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DESIGN OF HIGH-POWER ISOL TARGETS FOR RADIOACTIVE ION BEAM GENERATION AT THE RIA: AN OVERVIEW

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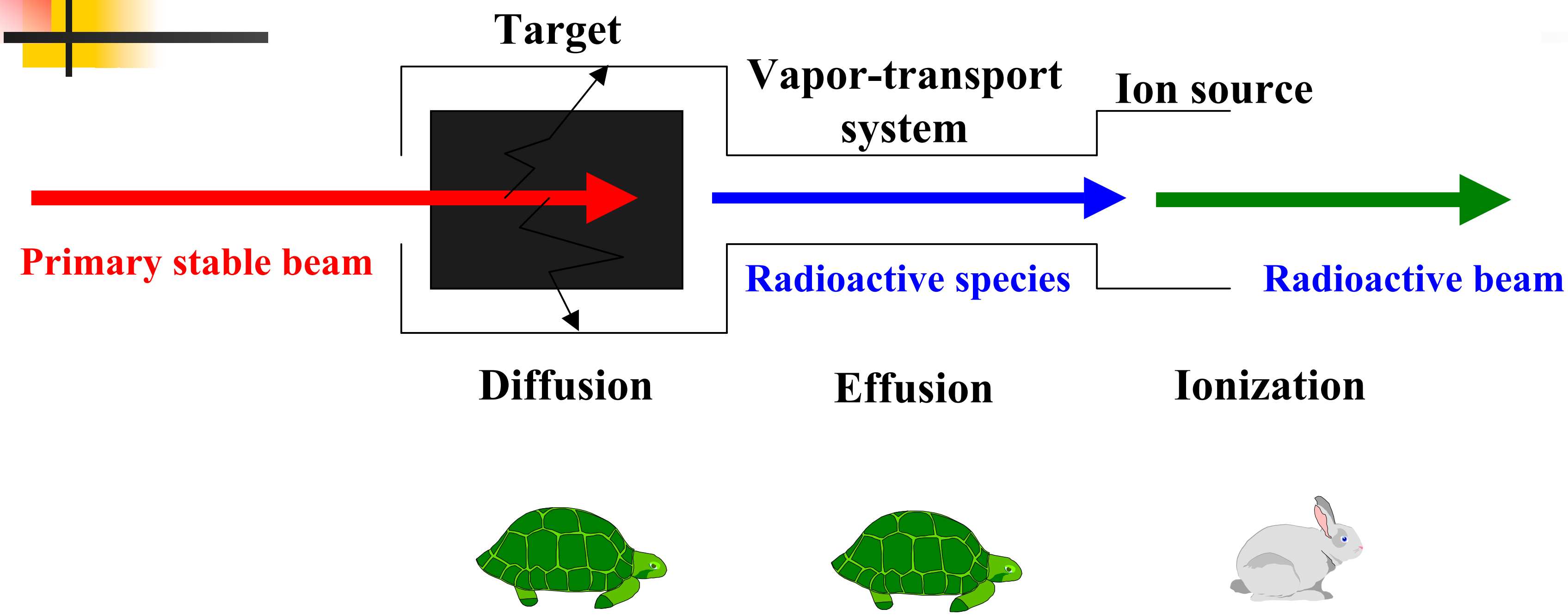
Schematic Representation of the ISOL Production Process



In order to minimize *diffusion* and *effusive-flow* delay times

Targets must be:

- Highly-refractory (high limiting-temperature);
- Small dimensioned (fast diffusion-release);
- Highly-permeable (fast effusive-flow, low density);
- Targets must be able to withstand high-levels of primary beam deposited heat.

Vapor-transport systems must be:

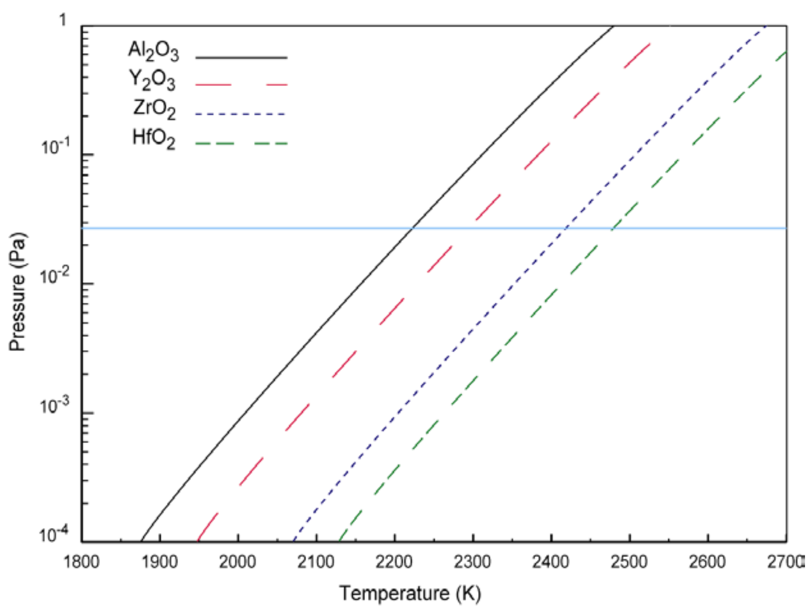
- Made of low enthalpy of adsorption materials and must be optimally coupled to the ion source in terms of size and geometry.

Target Material Selection: Limiting Vapor Pressure/Limiting Temperature

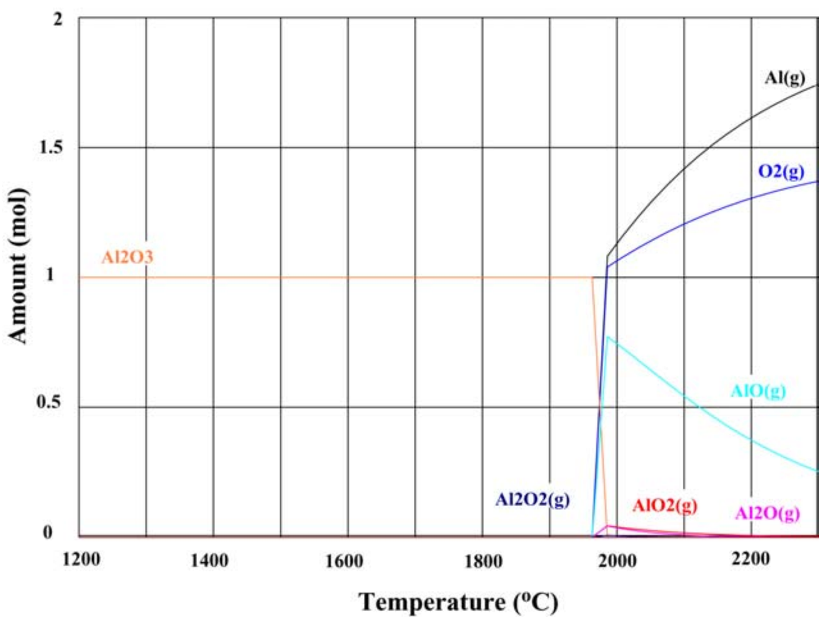
- Since the diffusion coefficient *D* strongly depends on *T*, it is desirable to heat the target as high as practical.

The limiting vapor pressure depends on the particular ion source used.

The limiting operating pressure is 2.67×10^{-2} Pa for an Electron Beam Plasma Ion Source.



Vapor pressure of Al_2O_3, Y_2O_3, ZrO_2 and HfO_2 versus temperature.



Thermal equilibrium composition of Al_2O_3 as a function of temperature.

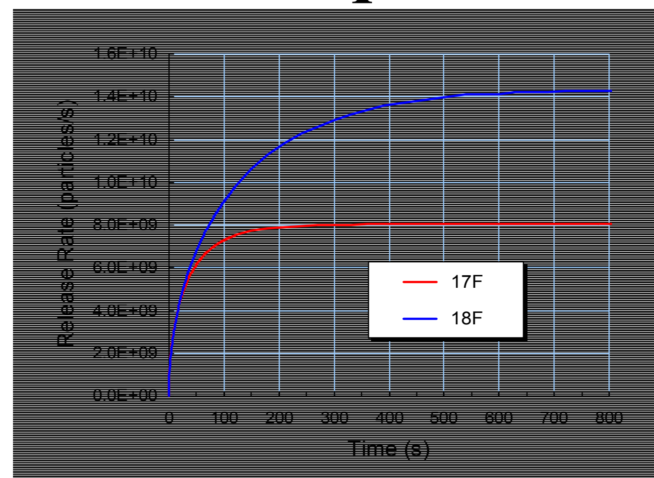
Candidate Spallation and Fission Target Materials for High-Energy (1-GeV) Proton Beam ISOL Facilities

Candidate Target Material	Limiting Temp. °K	Product Species
BeO	2503	He → F
C	2240	He → N
Al_2O_3	1998	He → Si
SiC	1973	He → P
TiC	2323	He → V
VC	2203	He → Cr
MnC_2	2973	He → Fe
Y_2O_3	2223	He → F; Al→ Zr
Zr	2303	P → Nb
ZrC	2648	P → Nb; He → N
ZrO_2	2323	He → F; Si → Nb
Nb	2353	P → Mo
NbC	2493	He → N; P → Mo
CeC_2	2663	He → N; Cu → Nd
CeS	2173	He → Cl; Cu → Nd
HfO_2	2473	He → Ta
Ta	2923	He → W
TaC	2613	He → W
W	3136	He → Re
WC	2753	He → Re
Re	2873	He → Os
ThC_2	2923	He → Pa
UC_2	2373	He → Np

To effect fast diffusion release, target materials must meet certain dimensional criteria ………

Diffusion from Targets : Fick's Second Equation:

$$\frac{\partial C}{\partial t} = D.\nabla^2 C + \frac{\sigma n I l}{ZeV} - \frac{0.693C}{\tau_{1/2}}$$



Thickness Requirements For Release of ~70% of Species within Their Lifetimes:

Planar geometry targets: $\langle x_p \rangle \approx \pi\{D\tau_{1/2}\}^{1/2}$

Cylindrical geometry targets: $\langle d_c \rangle \approx 4.8\{D\tau_{1/2}\}^{1/2}$

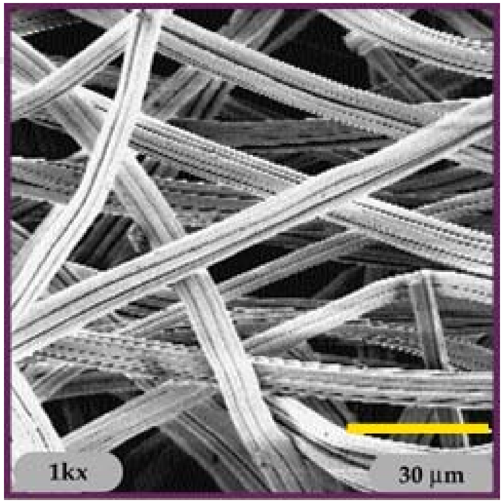
Spherical geometry targets: $\langle d_s \rangle \approx 2\pi\{D\tau_{1/2}\}^{1/2}$

High-Permeability Requirements

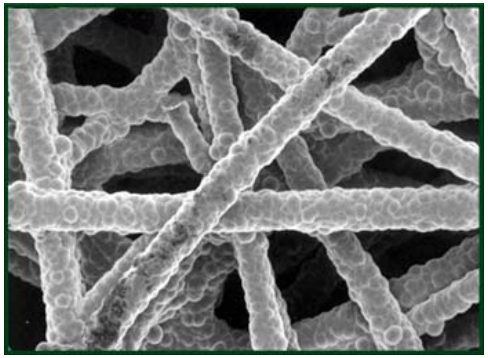
A few refractory materials can be procured in forms that are compatible in purity and dimension for RIB applications.

For example, the diffusion-release problem of $^{17,18}F$ has been solved by using highly permeable, thin fibrous Al_2O_3, ZrO_2 and HfO_2.

Scanning electron micrograph (SEM) of HfO_2 fibers used for $^{17,18}F$ RIB generation.



However, the number of such refractory materials is limited. Therefore, it is highly desirable to find a universal, low-density, highly-permeable matrix that can be coated with thin layers of any chosen target material.

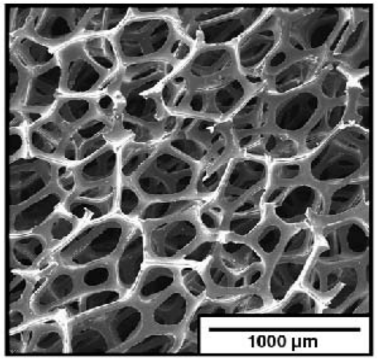


SEM of a CBCF matrix CVD coated with 6 µm of *SiC*.

SOLUTION

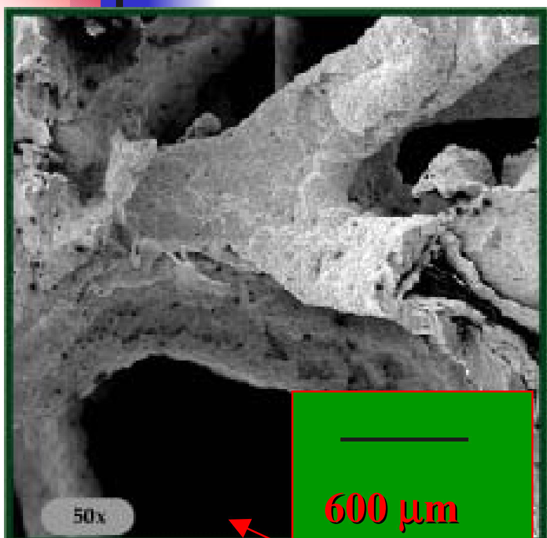
Carbon Bonded Carbon Fiber (CBCF) and Reticulated Vitreous Carbon Fiber (RVCF)

- Low density (1x, 2x, 4x or 6xRVCF)
- Easily machinable
- Good thermal properties
- Highly permeable

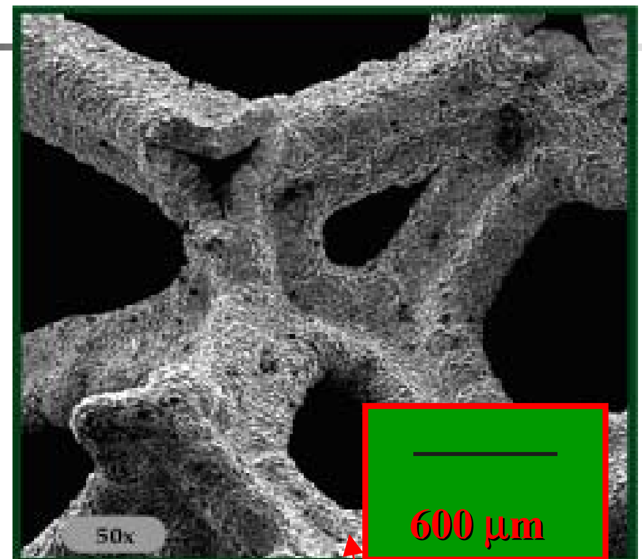


SEM of an uncoated RVCF.

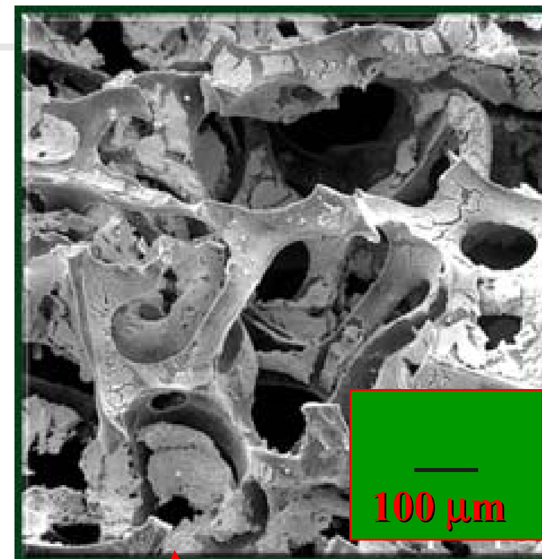
Methods are Available for Infiltration Coating of Complex Structure Matrices For Fabricating Optimal Thickness Spallation and Fission Targets



Ta on 2xRVCF



W on 2xRVCF



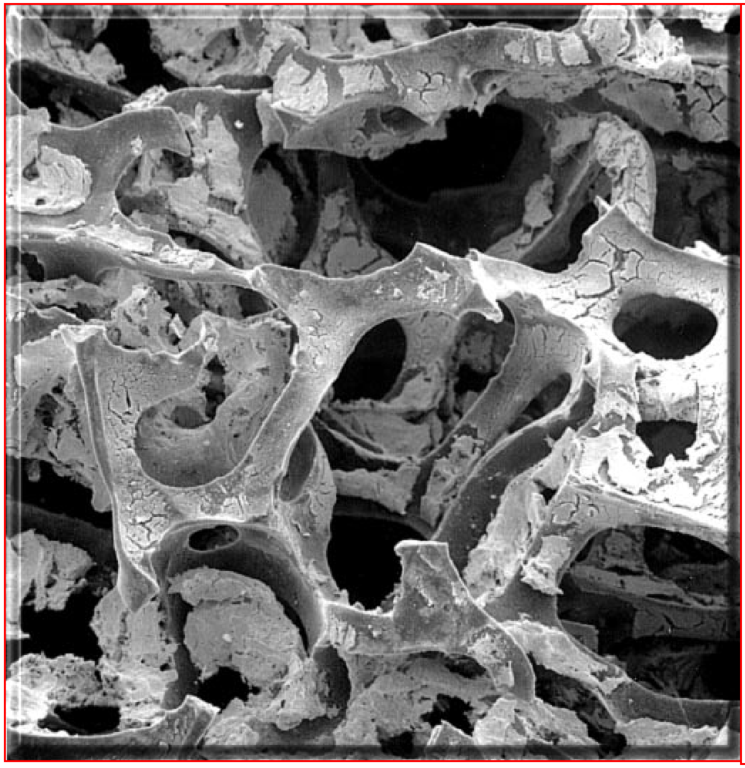
UC_2 on 2xRVCF

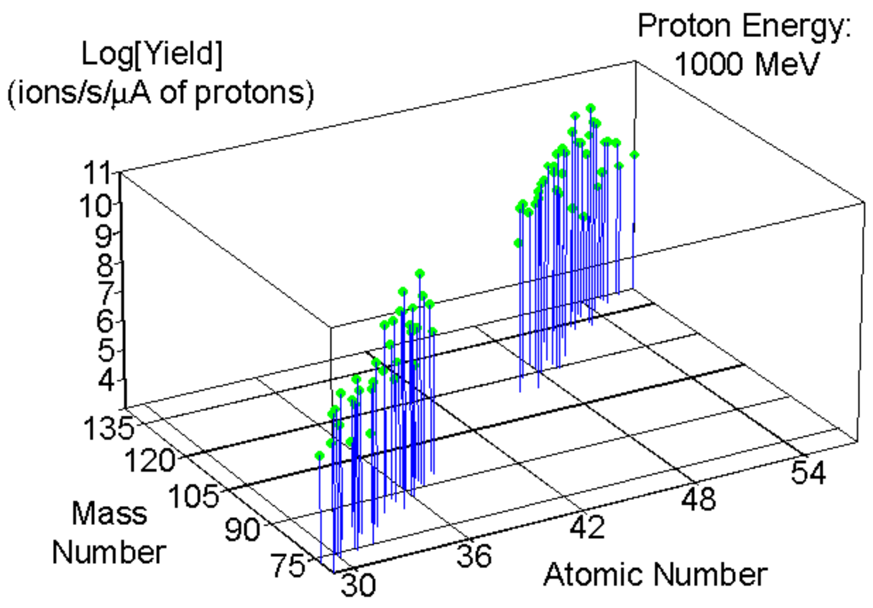
CVD/CVI

Chemical Reaction Deposition

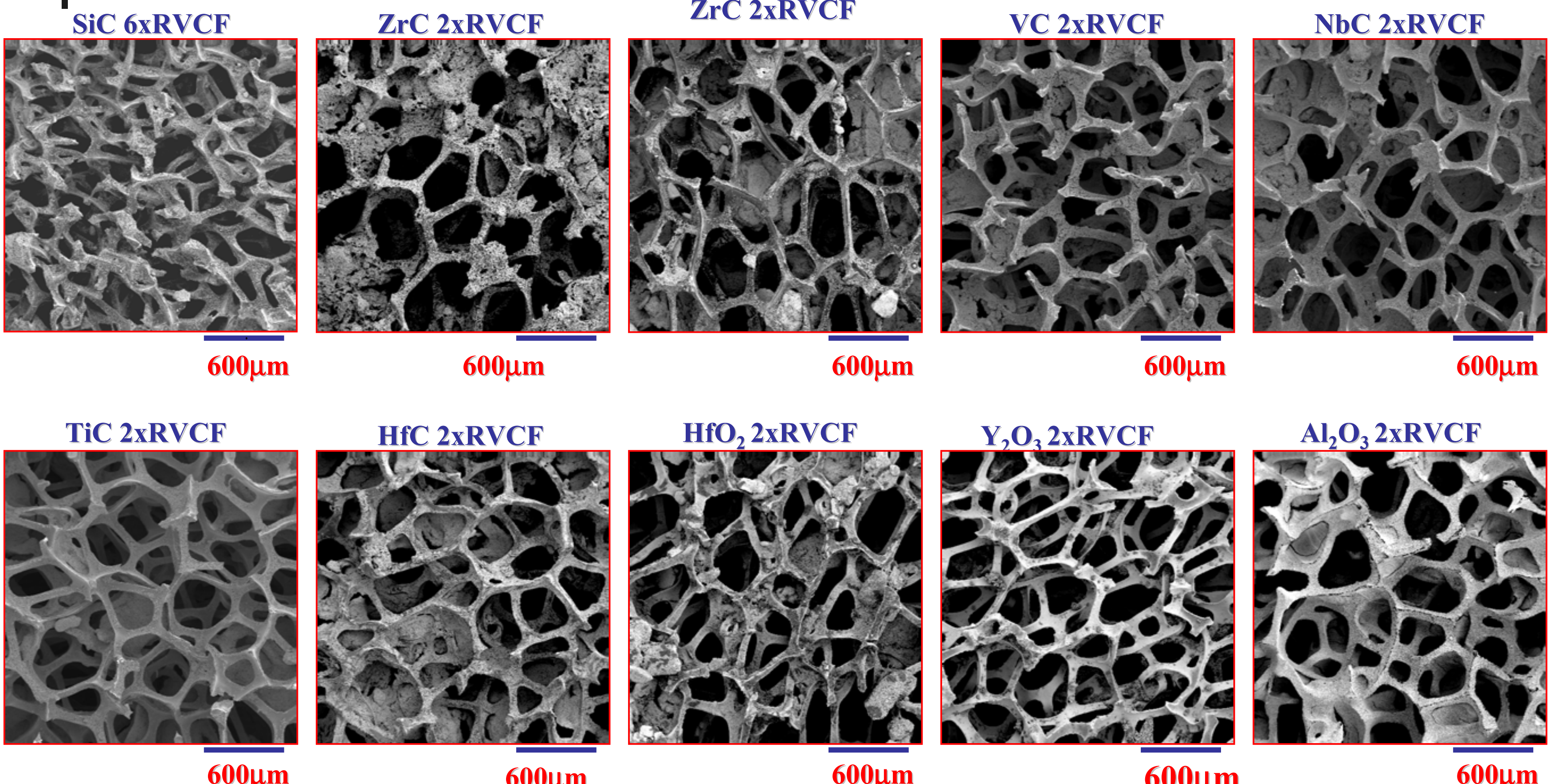
A Broad Spectrum of Neutron-Rich Radioactive Nuclei Can Be Produced Through Fission of UC_2 Deposited Either By Chemical or Paint Techniq1ues Onto RVCF

Yields(Ions/s/μA^1H) from UC_2 on RVCF

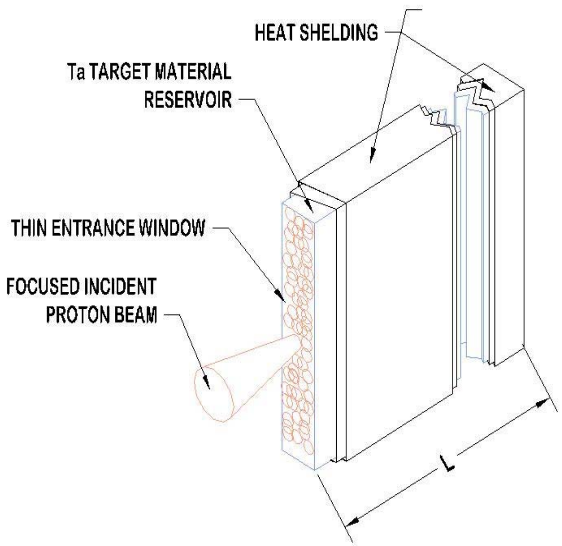


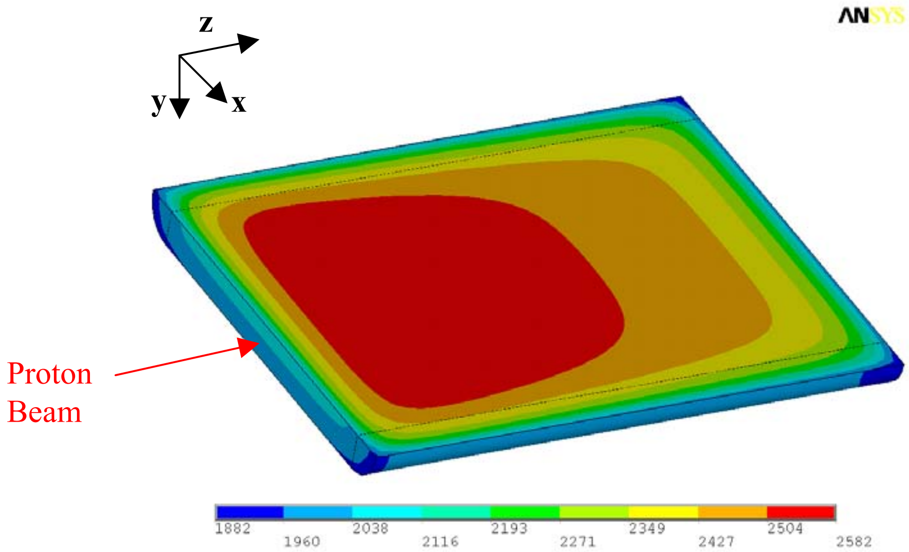


Various Carbide and Oxide Targets Formed by the Paint Technique



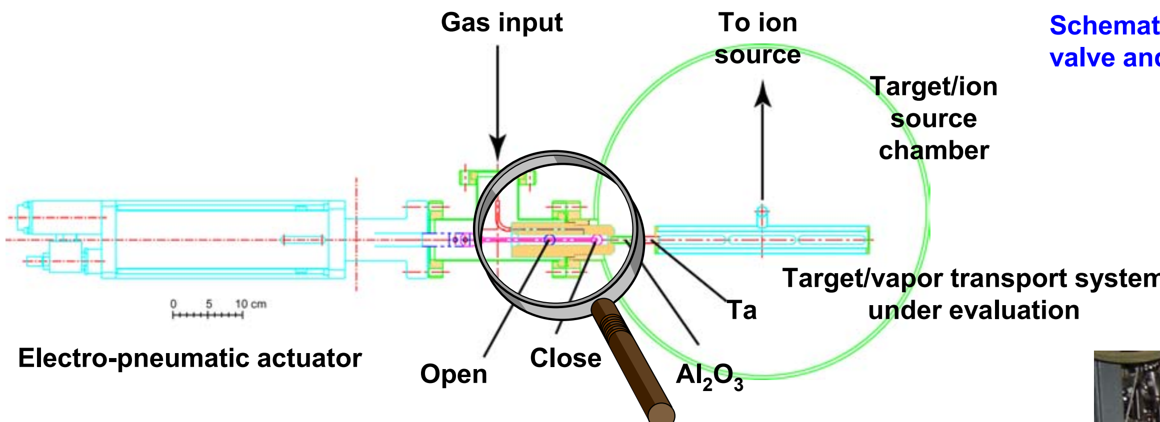
The Lissajous scan technique can be used to ensure homogenous target temperatures within reasonably sized targets under irradiation with 1 GeV, 400 kW proton beams. Target: UC_2; Target volume: *x*: 24 cm; *y*: 4 cm; *z*: 30 cm.



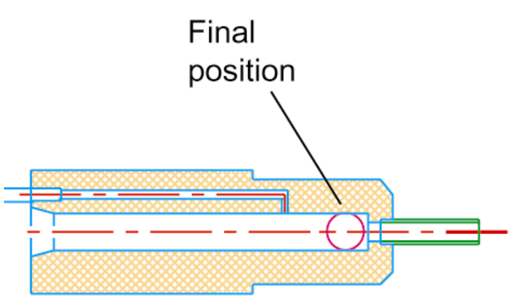


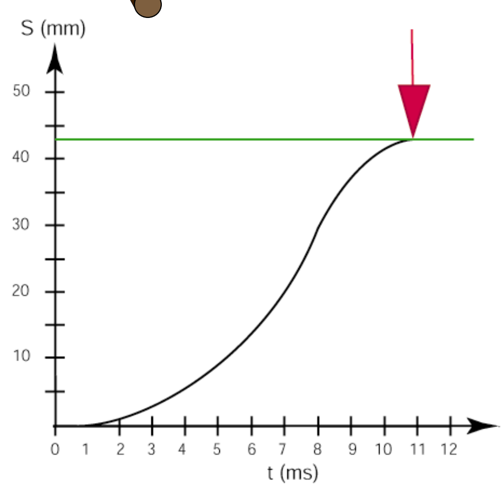
A Fast-Valve Experimental Apparatus for Measuring Effusive-flow Times Through Arbitrary Geometry and Size Vapor Transport Systems

- We have developed an experimental method that can be used to determine effusive-flow times of arbitrary geometry target/vapor transport systems. The technique utilizes a fast valve to measure effusive-flow times as short as 0.1 ms for any chemically active or inactive species through any target system, independent of size, geometry and materials of construction.

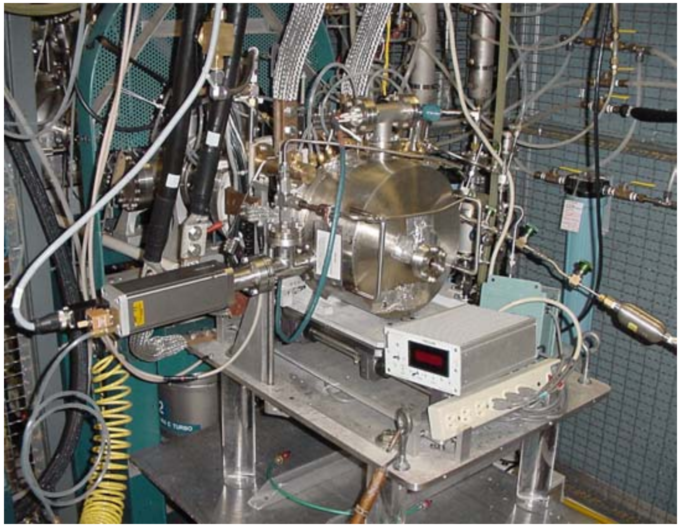


Schematic drawing of the fast valve and gas input system.

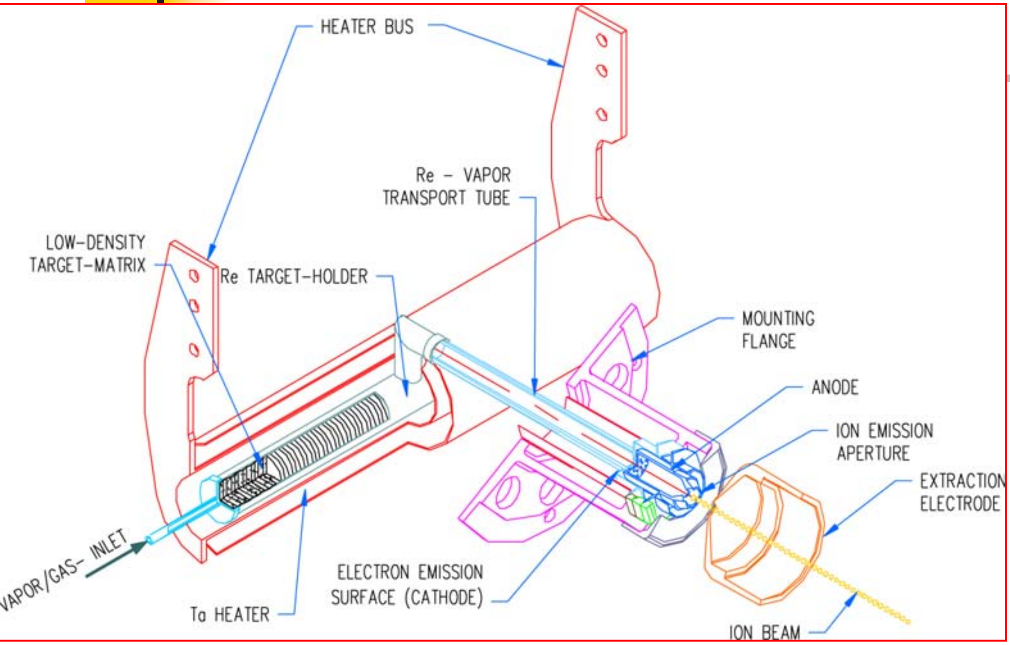


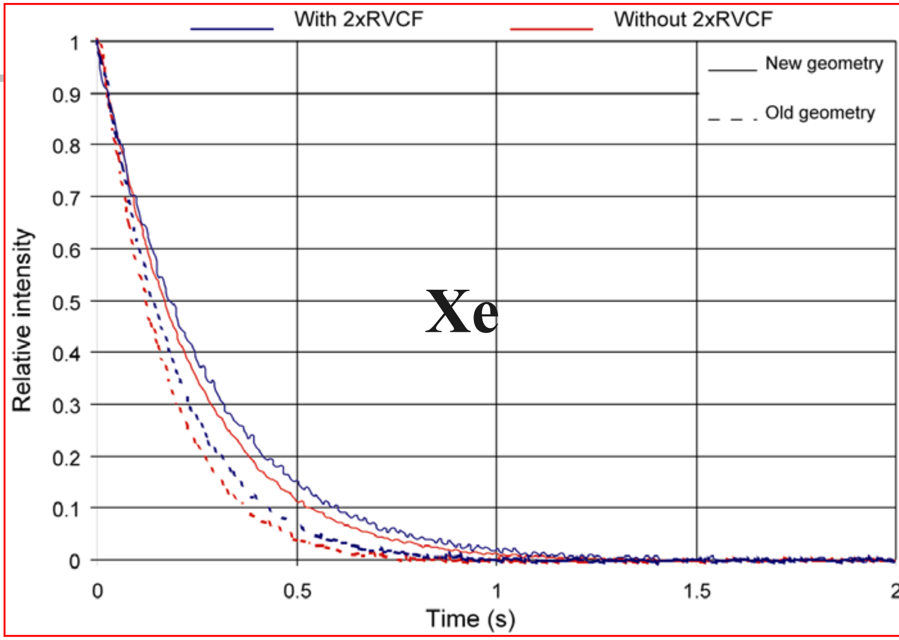


Photograph of the experimental apparatus



In Order to Minimize Effusive-Flow Delay Times, High Permeability Targets and Optimally Coupled Vapor Transport Systems Made Of Low Enthalpy of Adsorption Materials are Required





High Temperature Target Ion Source

Effusive-Flow time Spectra for Xe

A Partial Listing of Efforts Being Made at the Holifield Radioactive Ion Beam Facility (HRIBF) for ISOL Production of RIBs on Behalf of the RIA

- Selection of candidate refractory target materials based on the limiting vapor pressure/limiting temperatures of these materials;
- Custom engineering of targets with dimensional criteria commensurate with the diffusion release of ~70% of the isotope of interest within its lifetime;
- Conception and development of refractory fibers for RIB generation;
- Conception and development of highly permeable matrices for deposition of refractory target materials;
- Conception and development of close to universal infiltration method for controlled thickness deposition of generic refractory compounds onto complex structure target matrices;
- Measurement of thermal conductivities of fibrous/composite targets;
- Development of beam manipulation and scan techniques for controlling temperatures of ISOL targets during direct irradiation with 1 GeV, 400 kW proton beams;
- Conception, design and development of an experimental apparatus for characterizing effusive-flow times for arbitrary geometry target material reservoir/vapor-transport systems.