Micro-porous Sorbent for $^{99}Mo/^{99m}Tc$ Generator using (n,γ) ^{99}Mo

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Need for ^{99}Mo/^{99m}Tc isotopes

- **^{99m}Tc is the most widely used medical isotope worldwide**
- **The nuclear properties of ^{99m}Tc are ideal for medical imaging and it is used in almost 80% of all diagnostic procedure**
- **Total market demand of ^{99}Mo is approximately between 10,000 to 12,000 six-day Ci per week**
- **The demand for ^{99}Mo isotope for North America's market alone is almost 52% of the total world production**

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^{99}Mo Production Technologies

- **Uranium fission**
- **Solution reactor**
- **Neutron activation**
- **Cyclotron production**
- **Photo-fission route $^{100}Mo(\gamma,\nu)^{99}Mo$**
- **Neutron fission using spallation neutron sources $^{100}Mo(n, 2n)^{99}Mo$**

(Source: OECD Report, 2010)

Fission based ^{99}Mo Production

- Highly Enriched Uranium (HEU)
  - The majority of the world's ^{99}Mo supply comes from thermal fission using HEU as a target
  - Reactor outages have resulted in supply shortage
  - Continued concern over using HEU as target material
    - Proliferation issues
    - Waste generation

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Fission based ^{99}Mo Production (cont.)

- Low Enriched Uranium (LEU)
  - Limitations similar to HEU ^{99}Mo
  - Generates more waste volume classified HLW
  - Requires large specialized aging reactors
  - Still relies on uranium enrichment to produce target material

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Production of ^{99m}Tc using (n,γ) ^{99}Mo

- Production of ^{99}Mo via the neutron capture method draws attention as an alternative of fission process due to non-proliferation issues and it can be produced at multiple existing currently licensed reactor facilities in the U.S. and around the world, enhancing reliability of continuous supply
- Allows developing countries to create local medical isotope programs
- The main problem with neutron capture method is lower specific activity
- This limitation, however, can be overcome by the use of an adsorbent with higher capacity for molybdenum

Fission vs. Neutron Activation Process

$^{235}U(n, f)^{99}Mo$	$^{98}Mo(n,\gamma)^{99}Mo$
Requires enriched ^{235}U target	Requires high purity molybdenum
Produces high specific activity of ^{99}Mo	Produce low specific activity of ^{99}Mo
Generates high level radioactive waste	Generates minimal waste
Great concern about secondary fission product	No fission product
Export of highly controlled material required	Non-fissile material. No proliferation concerns.

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Medical Isotope Manufacture

- PESI Approach
  - PESI has completed initial development of a prototype ^{99m}Tc generator using a patent pending micro-porous composite (MPCM) resin
    - MPCM can adsorb commercially significant amounts of low specific activity ^{99}Mo produced by neutron activation
    - MPCM based ^{99}Mo/^{99m}Tc generator has the potential to allow neutron activated ^{99}Mo to contribute significantly to the supply chain

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MPCM

- MPCM is a biopolymer based micro-porous anionic functional composite resin
- MPCM resin is acid and radiation resistant and has been prepared using phase-inversion and sol-gel technique in the presence of a catalyst.
- The potential use of MPCM as an adsorbent for $^{99}Mo/^{99m}Tc$ generator has been studied in this work

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MPCM at a glance

- MPCM was prepared using phase inversion technique
- The surface area of MPCM is very high - 15 m^2/g with a pore volume of 0.012 cc/g
- MPCM is amorphous in nature
- Temperatures up to 100 °C do not adversely affect the adsorption capacity of MPCM
- MPCM resin is found to be resistant to extreme pH conditions
- The structure of MPCM has been demonstrated to maintain its integrity when exposed to 50,000 Krad Co-60 gamma radiation

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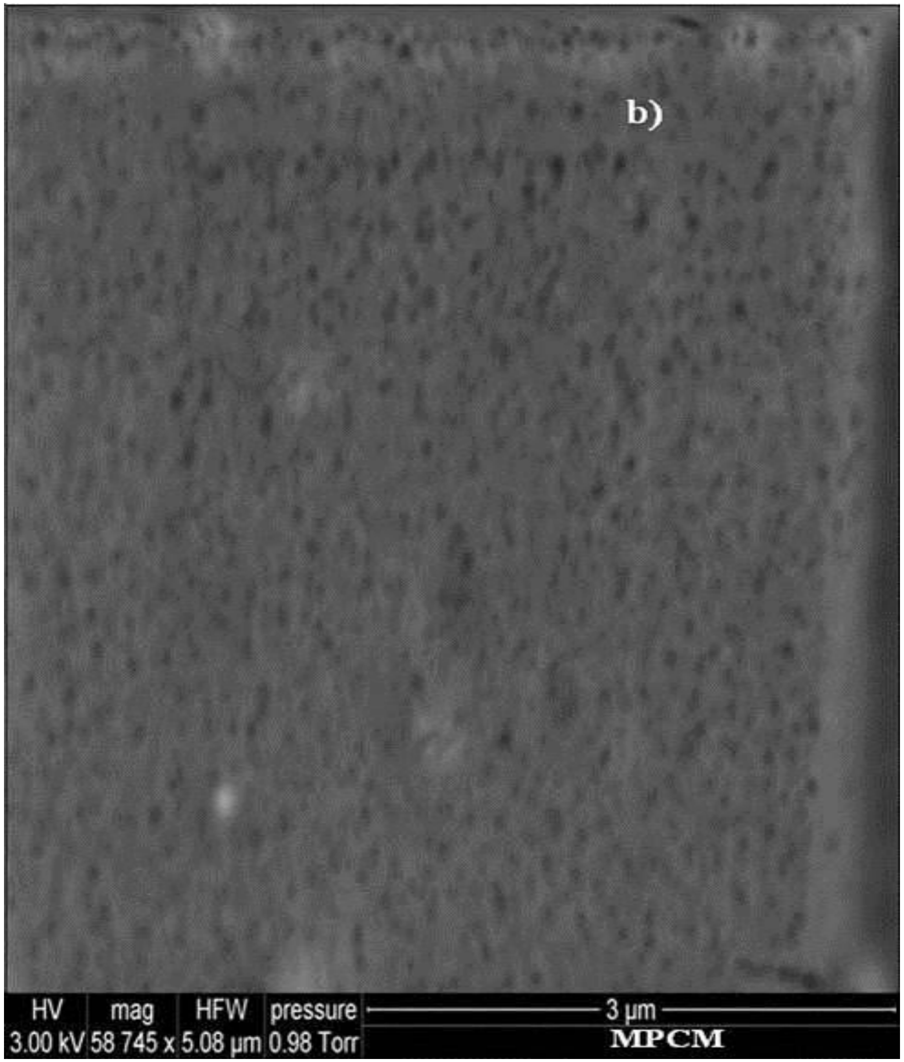
SEM micrograph of the MPCM surface



MPCM Key Properties

- MPCM has the capacity to adsorb up to 700 mg of Mo per dry gram compared to alumina that holds approximately 20 mg/g
- The elution efficiency of a MPCM based generator exceeds 80% of the ^{99m}Tc generated
- Cost effective to prepare
- Adsorbs ^{99}Mo quickly and efficiently
- Handling and hydraulic properties similar to alumina facilitate generator manufacture

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MPCM based ^{99}Mo/^{99m}Tc Generator

- MPCM high adsorption capacity allows the use of neutron activated ^{99}Mo within a footprint similar to current generator designs
- Creates US Supply Chain
- Internationally creates local supply chain
- Does not require the use of uranium targets
- No “orphan” waste generated
- Cost competitive at existing price structure

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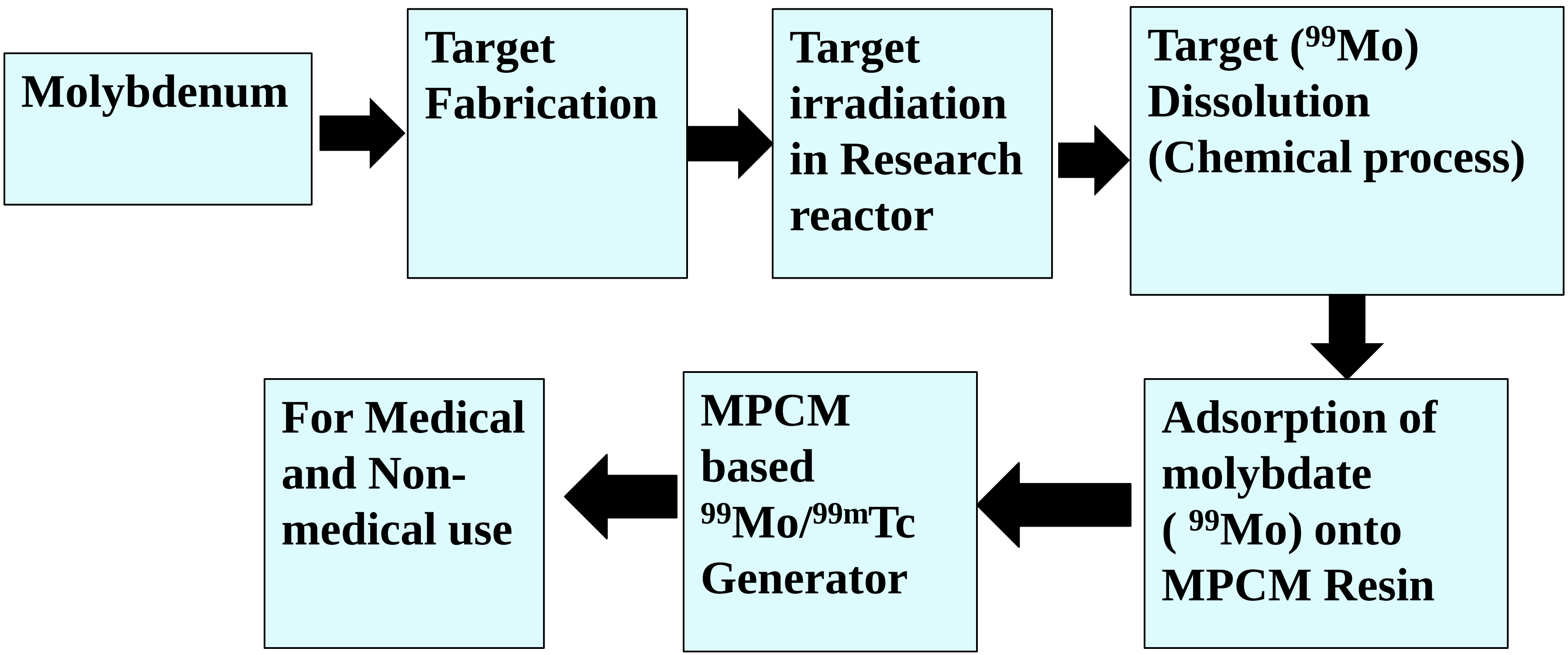
Flow diagram for the MPCM based ^{99m}Tc Production



Medical Isotope Manufacture

<u>Prototypical Test Results to date</u>

- Specific activity of ^{99}Mo in 1% molybdenum solution: 1.8 Ci ^{99}Mo/g Mo (using Mo-natural in irradiation target material)
- Adsorption cycle: 1hr
- Percent adsorbed: 95% of available Mo in the solution
- ^{99m}Tc release 90% +
- Column Bed Volume: 2.5 – 6.0 mL
- Experiments performed at PESI, POLATOM and MURR

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Typical Composition of tested Eluate

Items	Unit
Saline concentration	0.9% NaCl
^{99m}Tc Elution efficiency	≥ 80%
^{99}Mo/^{99m}Tc	< 0.15µCi/mCi of ^{99m}Tc
Al	< 10 mg/L
pH	4.5 – 7.5

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Demonstration of 4 Ci Generator Capacity

- Plans are underway for continued proof of concept testing at MURR and POLATOM to demonstrate the capability of producing a ~ 4 Ci MPCM generator

Summary

- MPCM was prepared using a combination of phase inversion and sol-gel methods in the presence of a catalyst.
- Maximum observed adsorption capacity of MPCM material for Mo was approximately 700 mg/g.
- MPCM based generator shows more than 80% ^{99m}Tc recovery from the column
- Experiments for a MPCM based generator of significantly higher ^{99}Mo capacity will be conducted shortly

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Timeline to Commercialization

- Perma-Fix has developed a resin that facilitates the use of $(n,\gamma)^{99}$Mo with minimal changes to generator operation
- We are in discussions to develop a $(n,\gamma)^{99}$Mo supply chain
- Conceptual design of a prototype generator is being finalized
- A subsidiary company, Perma-Fix Medical Corporation, has been established in Europe to raise capital, develop formal business relationships, and bring our MPCM generator technology to the world market
- FDA application process is anticipated to begin in 4th Quarter 2014

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Questions?

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