Abstract 039

Targets for Cyclotron Production of Tc-99m

E.J. van Lier[1], J. Garret[2], B. Guerin[3], S. Rodrigue[3], J.E. van Lier[3], S. McQuarrie[4], J. Wilson[4], K. Gagnon[4], M.S. Kovacs[5], J. Burbee[1], A. Zyuzin[1]

[1]*Advanced Cyclotron Systems Inc., Richmond, BC, Canada*

[2]*Brockhouse Institute for Materials Research, McMaster University, Hamilton, ON, Canada*

[3]*Sherbrooke Molecular Imaging Center, Université de Sherbrooke, QC, Canada*

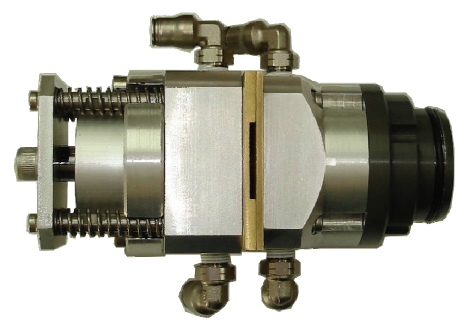
[4] *Dept Oncologic Imaging, Cross Cancer Institute, Edmonton, AB, Canada*

[5] *Department of Medical Biophysics, University of Western Ontario, London, ON, Canada*

Introduction: The measured yields of direct ^{99m}Tc production via ^{100}Mo(p,2n)^{99m}Tc suggest that ^{99m}Tc can be produced in quantities sufficient for supplying regional radiopharmacies[i, ii, iii], thereby reducing our reliance on reactor-derived ^{99}Mo. Cyclotron- and generator-produced ^{99m}Tc-radiopharmaceuticals were shown to be radionuclidically, chemically and biologically equivalent, giving matching images and identical kinetic and biodistribution patterns in animals, indicating that a medical cyclotron can produce USP-compliant ^{99m}Tc-radiopharmaceuticals for nuclear imaging procedures.[iv, v] In this work, several different ^{100}Mo target configurations were investigated and thick target yields were measured, validating the production of clinically useful quantities of ^{99m}Tc on a medical cyclotron.

Target Holders: Two different solid target holders were used to measure the thick target yields of the ^{100}Mo(p,2n)^{99m}Tc nuclear reaction. The straight 90° target holder has a heat removal capacity of 1.5 kW and while the 30° tilted solid target holder has a heat removal capacity of 3.0 kW. Two different solid target holders (Advanced Cyclotron Systems Inc., Richmond, BC, Canada) were installed on three compact medical cyclotrons (TR-19, Cross Cancer Institute, Edmonton, AB, TR-19 Centre Hospitalier Universitaire de Sherbrooke, Sherbrooke QC, Canada, GE PETrace, Lawson Health Research Institute, London ON, Canada).

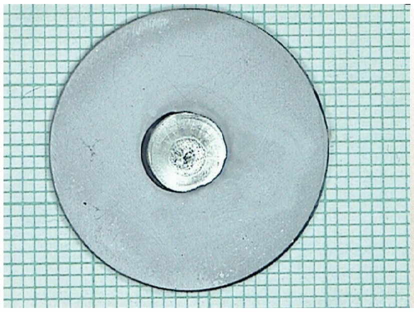
30° Solid Target Holder

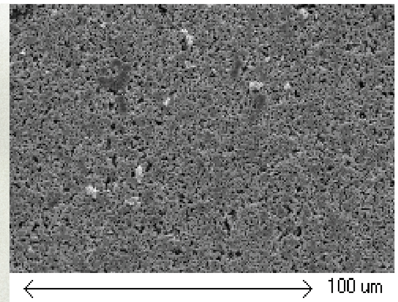


Straight Solid Target Holder

^{100}Mo Targetry. Molybdenum has been a metal of choice in accelerator targetry for several decades. With a high melting point, good thermal conductivity and chemical stability, molybdenum is nearly an ideal material for manufacturing high power targets. While a number of low and medium current cyclotron targets that use natural and enriched molybdenum isotopes have been developed and used for production of technetium isotopes: ^{94}Tc, ^{96}Tc and ^{99m}Tc [vi], a reliable process for preparation of enriched molybdenum targets has not yet been implemented. A number of standard target manufacturing techniques are being evaluated: melting, sintering, pressing/pelletizing, rolling, plating from solutions or molten salts, formation of low melting temperature Mo alloys, brazing or soldering ^{100}Mo to a target substrate, coating molybdenum with a protective layer, development of a thick target, plasma sputtering and other coating techniques.

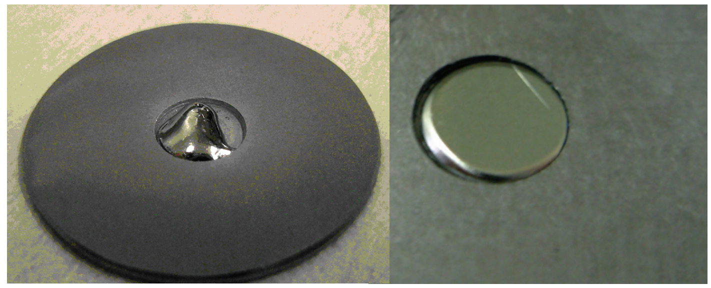
Mo Target Preparation: Between 100-450 mg natural and enriched ^{100}Mo (99.5%) were pressed into 6 and 9.5 mm pellets at between 25,000 N and 100,000 N. The pellets were sintered in wet or dry hydrogen at 800-900ºC, and subsequently mounted into a tantalum substrate, either by pressing or arc melting or electron beam melting at currents between 40-70 mA with different sweeping / focusing patterns.





1. Arc Melted Mo in tantalum 2. Pressed Mo in Ta (EOB) 3. SEM of pressed Mo

^{99m}Tc Production: ^{99m}Tc was produced via the ^{100}Mo(p,2n)^{99m}Tc nuclear reaction on a 19 MeV medical cyclotron using an incident proton energy of 15-17 MeV at current between 14-52 µA. After bombardment targets were subjected to electrochemical dissolution, ^{99m}Tc was purified by ion-exchange chromatography and recovered as pertechnetate.



Electron beam melting of Mo to Tatarget substrate

Results: Up to 44.7 GBq (1.2 Ci) (EOB) of ^{99m}Tc was produced after a 6-h bombardment at 16.4 MeV and 39 µA. This corresponds to a thick target production yield of 0.25 GBq/µA/h (6.8 mCi/µA/h) and 2.3 GBq/µA (63 mCi/µA) at saturation and is in good agreement with literature data.[I, II, III] The radionuclide purity of the cyclotron-produced ^{99m}Tc was >99.99%, as assessed by γ spectroscopy, exceeding USP requirements for generator-based ^{99m}Tc. The content of other technetium isotopes was measured after allowing sufficient time (4 days) for ^{99m}Tc decay and was below USP requirements of 0.01% for generator-produced ^{99m}Tc. No other radionuclidic impurities were found. The radiochemical purity of cyclotron-produced $^{99m}TcO_4^-$ was >99.5%, well above the USP requirement of 95%.

Conclusion: This study confirms that clinically useful quantities of ^{99m}Tc can be produced on medical cyclotrons installed worldwide. Extrapolating these results to the optimal energy of 22-24 MeV indicates that over 2 TBq of ^{99m}Tc can be produced daily for regional distribution on a high-current medium-energy cyclotron. Implementing networks of high-current medium energy cyclotrons would reduce reliance on nuclear reactors and attenuate the negative consequences associated with the use of fission technology.

---

[i] Scholten, B., Lambrecht, R.M., Cogneau, M., Vera Ruiz, H., Qaim, S.M., 1999. Excitation functions for the cyclotron production of ^{99m}Tc and ^{99}Mo. Appl. Radiat. Isotopes 51, 69–80

[ii] Takács, S.; Szűcs, Z., Tárkányi, F.; Hermanne, A.; Sonck, M Evaluation of proton induced reactions on ^{100}Mo: New cross sections for production of ^{99m}Tc and ^{99}Mo, J. of Radioanalytical and Nuclear Chemistry, 257,1 , 2003, 195-201(7)

[iii] Lebeda, O.; Pruszynski, M.: New measurement of excitation functions for (p,x) reactions on natMo with special regard to the formation of ^{95m}Tc, $^{96m+g}$Tc, ^{99m}Tc and ^{99}Mo, Appl. Radiat. Isot., in press, (personal communication)

[iv] Guérin, B.; Tremblay, S; Rodrigue, S.; Rousseau, J.A.; Dumulon-Perreault, V.; Lecomte, R.; van Lier, J.E.; Zyuzin, A.; van Lier, E.J. Cyclotron Production of ^{99m}Tc: An Approach to the Medical Isotope Crisis J. Nuclear Med., 2010;51:13N-16N

[v] Zyuzin, A.; Guérin, B.; van Lier, E.J.; Tremblay, S; Rodrigue, S.; Rousseau, J.A.; Dumulon-Perreault, V.; Lecomte, R.; van Lier, J.E.; Cyclotron production of ^{99m}Tc WTTC 13, Abstract

[vi] Qaim, S.M., Production of high purity ^{94m}Tc for positron emission tomography studies, Nuclear Medicine and Biology, 27, 4, 2000, 323-328