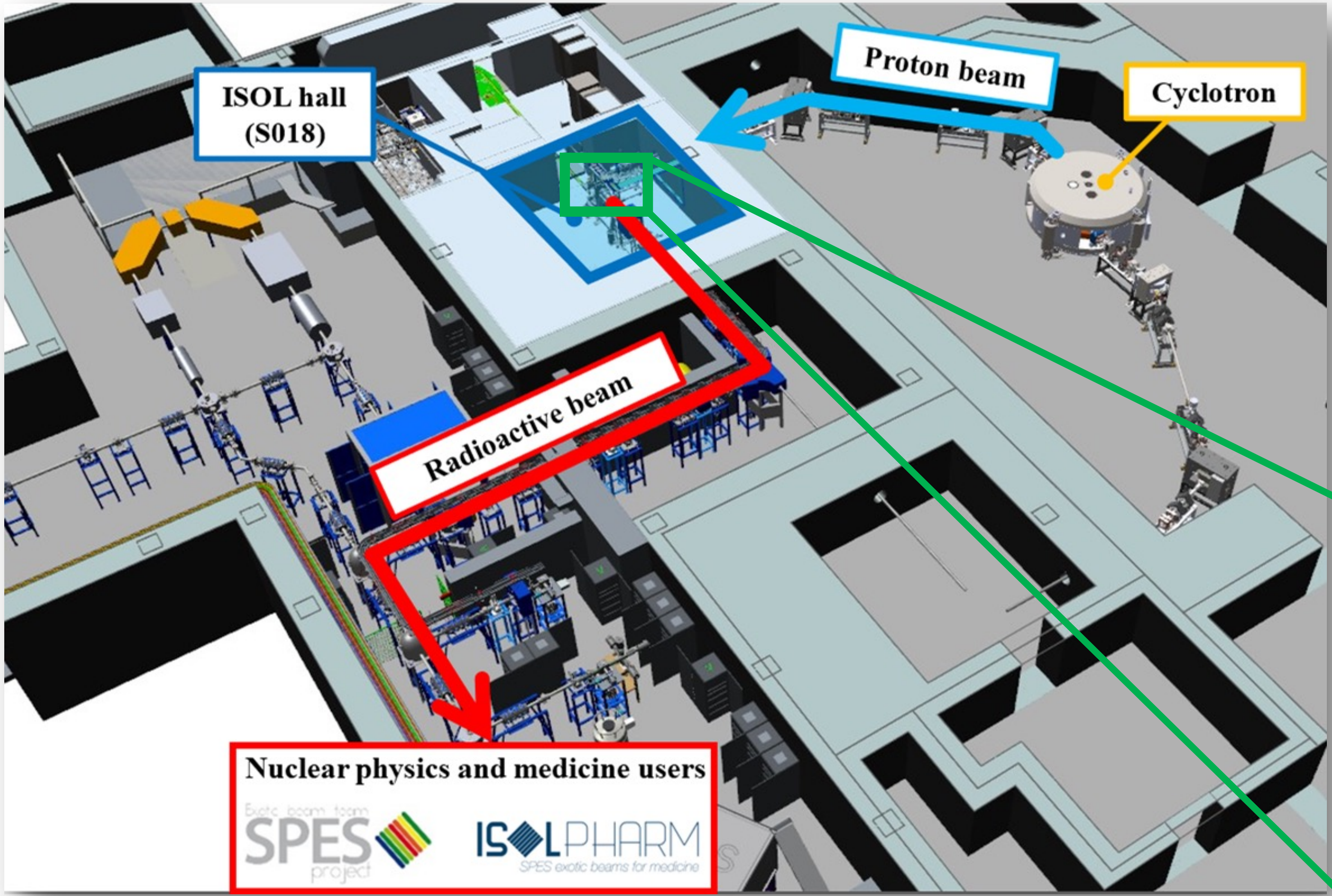
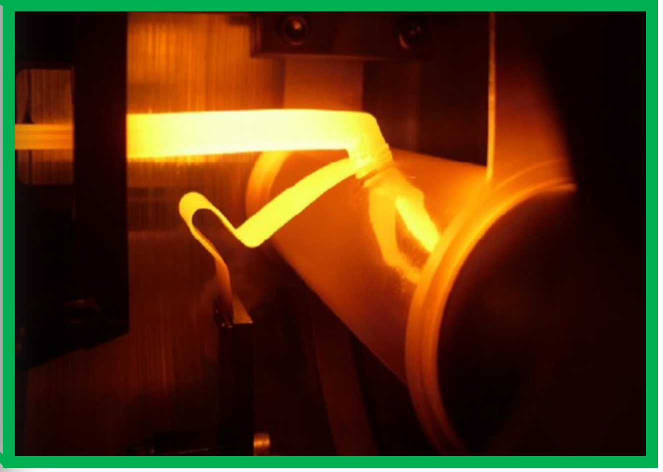
INNOVATIVE ISOL TARGETS FOR THE PRODUCTION OF MEDICAL RADIONUCLIDES

Stefano Corradetti, PRISMAP workshop on emerging infrastructures and technical developments, 22 November 2022

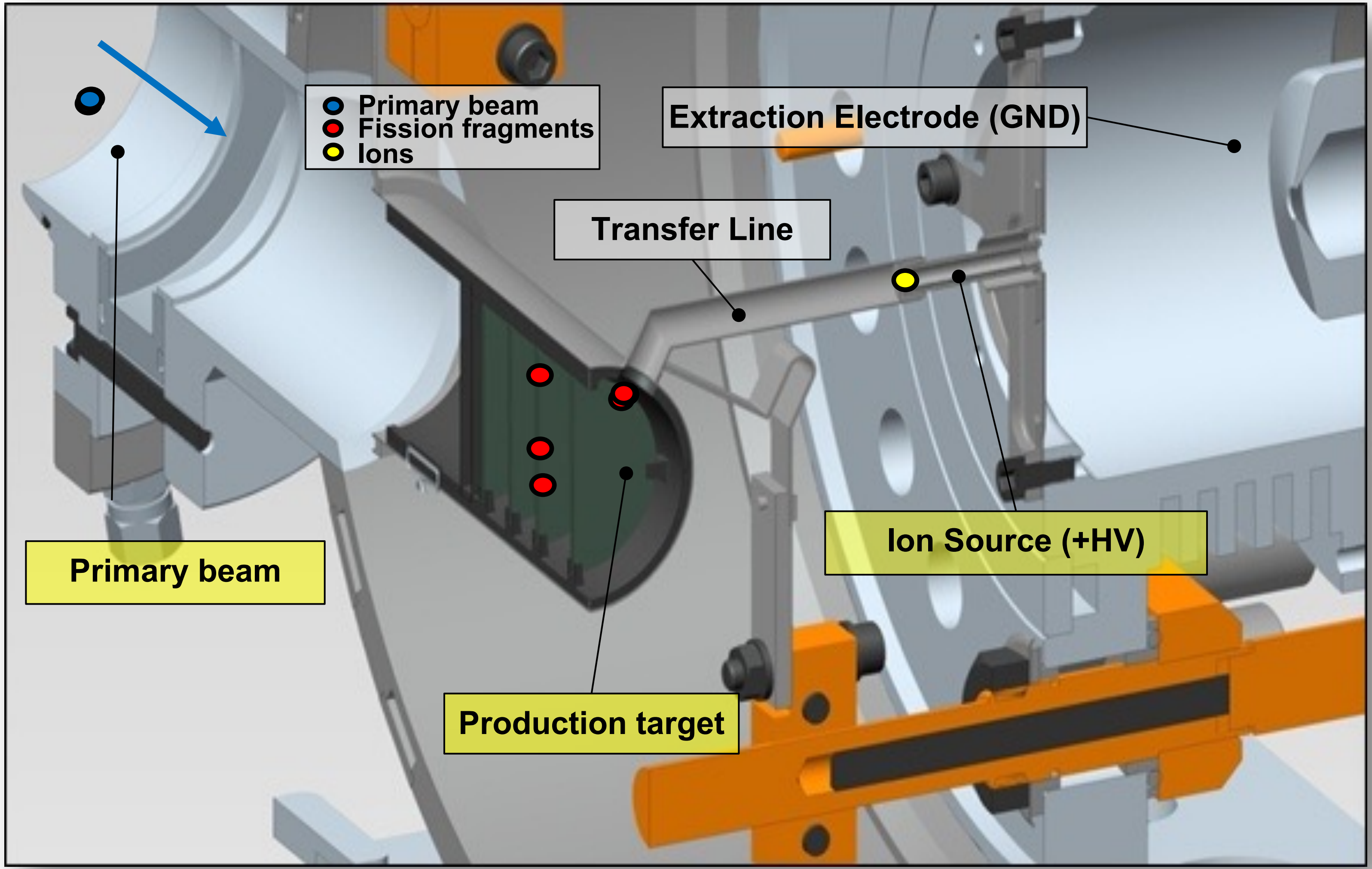
The SPES ISOL facility at INFN-LNL

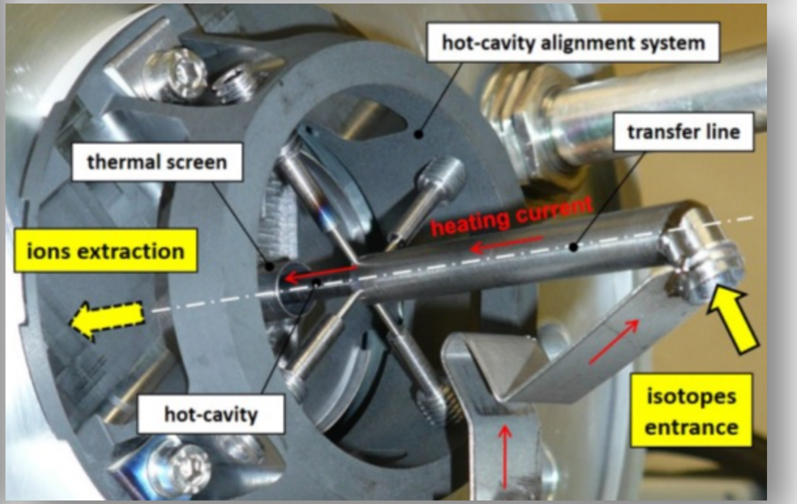


The SPES target-ion source



The SPES target





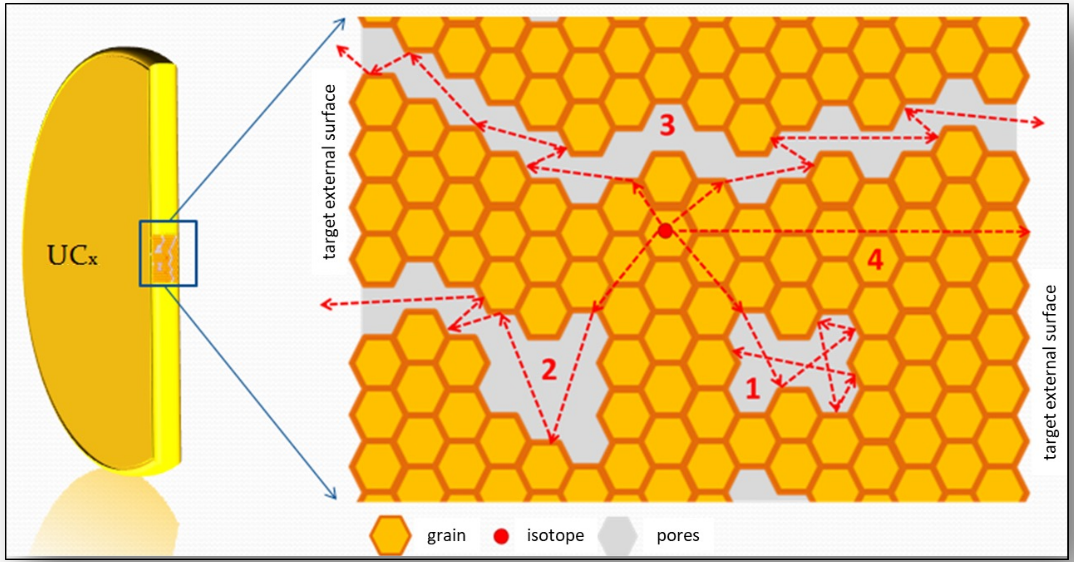
SPES (ISOL) target requirements

Target working conditions:

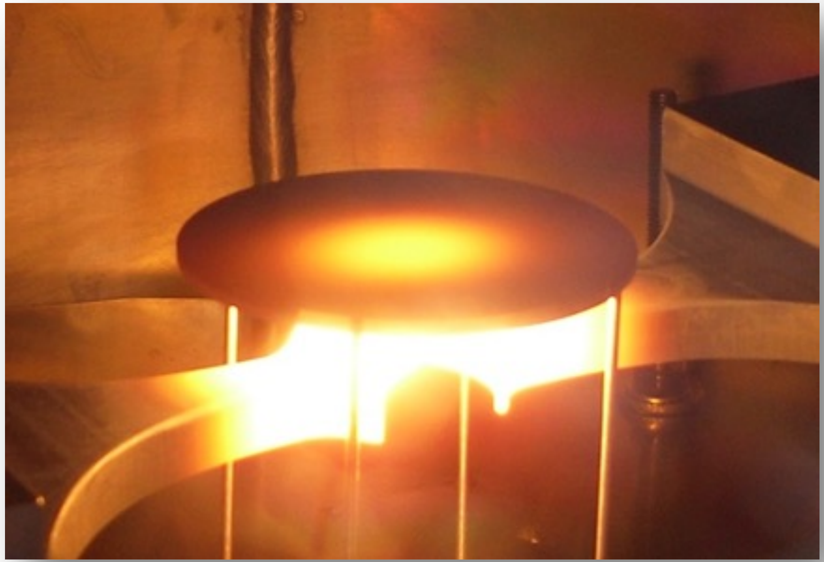
- Many days of continuous operation (10 ÷ 15)
- T = 1600 ÷ 2000 °C, even more in some cases
- 10 kW power
- High vacuum
- Radiation (p, n, γ, α, β, …)

Carbide/carbon composites (UC_2+2C, TiC+2C, ThC_2+2C, …)

Two sets of properties to optimize: nanostructure-porosity and thermo-mechanical



Open porosity and nanostructure to obtain fast release of isotopes



High thermal properties to efficiently dissipate heat

ISOL target material research in Europe and worldwide

Nuclear Instruments and Methods in Physics Research B 288 (2012) 34–41
Contents lists available at SciVerse ScienceDirect
Nuclear Instruments and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

An off-line method to characterize the fission product release from uranium carbide-target prototypes developed for SPIRAL2 project

B. Hy[a], N. Barré-Boscher[a], A. Özgümüs[a,b,*], B. Roussière[a], S. Tusseau-Nenez[a], C. Lau[a], M. Cheikh Mhamed[a], M. Raynaud[a], A. Said[a], K. Kolos[a], E. Cottereau[a], S. Essabaa[a], O. Tougait[c], M. Pasturel[c]

Nuclear Instruments and Methods in Physics Research B 317 (2013) 385–388
Contents lists available at ScienceDirect
Nuclear Instruments and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

Porous silicon carbide and aluminum oxide with unidirectional open porosity as model target materials for radioisotope beam production

M. Czapski[a,*], T. Stora[a], C. Tardivat[b], S. Deville[b], R. Santos Augusto[a], J. Leloup[b], F. Bouville[b], R. Fernandes Luis[c]

Journal of Nuclear Materials 440 (2013) 110–116
Contents lists available at SciVerse ScienceDirect
Journal of Nuclear Materials
journal homepage: www.elsevier.com/locate/jnucmat

Composite uranium carbide targets at TRIUMF: Development and characterization with SEM, XRD, XRF and L-edge densitometry

Peter Kunz[a,*], Pierre Bricault[a], Marik Dombsky[a], Nicole Erdmann[b], Vicky Hanemaayer[a], John Wong[a], Klaus Lützenkirchen[b]

Nuclear Instruments and Methods in Physics Research B 317 (2013) 402–410
Contents lists available at ScienceDirect
Nuclear Instruments and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

Recent developments of target and ion sources to produce ISOL beams

T. Stora[*]

Nuclear Instruments and Methods in Physics Research B 320 (2014) 83–88
Contents lists available at ScienceDirect
Nuclear Instruments and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

Intense $^{31-35}$Ar beams produced with a nanostructured CaO target at ISOLDE

J.P. Ramos[a,b], A. Gottberg[a,c], T.M. Mendonça[a,e], C. Seiffert[a,f], A.M.R. Senos[b], H.O.U. Fynbo[d], O. Tengblad[c], J.A. Briz[c], M.V. Lund[d], G.T. Koldste[d], M. Carmona-Gallardo[c], V. Pesudo[c], T. Stora[a,*]

Nuclear Instruments and Methods in Physics Research B 376 (2016) 8–15
Contents lists available at ScienceDirect
Nuclear Instruments and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

Target materials for exotic ISOL beams

A. Gottberg

Nuclear Instruments and Methods in Physics Research B 376 (2016) 81–85
Contents lists available at ScienceDirect
Nuclear Instruments and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

Target nanomaterials at CERN-ISOLDE: synthesis and release data

J.P. Ramos[a,b,*], A. Gottberg[a,1], R.S. Augusto[a,c], T.M. Mendonca[a], K. Riisager[d], C. Seiffert[a,e], P. Bowen[b], A.M.R. Senos[f], T. Stora[a,*]

Available online at www.sciencedirect.com
ScienceDirect
CERAMICS INTERNATIONAL
Ceramics International 41 (2015) 8093–8099
www.elsevier.com/locate/ceramint

Sintering kinetics of nanometric calcium oxide in vacuum atmosphere

J.P. Ramos[a,b], C.M. Fernandes[a], T. Stora[b], A.M.R. Senos[a,*]

Nuclear Inst. and Methods in Physics Research B 433 (2018) 60–68
Contents lists available at ScienceDirect
Nuclear Inst. and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

Development of radioactive beams at ALTO: Part 1. Physicochemical comparison of different types of UC_x targets using a multivariate statistical approach

Julien Guillot[a,*], Sandrine Tusseau-Nenez[b], Brigitte Roussière[a], Nicole Barré-Boscher[a], François Brisset[c], Sylvain Denis[d]

Nuclear Inst. and Methods in Physics Research B 440 (2019) 1–10
Contents lists available at ScienceDirect
Nuclear Inst. and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

Development of radioactive beams at ALTO: Part 2. Influence of the UC_x target microstructure on the release properties of fission products

Julien Guillot[a,*], Brigitte Roussière[a], Sandrine Tusseau-Nenez[b], Denis Grebenkov[b], Nicole Barré-Boscher[a], Elie Borg[a], Julien Martin[a]
[a] Institut de Physique Nucléaire d'Orsay CNRS/IN2P3 UMR 8608 - Université Paris Sud - Université Paris Saclay, F-91406 ORSAY Cedex, France
[b] Laboratoire de Physique de la Matière Condensée, CNRS, Ecole Polytechnique - Université Paris Saclay, Route de Saclay, F-91128 Palaiseau, France

Journal of the European Ceramic Society 37 (2017) 3899–3908
Contents lists available at www.sciencedirect.com
Journal of the European Ceramic Society
journal homepage: www.elsevier.com/locate/jeurceramsoc

Development of a processing route for carbon allotrope-based TiC porous nanocomposites

J.P. Ramos[a,b,*], A.M.R. Senos[c], T. Stora[b], C.M. Fernandes[c], P. Bowen[a,**]

Journal of the European Ceramic Society 38 (2018) 4882–4891
Contents lists available at ScienceDirect
Journal of the European Ceramic Society
journal homepage: www.elsevier.com/locate/jeurceramsoc

Original Article

Thermal stability of nanometric TiC-carbon composites: effects of carbon allotropes and Zr milling impurities

J.P. Ramos[a,b,*], T. Stora[b], A.M.R. Senos[c], P. Bowen[a,*]

Nuclear Inst. and Methods in Physics Research B 463 (2020) 201–210
Contents lists available at ScienceDirect
Nuclear Inst. and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

Thick solid targets for the production and online release of radioisotopes: The importance of the material characteristics – A review

J.P. Ramos

Nuclear Instruments and Methods in Physics Research B 394 (2017) 153–155
Contents lists available at ScienceDirect
Nuclear Instruments and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

Influence of target thickness on the release of radioactive atoms

Julien Guillot[a,*], Brigitte Roussière[a], Sandrine Tusseau-Nenez[b], Nicole Barré-Boscher[a], Elie Borg[a], Julien Martin[a]

Nuclear Inst. and Methods in Physics Research B 463 (2020) 367–370
Contents lists available at ScienceDirect
Nuclear Inst. and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

UC_x target production at TRIUMF in the ARIEL era

Marla Cervantes[a,b], Pauline Fouquet-Métivier[c], Peter Kunz[a,d], Laura Lambert[a,1], Anders Mjos[a], Thomas Day Goodacre[a], John Wong[a], Alexander Gottberg[a,b,*]

Nuclear Inst. and Methods in Physics Research B 463 (2020) 262–268
Contents lists available at ScienceDirect
Nuclear Inst. and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

High-power target development for the next-generation ISOL facilities

Lucia Popescu[*], Donald Houngbo, Marc Dierckx

ISOL target material research in Europe and worldwide

How to produce: standard technique

Weighing raw materials

↓

Mixing

↓

Grinding

↓

Pressing

↓

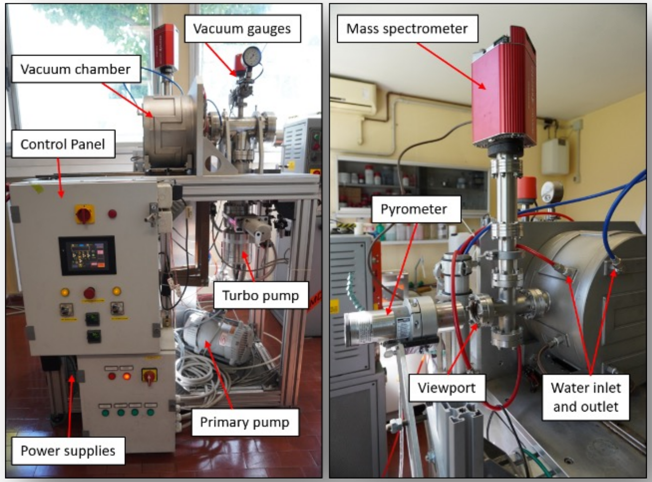
Heat treatment(s) in high vacuum furnaces

Optimization of properties by:

- Choice of carbon/metal precursors and additives
- Heat treatment parameters

La_2O_3 + C after pressing

LaC_2 + 2C after heat treatment



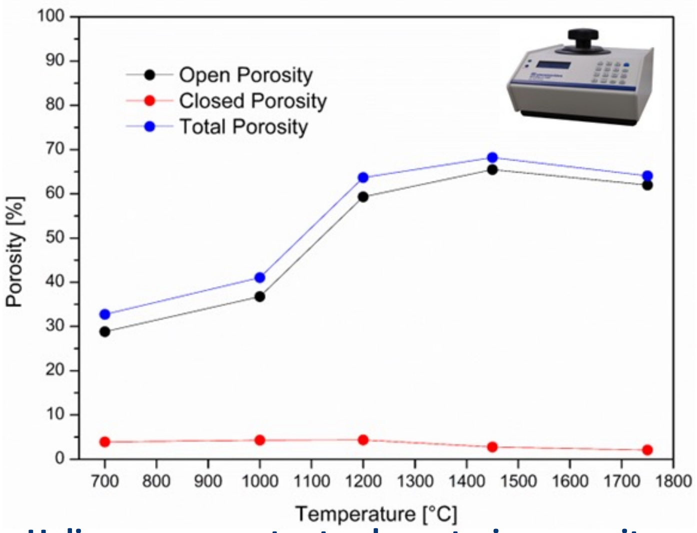
TiO_2 (micro) + 5C (graphite) → TiC + 2C + 2CO

Total porosity	60 %
Porosity type	Mainly open, macro
Specific Surface Area	Negligible

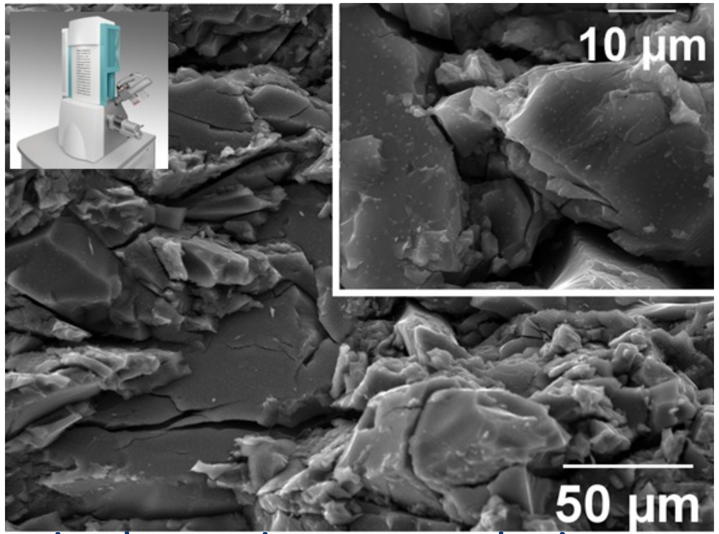
Activity in collaboration with UNIPD: DFA, DII, DTG

S. Corradetti et al., Nuclear Instruments and Methods in Physics Research B 488 (2021) 12–22

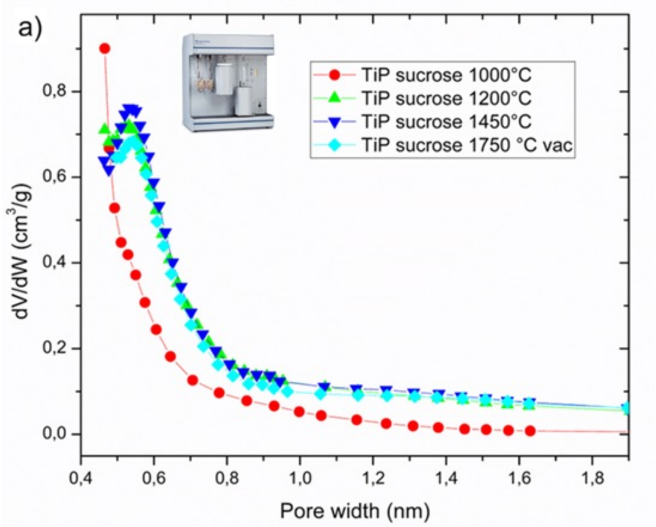
How to characterize: porosity and micro(nano)structure



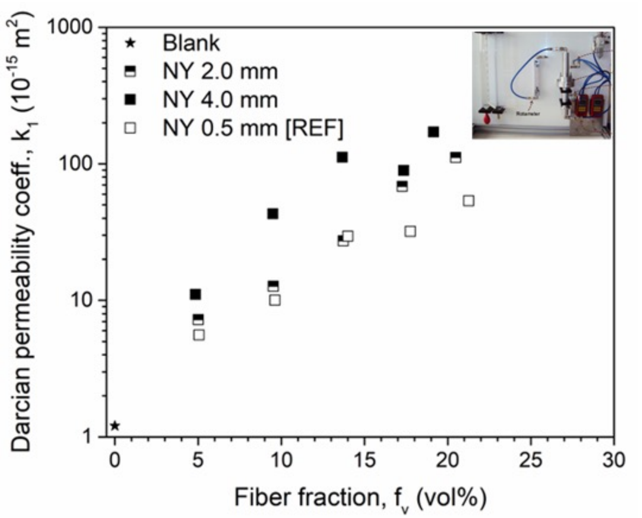
Helium pycnometry to characterize porosity



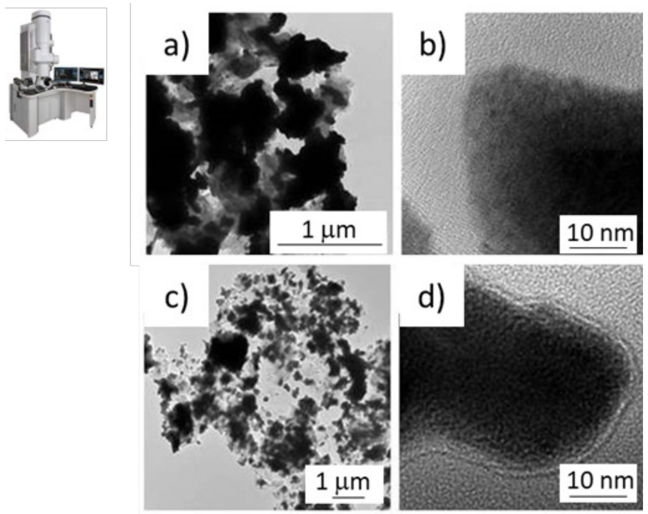
Scanning electron microscopy to study microstructure



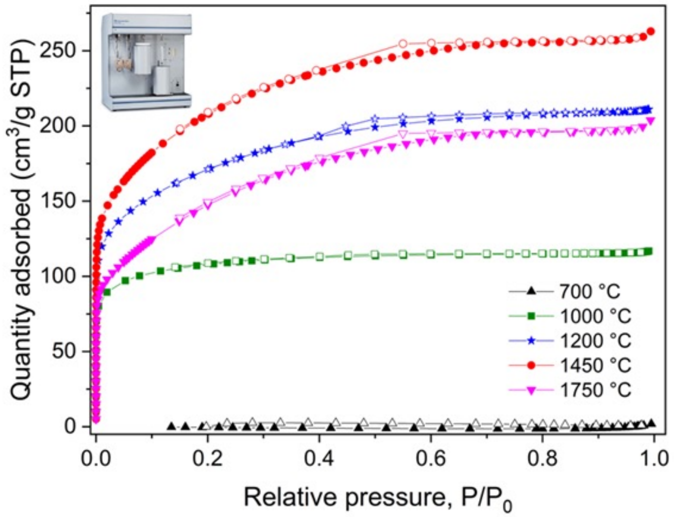
Gas physisorption to calculate pore size



Gas permeability to characterize open porosity

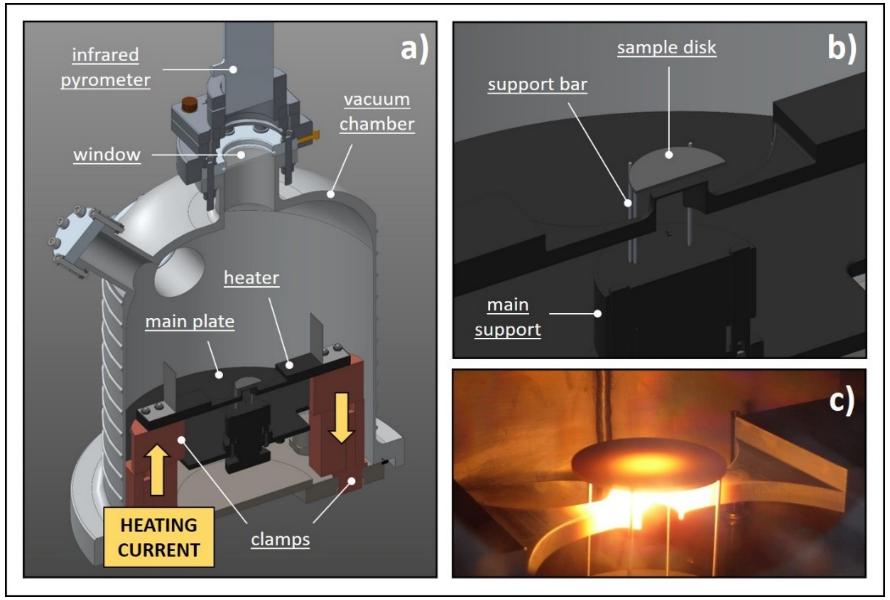


Transmission electron microscopy to study nanostructure

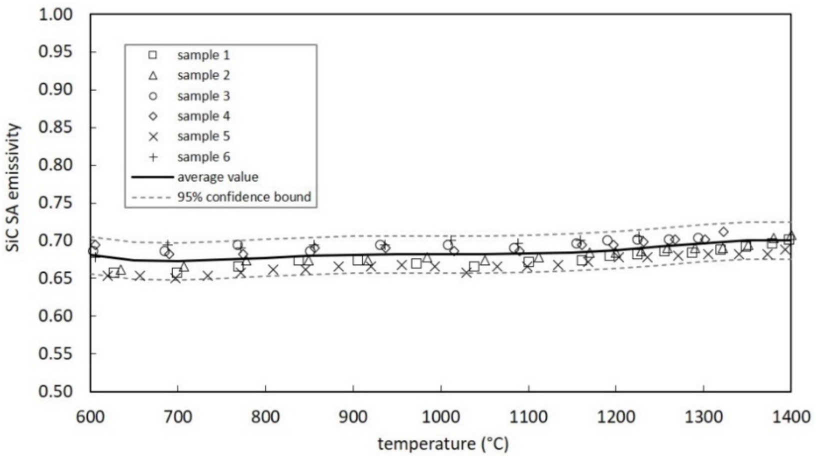


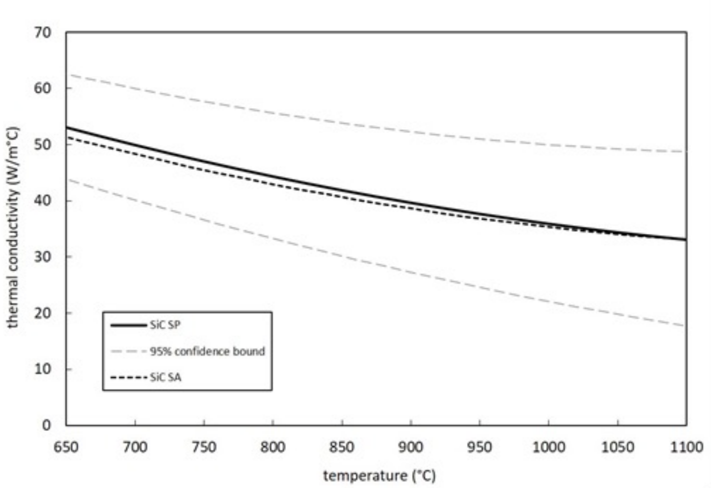
Gas physisorption to calculate specific surface area

How to characterize: thermomechanical properties



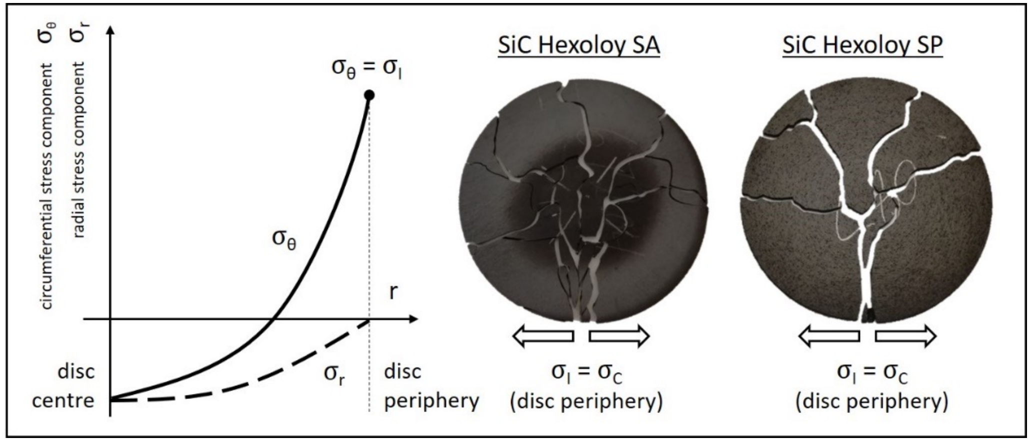
Thermal characterization

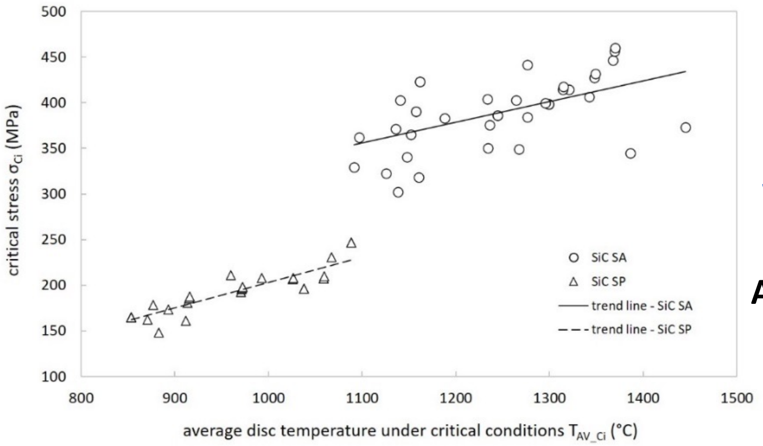




Obtainable data: emissivity and thermal conductivity

Structural characterization





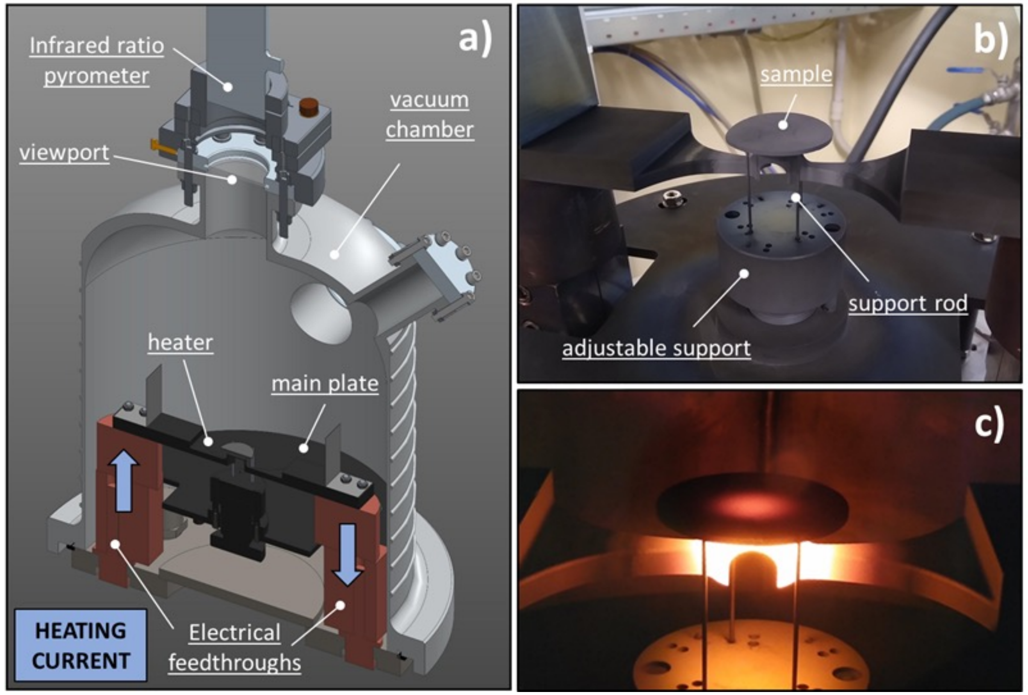
Obtainable data: critical stress under irradiation, probability of survival under irradiation without undergoing failure

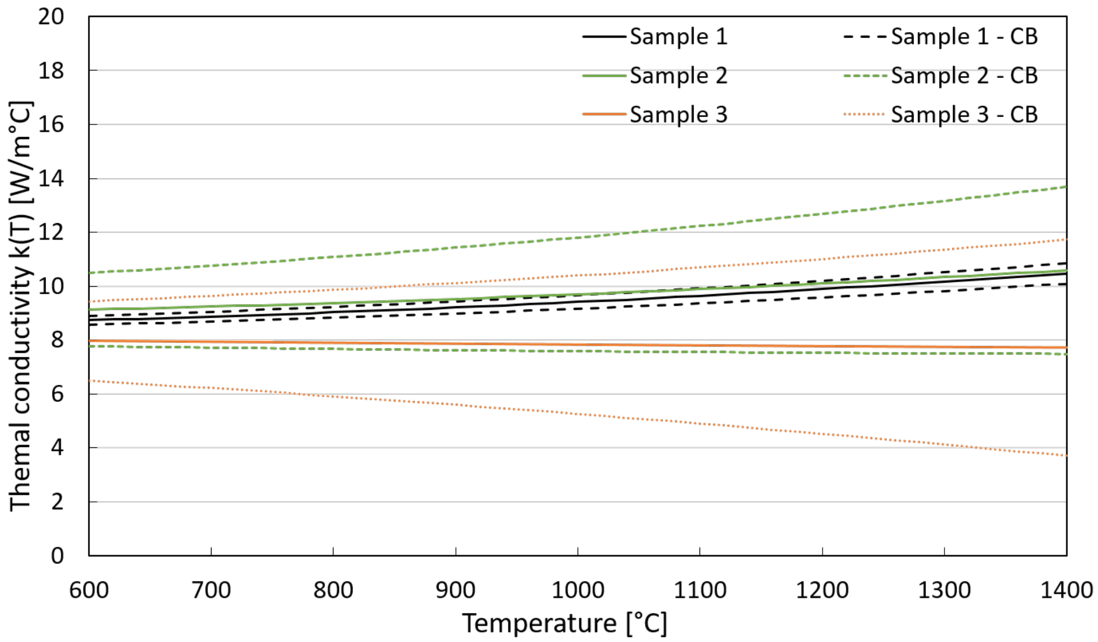
Activity in collaboration with UNIPD: DII

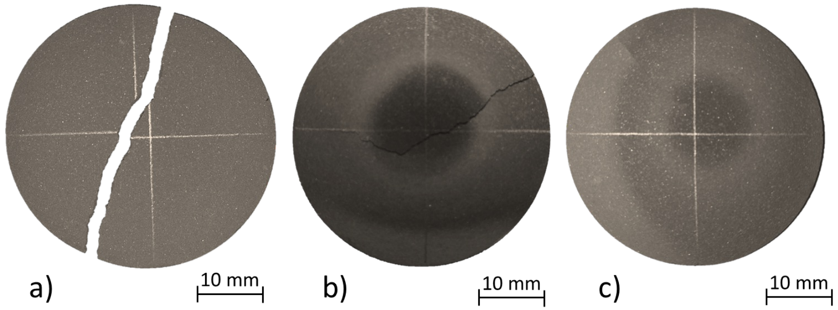
M. Manzolaro et al., Review of Scientific Instruments 84 (2013) 054902

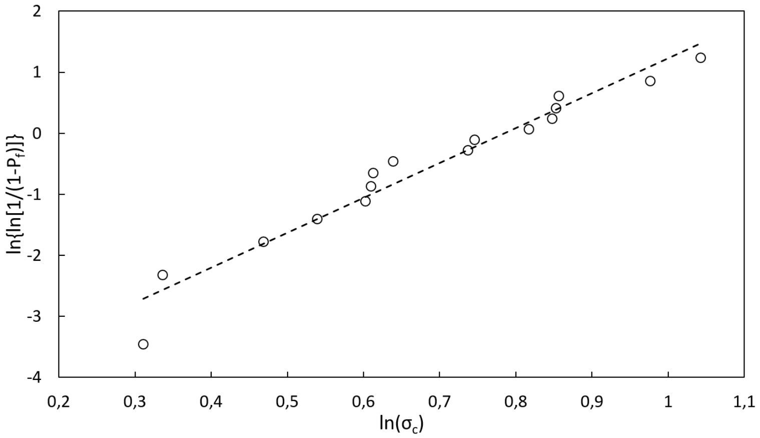
M. Manzolaro et al., Materials 14 (2021) 2689

Thermal and Structural characterization of a TiC/C target (T10.1)





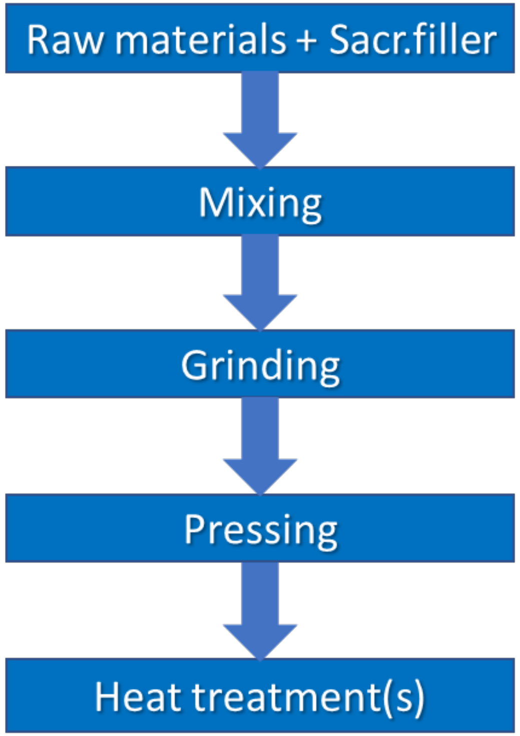


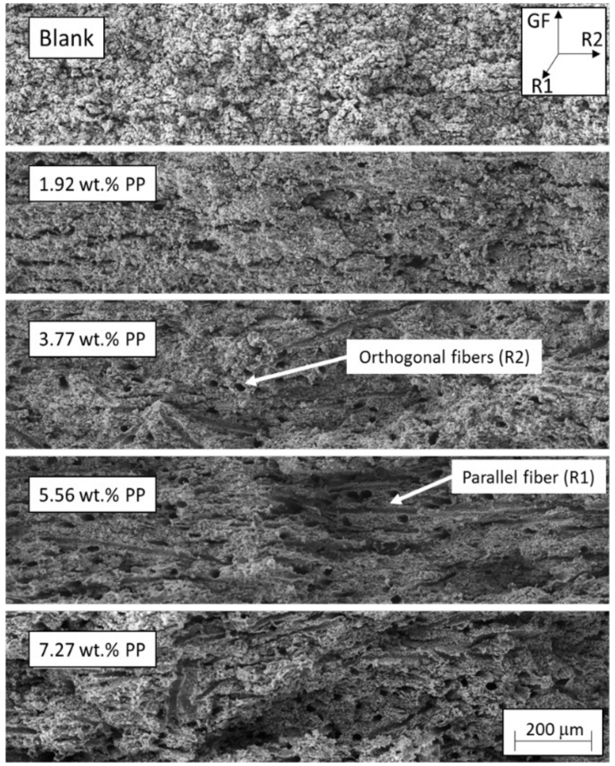


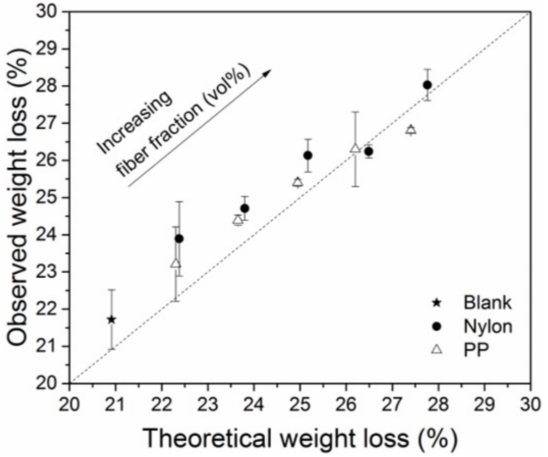
M. Ballan, S. Corradetti, M. Manzolaro, G. Meneghetti, A. Andrighetto, 'Thermal and Structural characterization of a titanium carbide/carbon composite for nuclear applications', (very) soon on Materials

Funding: This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101008571 (PRISMAP – The European medical radionuclides program).

Example of innovative target materials: use of sacrificial fillers

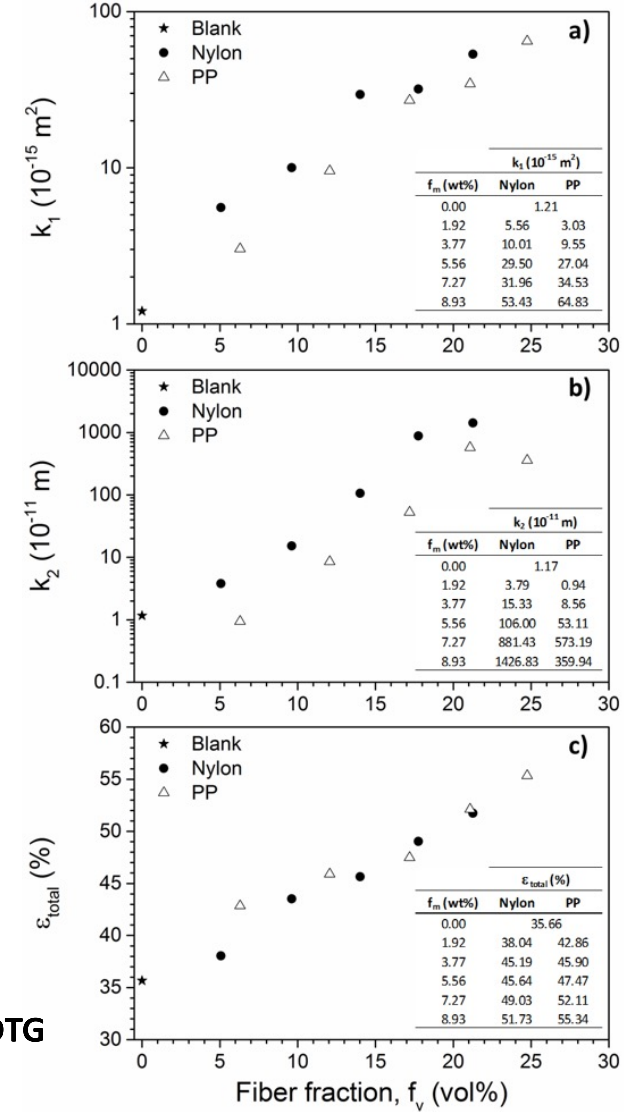






Fibers allow to obtain similar permeability but with lower vol% of filler (lower total porosity) with respect to PMMA microspheres

	K_1 ($*10^{-14}m^2$)	f_v (vol%)	Total porosity (%)
PP fibers	6.5	24.8	51.7
Nylon fibers	5.3	21.5	55.3
PMMA	9.4	60.6	74.0



Optimization of properties by:

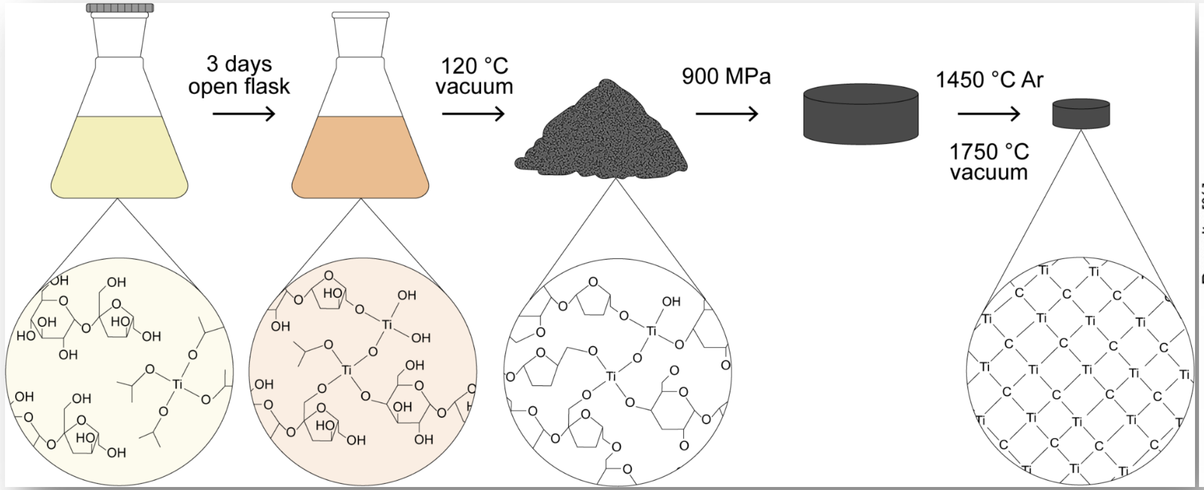
- Choice of carbon/metal precursors
- Quantity and type of sacrificial fillers
- Heat treatment parameters

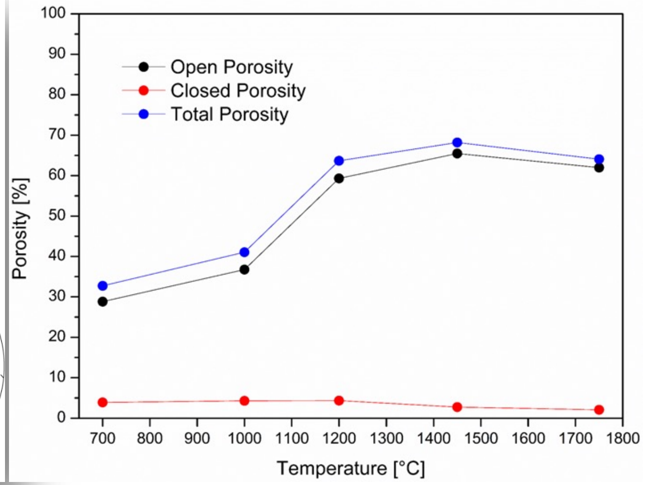
Activity in collaboration with UNIPD: DFA, DII, DTG

S. Corradetti et al., Ceramics International 42 (2016) 17764
S. Corradetti et al., Ceramics International 46 (2018) 4483

Example of innovative target materials: use of sol-gel

Ti alkoxide sol → Gel → Drying → Pressing → Heat treatment(s)





TiiP + ph. resin → TiC + 2C

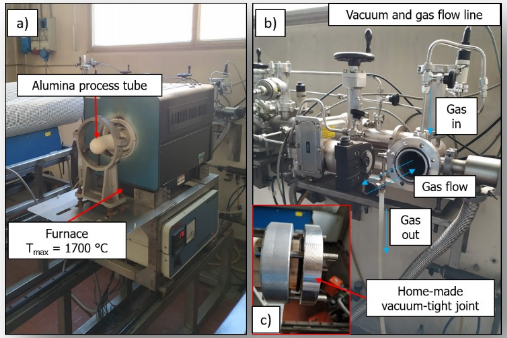
Total porosity	65 %
Porosity type	Mostly open, meso (<50 nm)
Specific Surface Area	Very high (530 m^2/g)

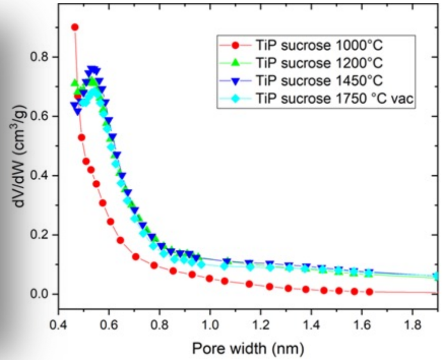
TiiP + sucrose → TiC + 2C

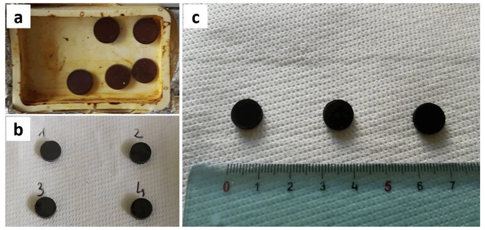
Total porosity	65 %
Porosity type	Totally open, micro (< 2 nm)
Specific Surface Area	Very high (650 m^2/g)

Optimization of properties by:

- Choice of initial reagents type, amount and proportions
- Temperature, pH of each production phase
- Heat treatments parameters







Activity in collaboration with UNIPD: DFA, DII

A. Zanini et al., Microporous and Mesoporous Materials 337 (2022) 111917

S. Corradetti et al., Ceramics International 46 (2020) 9596

Example of innovative target materials: use of new U/C sources

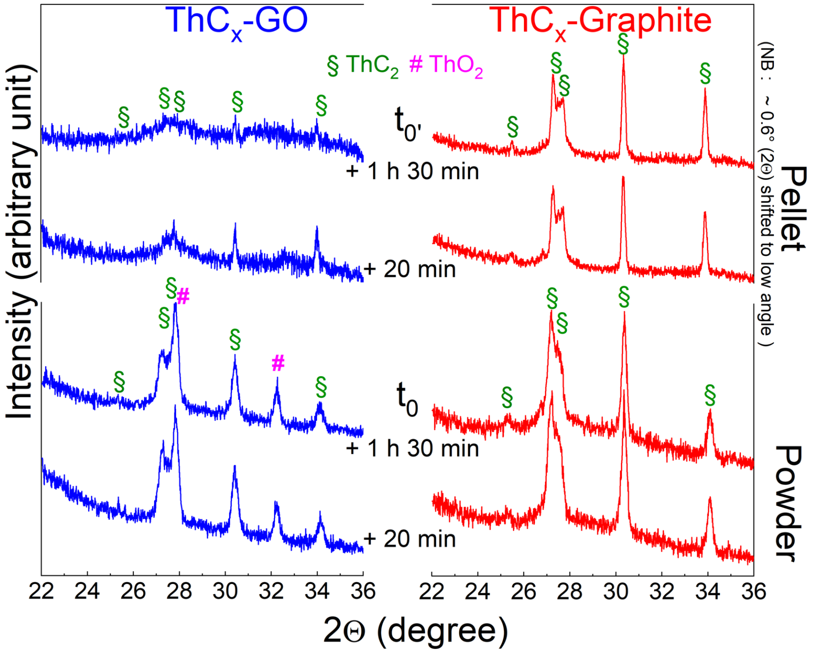
nano-UO_2 + MWCNTs ⟶ ISOLDE nano-UCx!

Use of graphene as a carbon source:

- Improvement of thermal properties
- No effect on reactivity and reaction completion*

$UO_2 + 6C \longrightarrow UC_2 + 2C + 2CO$

$ThO_2 + 6C \rightarrow ThC_2 + 2C + 2CO$



* If using graphene and not unreduced graphene oxide


Will Any Crap We Put into Graphene Increase Its Electrocatalytic Effect?

Lu Wang, Zdenek Sofer, and Martin Pumera*

Cite this: ACS Nano 2020, 14, 1, 21–25
Publication Date: January 14, 2020
https://doi.org/10.1021/acsnano.9b00184
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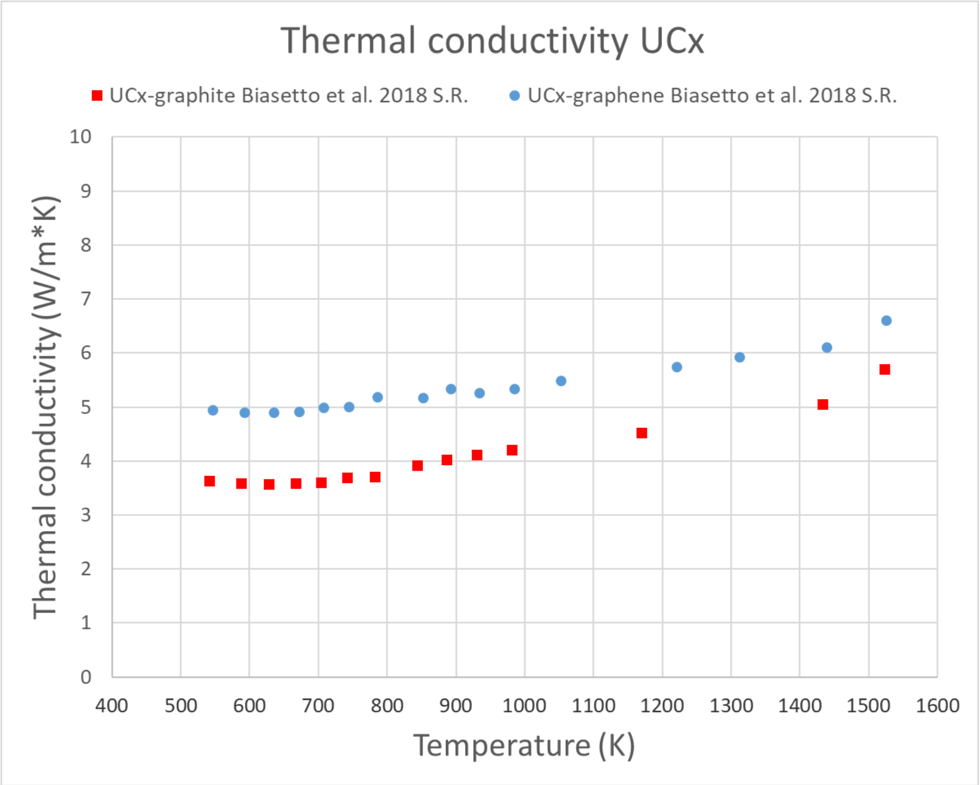


Activity in collaboration with JRC-Karlsruhe and UNIPD: DFA, DTG

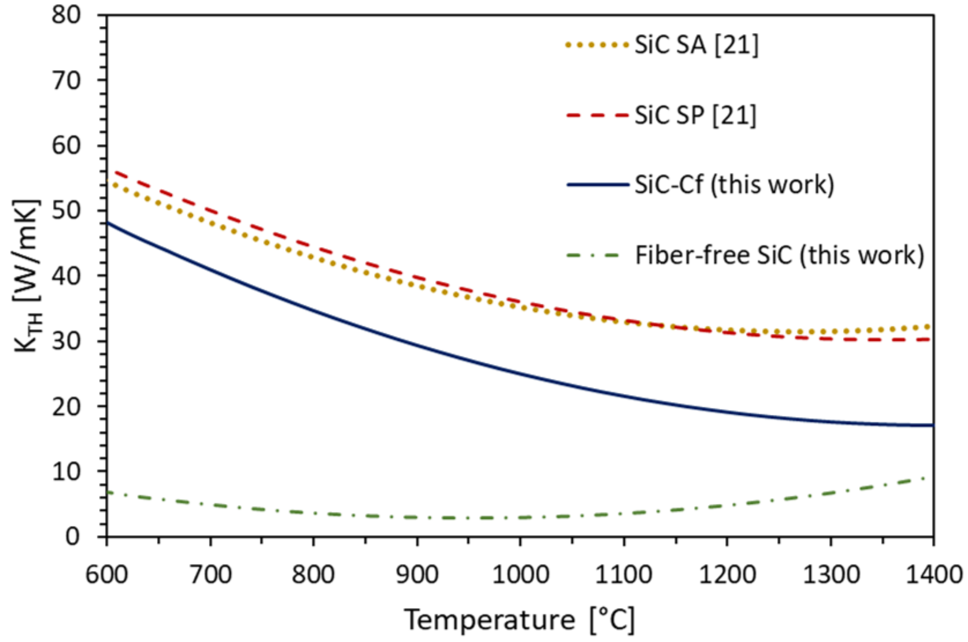
L. Biasetto et al., Scientific Reports 8 (2018) 8272

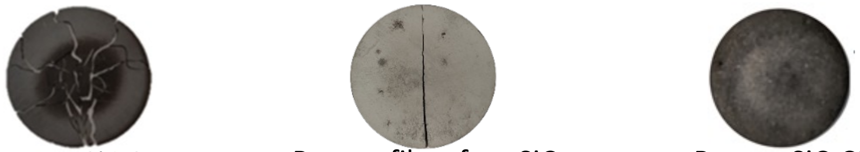
S. Corradetti et al., Scientific Reports 11 (2021) 9058

Example of innovative target materials: use of fibers

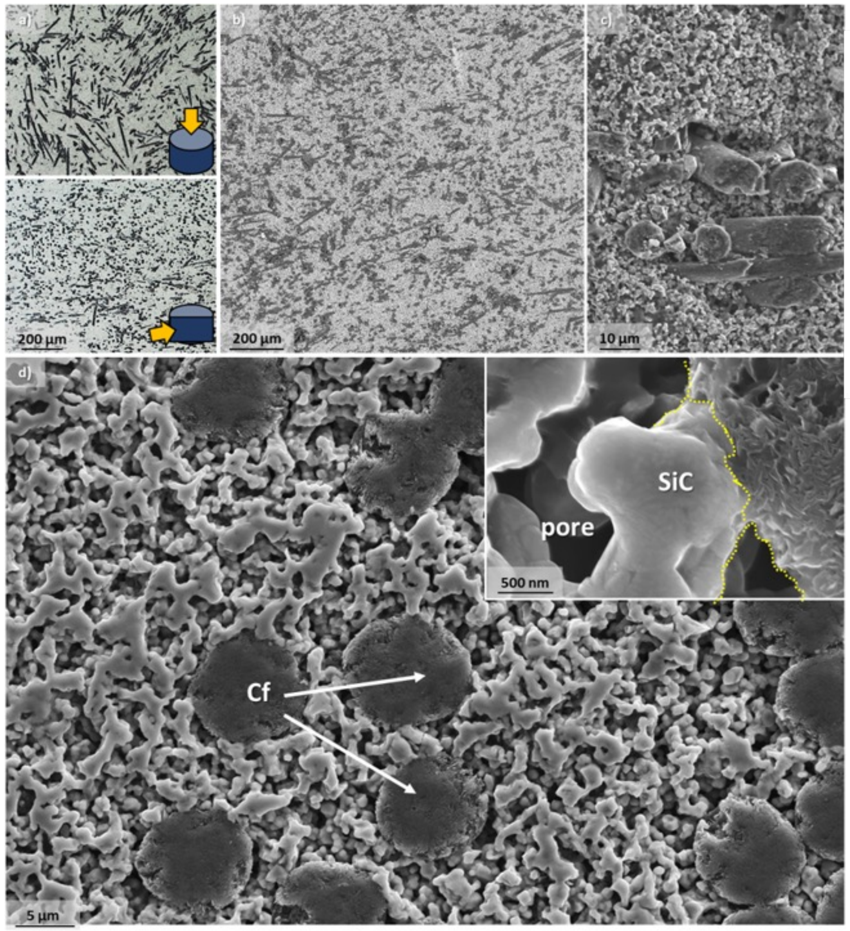
Use of dispersed carbon fibers:

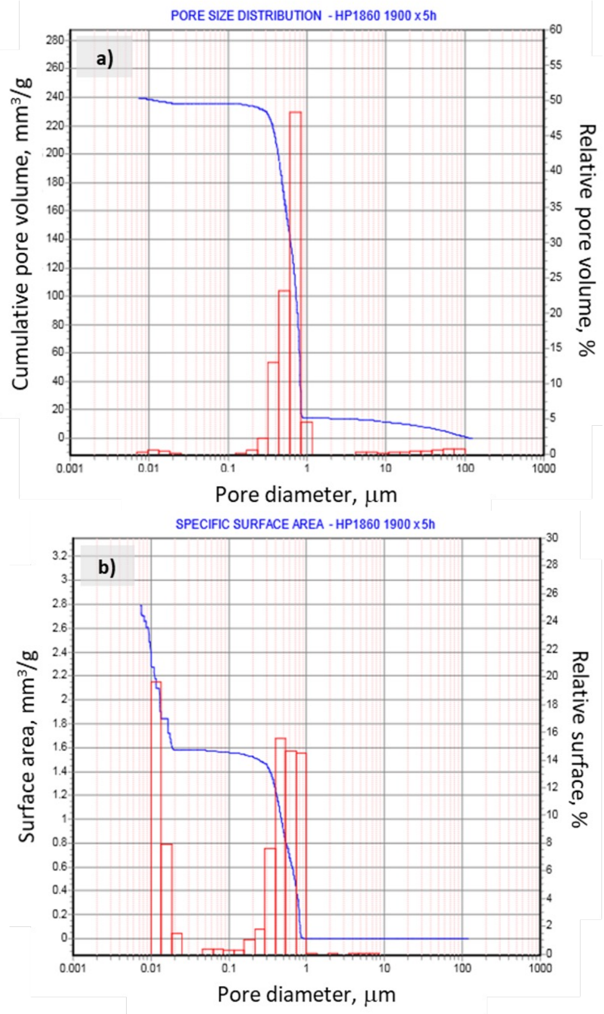
- Porosity, but…
- Good thermal properties, and…
- Improved resistance to thermal induced stresses





Dense SiC SA | Porous fiber-free SiC | Porous SiC-Cf

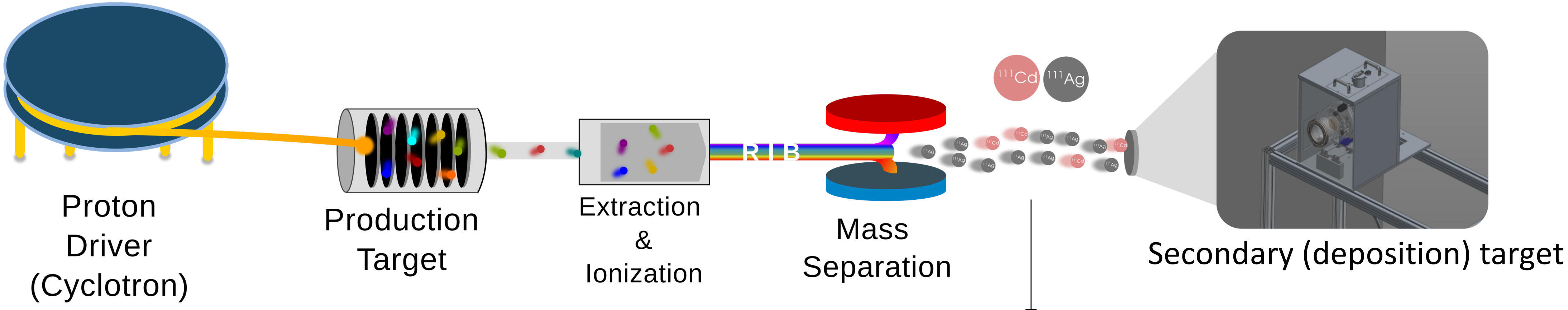


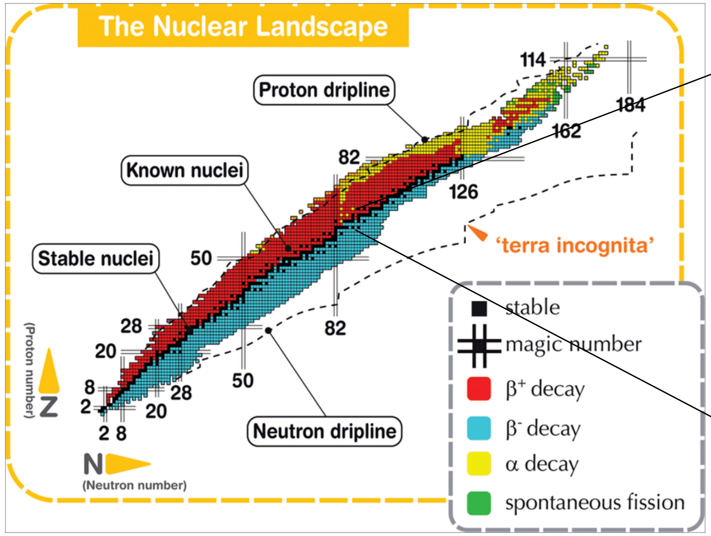


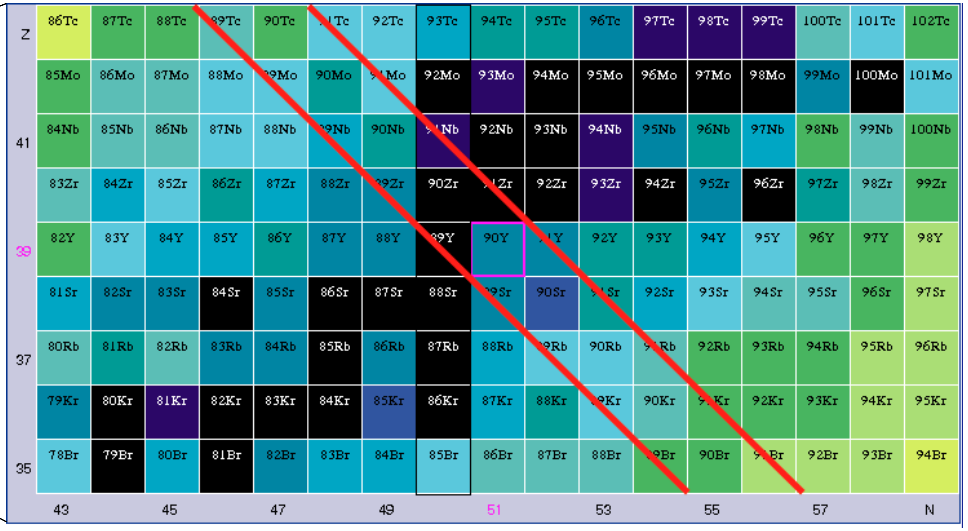
Activity in collaboration with CNR-ISSMC

L. Silvestroni et al., Journal of the European Ceramic Society 42 (2022) 6750

The ISOLPHARM project



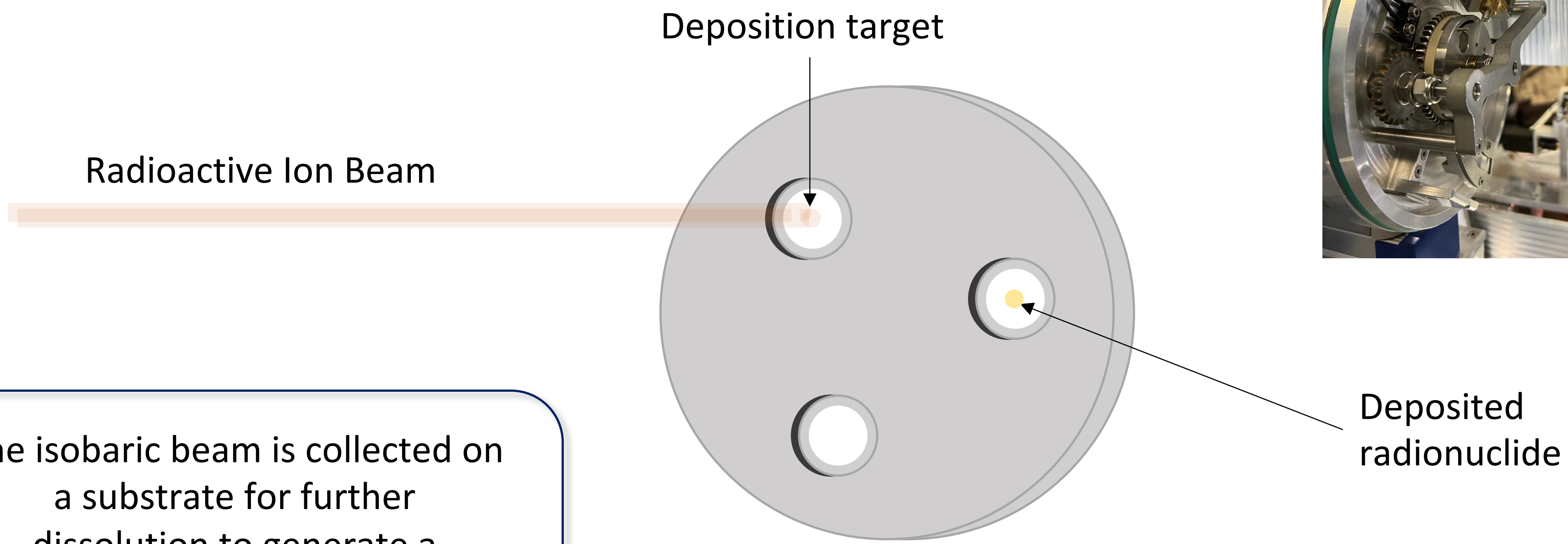


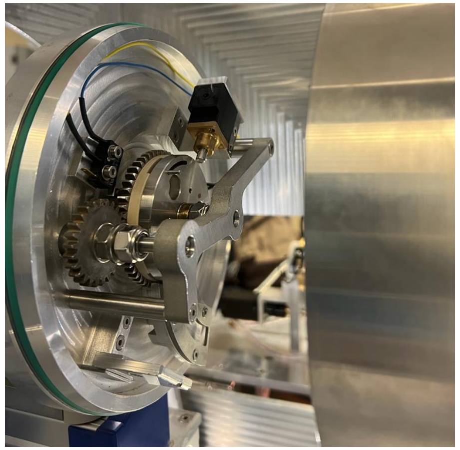


Isobaric Radioactive Ion Beam – excellent radionuclide purity

The deposition target

ISOL(PHARM) Radionuclide Implantation Station (IRIS)



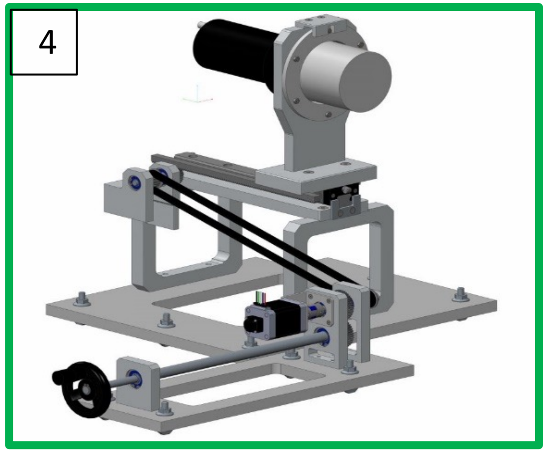


The isobaric beam is collected on a substrate for further dissolution to generate a solution for radiolabelling of pharmaceuticals

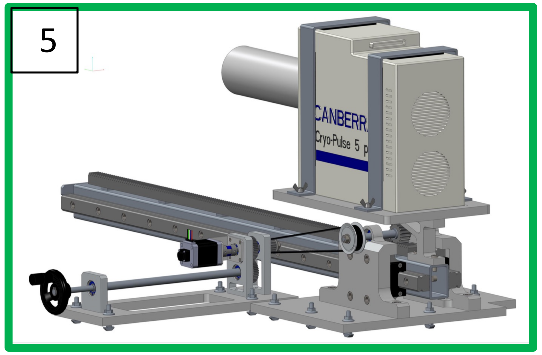
Deposition test on different implantation substrates.

IRIS (ISOLPHARM Radionuclide Implantation Station)

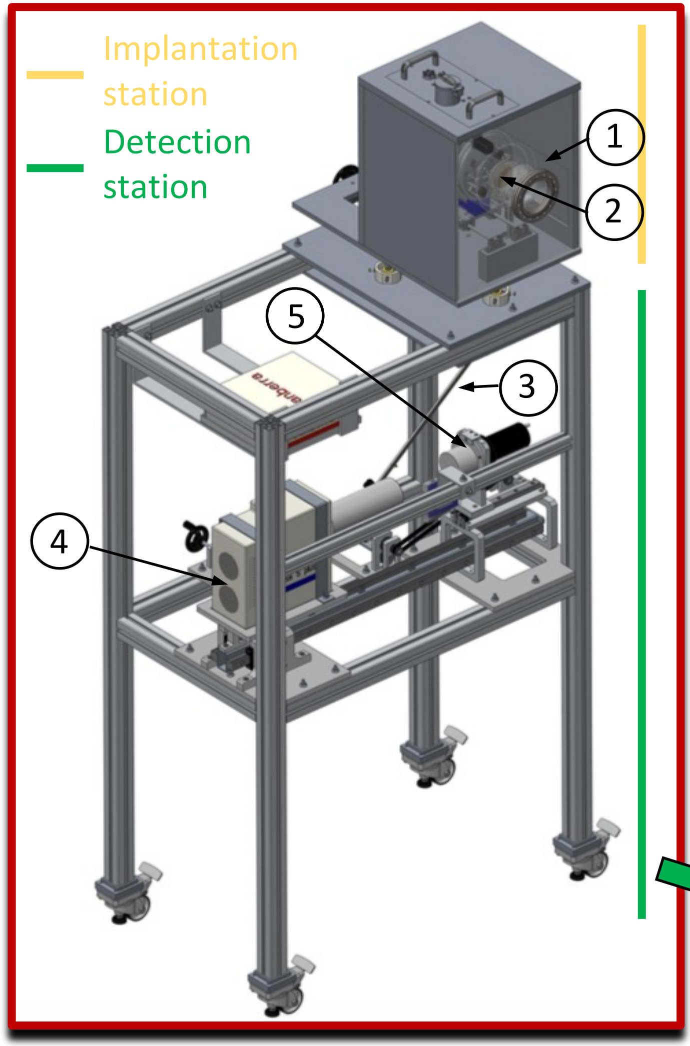
$LaBr_3$ Detector



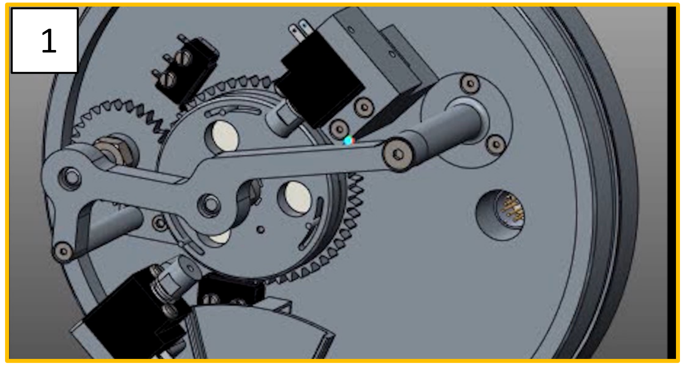
HPGe detector



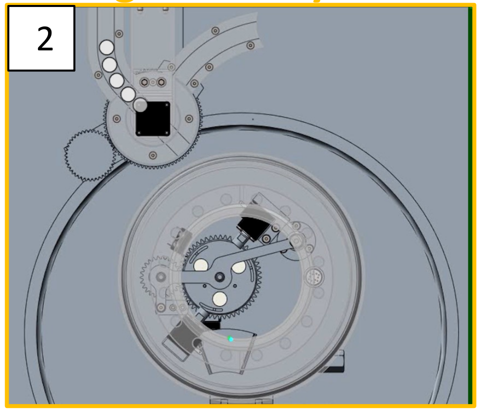
IRIS



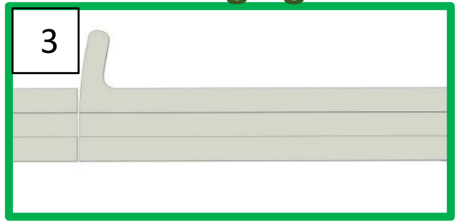
Target rotating support



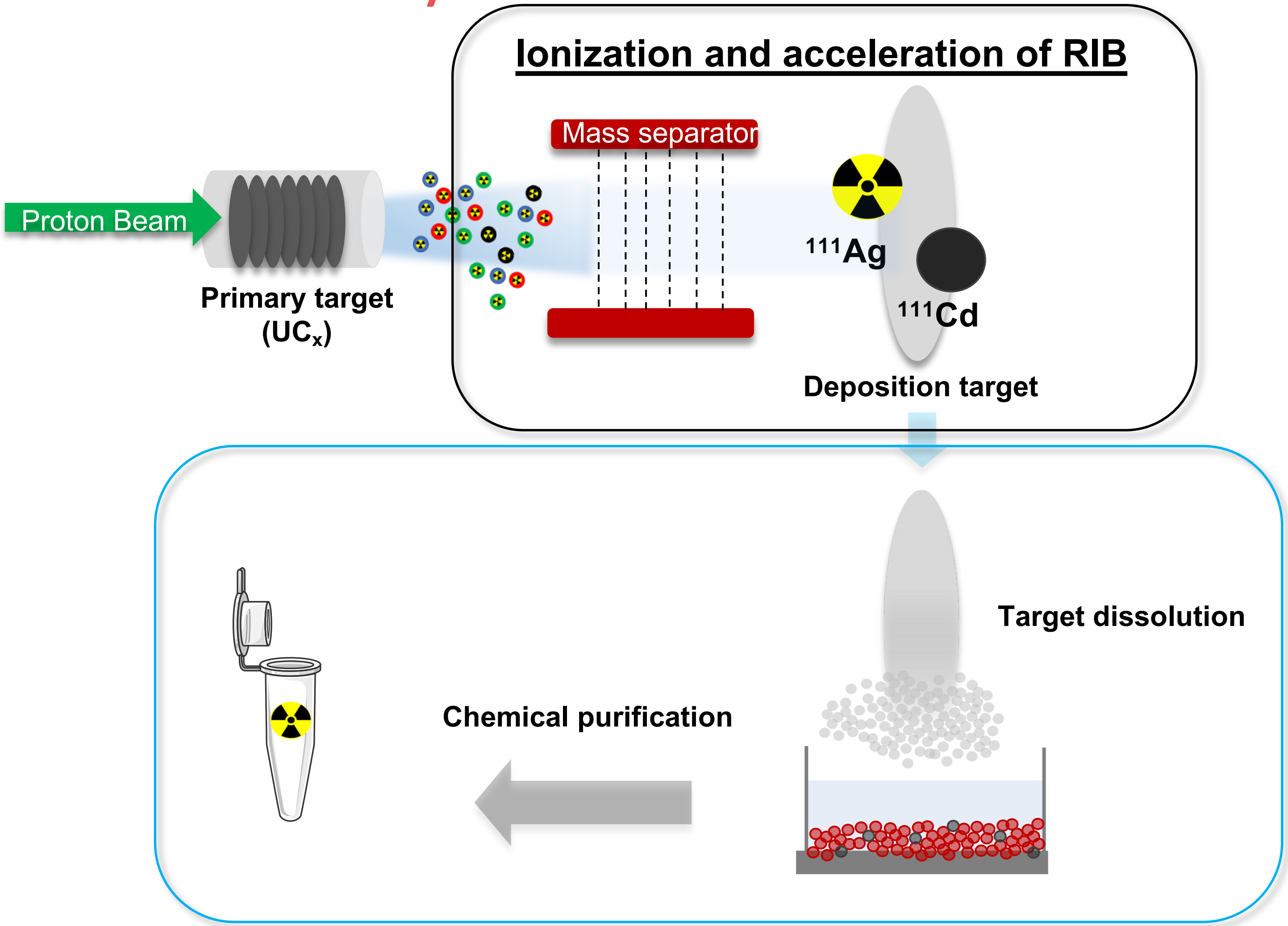
Target refill system

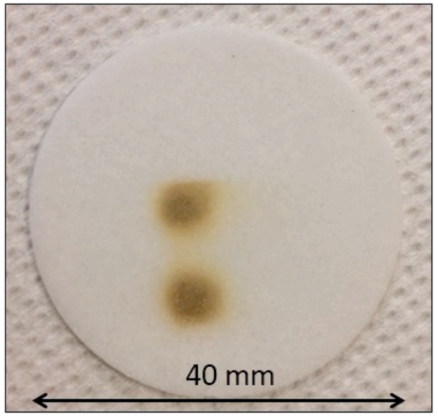


Discharge guide

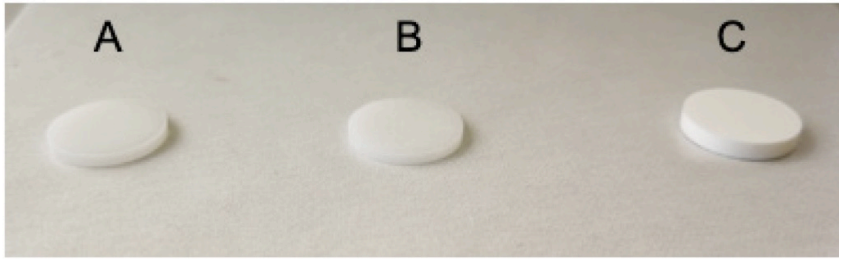


Ion Recovery





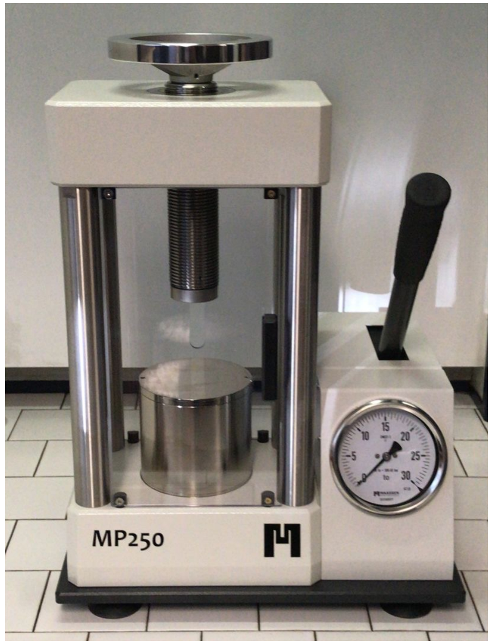
107-Ag and 109-Ag



Different materials to get high resistance and radionuclide recovery

Production method

Targets production



- Sodium chloride
- Sodium nitrate

Saline

- Dextrates
- Cellulose

Pharma

Production conditions

Mass variation

Pressure force variation

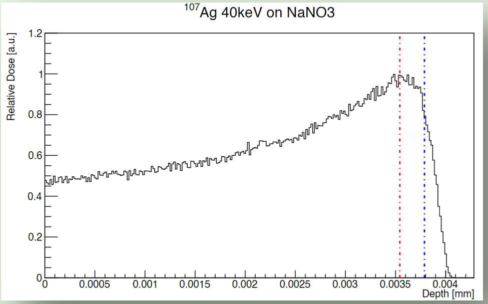
Pressing time variation

Activity in collaboration with UNIPD: DSF, DSC

M. Ballan et al., Applied Radiation and Isotopes 164 (2020) 109258

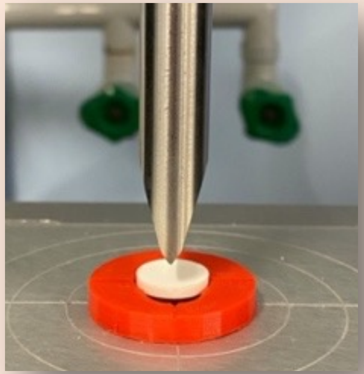
M. Ballan et al., Applied Radiation and Isotopes 175 (2021) 109795

Characterization



Implantation depth

Porosity



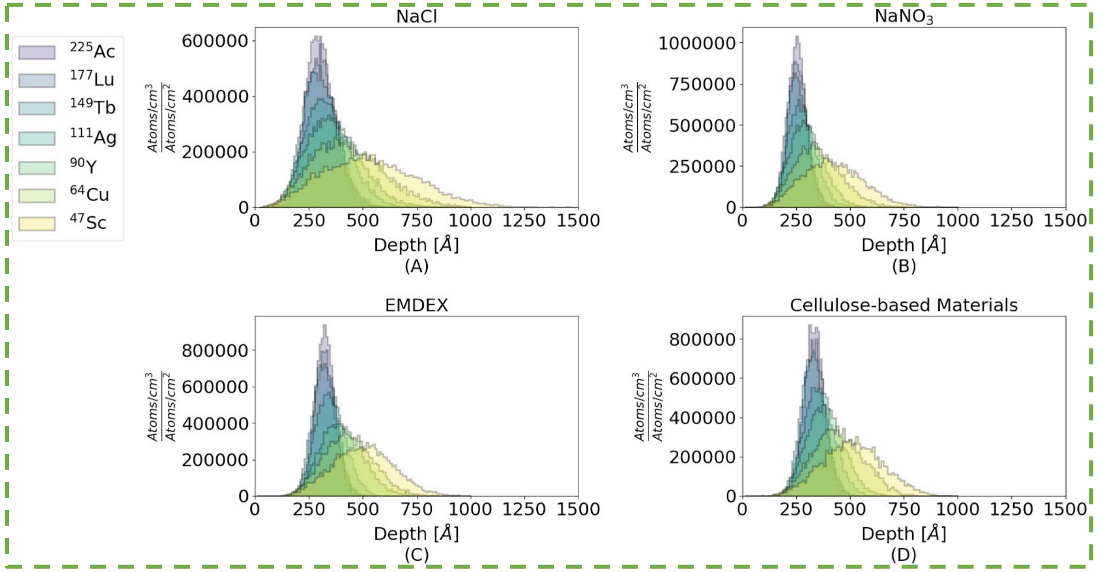
Breaking load

Disaggregation

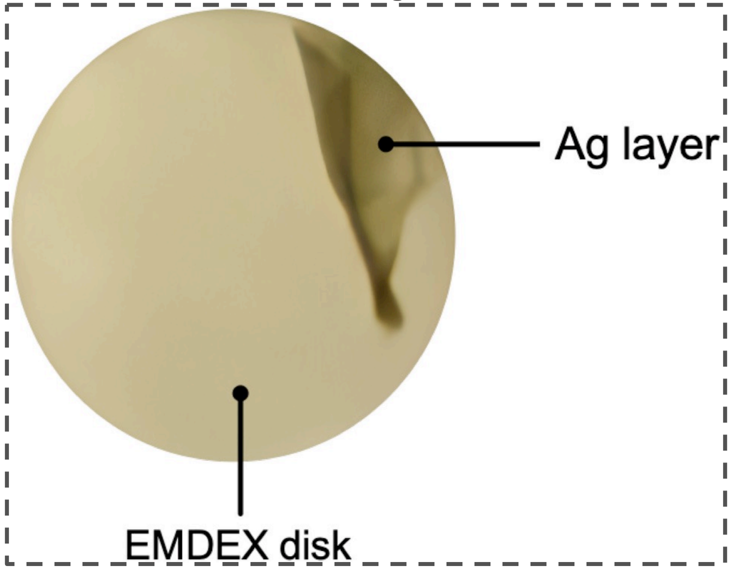
Metals deposition

Recent results

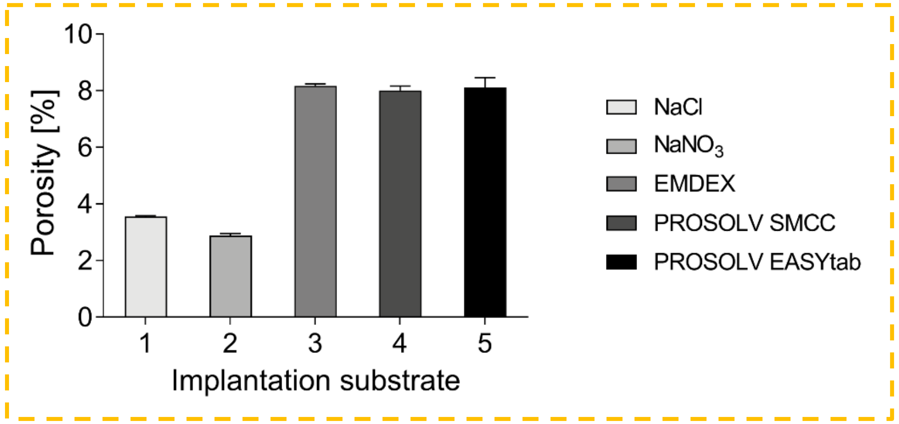
Implantation depth



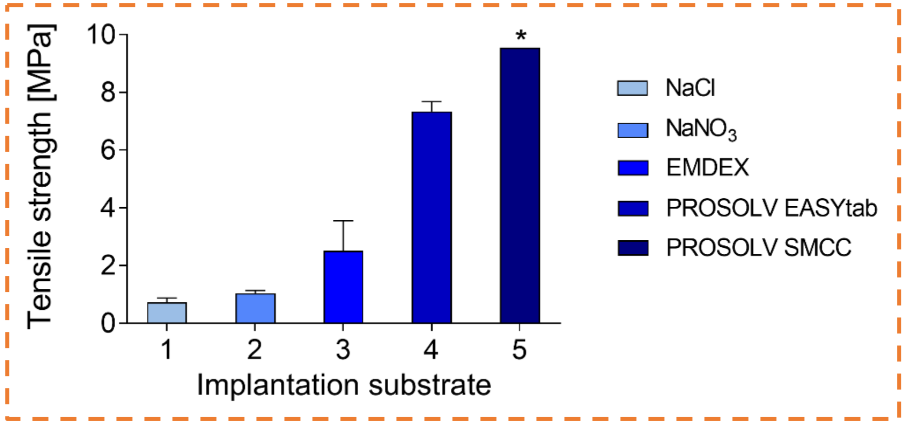
Metals deposition



Porosity



Breaking load



THANK YOU FOR YOUR ATTENTION!

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PRISMAP PROJECT

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