European Commission

Exploring spectroscopic and morphological data as new signatures for uranium ore concentrates

D. M. L. Ho, D. Manara, Z. Varga, L. Fongaro, A. Nicholl,
M. Ernstberger, A. Berlizov, P. Lindqvist-Reis, T. Fanghänel and K. Mayer

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IAEA Nuclear forensics conference (7-10 July 2014)

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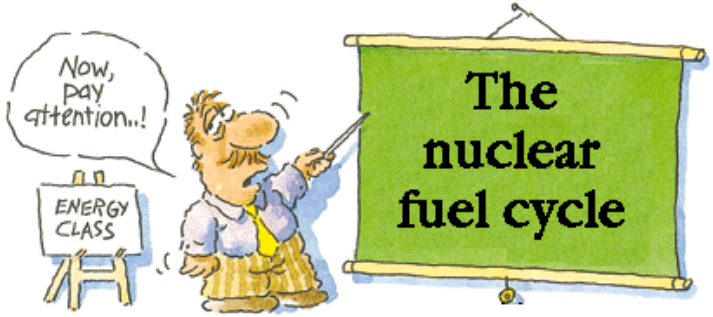
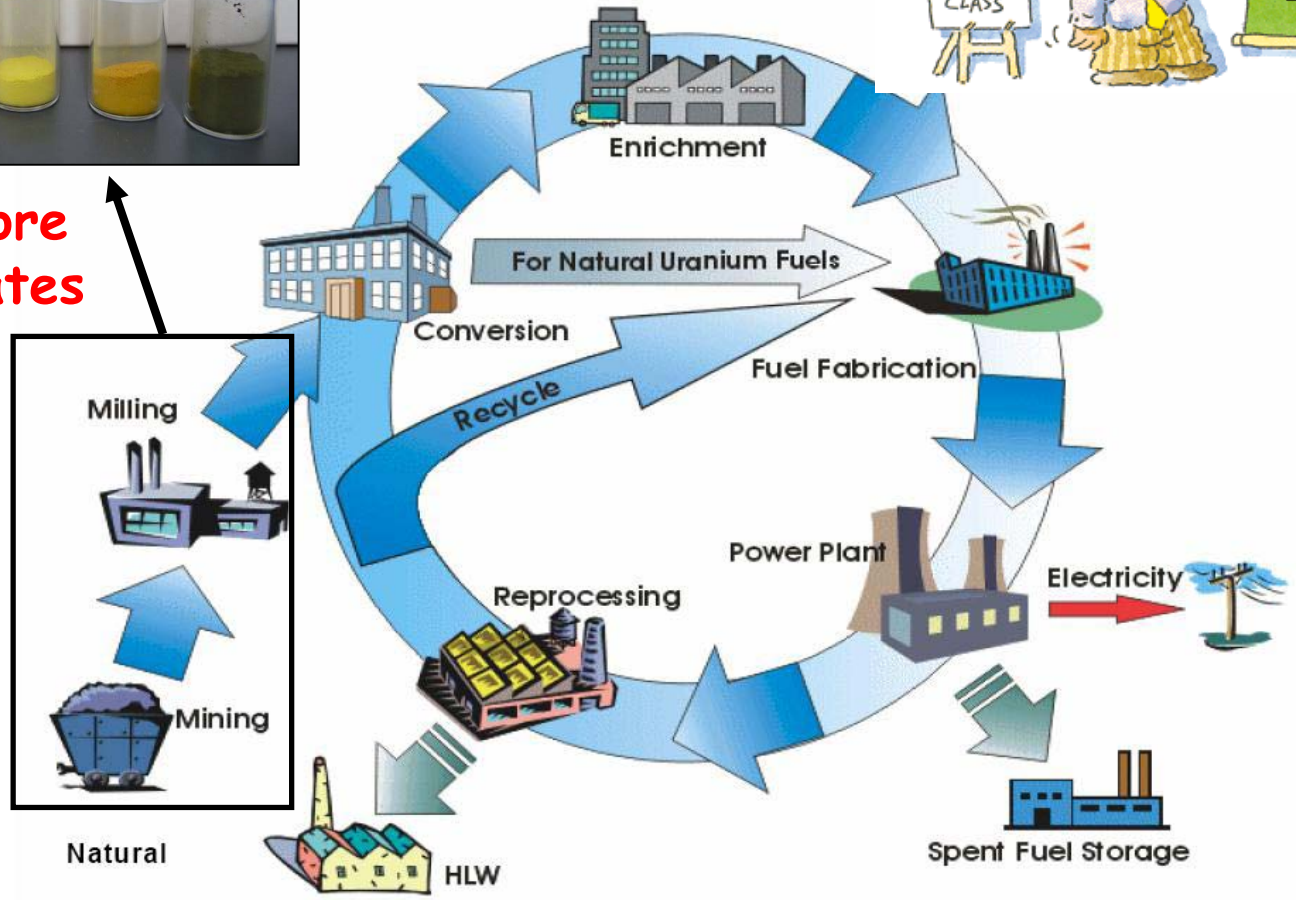
Stimulating innovation
Supporting legislation

Introduction

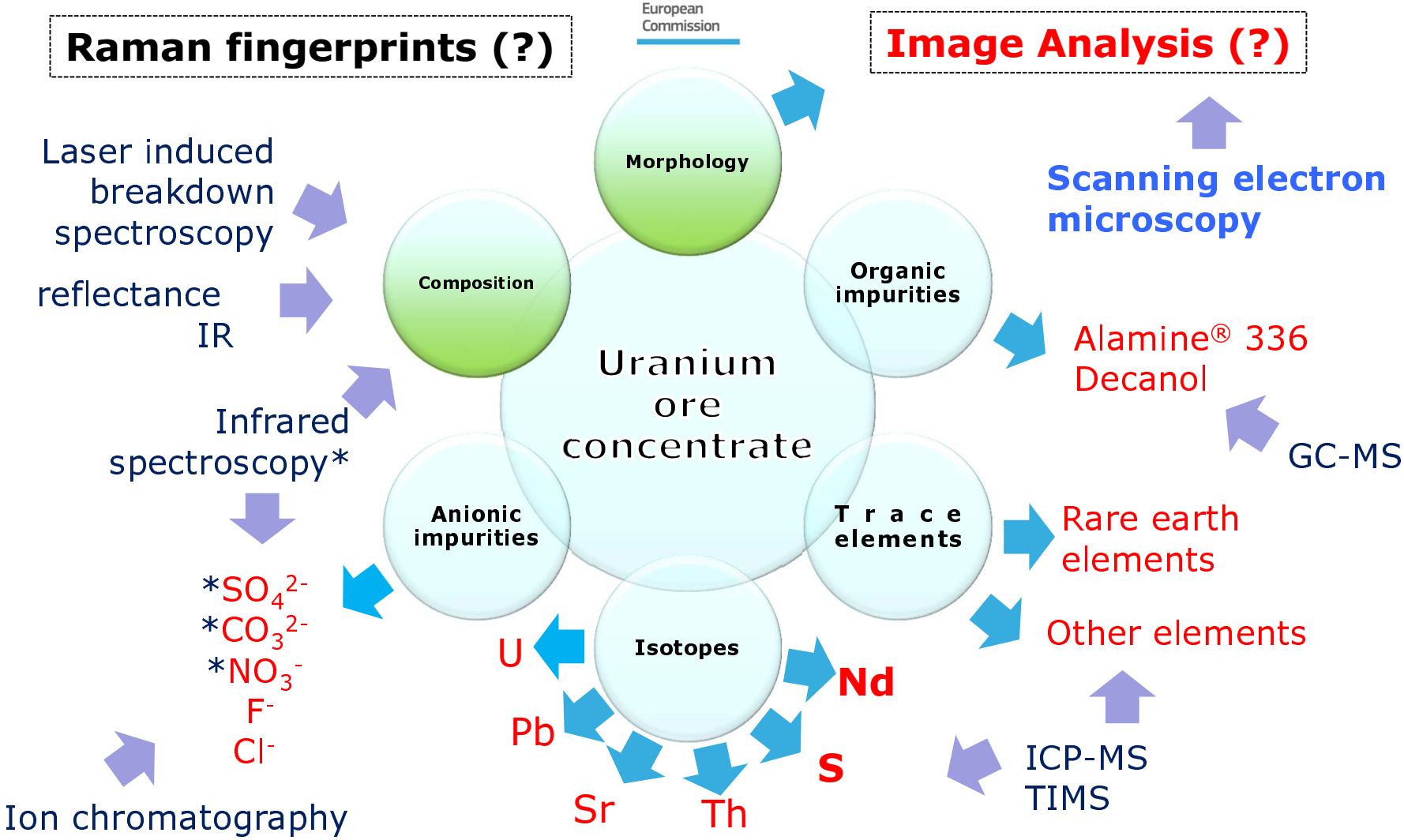
Uranium ore concentrates





Introduction

Current signatures based on literature



Methods

1. Raman spectroscopy

Raman spectroscopy (Bulk analysis)

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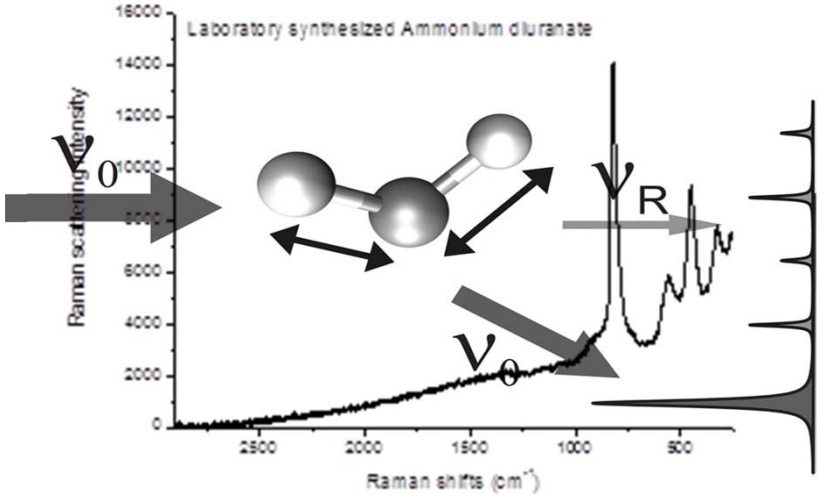

http://www.wiley-vch.de/books/sample/3527405062_c01.pdf
http://www.nomenrl.com
http://www.bruker.com
http://www.physik.fu-berlin.de

A *laser* (υ_0) is used to excite the molecules to virtual states. As a result of the interaction with molecules, incident photons are scattered *inelastically* (only 1 out of 10^8 photons) → Raman effect (υ_R)

Results:
Raman spectroscopy

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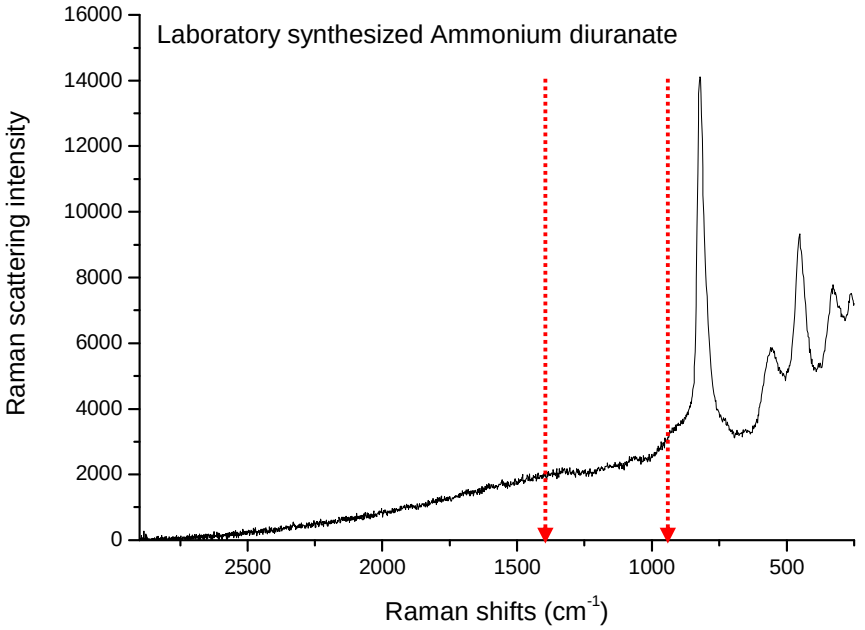
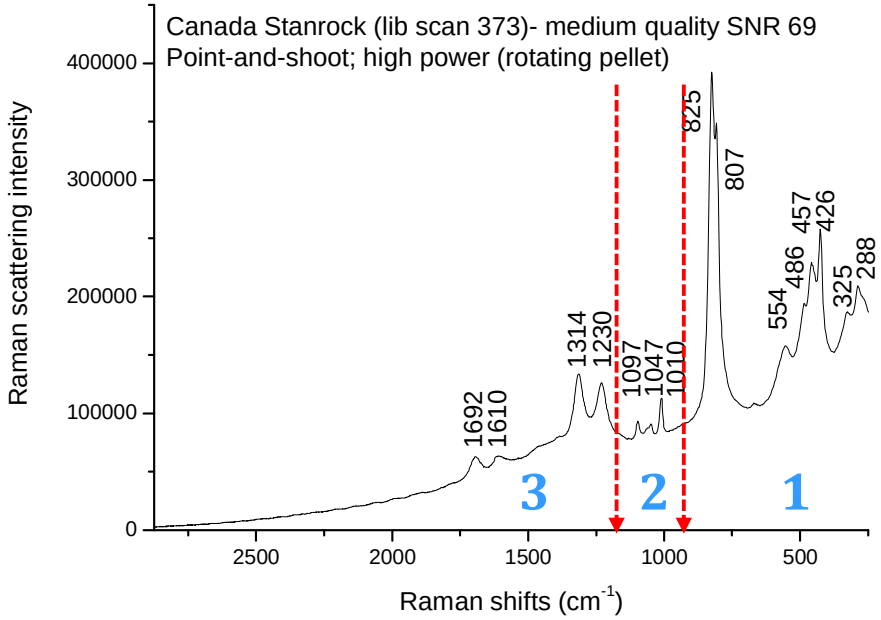
Applicability of Raman spectroscopy to nuclear forensics





Raman bands relating to:

1. **Uranium compound**
2. **Process related impurities**
3. **Electronic transitions (non-Raman effects)**

D.M.L. Ho, D. Manara, Zs Varga, A.Berlizov, Th. Fanghänel and K. Mayer, Radiochimica Acta 12 (2013) 779-784.

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Results:
Raman spectroscopy

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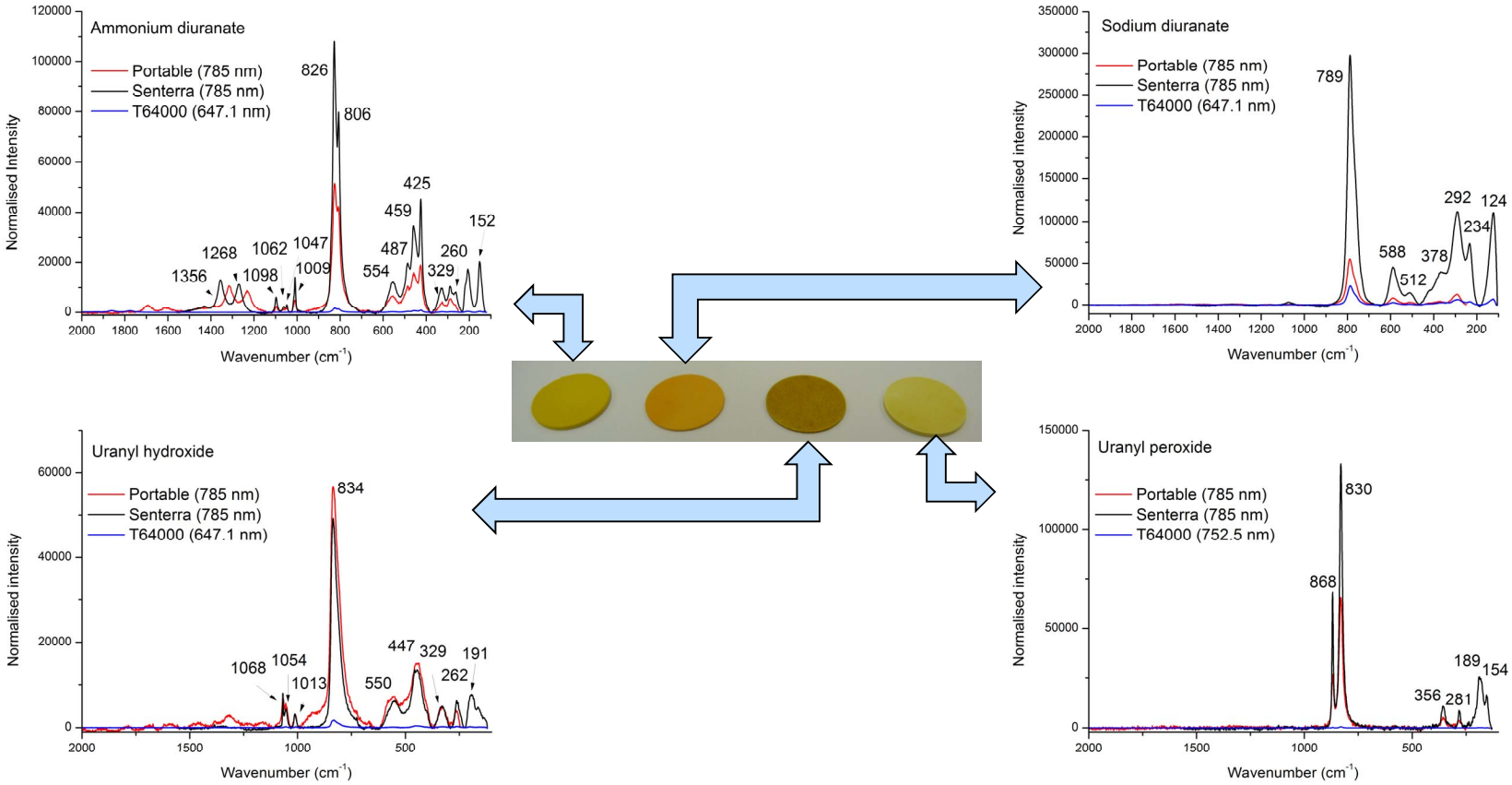
Comparison of 3 different dispersive Raman spectrometers

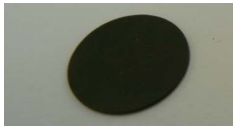


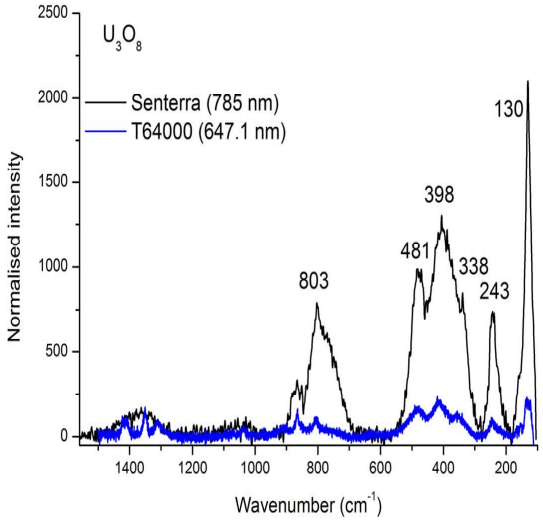
D.M.L. Ho, D. Manara, P. Lindqvist-Reis, Th. Fanghänel and K. Mayer, Vibrational Spectroscopy 73 (2014) 102-110.

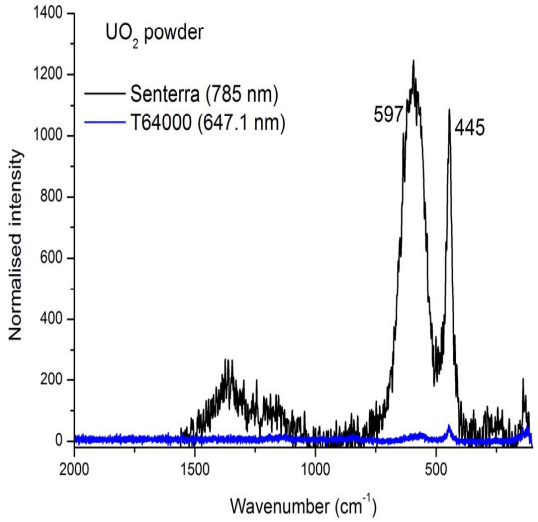
Results:
Raman spectroscopy

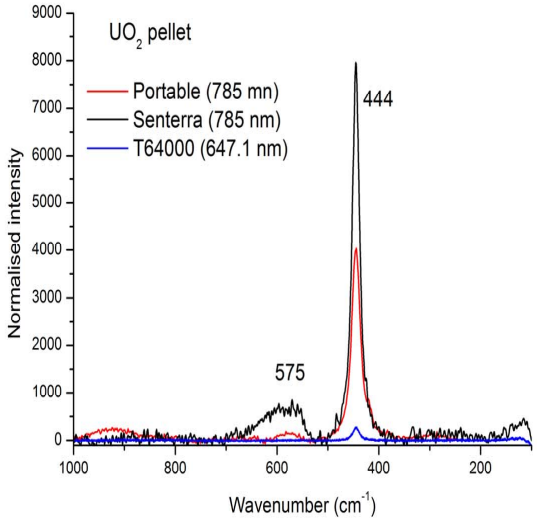
European Commission

Comparison of 3 different dispersive Raman spectrometers









D.M.L. Ho, D. Manara, P. Lindqvist-Reis, Th. Fanghänel and K. Mayer, Vibrational Spectroscopy 73 (2014) 102-110.

Results:
Raman spectroscopy

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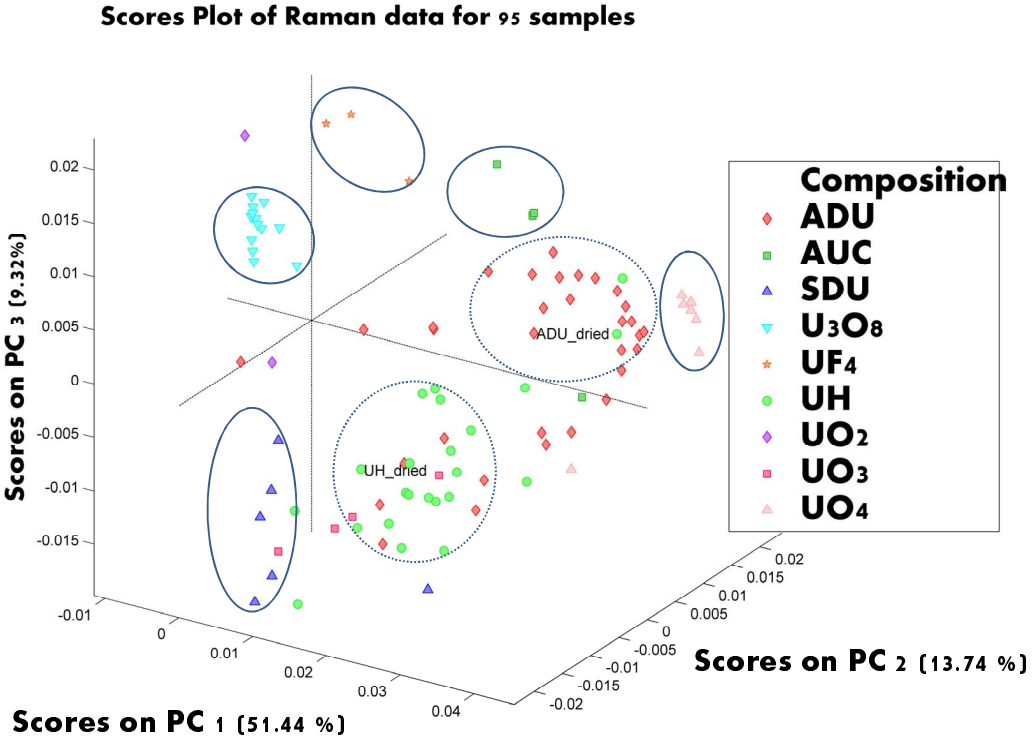
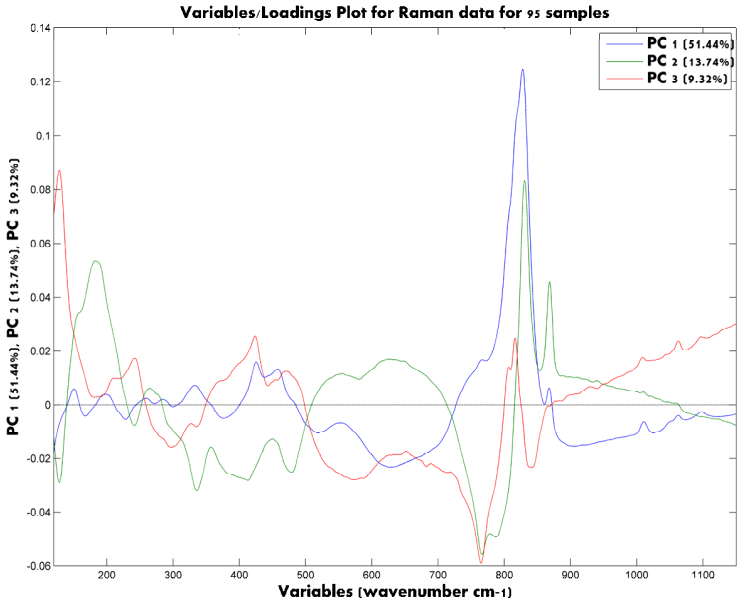
Unsupervised classifications of UOCs + other uranium compounds using principal component analysis (PCA)





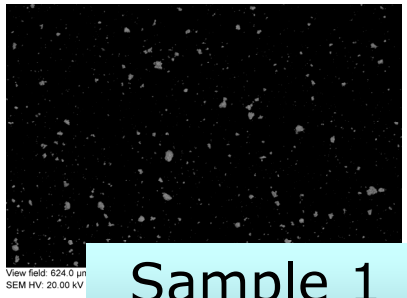
D.M.L. Ho, Z. Varga, L. Fongaro, P. Lindqvist-Reis, Th. Fanghänel and K. Mayer, Forensic Science International, -to be submitted for publication (together with AWE/Liverpool)

Methods

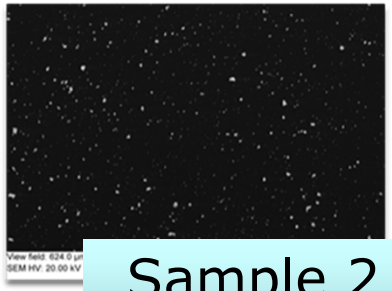
2. Image analysis of UOC

Morphology	17 samples (2-5 images per sample at 500x magnification)	Total of 65 images	30 descriptors of shapes and sizes obtained	**PCA analysis**
Image texture analysis	26 samples (5 images per sample at 1000x magnification)	Total of 130 images	Using Angular Measure Technique (based on angular measure algorithm)	**PCA analysis**

Sizes & shapes

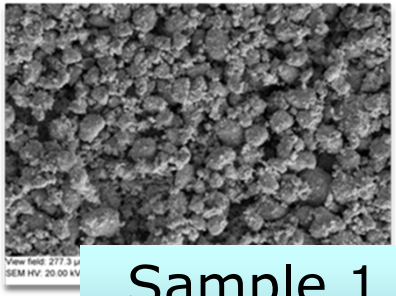


Sample 1

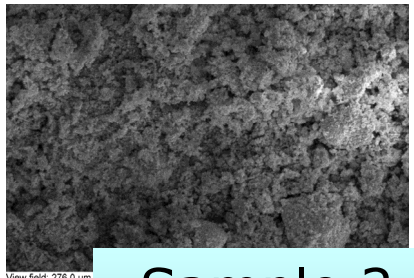


Sample 2

Image texture analysis



Sample 1



Sample 2

K.H. Esbensen, K.H. Hjelmen and K. Kvaal,
'The AMT Approach in Chemometrics-First Forays',
Journal of Chemometrics 10 (1996) 569-590.

Results:
Image Analysis

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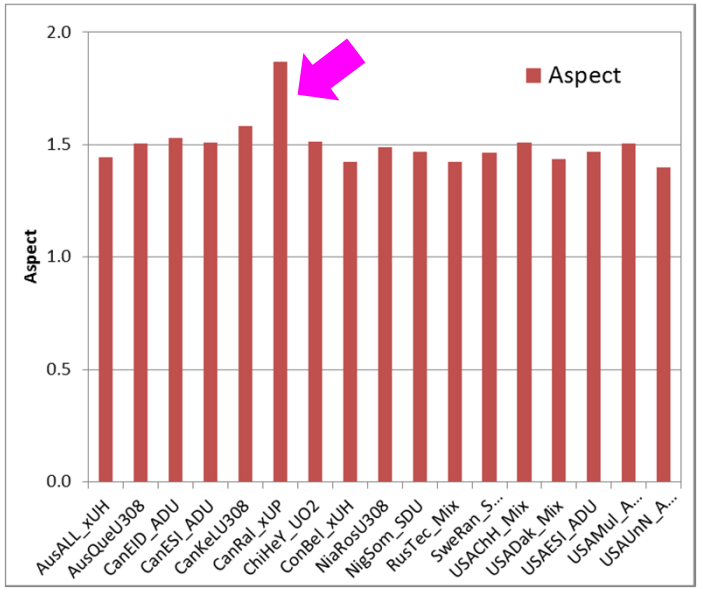
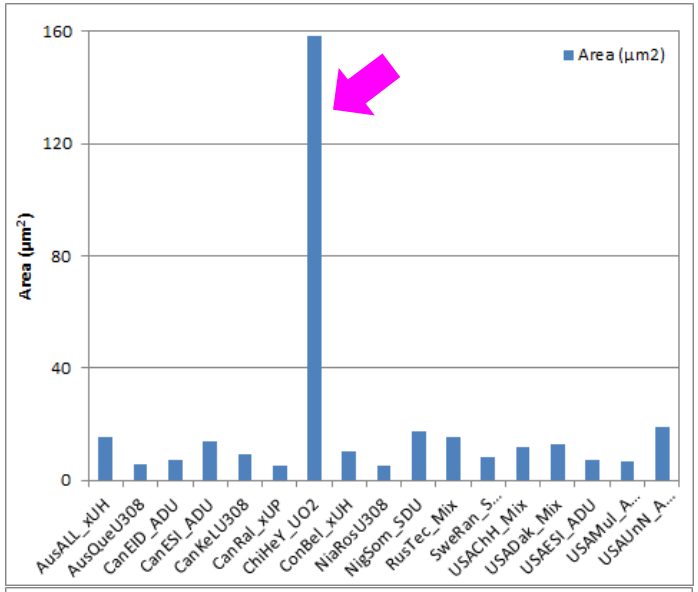
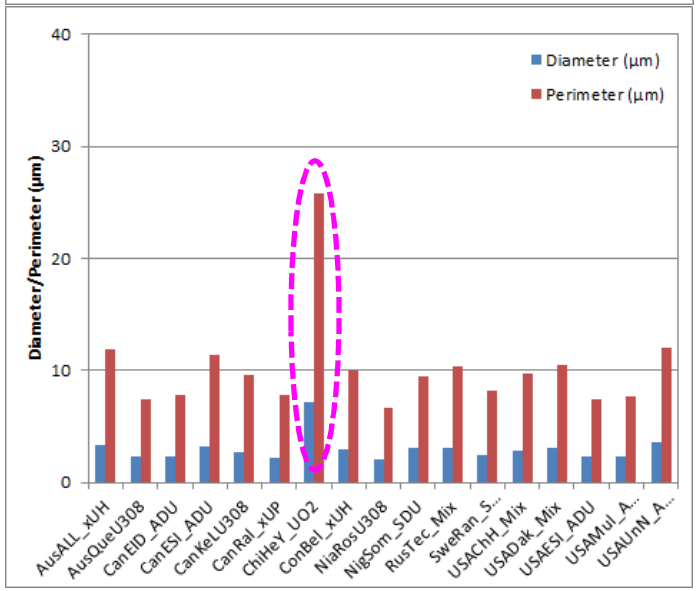
Morphology

Sample name	Area (µm2)	Diameter (µm)	Perimeter (µm)	Aspect
AusALL_xUH	15.16±0.53	3.38±0.08	11.88±0.32	1.44±0
AusQueU308	5.56±0	2.25±0	7.48±0	1.5±0
CanEID_ADU	7.15±0	2.32±0	7.85±0	1.53±0
CanESI_ADU	13.82±0.06	3.16±0.02	11.35±0.08	1.51±0.03
CanKeLU308	9.35±0.67	2.67±0.09	9.54±0.4	1.58±0.02
CanRal_xUP	5.21±0	2.13±0	7.83±0	1.87±0
ChiHeY_UO2	158.4±84.86	7.22±1.86	25.75±6.92	1.51±0.06
ConBel_xUH	10.23±0.48	3.01±0.07	9.93±0.23	1.42±0.02
NiaRosU308	5.36±0.59	2.08±0.07	6.63±0.26	1.49±0.02
NigSom_SDU	17.4±26.55	3.01±2.13	9.44±6.26	1.47±0.01
RusTec_Mix	15.37±4.89	3.13±0.32	10.4±1.32	1.42±0.02
SweRan_SDU	8.17±0.77	2.49±0.12	8.22±0.51	1.46±0.02
USAChH_Mix	11.91±1.22	2.76±0.12	9.69±0.55	1.51±0.02
USADak_Mix	12.98±2.03	3.12±0.09	10.48±0.42	1.44±0.01
USAESI_ADU	7.32±2.27	2.29±0.18	7.36±0.73	1.47±0.01
USAMul_ADU	6.91±0.96	2.31±0.1	7.67±0.5	1.51±0.03
USAUnN_ADU	18.97±1.66	3.54±0.15	12.02±0.5	1.4±0.03







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Results:
Image Analysis

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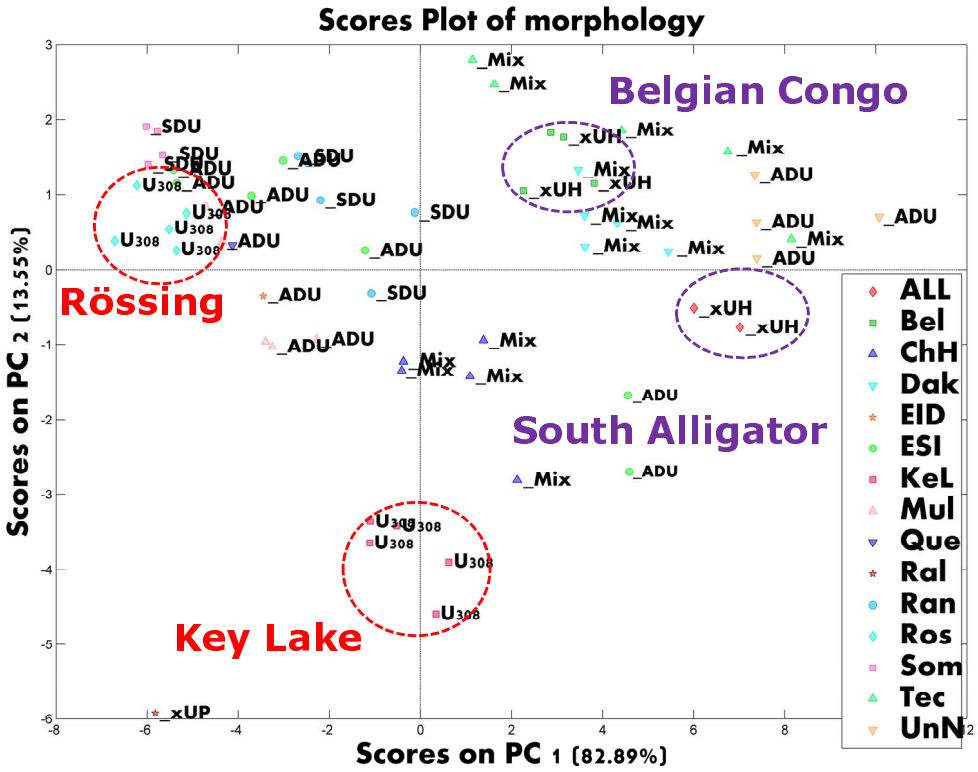
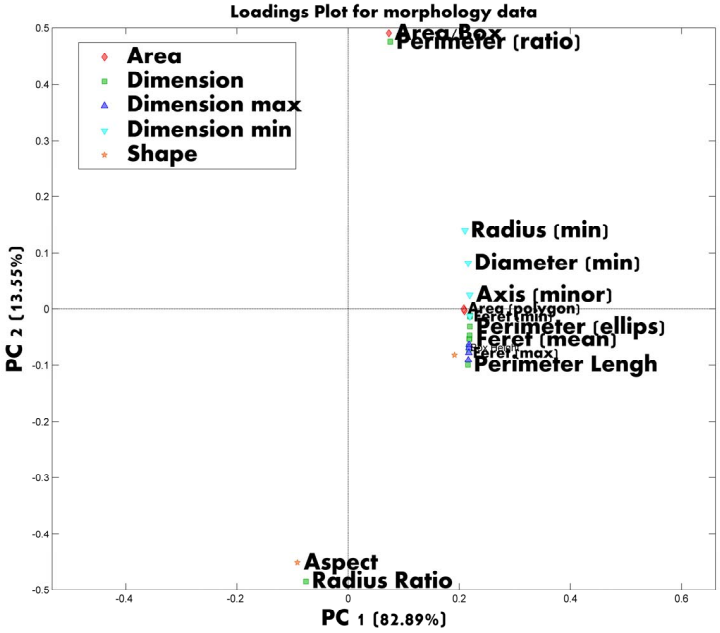
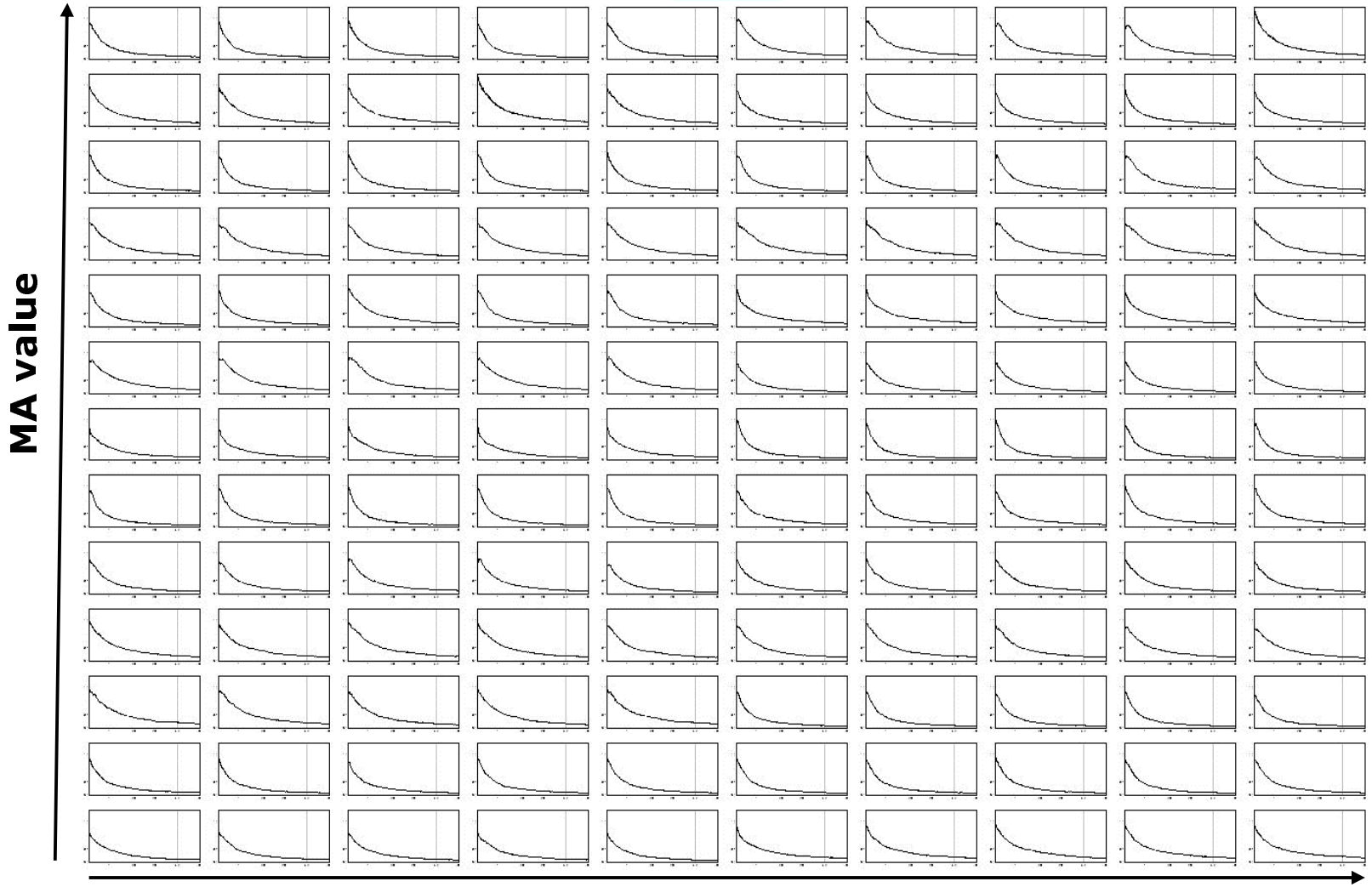
Morphology





Results:
Image texture analysis



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'The AMT Approach in Chemometrics-First Forays',
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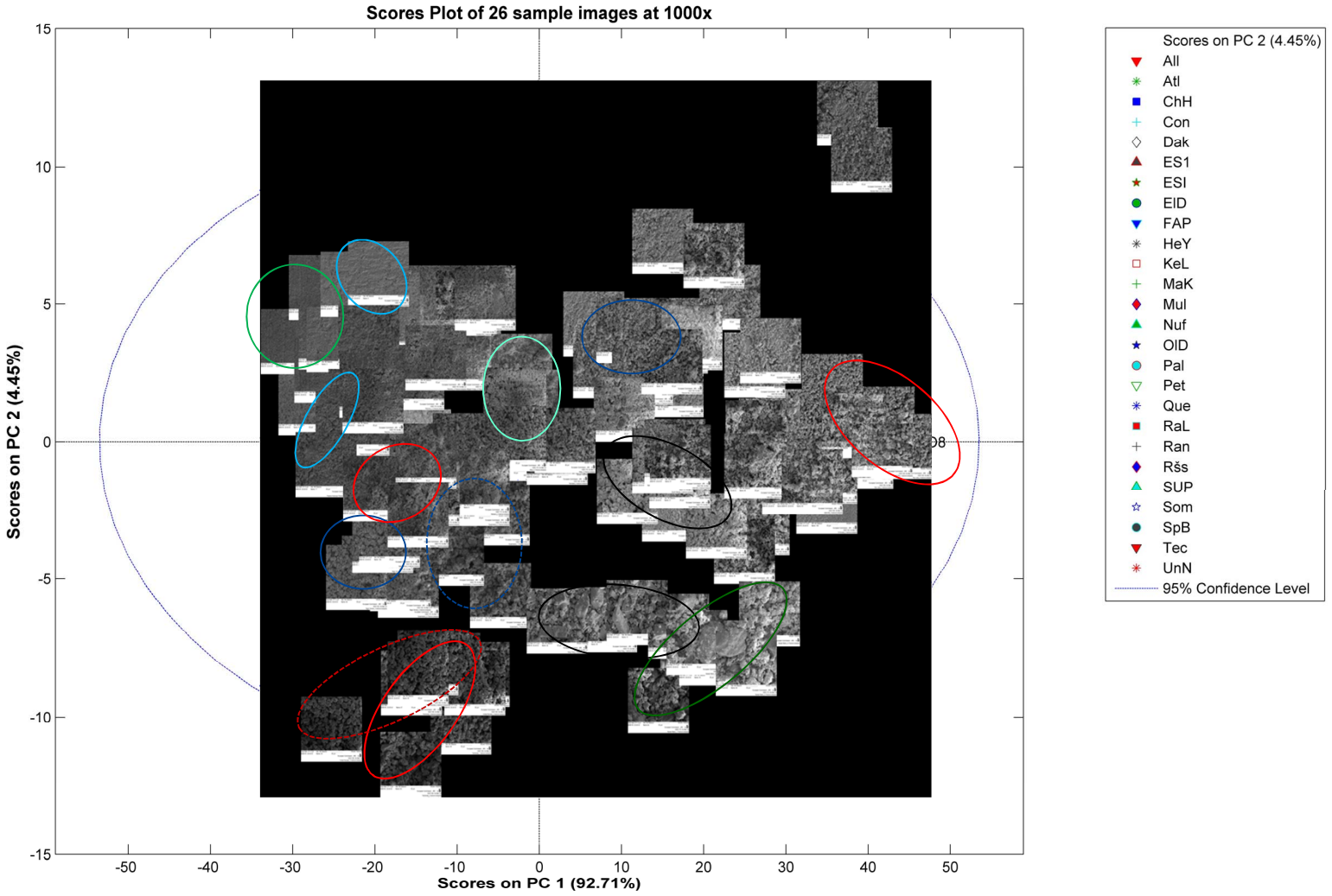
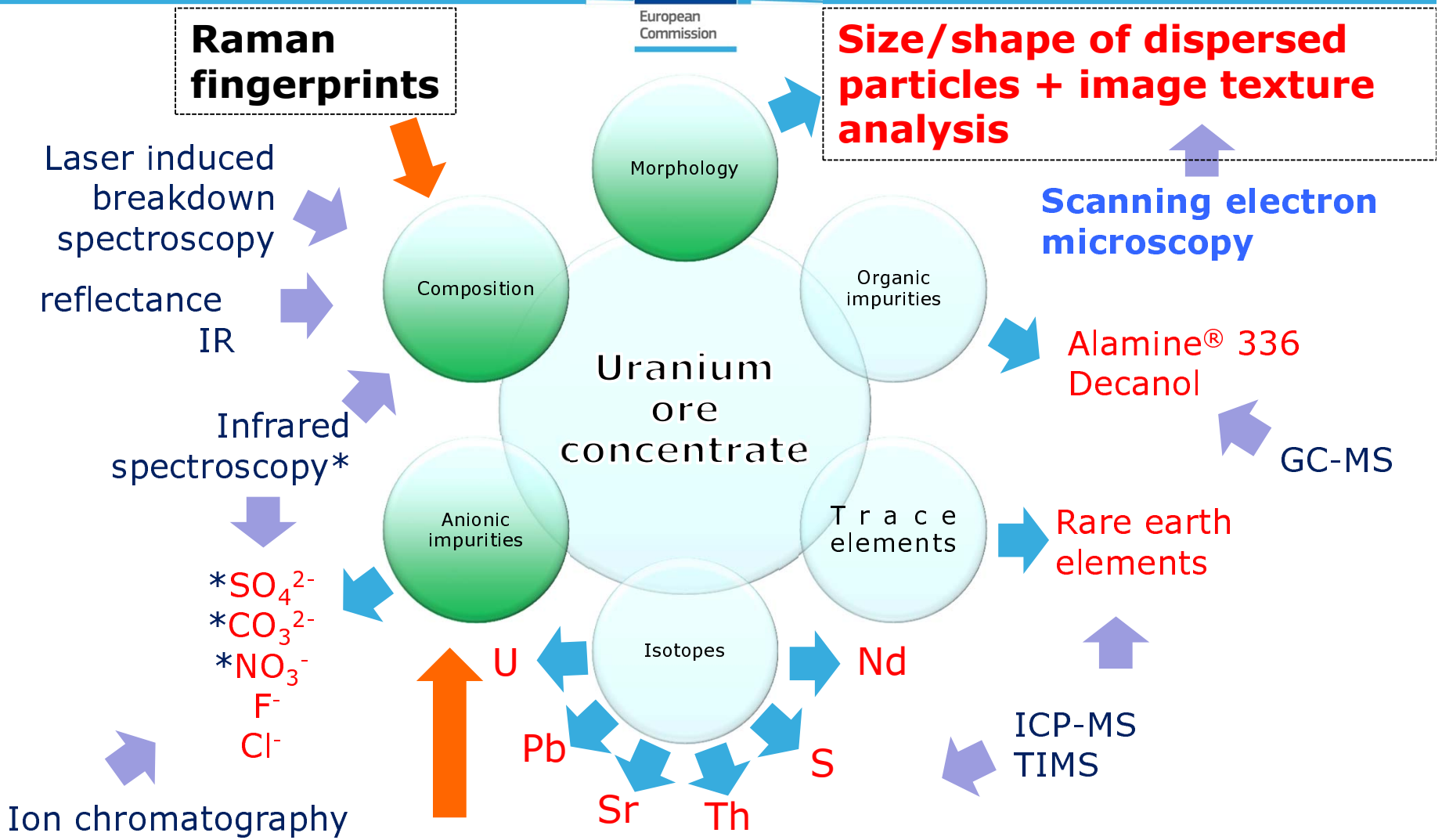


Summary


Raman fingerprints
Size/shape of dispersed particles + image texture analysis
Scanning electron microscopy
Laser induced breakdown spectroscopy
reflectance IR
Infrared spectroscopy*
*SO_4^{2-}
*CO_3^{2-}
*NO_3^-
F^-
Cl^-
Ion chromatography
Raman fingerprints
Morphology
Composition
Organic impurities
Uranium ore concentrate
Anionic impurities
Trace elements
Isotopes
Alamine® 336
Decanol
GC-MS
Rare earth elements
ICP-MS
TIMS
U
Nd
Pb
S
Sr
Th

Acknowledgements

- Dieter Schild

  (Institute for Nuclear Waste Disposal, Karlsruhe)

- International Atomic Energy Agency, Vienna

  (for hand-held Raman and UOC samples)

- Springfields, UK for the UOC samples