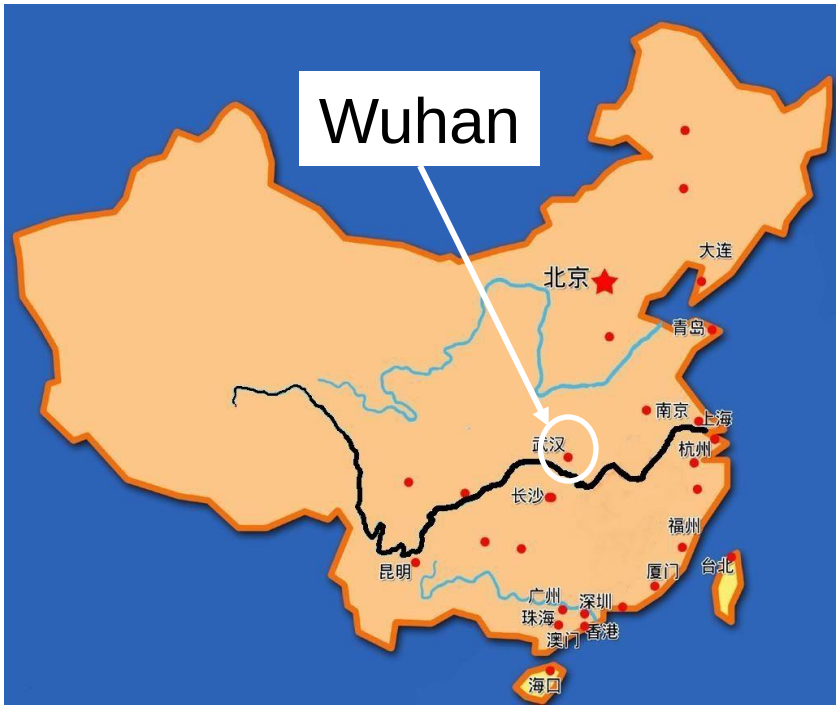
About Wuhan and WHUT



Wuhan city:

1) At the intersection of Yangtze River.
2) Largest city in Central China.
3) 3500-year history.

WHUT:

1) Student: ~50,000; faculty: ~3,300.
2) Ranking in the world: ~400 (THE Ranking).
3) Best University in glass and ceramics (in China).

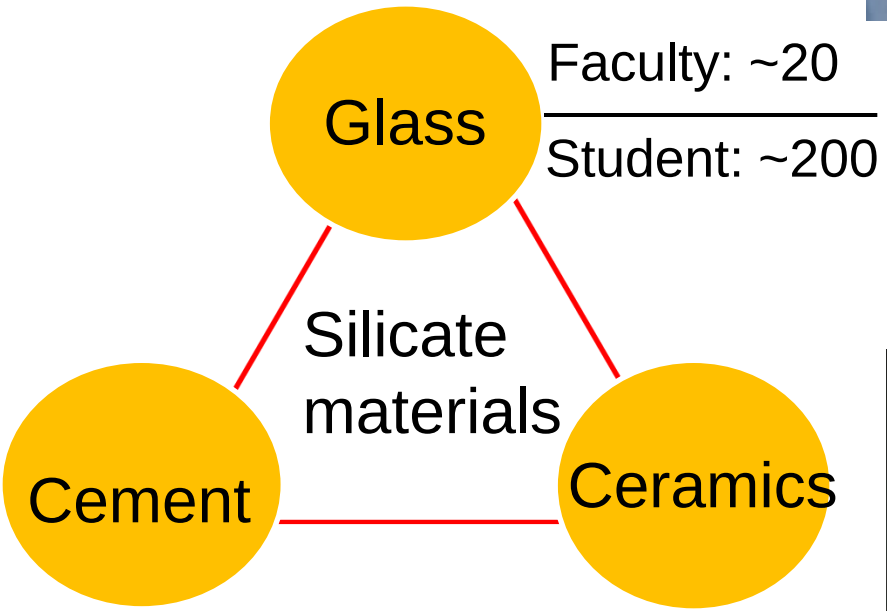
Bird view of WHUT

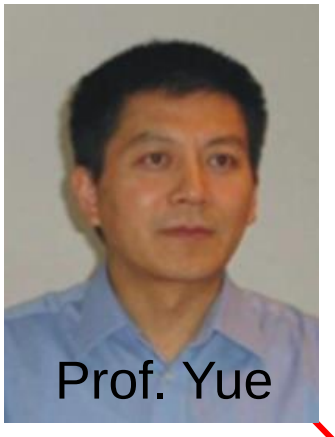
About SMART Lab

Faculty and student:

- Faculty: ~65.
- Post-doc.: ~10.
- Student: ~500,
  Intl. stud.: 15.

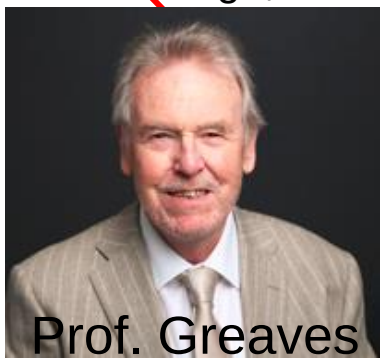
Research areas:





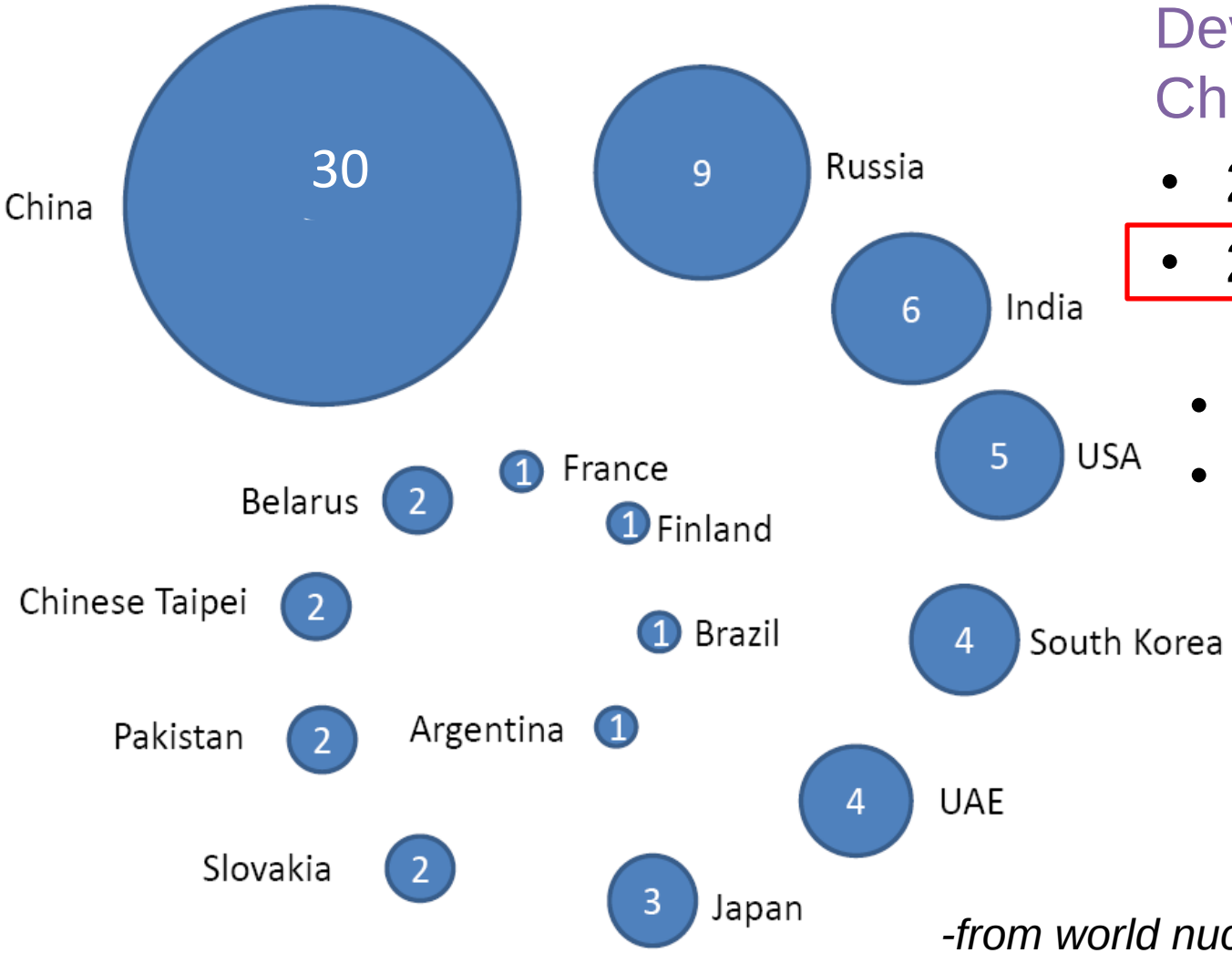
World-renowned glass scientist @ SMART

Adjunct prof.



Background – growing of China nuclear power

Reactors under construction



Development plan of China nuclear power:

- 2020: 58 GW;
- 2035: 150 GW.

- ~10% of the total;
- 2nd world largest NNPs country.

-from world nuclear association (2015)

Fastest-growing in the world.

Background – China nuclear waste management

High-level waste

Intermediate/low-level waste

Optional

Glass

Cement

A typical China Nuclear Waste

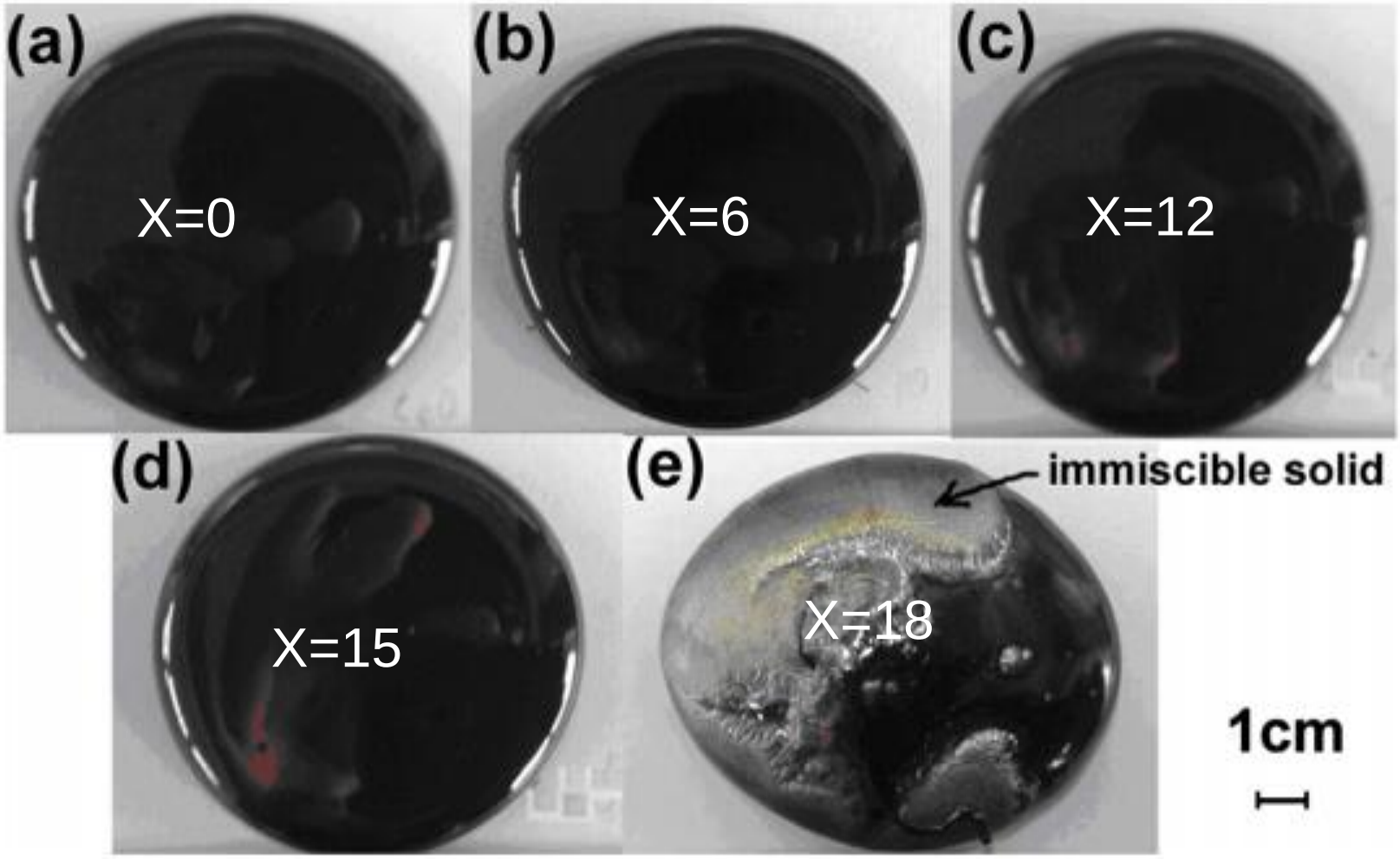
- High Fe, Na, S, RE.

(Oxides)	(Total oxides in VPC simulant)/(g • L^{-1})
Al_2O_3	9. 116
BaO	0. 010
Cr_2O_3	1. 625
Cs_2O	0. 695
Fe_2O_3	20. 513
K_2O	1. 293
La_2O_3	15. 177
MnO_2	0. 105
MoO_3	1. 154
Na_2O	46. 870
NiO	3. 604
P_2O_5	0. 349
SO_3	4. 418
SrO	0. 180
TiO_2	n. d. [4]
V_2O_5	4. 612
Y_2O_3	0. 072

- Waste loading in BSi glass: 16%.

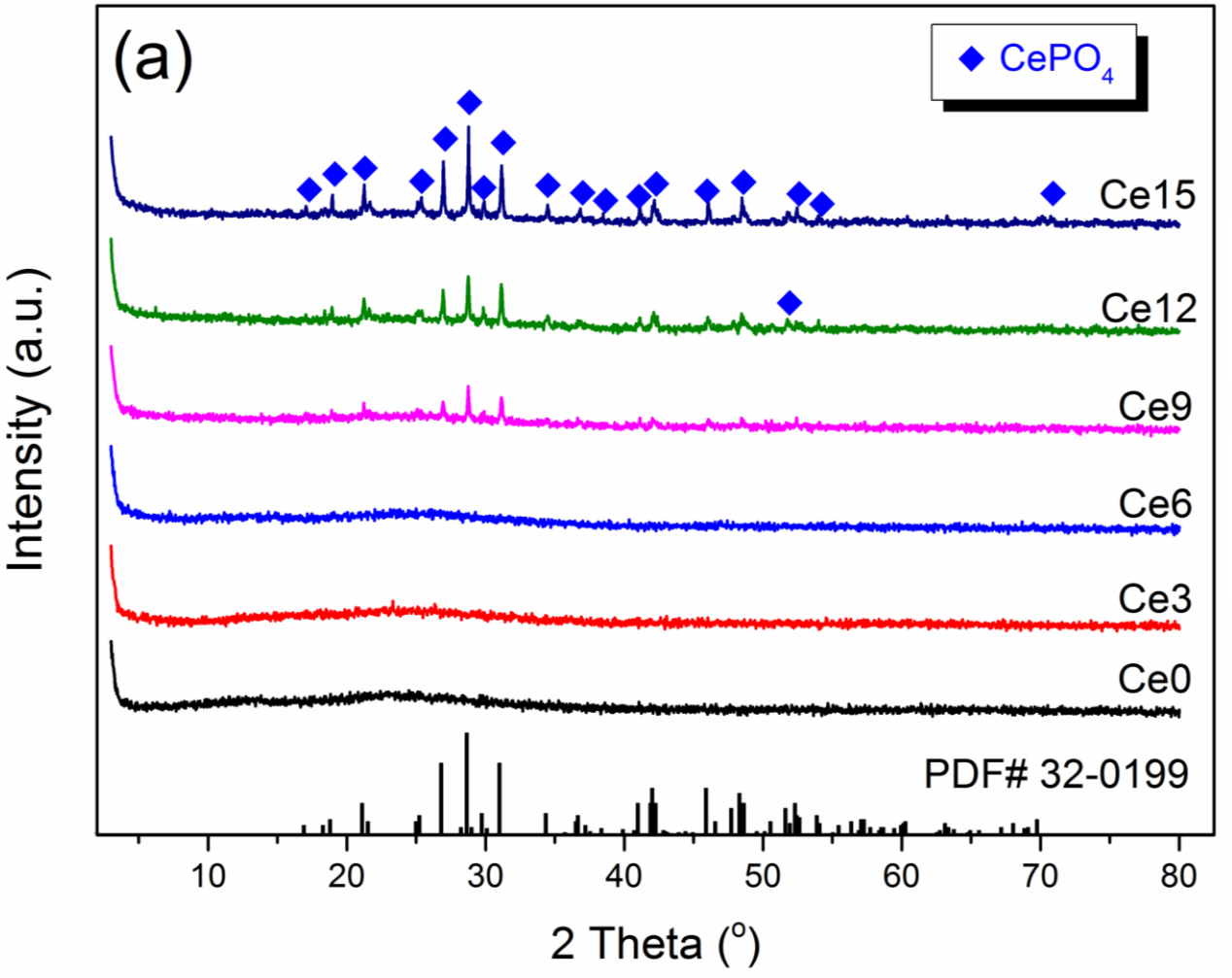
FeP glass immobilizing Re

$xCeO_2$-(100−x)(36Fe_2O_3-10B_2O_3-54P_2O_5) in mol%



Photos of FeP glasses containing different amounts of Ce

FeP glass immobilizing Re

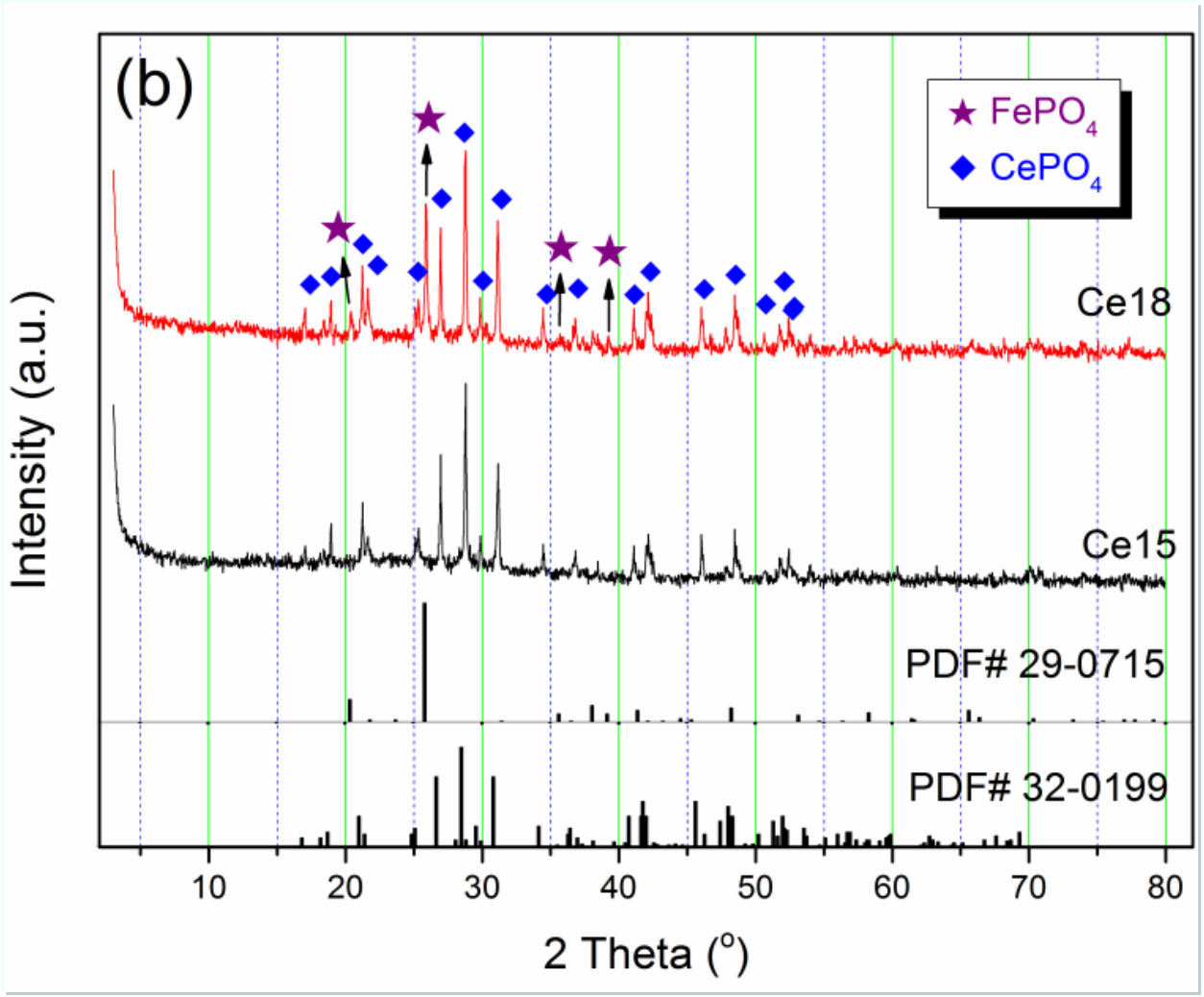


- Monazite ($CePO_4$) formed, when X≥9.
- Monazite is a durable phase.

XRD patterns of FeP glasses

Fu Wang, *et al*. ***J. of Non-Cryst. Solids,*** 409 (2015) 76-82 .

FeP glass immobilizing Re



- $FePO_4$ formed, when X≥18.
- $FePO_4$ is an undurable phase.

XRD patterns of FeP glasses

Fu Wang, *et al*. ***J. of Non-Cryst. Solids,*** 409 (2015) 76-82 .

Glass-ceramics

Motivation

Barium borosilicate glass

（improve sulfate solubility）

Zirconolite, titanite phases

（improve TRUs solubility）

Melting-thermal treatment

1200°C-3h

$T_g < T < T_c$ -4h

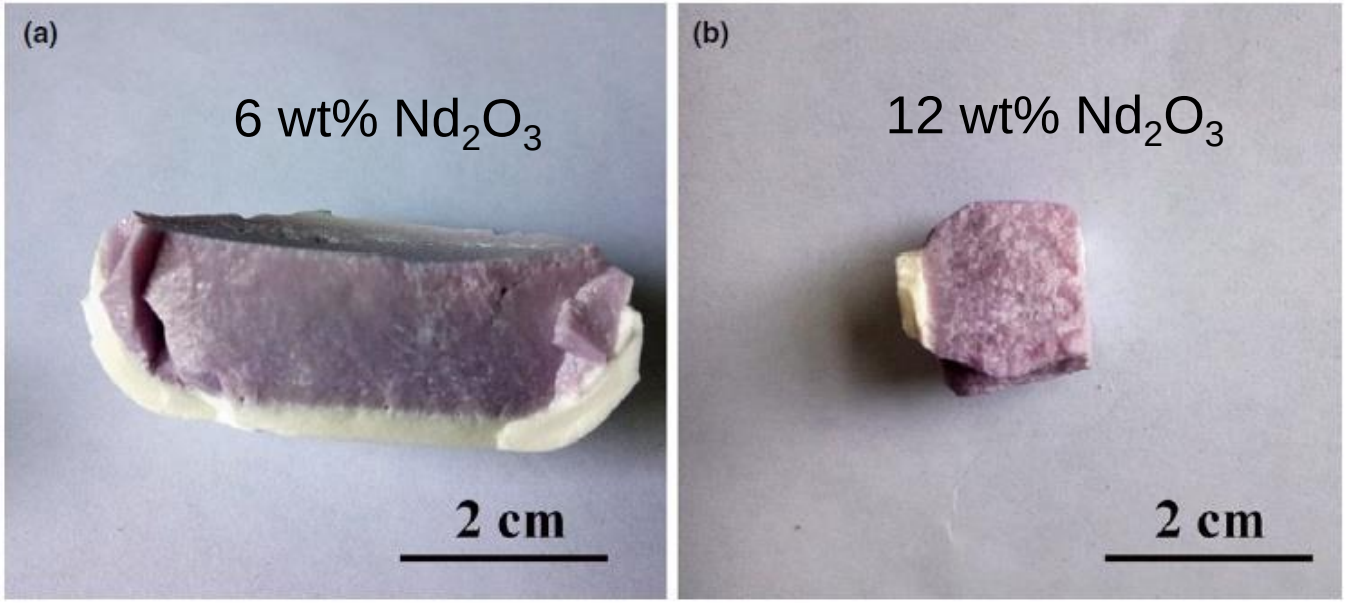
Barium borosilicate glass-ceramics containing zirconolite, titanite phases

BaBSi glass-ceramics (Nd effect)

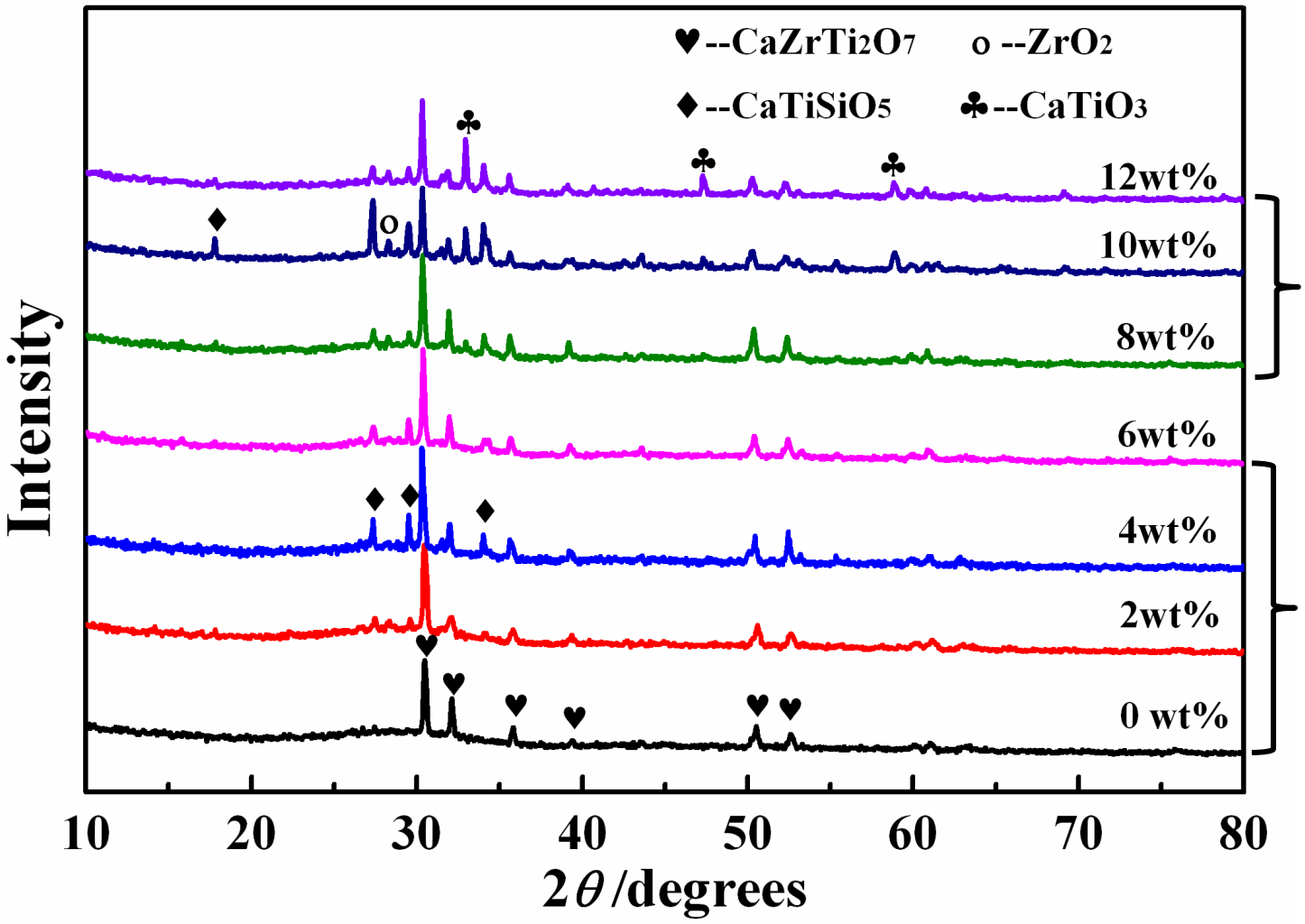
Composition of glass-ceramics (wt%)

Samples	SiO_2	B_2O_3	Na_2O	BaO	CaO	TiO_2	ZrO_2	Nd_2O_3
Nd–0	27.50	11.00	5.50	11.00	12.77	18.19	14.03	0
Nd–2	26.50	10.60	5.30	10.60	12.77	18.19	14.03	2
Nd–4	25.50	10.20	5.10	10.20	12.77	18.19	14.03	4
Nd–6	24.50	9.80	4.90	9.80	12.77	18.19	14.03	6
Nd–8	23.50	9.40	4.70	9.40	12.77	18.19	14.03	8
Nd–10	22.50	9.00	4.50	9.00	12.77	18.19	14.03	10
Nd–12	21.50	8.60	4.30	8.60	12.77	18.19	14.03	12

Photos of glass-ceramics



BaBSi glass-ceramics



$CaZrTi_2O_7$+
$CaTiSiO_5$+
ZrO_2+
$CaTiO_3$

$CaZrTi_2O_7$+
$CaTiSiO_5$

XRD patterns with different contents of Nd_2O_3

L. Wu*, et al. ***J. Am. Ceram. Soc.,*** 99 (2016) 4093-4099.

Fluoride wastes from molten salt reactors

- MSR utilizes liquid molten fluoride salts as coolant, or even the fuel in the molten salt mixture.

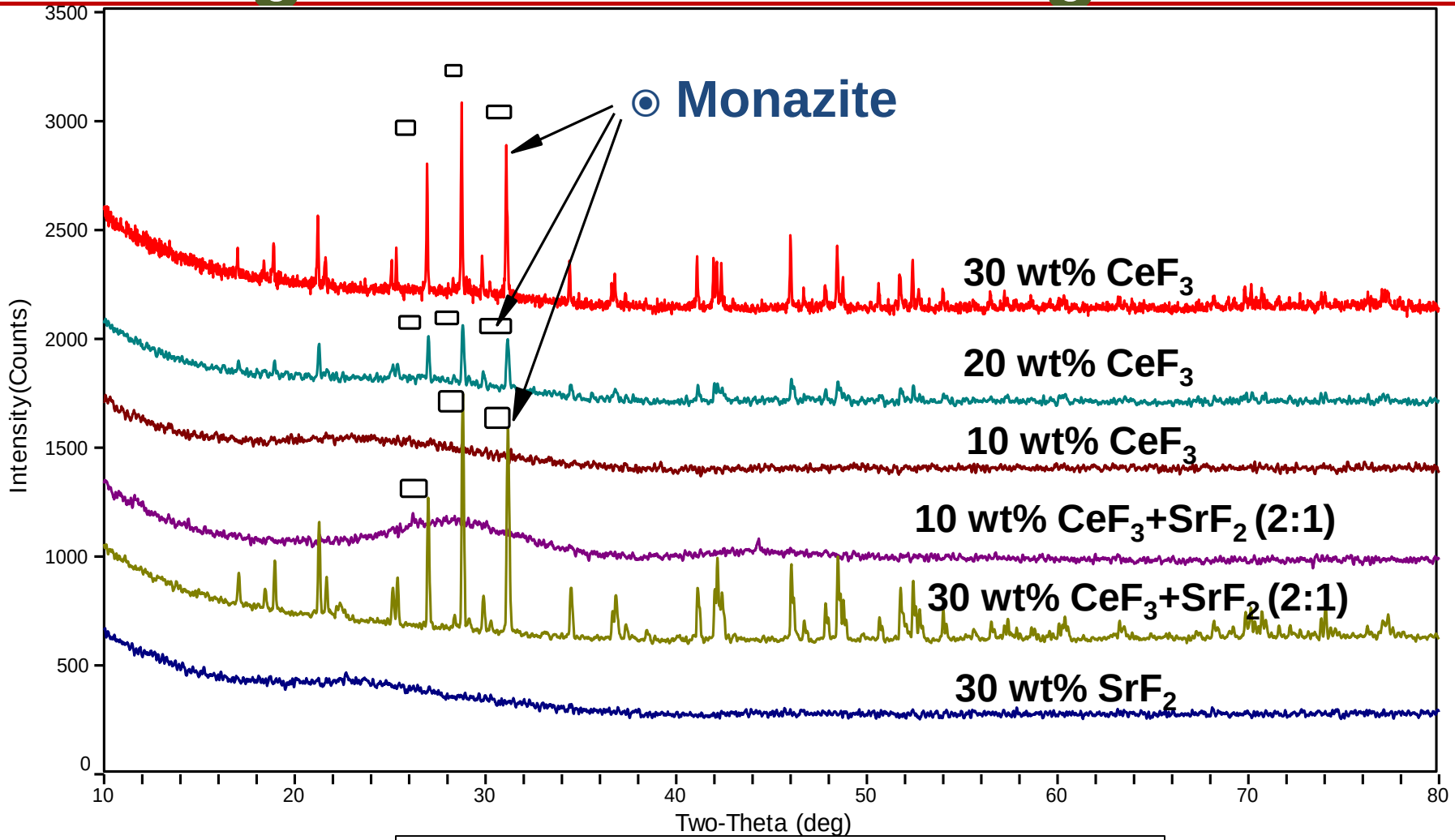
- Reprocessing includes fluorination, distillation to separate uranium and other FPs from fluoride salts.

- Typical simulated fluoride wastes (mol%)

  - 18.8LiF-23.8NaF-0.1MgF_2-57KF-0.3PF(SrF_2-SrF-CeF_3)
  - 8.4CsF-8.3SrF_2-37.8SmF_3-29.7ZrF_4-15.8CeF_4

Yanbo Qiao, et al., China Academy of Sciences.

FeBP glass immobilizing fluorides

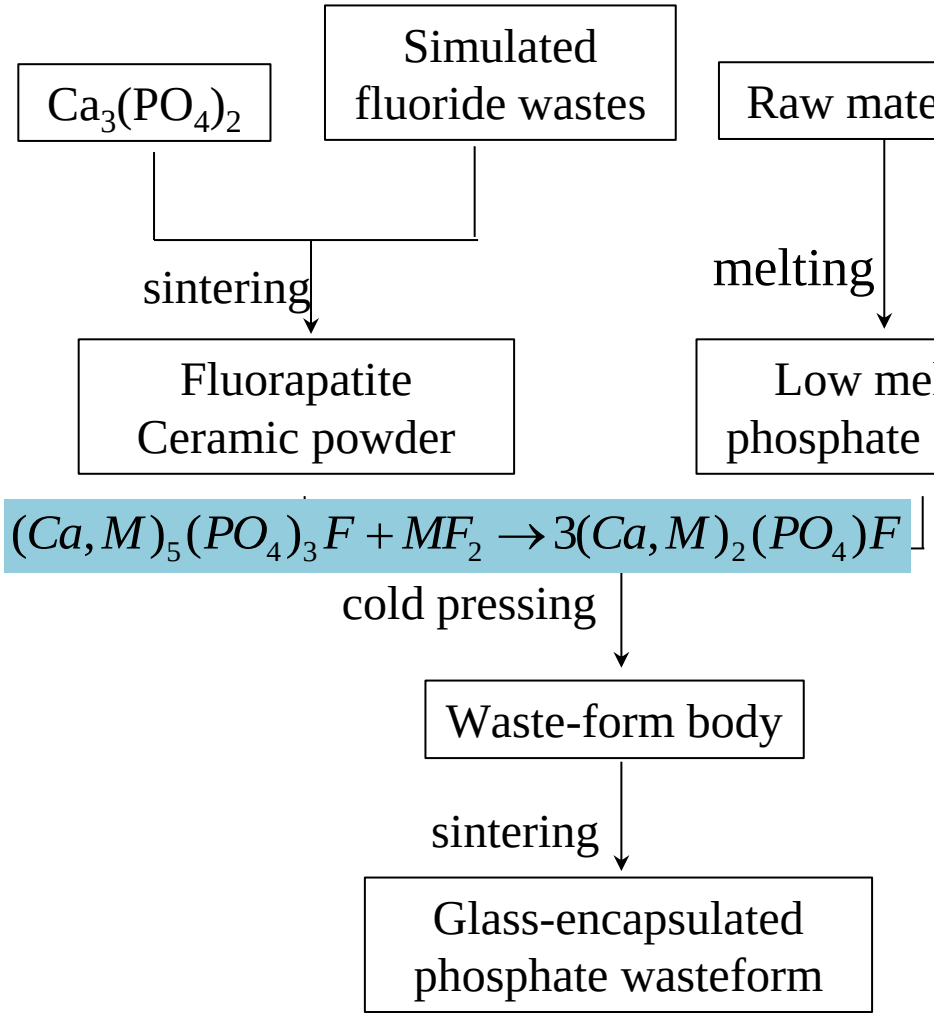


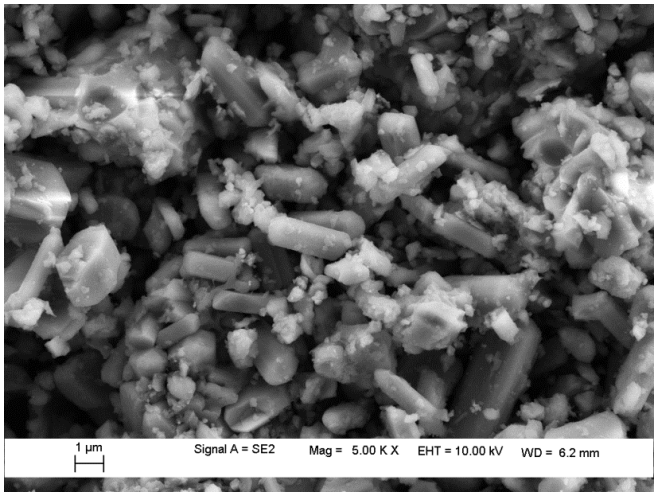
XRD patterns of FeBP glasses

- Monazite formed when CeF_3 ≥20 wt%.
- No crystallization when SrF_2 =30 wt%.

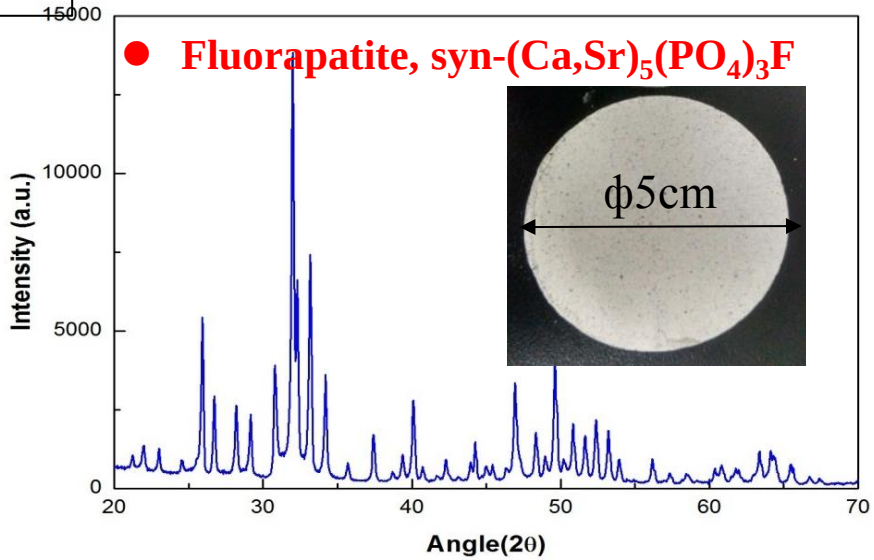
Phosphate glass encapsulated waste-form

Experimental





Fluorapatite crystals with hexagonal



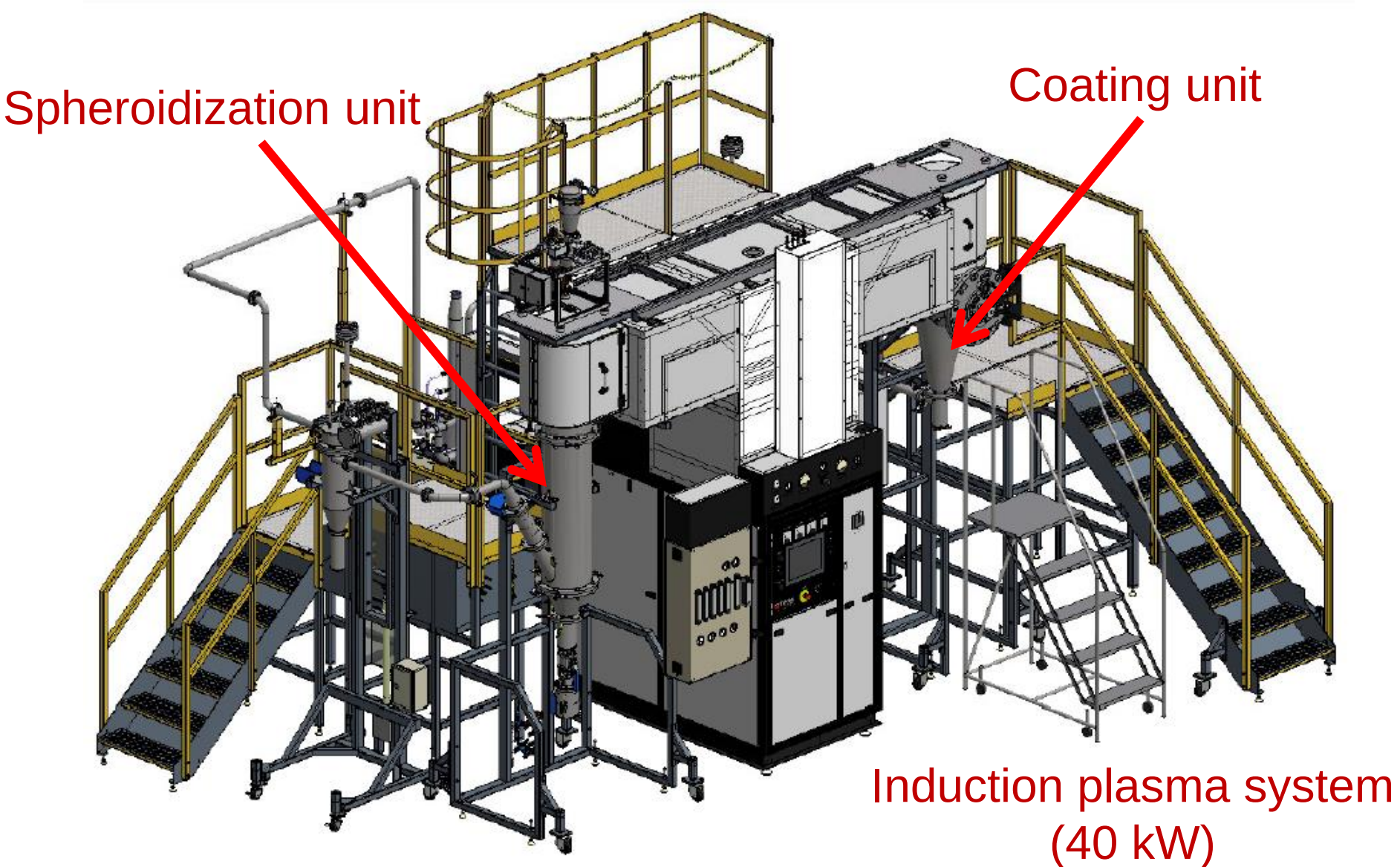
XRD pattern and wasteform photo (SrF_2 as simulant)

Works doing @ WHUT - ISG corrosion study

As-received ISG sample

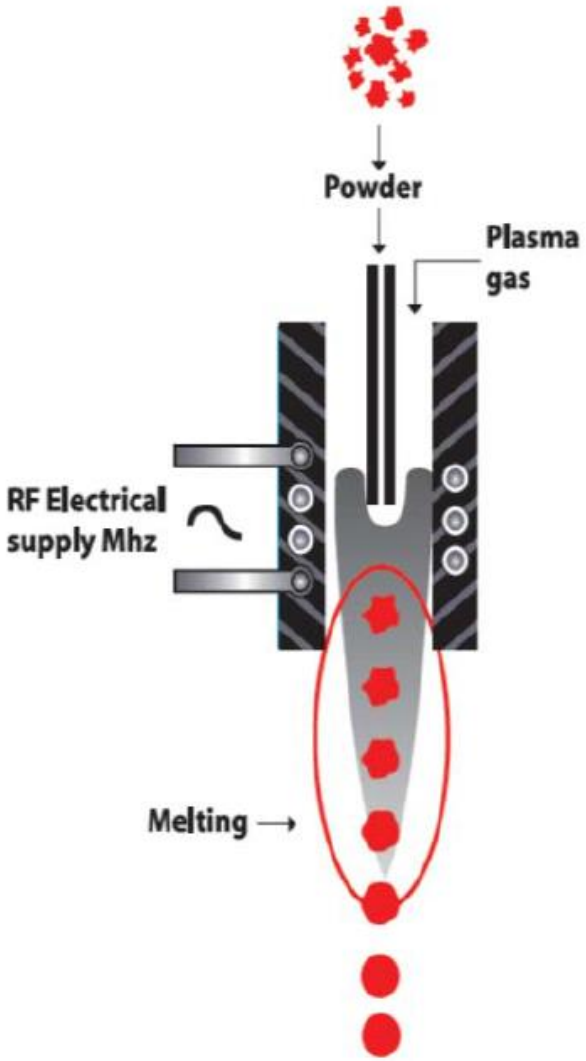
Works doing @ WHUT - ISG corrosion study

Assessment of PCT (surface area)

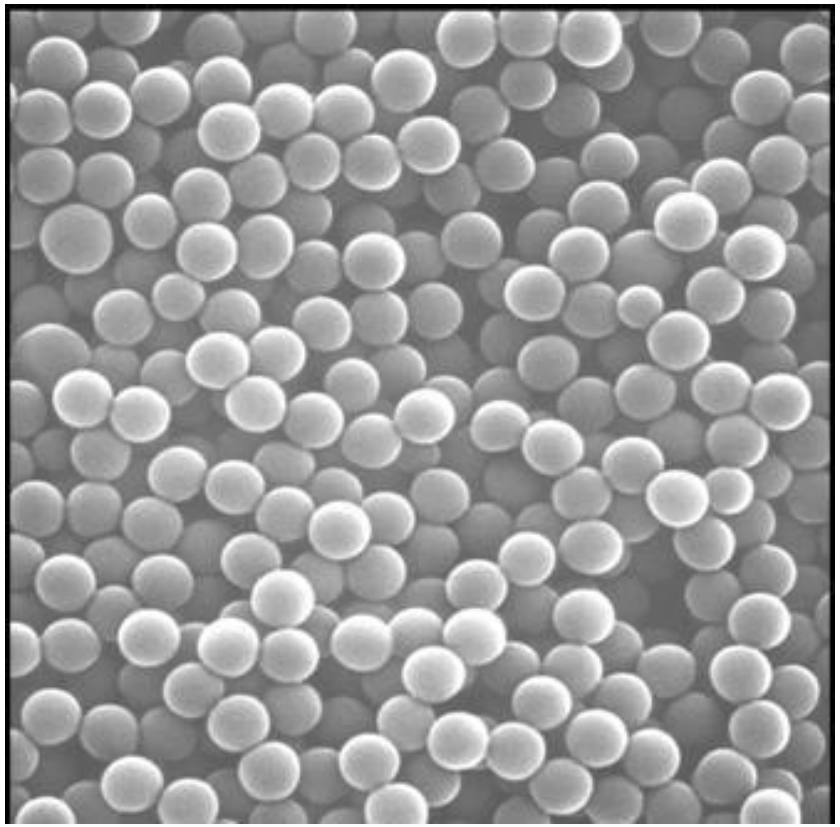


Works doing @ WHUT - ISG corrosion study

Assessment of PCT (surface area) – glass spheroidization



Powder spheroidization



Uniform size of glass beads with smooth surface

Summary and outlooks

- HLW generated from defense program is urgent to be vitrified, and a large amount of HLW will be produced from reprocessing of spent nuclear fuel soon.

- R&D of China nuclear waste vitrification is in the preliminary stage, and is very needed, in order to construct our own vitrification facility.

Thanks for your attention and comments!

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