

PAUL SCHERRER INSTITUT



Emilio Andrea Maugeri:: Scientist :: Paul Scherrer Institut

Targetry of Rare Isotopes at PSI

30th Conference of the International Nuclear Target Development Society_ INTDS2022

Samples of Radioactive Materials

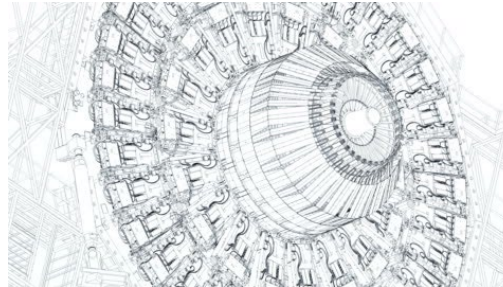
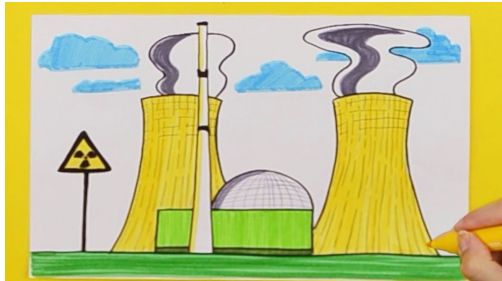
Can not be found in nature



Rare and very Costly



Must be produced in
Nuclear power plant,
Accelerators
Or retrieved from
radioactive waste



Thursday, 29.09.2022

Session: Isotope production (chair: G. Sibbens)

9:00–9:30 Water as a target for heavy ion irradiations
(invited G. Severin, MSU, FRIB, USA)

9:30–9:50 Isotope production at PSI (R. Dressler, PSI, Switzerland)

Samples of Exotic Radionuclides



Sources

Targets

Radiations



Radioactive Ions

Radioactive beam
Radioactive Samples

α - and γ - standard

Nuclear data measurements:

Half-life measurement
Decay branching fractions
Emission intensity

Interaction of radiation with matter

Nuclear industry
Nuclear medicine

PRL 114, 041101 (2015)

PHYSICAL REVIEW LETTERS

week ending
30 JANUARY 2015



Settling the Half-Life of ^{60}Fe : Fundamental for a Versatile Astrophysical Chronometer

A. Wallner,^{1,2} M. Bichler,³ K. Buczak,^{2,3} R. Dressler,⁴ L. K. Fifield,¹ D. Schumann,⁴ J. H. Sterba,³
S. G. Tims,¹ G. Wallner,⁵ and W. Kutschera²

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(Received 21 August 2014; published 28 January 2015)

Samples of Exotic Radionuclides



Targets

Samples of Exotic Radionuclides



Targets

Detector

Particle beam



Cross section measurement

Nuclear astrophysics

Nuclear industry

Nuclear structure

Fundamental Science

Nuclear physics

Synthesis of new elements

(Super Heavy Elements)

Nuclear physics/ chemistry

Synthesis radionuclides for

Nuclear medicine applications

Thursday, 29.09.2022

Session: Isotope production (chair: G. Sibbens)

9:50–10:10 A Missing link: towards the preparation of a ^{32}Si target for nuclear astrophysics experiments (M. Veicht, EPFL & PSI, Switzerland)

Friday, 30.09.2022

Session: Stable targets II (chair: B. Lommel)

9:30–9:50 Production of PbSe targets for neutron capture cross section studies (N. Chiera, PSI, Switzerland)

Wednesday, 28.09.2022

Session: High power targets (chair: D. Schumann)

9:50–10:10 The PSI Meson Target facility and its upgrade IMPACT-HIMB (D. Kiselev, PSI, Switzerland)

10:10–10:30 IMPACT-TATTOOS as part of the infrastructure roadmap Switzerland initiative: Challenges of the design concepts (R. Eichler, PSI & Univ. Bern, Switzerland)

Thursday, 29.09.2022

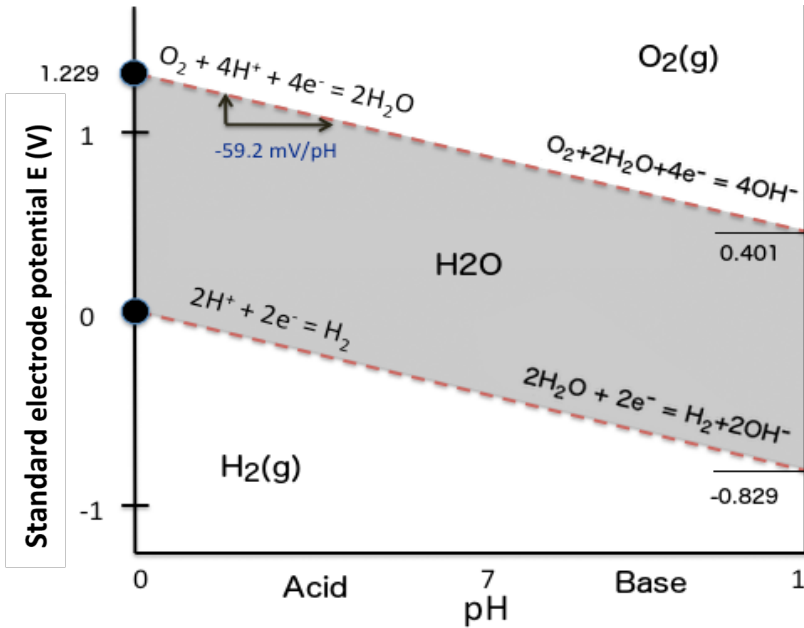
Session: Medical application (chair: E. Maugeri)

11:20–11:40 Target preparation for radionuclide development towards medical application at Paul Scherrer Institut (Z. Talip, PSI, Switzerland)

Target production: Molecular Plating

NUCLEAR INSTRUMENTS AND METHODS 16 (1962) 355-557; NORTH-HOLLAND PUBLISHING CO.

Electrochemical window
From +1.229 to -0.829



MOLECULAR PLATING: A METHOD FOR THE ELECTROLYTIC FORMATION OF THIN INORGANIC FILMS

W. PARKER

Dept of Physics, Chalmers University of Technology, Gothenburg, Sweden

and

R. FALK

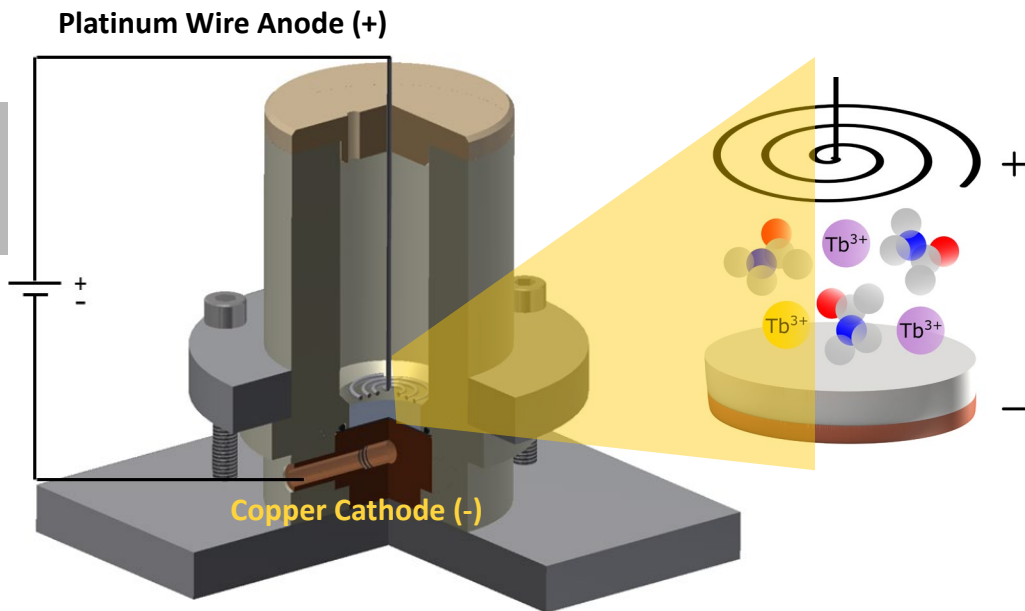
Nobel Institute for Physics, Stockholm 50, Sweden

Received 7 June 1962

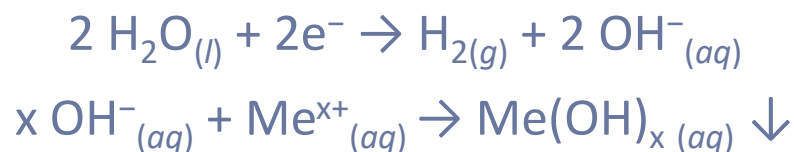
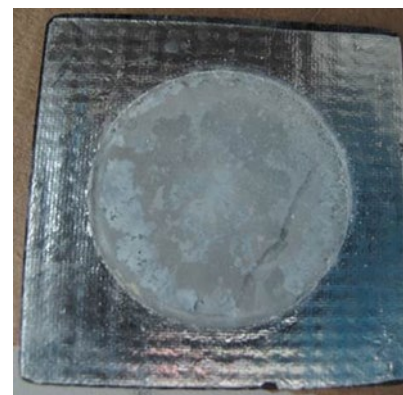
PERIODIC TABLE OF THE ELEMENTS

1																2		18																	
H Hydrogen 1.008																		He Helium 4.003																	
3 Li Lithium 6.941		4 Be Beryllium 9.012												5 B Boron 10.811		6 C Carbon 12.011		7 N Nitrogen 14.007		8 O Oxygen 15.999		9 F Fluorine 18.998		10 Ne Neon 20.180											
11 Na Sodium 22.990		12 Mg Magnesium 24.305												13 Al Aluminum 26.982		14 Si Silicon 28.086		15 P Phosphorus 30.974		16 S Sulfur 32.065		17 Cl Chlorine 35.453		18 Ar Argon 39.948											
19 K Potassium 39.098		20 Ca Calcium 40.078		21 Sc Scandium 44.956		22 Ti Titanium 47.867		23 V Vanadium 50.942		24 Cr Chromium 51.996		25 Mn Manganese 54.938		26 Fe Iron 55.845		27 Co Cobalt 58.933		28 Ni Nickel 58.693		29 Cu Copper 63.546		30 Zn Zinc 65.399		31 Ga Gallium 69.723		32 Ge Germanium 72.640		33 As Arsenic 74.922		34 Se Selenium 78.960		35 Br Bromine 79.904		36 Kr Krypton 83.800	
37 Rb Rubidium 85.468		38 Sr Strontium 87.620		39 Y Yttrium 88.906		40 Zr Zirconium 91.224		41 Nb Niobium 92.906		42 Mo Molybdenum 95.938		43 Tc Technetium 98.000		44 Ru Ruthenium 101.070		45 Rh Rhodium 102.906		46 Pd Palladium 106.420		47 Ag Silver 107.868		48 Cd Cadmium 112.411		49 In Indium 114.818		50 Sn Tin 118.710		51 Sb Antimony 121.760		52 Te Tellurium 127.600		53 I Iodine 126.905		54 Xe Xenon 131.293	
55 Cs Cesium 132.905		56 Ba Barium 137.327		57-71 Lanthanides		72 Hf Hafnium 178.490		73 Ta Tantalum 180.948		74 W Tungsten 183.840		75 Re Rhenium 186.207		76 Os Osmium 190.230		77 Ir Iridium 192.222		78 Pt Platinum 195.078		79 Au Gold 196.967		80 Hg Mercury 200.590		81 Tl Thallium 204.383		82 Pb Lead 207.200		83 Bi Bismuth 208.980		84 Po Polonium 209.000		85 At Astatine 210.000		86 Rn Radon 222.000	
87 Fr Francium 223.000		88 Ra Radium 226.000		89-103 Actinides		104 Rf Rutherfordium 261.000		105 Db Dubnium 262.000		106 Sg Seaborgium 266.000		107 Bh Bohrium 264.000		108 Hs Hassium 277.000		109 Mt Meitnerium 278.000		110 Ds Darmstadtium 281.000		111 Rg Roentgenium 282.000		112 Cn Copernicium 285.000		113 Nh Nihonium 286.000		114 Fl Flerovium 289.000		115 Mc Moscovium 290.000		116 Lv Livermorium 293.000		117 Ts Tennessine 294.000		118 Og Oganesson 294.000	
57 La Lanthanum 138.905		58 Ce Cerium 140.116		59 Pr Praseodymium 140.908		60 Nd Neodymium 144.240		61 Pm Promethium 145.000		62 Sm Samarium 150.360		63 Eu Europium 151.964		64 Gd Gadolinium 157.250		65 Tb Terbium 158.925		66 Dy Dysprosium 162.500		67 Ho Holmium 164.930		68 Er Erbium 167.259		69 Tm Thulium 168.934		70 Yb Ytterbium 173.040		71 Lu Lutetium 174.967							
89 Ac Actinium 227.000		90 Th Thorium 232.038		91 Pa Protactinium 231.036		92 U Uranium 238.029		93 Np Neptunium 237.000		94 Pu Plutonium 244.000		95 Am Americium 243.000		96 Cm Curium 247.000		97 Bk Berkelium 247.000		98 Cf Californium 251.000		99 Es Einsteinium 252.000		100 Fm Fermium 257.000		101 Md Mendelevium 258.000		102 No Nobelium 259.000		103 Lr Lawrencium 260.000							

Target production: Molecular Plating



- organic solvent,
- starting material: neutral salt, such as $\text{Me}(\text{NO}_3)_x$
- high voltage (100–600 V), low current (few mA)
- **90-95% yield**



but...

Me^{3+} can also react with other anionic species resulting from electrolysis of the organic solvent resulting into a complex speciation

➤ **Co-deposition of other elements**

Target characterization: SEM

5 μL of ${}^{\text{nat}}\text{Ho}(\text{NO}_3)_3 \cdot 5\text{H}_2\text{O}$ in 0.01 M HNO_3 [0.128 mg/ μL]
5 μL 330 Bq of ${}^{166\text{m}}\text{Ho}$ diluted in 0.01 M HNO_3

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE - EPFL

EPFL

PAUL SCHERRER INSTITUT - PSI

PAUL SCHERRER INSTITUT
PSI

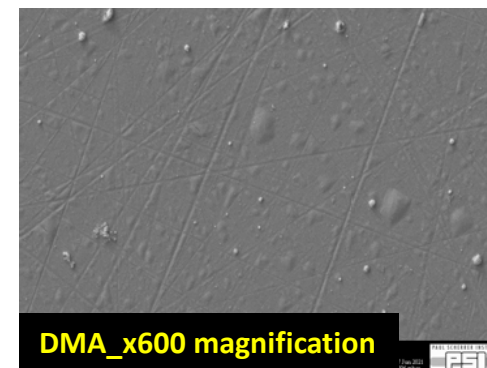
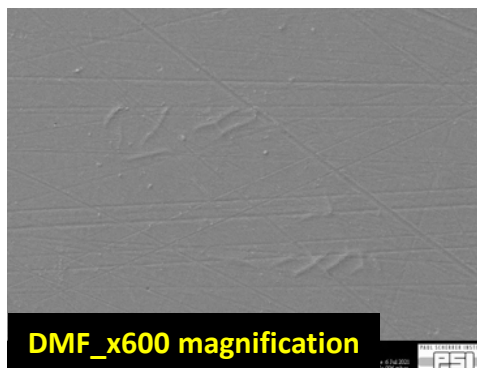
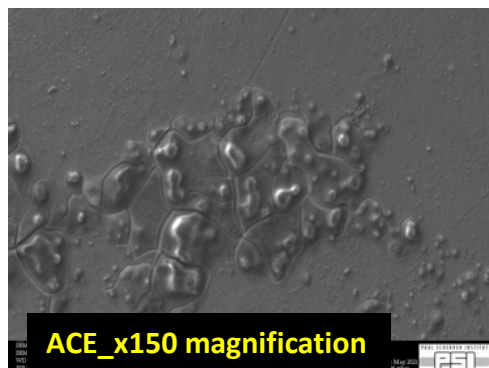
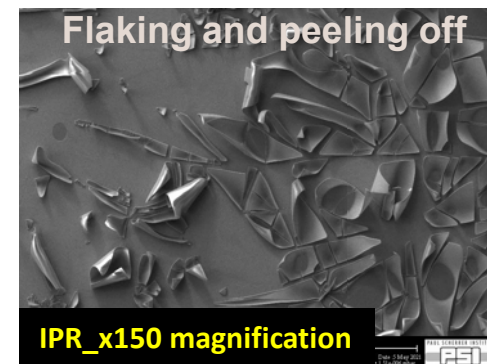
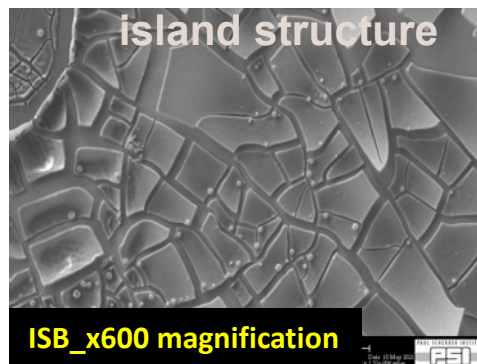
LABORATORY OF RADIOCHEMISTRY

Characterisation of holmium targets produced by molecular plating for the HOLMES experiment

Author: Guilhem DE BODIN DE GALEMBERT
Academic supervisor: Prof. Dr. Andreas PAUTZ
PSI supervisor: Dr. Emilio Andrea MAUGERI

August 6, 2021

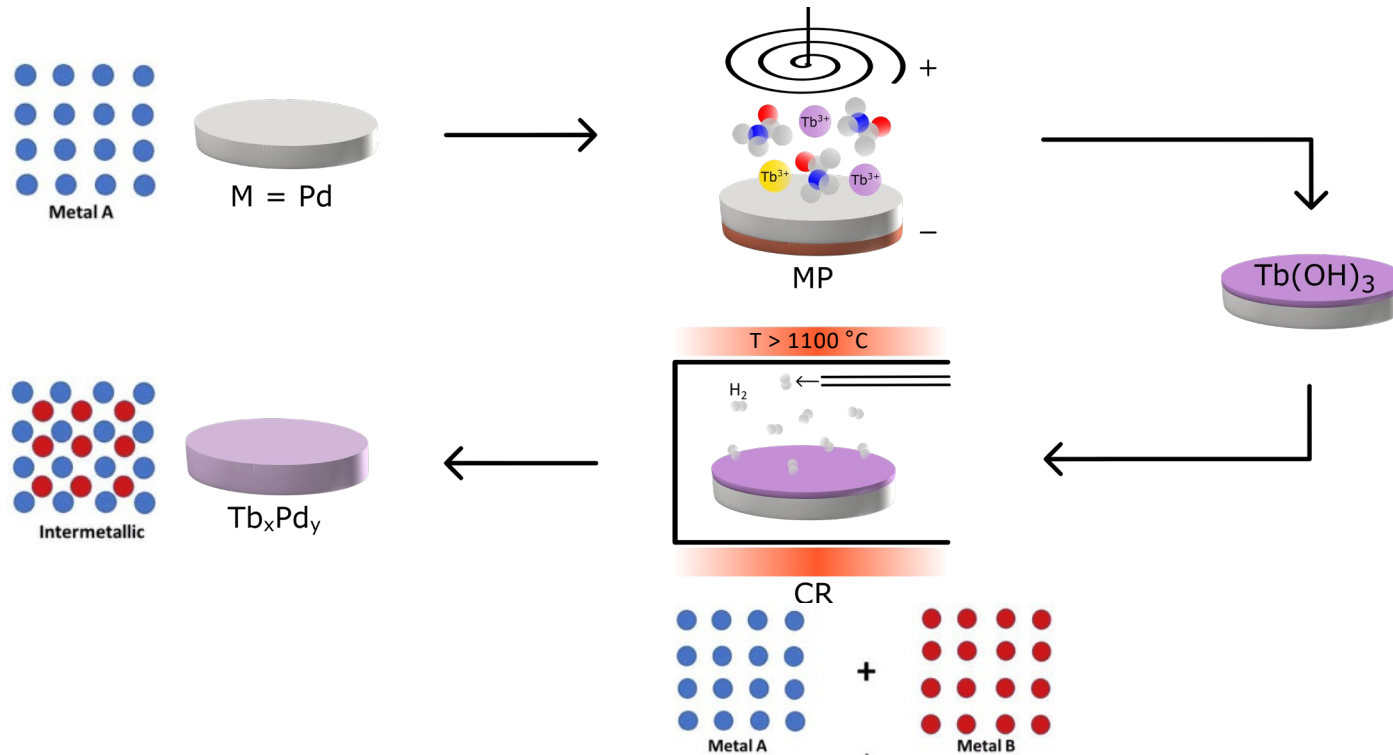
Solvent	Dielectric constant at 20 °C [-] [29]	Vapour pressure at 25 °C [kPa] [30]
Isobutanol	17.93	1.53
Propan-2-ol (Isopropanol)	20.18	5.78
Acetone	21.01	30.80
Ethanol	25.3	7.87
Methanol	33.0	16.94
N,N-Dimethylformamide (DMF)	38.25	0.44
N,N-Dimethylacetamide (DMAc)	38.85 ⁴	0.17



➤ Less volatile solvent allow obtaining more uniform and thinner targets

Dr. E. Müller Manager of Electron Microscopy Facility at PSI (EMF)

Targetry production: Molecular Plating + Coupled Reduction



Many advantages over molecular plated samples

- High thermal conductivity
- High electrical conductivity
- High chemical stability
- High mechanical stability

...for samples that need to withstand high stress level

Monday, 26.09.2022

8:30–9:00 Registration (Foyer of the Auditorium)

9:00–9:30 Welcome: A. Pautz (Head of the NES department),
C. Stodel (President of INTDS), D. Schumann (conference chair)

Session: Target characterization (chair: K. Eberhardt)

9:30–9:50 Targetry of rare isotopes at PSI (E. A. Maugeri, PSI, Switzerland)

9:50–10:10 Thickness and uniformity analysis of thin and heat resistant targets
(V. Capirossi, DISAT, INFN, Italy)

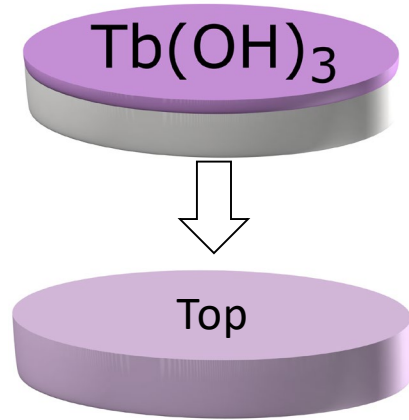
10:10–10:30 Analysis of thin Tb/Pd intermetallic targets prepared by the coupled
reduction reaction (N. Carboni, PSI, Switzerland)

Target characterization: SEM/ α -spectroscopy/ Auto-radiography



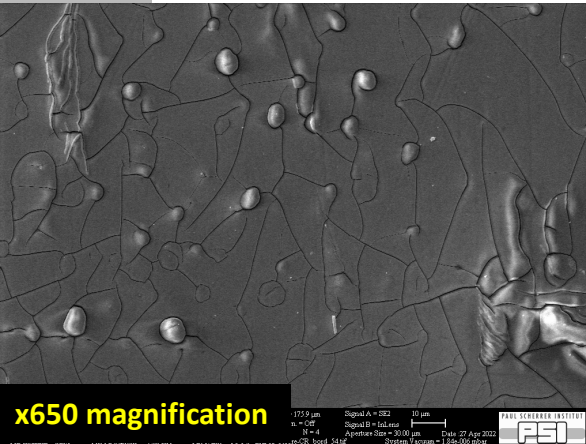
^{149}Tb (10 MBq) as alpha emitting tracer

Sample before CR

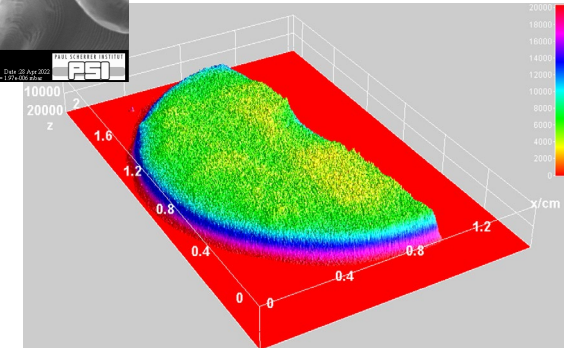
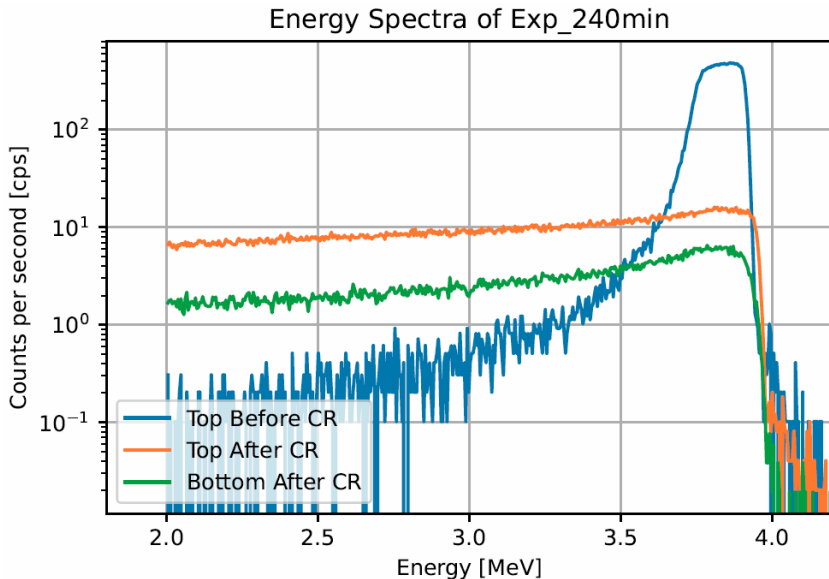
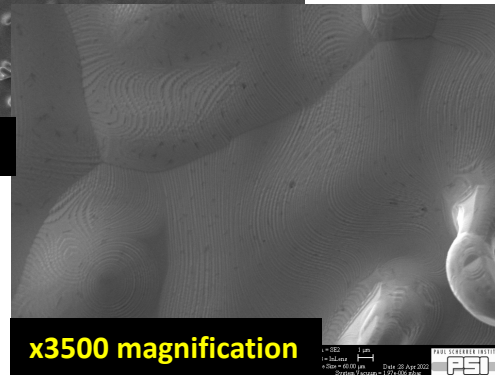
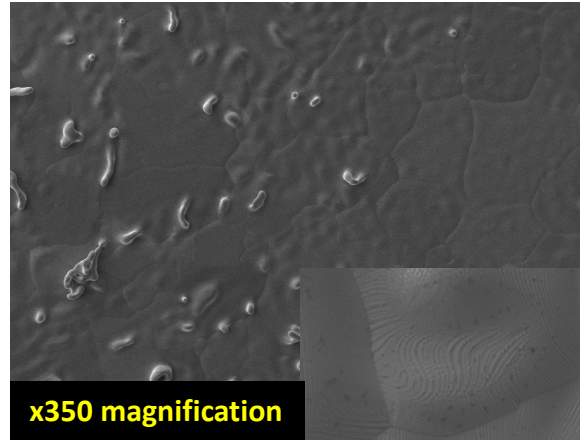


Sample after CR

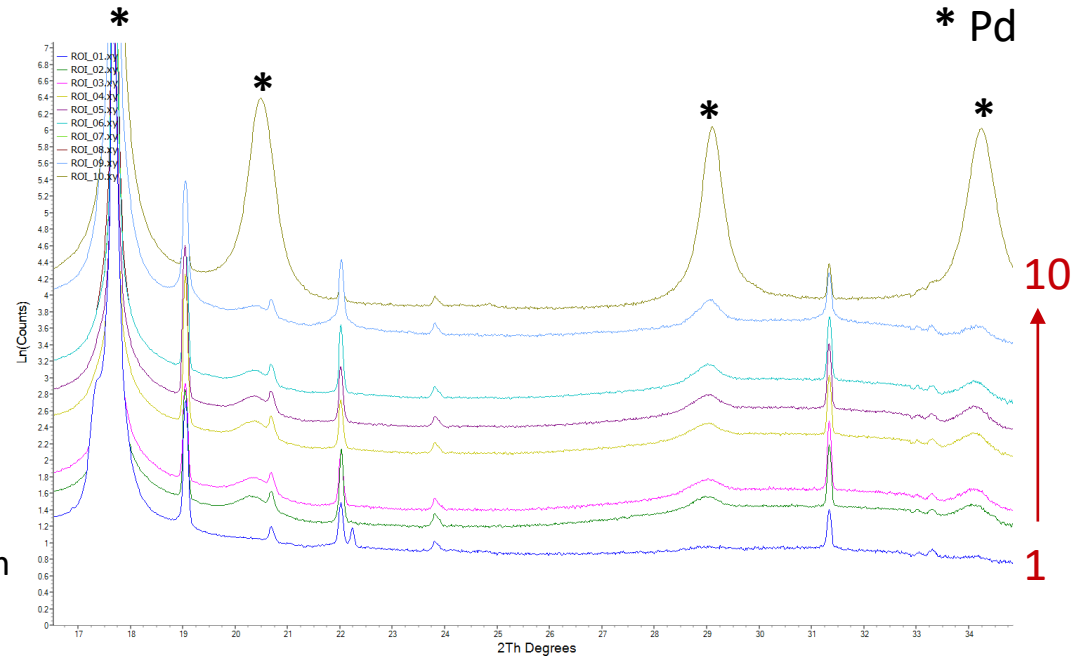
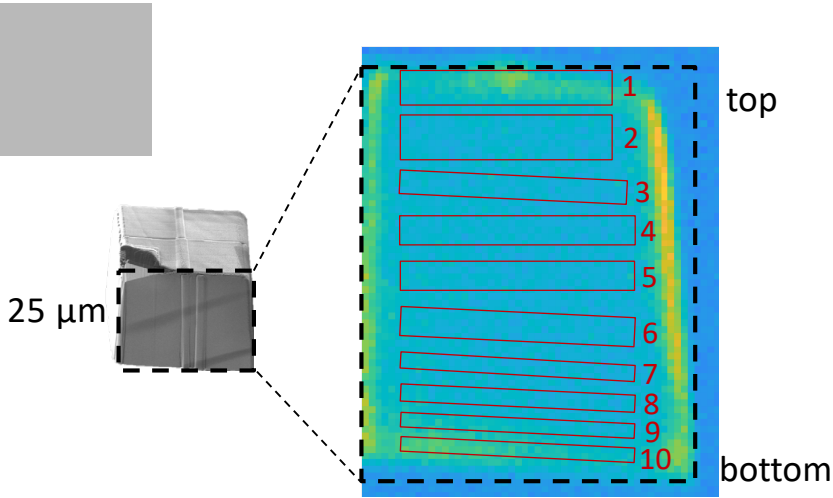
Before CR (Exp_5min)



After CR (Exp_5min)



Transmission XRD at SLS-PSI



- Pd XRD pattern visible over whole thickness
- Additional XRD pattern → possibly caused by intermetallic



Target characterization at PSI

alpha spectroscopy



liquid scintillation counter



TriCarb CA2110 scintillation counter

gamma spectroscopy



HPGe detector Canberra GmbH

Inductively coupled plasma mass spectrometry (ICP-MS)

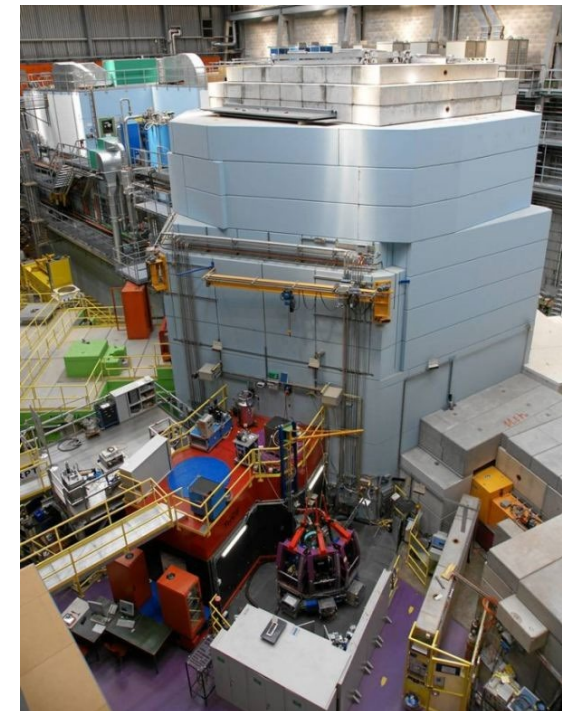


Element 2, Thermo Fisher Scientific,

Inductively Coupled Plasma Optical Emission spectroscopy (ICP-OES)



Neutron Activation Analysis



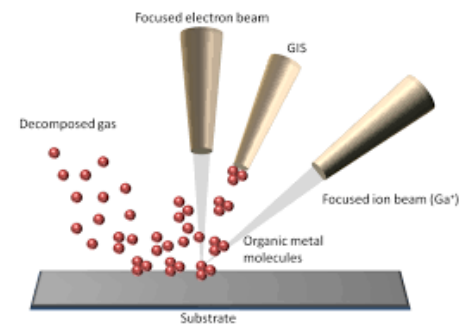
Target characterization at PSI



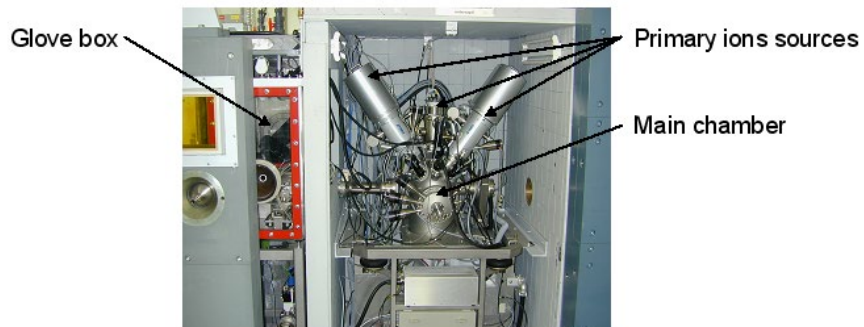
Scanning Electron Microscopy/EDX



Transmission Electron Microscopy



Focused ion beam



Secondary Ion Mass-Spectrometer



Electron Probe Microanalysis

Thanks to Dorothea Schumann for paving the way for
My thanks go to recognition of targetry and, more generally, of chemistry in
a “physicists world”

- Noemi Cerboni
- Guilhem Galembert
- Balázs Szekér
- Grazyna Makowska
- Elisabeth Müller
- Dressler Rugard
- Eichler Robert
- Tiebel Georg

