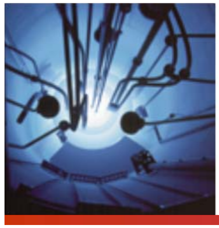


Institut für Kernchemie

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Thin stable targets and actinide targets for high power applications – status and perspectives

Klaus Eberhardt

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

HELMHOLTZ Institut Mainz

- Targets for nuclear applications
- Actinide target production
- Target characterization
- New developments
- Future tasks

ECOS 2012 – June, 18.-21. 2012 – Loveno di Menaggio, Italy

Targets for nuclear applications

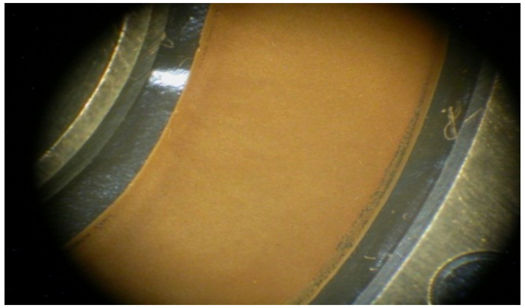
Nuclear structure investigations

^{40}Ar +	^{58}Ni
^{60}Ni +	^{89}Y
^{40}Ca +	^{96}Zr
^{76}Ge +	^{92}Mo
^{40}Ar +	^{208}Pb
^{40}Ar +	^{232}Th
^{40}Ar +	^{238}U

C/^{238}U/C-Target produced @ GSI
[Courtesy GSI Targetlab]

SHE production

- E114 (Fl) ⇒ $^{244}Pu(^{48}Ca,xn)$
- E115 ⇒ $^{243}Am(^{48}Ca,xn)$
- E116 (Lv) ⇒ $^{248}Cm(^{48}Ca,xn)$
- E117 ⇒ $^{249}Bk(^{48}Ca,xn)$
- E119 ⇒ $^{249}Bk(^{50}Ti,xn)$
- E120 ⇒ $^{248}Cm(^{54}Cr,xn)$
- E120 ⇒ $^{249}Cf(^{50}Ti,xn)$



Ti/^{244}Pu-Target produced @ JGU

Targets for nuclear applications

Ni	Y	Zr	Mo	Pb	Th	U	Pu	Am	Cm	Bk	Cf

stable / available — radioactive / rare

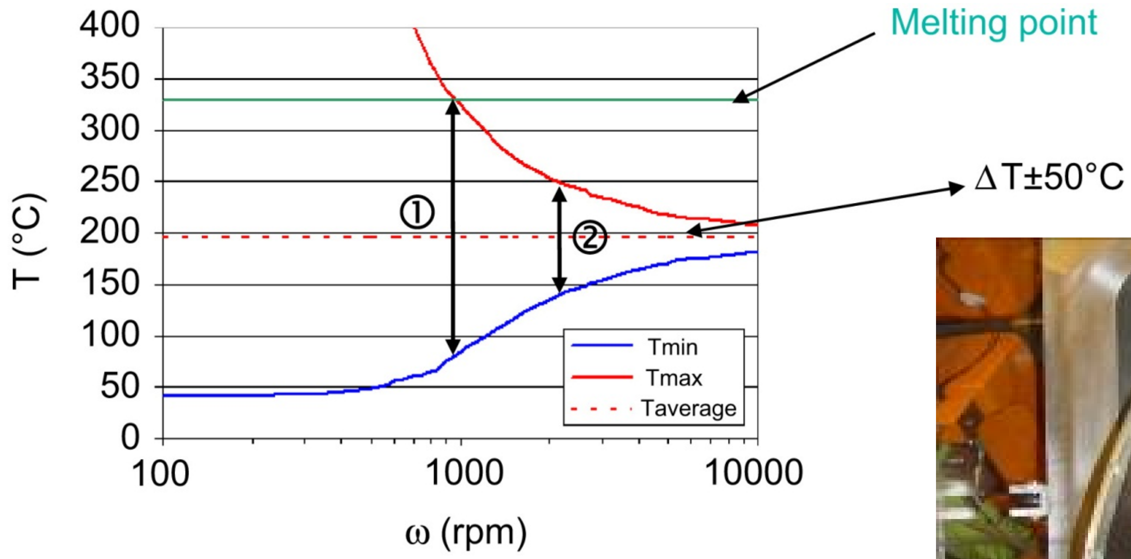
- Stable
- Unlimited availability
- Thick targets, foils, often self-supporting
- Production techniques:
  - Rolling
  - PVD
  - CVD
  - Sputtering ……

↔

- Unstable
- Limited availability
- High specific activity (in some cases)
- Production techniques:
  - Painting
  - PVD ($^{238}UF_4$ / ^{248}Cm)
  - Sputtering (^{238}U)
  - Electrodeposition

High beam intensities ⇒ Rotating target wheels

^{70}Zn-beam (10 pμA,334 MeV) on ^{208}Pb-target (450 μg/cm^2 / C-backing)



[C. Stodel *et al.*, Nucl. Instrum. Methods A 613 (2010) 480]

Target	Mp [°C]
Bi	271
Pb	327
Bi_2O_3	817
PbS	1118
U	1405

GANIL Target wheel. Courtesy C. Stodel

High beam intensities ⇒ Rotating target wheels

TASCA target wheel @ GSI:

- Target area: 6 cm^2
- 4 targets per wheel
- 12 mg per wheel @ 500 $\mu g/cm^2$

Backing:

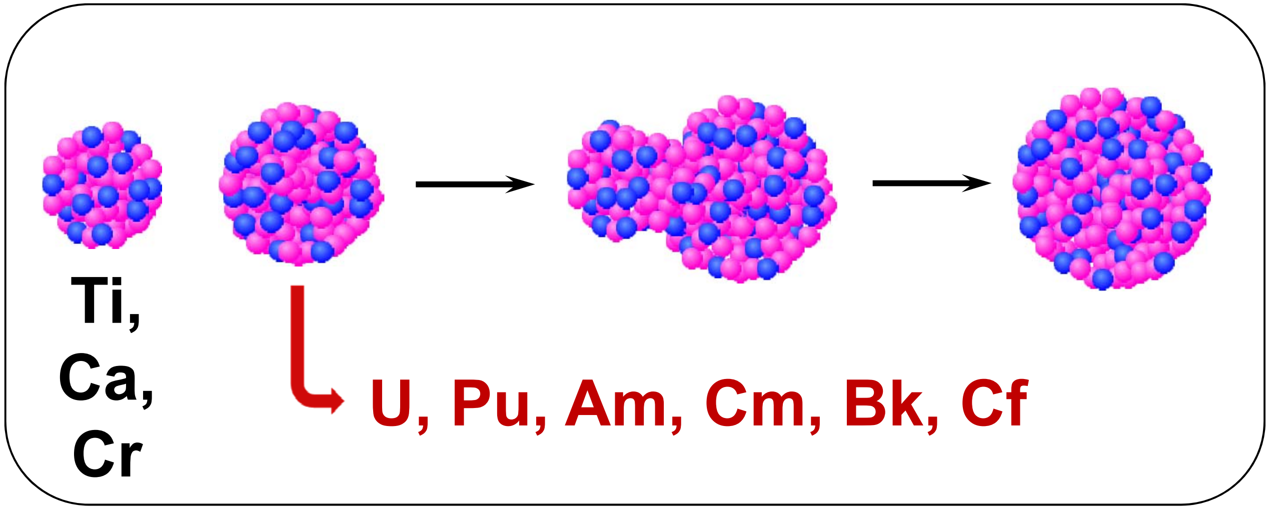
- Ti-foils (2 µm)
- Foils are glued onto Al-frame

Beam intensities:

DC-beam: 1-2 pµA

Pulsed beam (25% duty cycle):
1 pµA ≈ 4 pµA (Peak current)

Actinide targets for SHE production



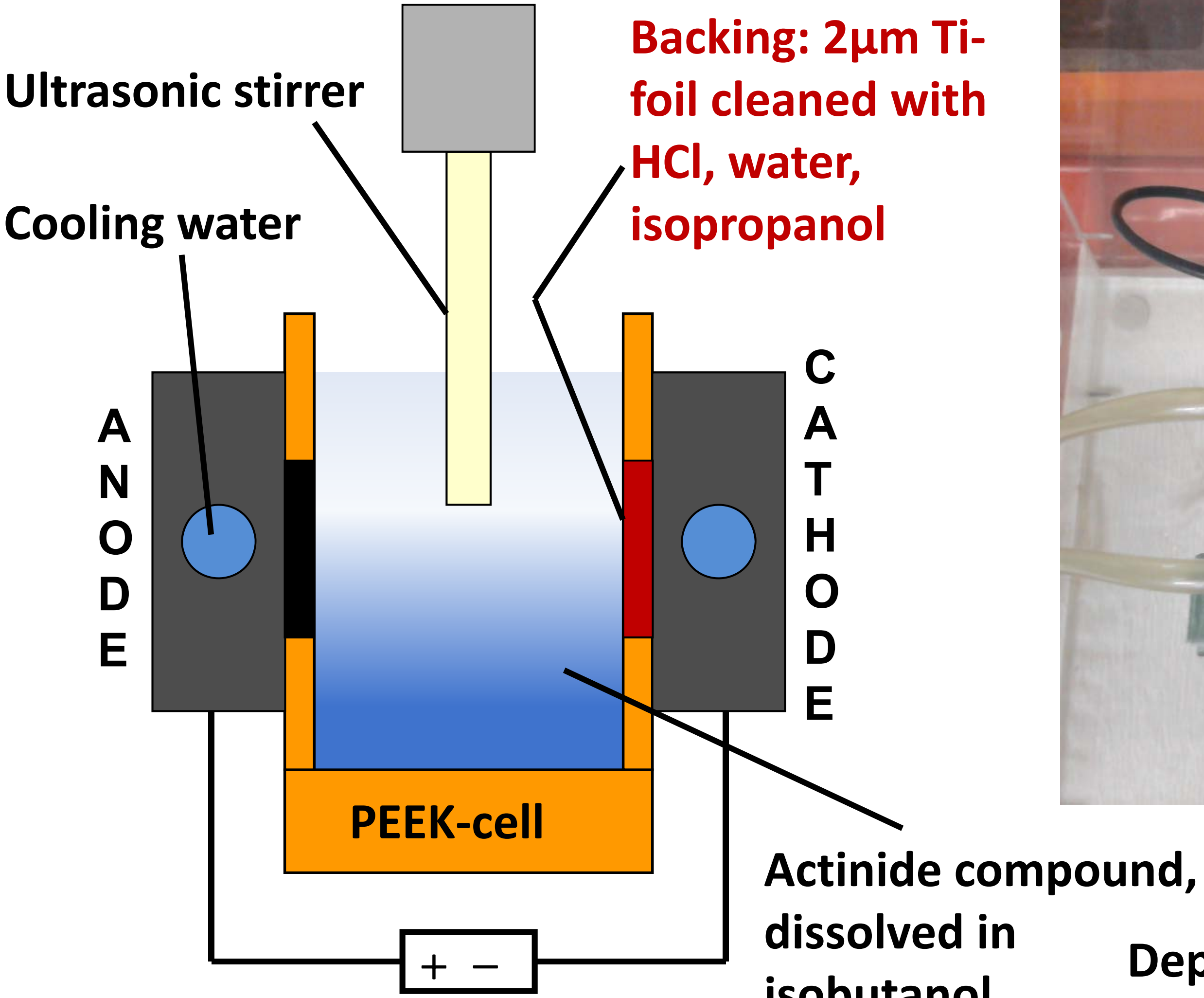
Requirements:

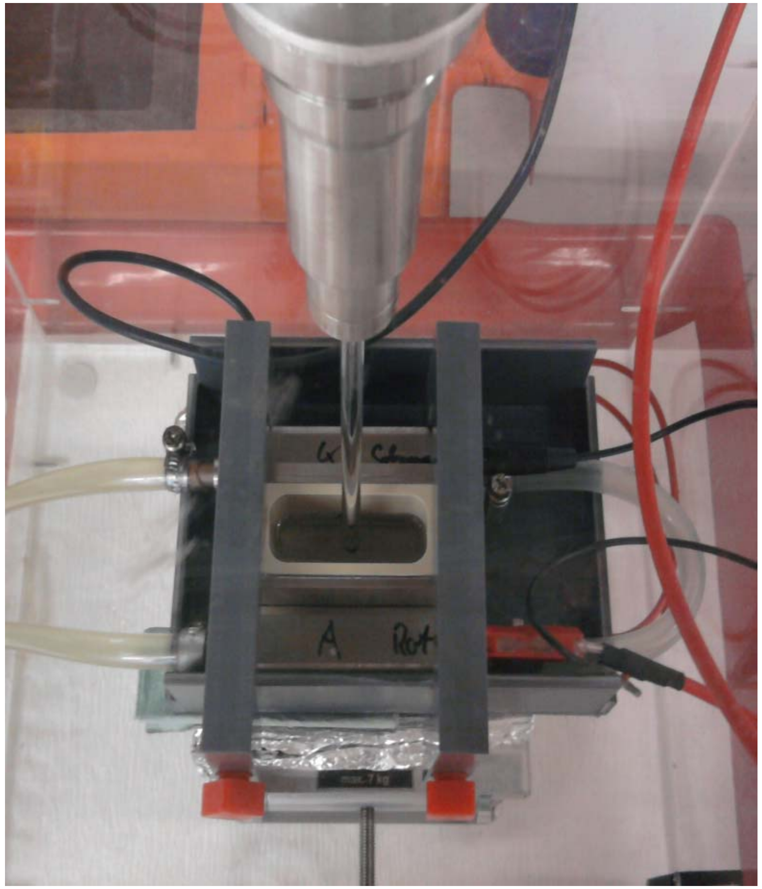
- Chemical purification prior to deposition (if necessary)
- Recovery of used target material (sooner or later……)
- Small and simple set-up
- High deposition yield
- Target thickness: 500 µg/cm^2

Production techniques:

- Painting
- Sputtering (^{238}U)
- PVD ($^{238}UF_4$ / ^{248}Cm)
- Molecular Plating is the only preparation method for rare isotopes

Actinide deposition by Molecular Plating



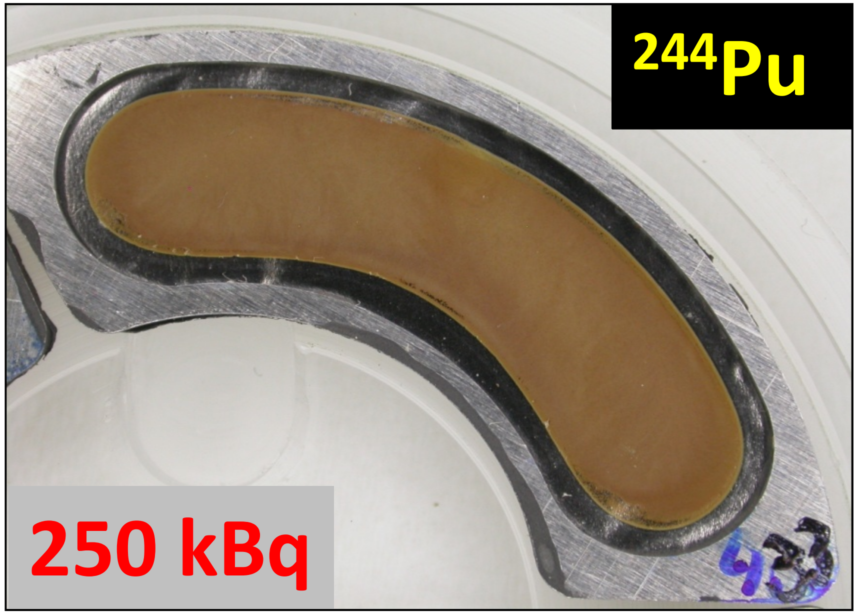


Voltage: 100 V - 1500 V

Deposition time: 3-6 hours

[Cell design according to H. Haba [RIKEN], TASCA05, Oslo, Oct. 2005]

Deposition of actinides by MP

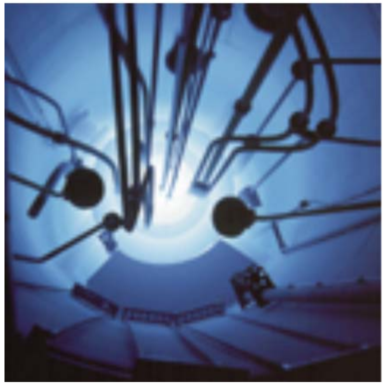


Deposition of actinides by MP

Molecular Plating

- **Deposition Yield: up to 90% for actinides**
- **Thickness: 500-1000μg/cm² possible in a single deposition step**

Standard target characterization techniques

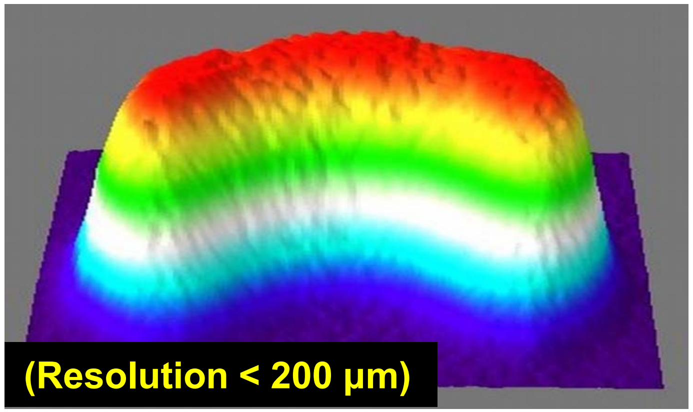


Deposition yield:

- α-particle spectroscopy
- γ-spectroscopy
- Neutron Activation Analysis

Layer homogeneity:

- α-particle spectroscopy
- Radiographic Imaging

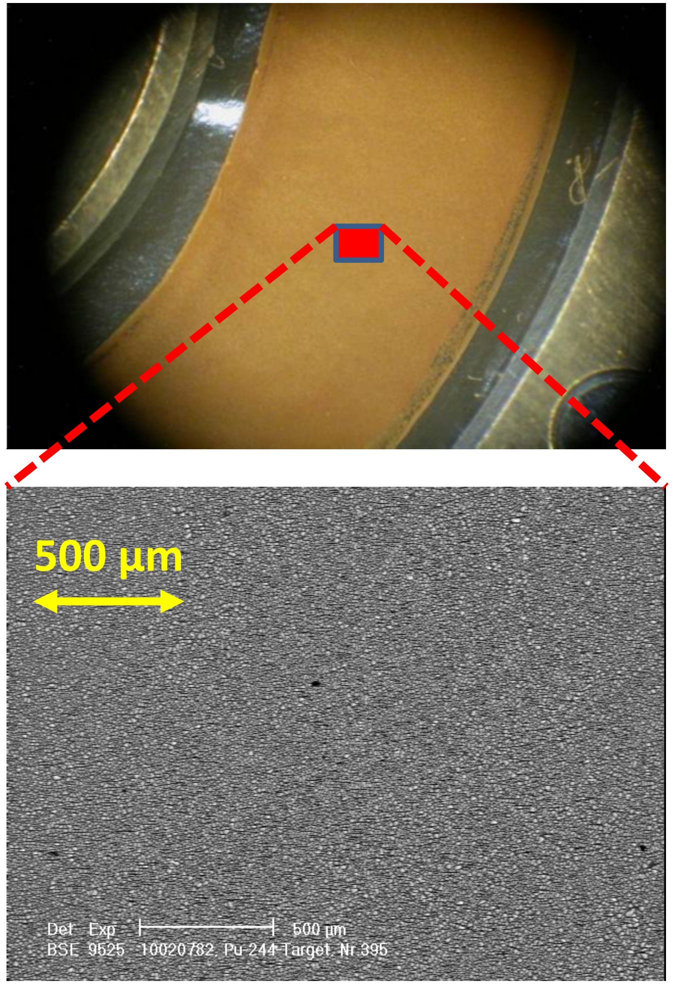


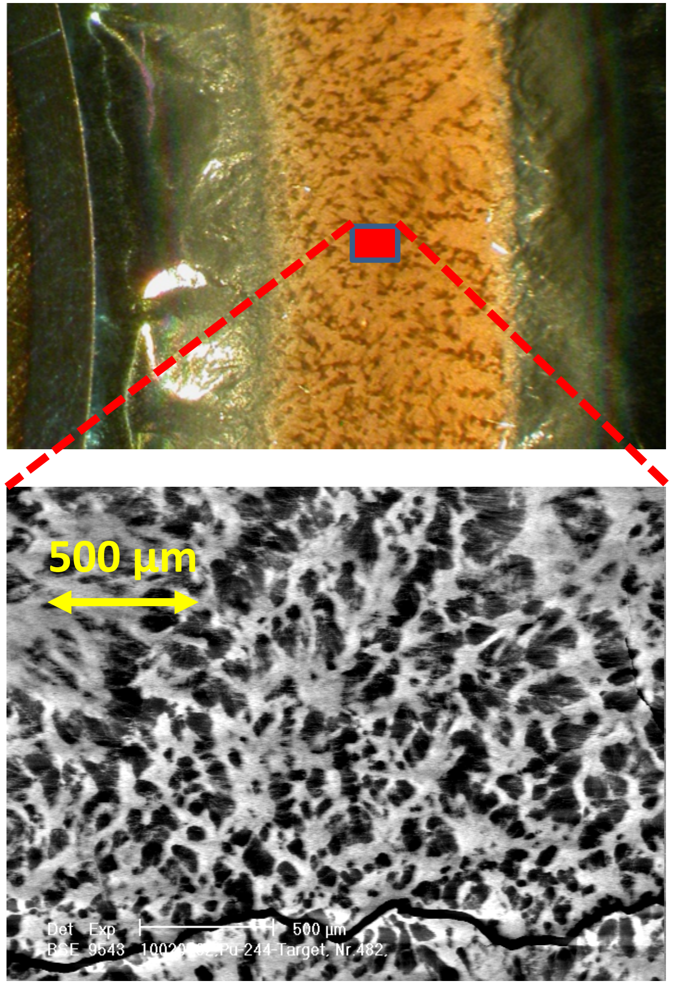
[D. Liebe et al., Nucl. Instr. and Meth. A 590 (2008) 145]

High beam doses ⇒ Change in layer morphology

Fresh ^{244}Pu-target layer

^{244}Pu-target irradiated with ^{48}Ca. Beam dose > 5x10^{18}



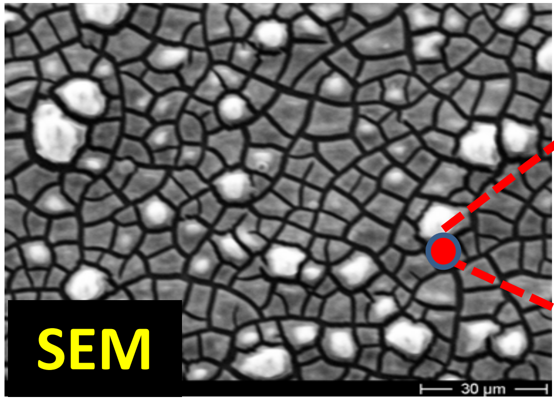


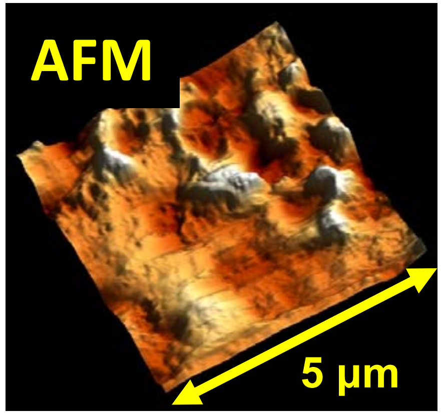
SEM-pictures: Courtesy K. Lützenkirchen, ITU

Properties of layers produced by MP

Studies on layer growth mechanism:

- Scanning Electron Microscopy (SEM) ⇒ µm-resolution
- Atomic Force Microscopy (AFM) ⇒ 10-100 nm-resolution





Nd as model element

[A. Vascon et al., Nucl. Instr. and Meth. A 655 (2011) 72]

Studies on the hemical composition:

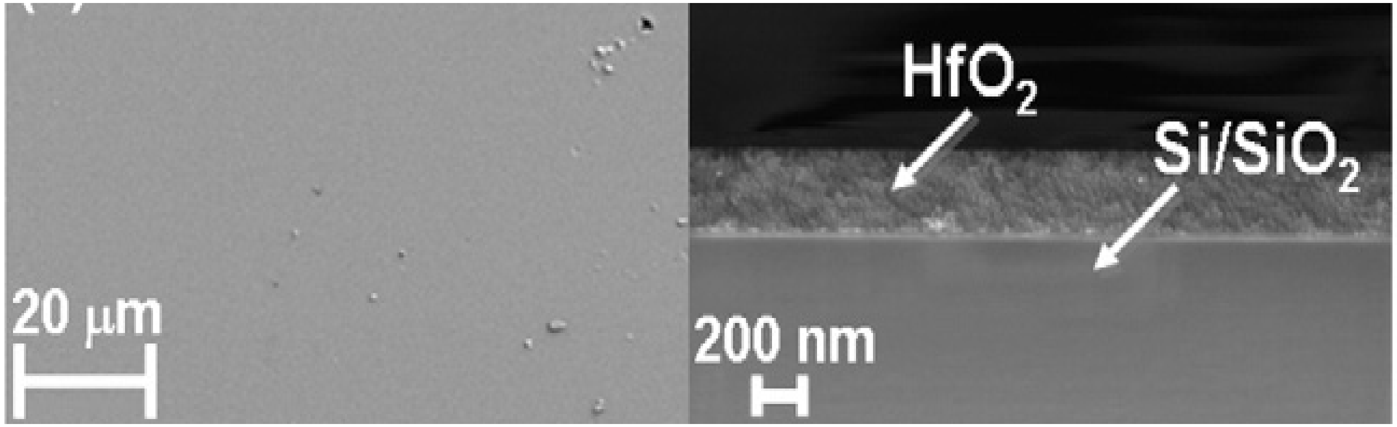
- X-ray Fluorescence (XRF)
- Photoelectron Spectroscopy (XPS)

Alternative target production techniques I

- **Polymer-assisted deposition (PAD):**

Metal-oxide mixed with polymer solution. Spin-coating of silicon substrate with metal-organic film. Target thickness up to 600 µg/cm^2 possible. No irradiation tests with actinide elements so far.

[M. Garcia *et al.*, Nucl. Instrum. Methods A 613 (2010) 396]



Target surface **Cross section view**

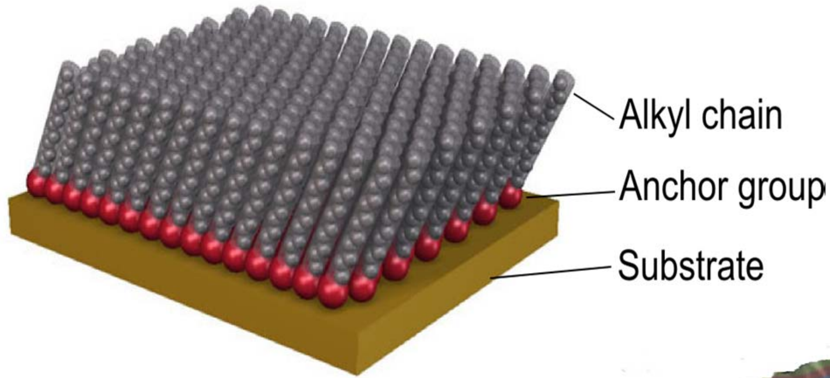
Alternative target production techniques II

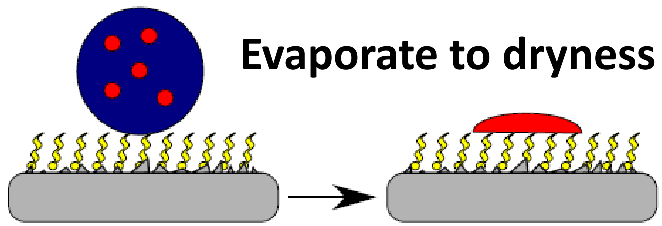
- **Superhydrophobic surfaces:**

Modification of a substrate with self-assembled monolayer (SAM) of alkyl chains. Homogenious deposition of metal-oxide/nitrate from aqueous solution by simple evaporation of single drops. No irradiation tests with actinide elements so far.

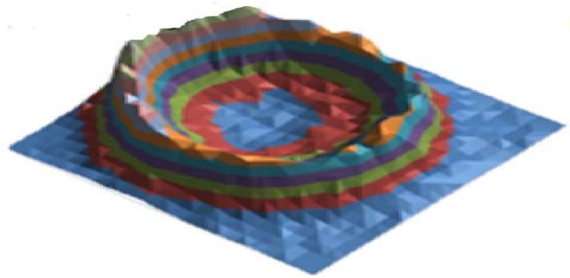
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

[D. Renisch *et al.*, Nucl. Instrum. Methods A 676 (2012) 84]

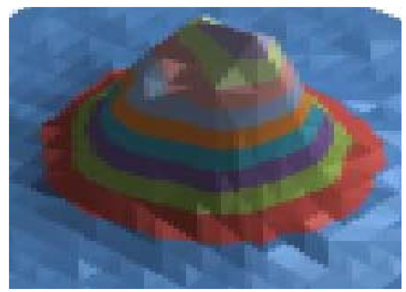




Evaporation of a single drop of Am-241(nitrate) solution. Activity distribution by RI:



Untreated Ti-surface



Modified Ti-surface

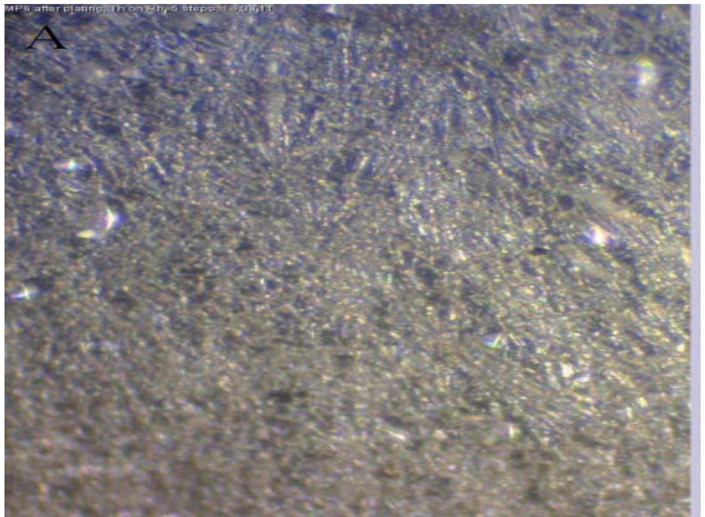
Alternative target production techniques III

- **Intermetallic targets:**

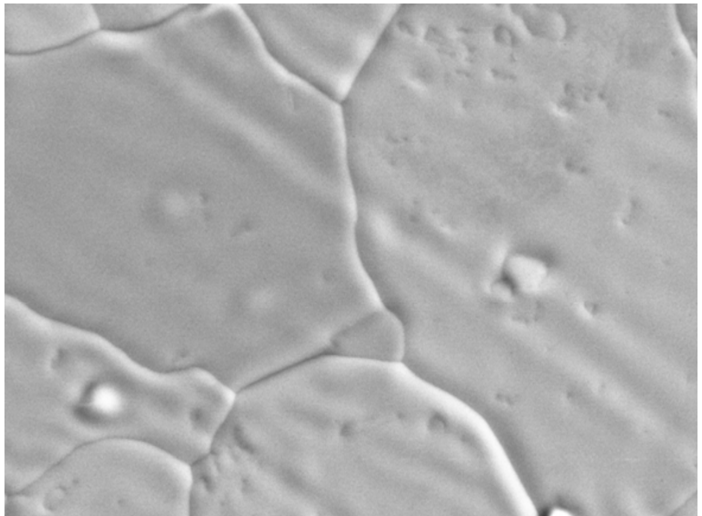
Molecular Plating of a lanthanide/actinide compound on a Pd backing. Subsequent reduction by heating the target in a hydrogen atmosphere. Formation of intermetallic Ac-Pd phases. First in-beam irradiation tests performed.

PAUL SCHERRER INSTITUT

[I. Usoltsev *et al*., contribution to TAN 11]



Gd-layer produced by MP



Intermetallic phase

Targets for high intensity beams: Status

- **Rotating target wheels** used to distribute heat load
- **Stable targets:** Produced with a variety of techniques and chemical compounds
- **Actinide targets:** For rare isotopes only Molecular Plating is feasible to produce stable layers with thicknesses ≥ 500 μg/cm^2
- **Beam intensities:** ≈ 1 pμA (DC-beam)
  ≈ 4 pμA (Pulsed, 25% duty cycle)
- **Target stability:** Beam dose limit depends on target-backing-combination

Targets for high intensity beams: Tasks

- Further investigation of alternative target preparation techniques
- Systematic studies on target performance for beam intensities exceeding 1-2 pμA (DC) and high beam doses ⇒ beam time requirements
- Application of different analytical techniques to study target layer properties (chemical- and physical-) prior to and subsequent to irradiation in order to under-stand target-backing-interaction

Is there a completely new approach for actinide target preparation? Dream: „Self supporting“ actinide target

International collaboration irrevocable to develop thin targets for high power applications

INTDS 2012

26th World Conference of the International Nuclear Target Development Society

Targets for Accelerator-Based Research

Mainz, Germany, August 19 - 24, 2012

www.gsi.de/intds2012

Scientific Advisory Committee:

- Christoph E. Düllmann, HI Mainz, Johannes Gutenberg-Universität, Mainz & GSI, Darmstadt, Germany
- Klaus Eberhardt, Johannes Gutenberg-Universität, Mainz, Germany
- David Gilliam, NIST, Wahington, USA
- Birgit Kindler, GSI, Darmstadt, Germany
- Bettina Lommel, GSI, Darmstadt, Germany
- Dannie Steski, BNL, Upton NY, USA
- Thomas Stöhlker, HI Jena, Germany
- Anna Stolarz, HIL-UW, Warsaw, Poland
- Atsushi Yoshida, Riken, Japan

Local Organizing Committee:

- Klaus Eberhardt, Johannes Gutenberg-Universität, Mainz, Germany
- Birgit Kindler, GSI, Darmstadt, Germany
- Tatiana Litvinova, GSI, Darmstadt, Germany
- Bettina Lommel, GSI, Darmstadt, Germany
- Siglind Raiss, GSI, Darmstadt, Germany
- Petra Sach-Muth, Johannes Gutenberg-Universität, Mainz, Germany
- Brigitta Schausten, GSI, Darmstadt, Germany

Topics:

- Preparation Techniques for Thin Films and Foils
- Stripper Foils
- Radioactive Targets
- High Power Targets
- Liquid and Gas Targets
- Isotopic Enrichment and Materials
- Target Characterization
- Targets and Coatings for Medical Radioisotope Production

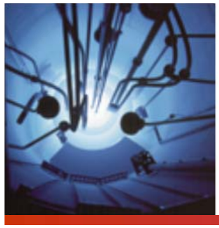
Contact:

Email: intds2012@gsi.de
Web: www.gsi.de/intds2012

Dr. Klaus Eberhardt
Johannes Gutenberg-Universität Mainz
Institut für Kernchemie
Fritz-Strassmann-Weg 2
D-55128 Mainz
Germany
Telephone: ++49 (0) 6131 39-25846
Telefax: ++49 (0) 6131 39-24488

Dr. Bettina Lommel
GSI Helmholtzzentrum für Schwerionenforschung GmbH
Target Laboratory
Planckstrasse 1
D-64291 Darmstadt
Germany
Telephone: ++49 (0) 6159 71-2691
Telefax: ++49 (0) 6159 71-2166

JGU Johannes Gutenberg Universität Mainz — Helmholtz Association, Helmholtz Institute Mainz — GSI — Helmholtz Gemeinschaft, Helmholtz-Institut Jena — INTDS



Thanks to:

JG|U
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Lawrence Livermore National Laboratory providing Cm-248

Oak Ridge National Laboratory providing Am-243 and Bk-249

OAK RIDGE National Laboratory

Lawrence Berkeley National Laboratory providing Cf-249

BERKELEY LAB

A. Kühnle, Institute of Physical Chemistry for AFM-measurements

JG|U
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

BMBF for financial support

Bundesministerium
für Bildung
und Forschung

….and you for your attention