International Symposium on Technology Development for Nuclear Nonproliferation and Nuclear Security

Nuclear Forensics for Nuclear Security

− Present Situation in Japan −

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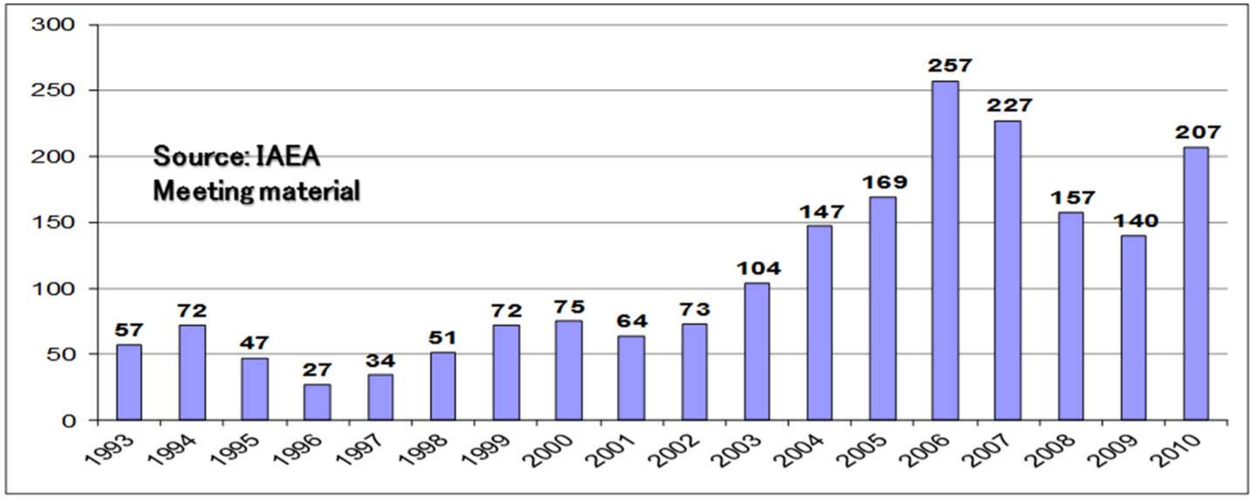
Threat of Nuclear Terrorism and the Issue of Nuclear Material Management

[Threat of Nuclear Terrorism]

- Theft of a nuclear weapon
- Theft of nuclear material for creating improvised nuclear device (IND)
- Theft of radiological material for creating Dirty Bomb or Radiological Dispersal Device (RDD)
- Sabotage of nuclear facility or transportation of radiological material

Total 2,331 cases of nuclear security events reported to IAEA Illicit (Incident) Trafficking Data Base (ITDB) between 1993 and December 31, 2012

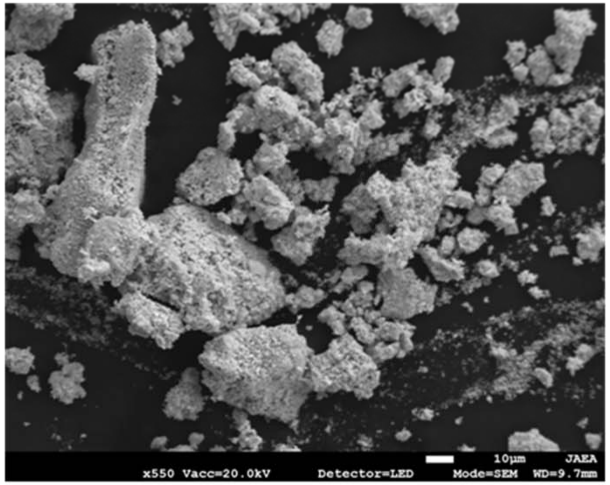


HEU uncovered
in Georgia
Source: IAEA

Source: "IAEA ITDB 2013 Fact Sheet", http://www-ns.iaea.org/downloads/security/itdb-fact-sheet.pdf

Nuclear Forensics ?

- Process of identifying the source of nuclear or radioactive material used in illegal activities, to determine the point of origin and routes of transit involving such materials.



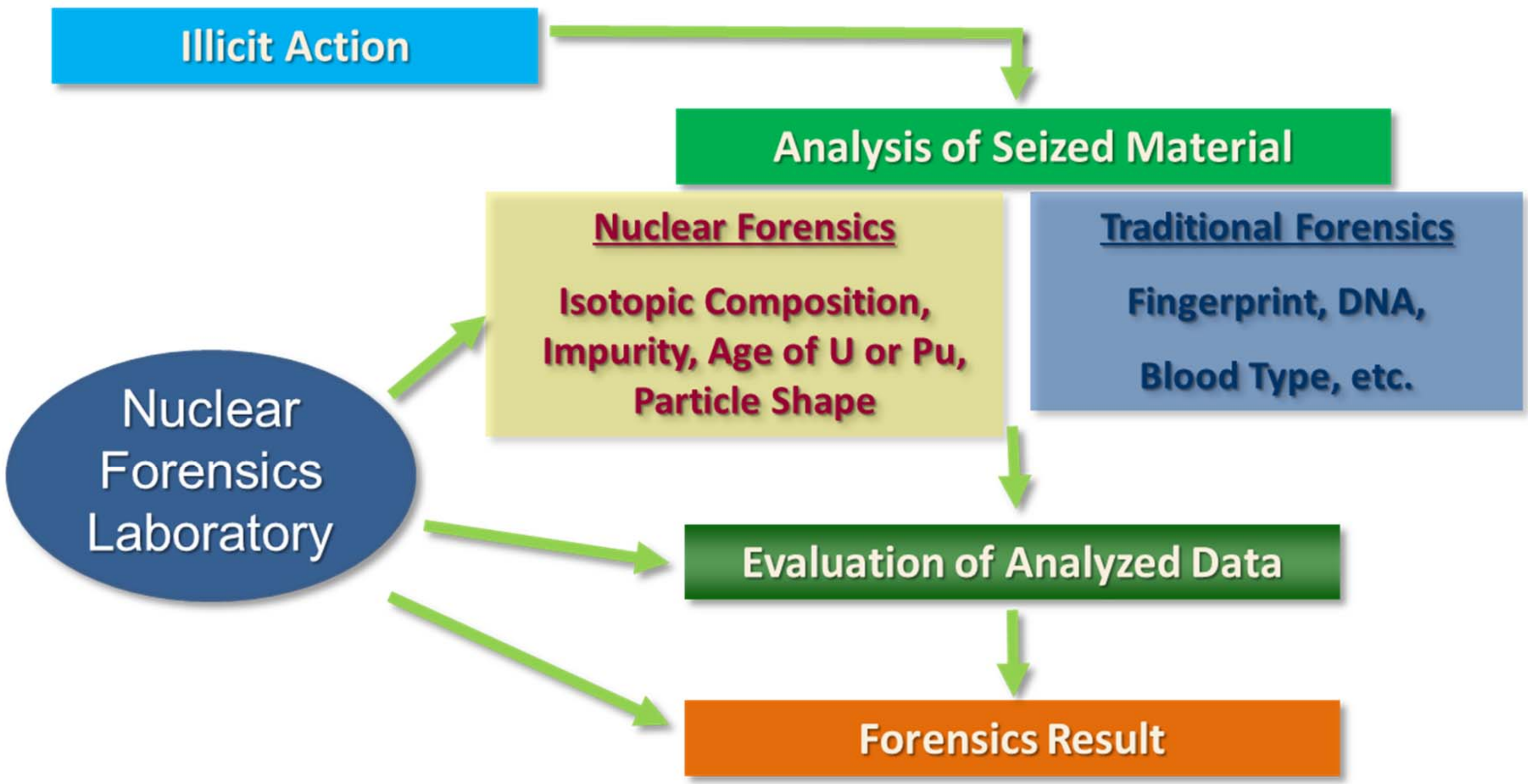
An uranium sample produced in Japan

"Signatures"

<u>"Attributions" of NMs and RMs</u>

- <u>What</u> is this ?
- What's the <u>purpose</u> ?
- <u>When</u> is it produced ?
- <u>Where</u> is it produced ?
- <u>How</u> is it produced ?

Analysis of Illicit Nuclear Material



U Case Study

- In June 2003, four uranium dioxide pellets were seized
- All the pellets showed identical geometry
  - they had a central hole and they were dished
- The pellets were weighed and their dimensions were measured

Pellet no.	Weight (g)	Height	Dimensions (mm)	
			Diameter	Hole
1	14.6672	14.12	11.45	2.1
2	14.7614	14.26	11.44	2.1
3	15.3979	14.91	11.45	2.1
4	14.8626	14.46	11.45	2.1

From *M. Wallenius et al., Forensics Science International, vol. 156, pp. 55-62 (2006)*

U Isotopic and Elemental Content

- The isotopic composition of uranium was determined by mass spectrometry using both TIMS and MC-ICP-MS

Technique	^{234}U	^{235}U	^{236}U	^{238}U
TIMS	0.0147 ± 0.0010	2.0005 ± 0.0010	0.0071 ± 0.0067	97.9778 ± 0.0019
MC-ICP-MS	0.0142 ± 0.0002	2.0005 ± 0.0001	0.0071 ± 0.0000	97.9782 ± 0.0010

- The uranium content in the pellets was determined by potentiometric titration, HKED, and IDMS

Technique	U Content (%)
HKED	87.43 ± 0.32
Titration	87.90 ± 0.13
IDMS	87.99 ± 0.24

From *M. Wallenius* et al., *Forensics Science International, vol. 156, pp. 55-62 (2006)*

Chemical Impurities Using ICP-MS

Element	Concentration (PPM)
Al	6.08 ± 0.73
Ca	18.4 ± 2.2
Cr	6.12 ± 0.73
Cu	1.80 ± 0.22
Fe	91.9 ± 7.4
K	44.7 ± 3.6
Mg	4.71 ± 0.57
Mn	1.13 ± 0.14
Na	17.9 ± 2.1
Ni	5.14 ± 0.62
Zn	3.40 ± 0.41

From *M. Wallenius et al., Forensics Science International, vol. 156, pp. 55-62 (2006)*

Age Determination

- Age since chemical separation was determined using two parent daughter relationships:
  - $^{235}U \rightarrow {}^{231}Pa$ ($t_{1/2}$=7.038×10^8 years)
  - $^{234}U \rightarrow {}^{230}Th$ ($t_{1/2}$=2.455×10^5 years)

- The age of the material was determined to be 12.6 ± 0.8 years at the measurement date of June 16, 2003
  - thus, the pellet was most likely produced on or about November 8, 1990

From *M. Wallenius et al., Forensics Science International, vol. 156, pp. 55-62 (2006)*

Conclusion for U Case study

- It was determined with high confidence that this material was from an RBMK fresh fuel batch from the Ignalina Unit 2 reactor in Lithuania and produced by the MZ Electrostal in Moscow.

- There is a report of a theft of a fresh fuel assembly from Ignalina in 1992.

From *M. Wallenius et al., Forensics Science International, vol. 156, pp. 55-62 (2006)*

Japan's National Statement at Nuclear Security Summit (Washington D.C. April 2010)

Japan will make increased contributions to the international community by <u>establishing these technologies with more precise and accurate capabilities in detection and forensics</u> within an approximate three year time frame and sharing the fruits of these new technologies with the international community.

Response of Japan Atomic Energy Agency (JAEA)

- JAEA, which possesses sufficient capabilities to fulfill the mission of analytical technology development for nuclear forensics (NF), has initiated R&D project from 2011 JFY.

Challenges towards Establishment of NF Capabilities in Japan

Japan's Challenges

The JAEA can contribute to these themes.

- Establishment and improvement of NF analysis technologies
- Development of National Nuclear Forensics Library (NNFL)
- Establishment of NF analysis Lab. (analytical devices and system)
- Human resource development

- Establishment of national framework including national response plan
- Collaborations with traditional forensics
- Establishment of international cooperative system

JAEA's Contributive Area

- Establishment of “technical” NF capabilities
- Information collection and support for national frameworks including national response plan

JAEA R&D Project for developing Nuclear Forensics Technologies

Analysis of Seized Material

Nuclear Forensics

1. Isotopic Composition
2. Impurity
3. Age of U or Pu
4. Particle Shape

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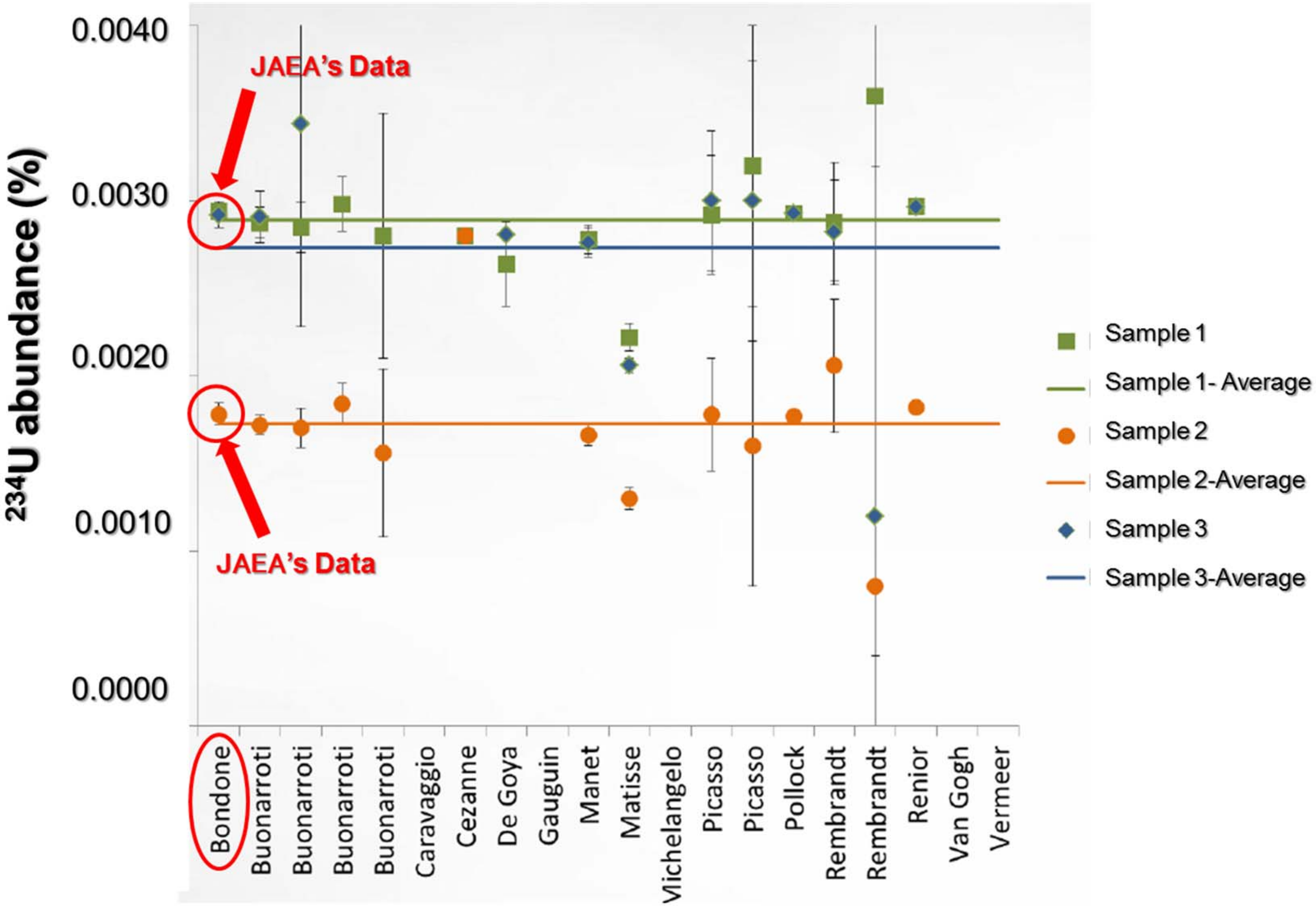
5. Nuclear Forensics Laboratory

1. Isotopic Composition Measurement

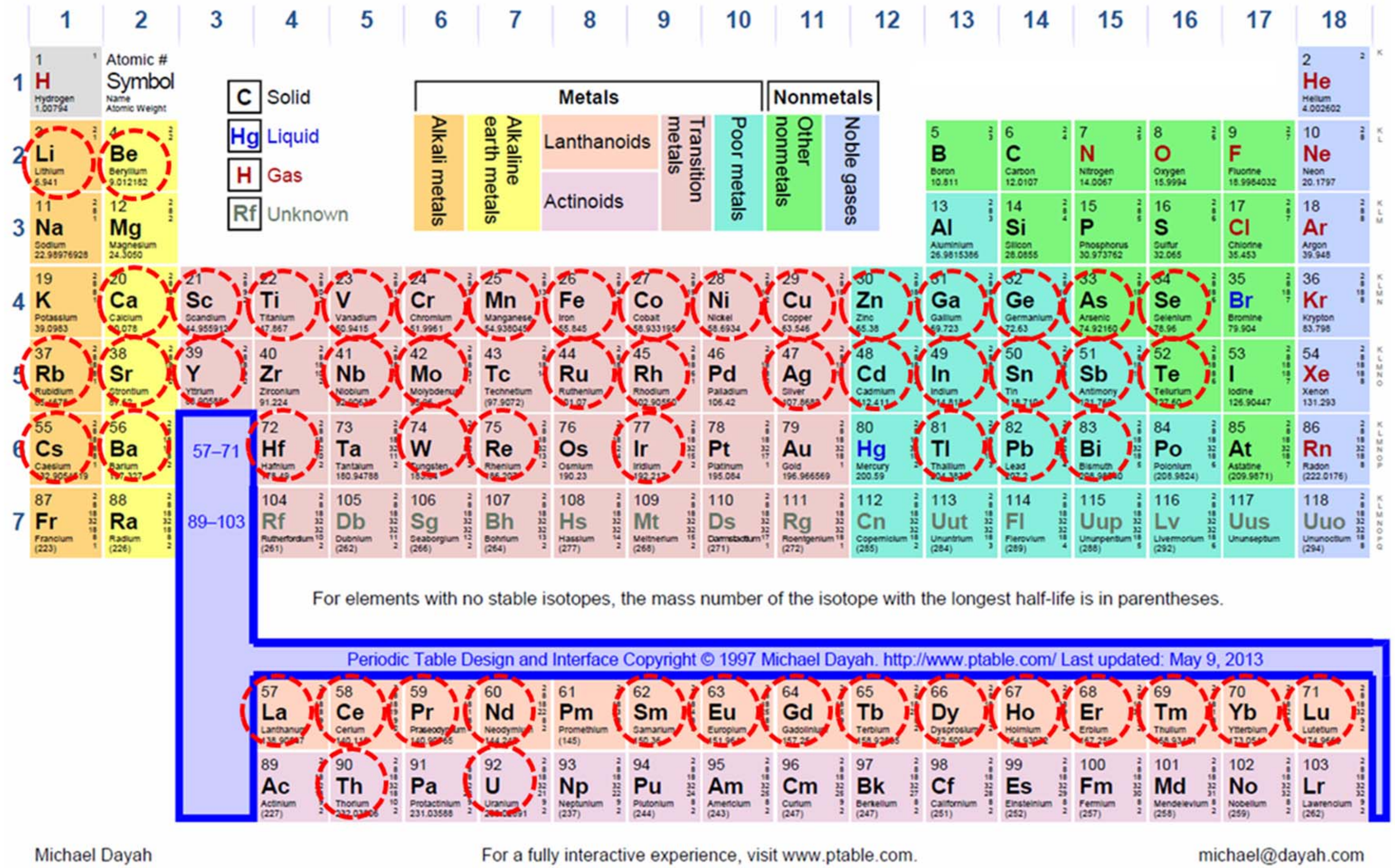
A result of Nuclear Forensics International Technical Working Group (ITWG) Collaborative Materials Exercise 4 (CMX-4)



2. Impurity Measurement

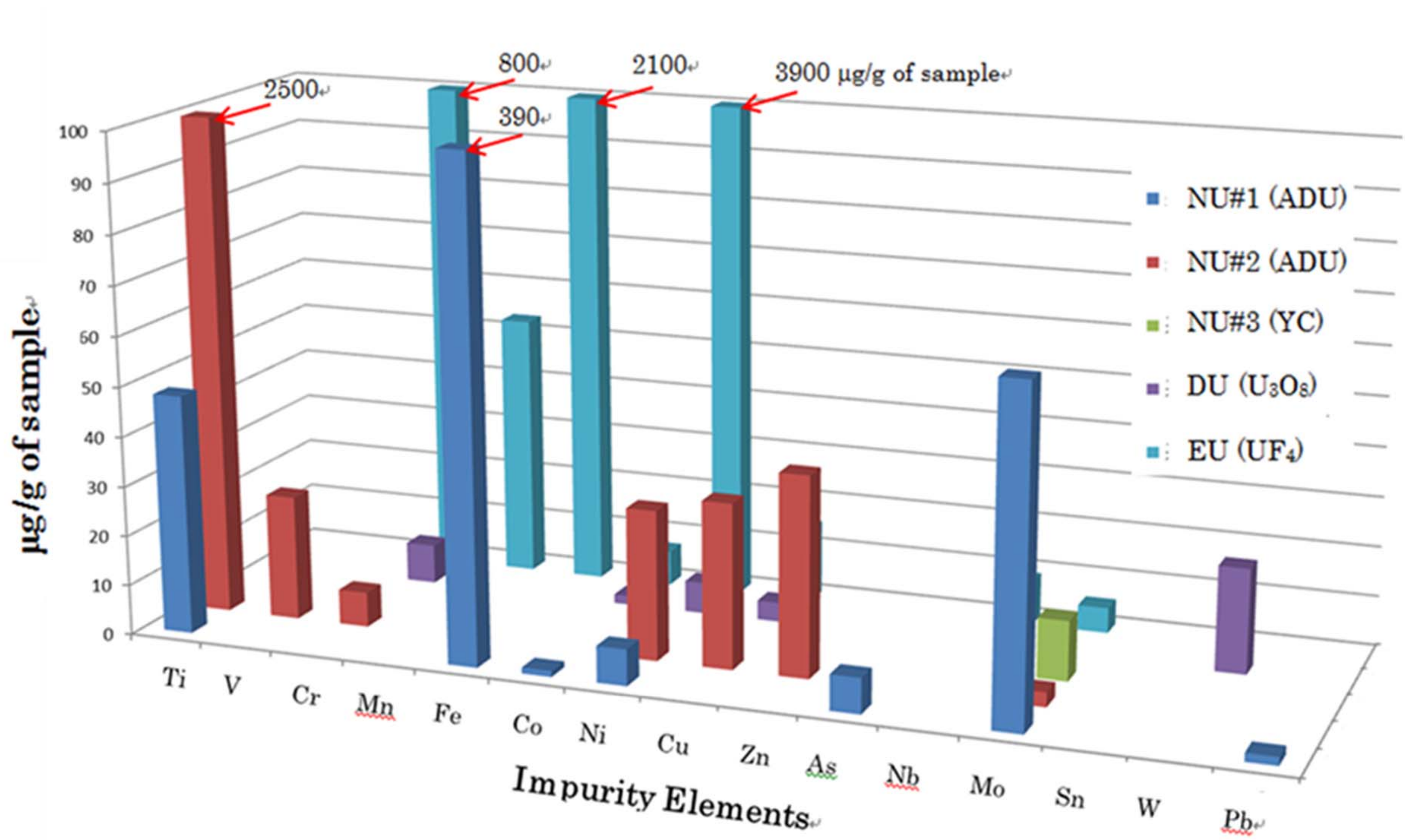
Impurity quantitation test using ICP-MS

All impurity elements could be important "Signature" in NF analysis.



: Now measurable by ICP-MS at JAEA

Result of Impurity Measurement

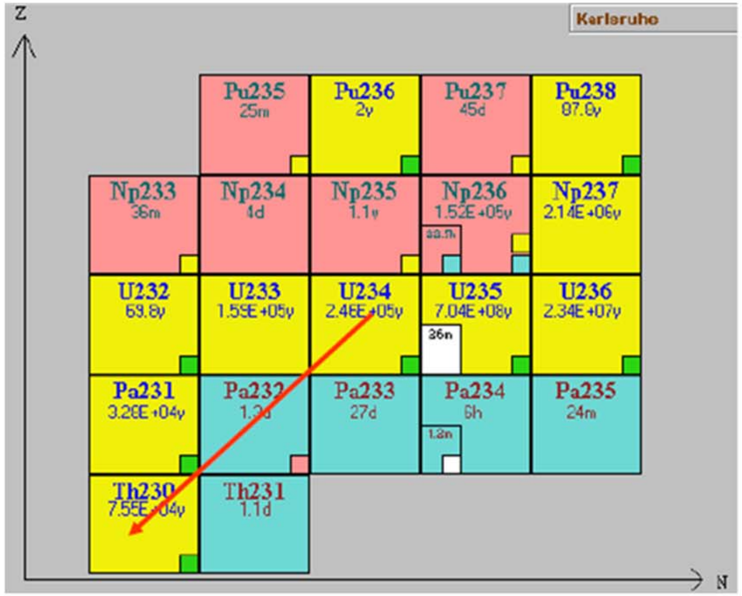


Impurities contained in several uranium samples

3. Uranium Age Determination

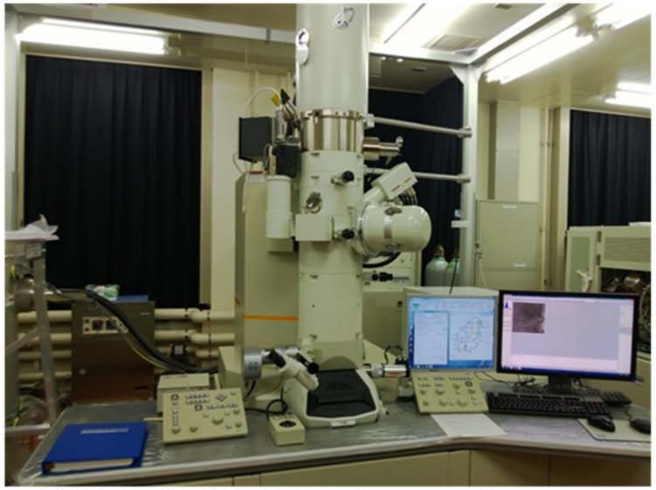
- The age of nuclear material is essential information to identify the source of the material, and ^{234}U-^{230}Th chronometer is widely applied to NF.

- We conducted procedure exchange and inter-laboratory comparison exercise on uranium age dating between Department of Energy (DOE) of US and JAEA, where the same NBL standard materials of CRM U050 were independently analyzed

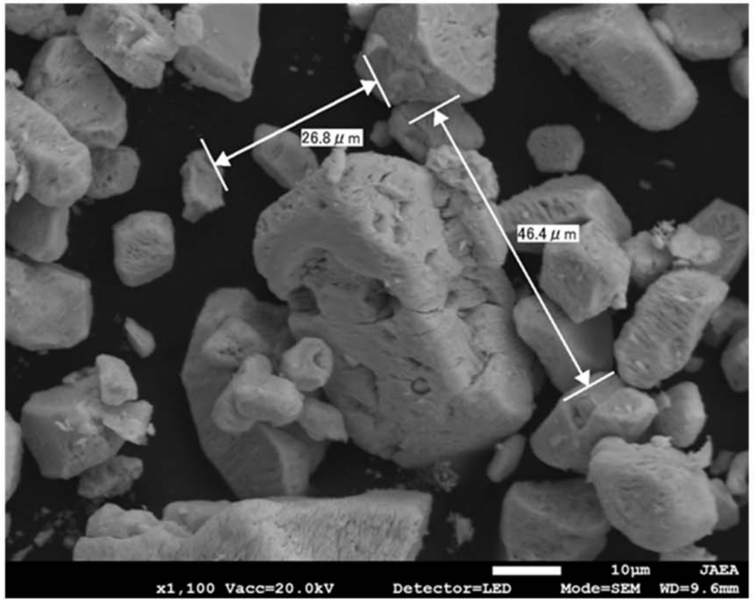


- The analysis of age determination on the uranium oxide standard was already performed and the time of its purification can be estimated to be August 4 of 1957 from the JAEA's result.

4. Particle Analysis



TEM (JEM-2100F) for Nuclear Forensics



Particle image of the yellow cake observed by SEM

<u>Expected Analysis by TEM</u>

- Particle analysis (particle/lattice image)
- Other crystal analysis
- Elemental compositions and their chemical-bonding states by EELS (electron energy-loss spectroscopy)

5. Development of Prototype Nuclear Forensics Library (NNFL)

<u>The NNFL Development in 2011- 2013 JFY</u>
- Database of Nuclear Materials (NMs)
- Basic Data Handling Functions (Data Entry, Search & Update)

<u>Current Status</u>
- <u>Database</u> design based on items of NMs and nuclear fuel cycle facilities in JAEA (completed)
- A model database for the review of data structure and the basic <u>data handling functions</u> (proto-type was already developed)
- Data survey and <u>data gathering</u> of NMs available in JAEA in order to populate the prototype library (in progress)

General Concept of an NNFL

- Minimum function required for an NNFL

<u>Database</u>
- An organized collection of data.
- Data structure should be designed according to its objectives and kinds of collected data.

<u>Data handling (query & Interface)</u>
- Data handling functions should be designed according to the database structure appropriately.

6. International Collaborations

- **<u>Collaboration with US-DOE（Project Action Sheet: PAS</u>）**
  - Uranium age determination (PAS19): inter-laboratory comparison
  - Evaluation of fuel attributions (PAS20 and 29): Information exchange and inter-laboratory comparison
  - NNFL (PAS21): establishment of proto-type NNFL at JAEA
- **<u>Collaboration with EC-JRC</u>**
  - Uranium age determination: information exchange and sample provision for inter-laboratory comparison in progress
- **<u>Others</u>**
  - Contribution on the activities of GICNT, ITWG and IAEA
  - Information exchange for establishment of the national framework and response plan in Japan
  - Participation to table top exercise on NNFL (*Galaxy Serpent*)

NF Capability in Japan

- Japan should improve capability to search for, confiscate, and establish safe control over unlawfully held nuclear or other radioactive materials and substances or devices using them.

- In view of construction of NF regime, the pertinent agencies* in Japan must cooperate with one another.

**Nuclear Regulation Authority, National Police Agency, Japan Coast Guard, Ministry of Foreign Affairs, Ministry of Finance Japan, Ministry of Education, Culture, Sports, Science and Technology, Ministry of Defense, and so on*

- It is necessary to organize Japan's own system for NF by establishing a national NF laboratory and collaborating with traditional forensics which targets the evidences of finger prints, DNS, etc.

Future Considerations

- Efforts to establish national frameworks including national response plan
- Increase internal cooperation with government and other labs to continue R&Ds toward establishment of national NF capabilities.

Conclusions

- JAEA has initiated the R&D project on nuclear forensics (NF) technologies from 2011 JFY.
- R&Ds on fundamental NF analysis technologies and prototype NNFL have been finished in 2013 JFY. The results will be shared with international community.

➢ Implementation and advanced NF technologies including NNFL is on going after 2014 JFY.

➢ To achieve the establishment of national NF capabilities, it is required to make efforts on national frameworks including national response plan in Japan.

Thank you.

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