ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPML131

A NEW PRODUCTION PROCESS FOR UC_x TARGETS FOR RADIOACTIVE ISOTOPE BEAMS AT TRIUMF

M. S. Cervantes*[1,2], A. Gottberg [1,2], [1] University of Victoria, Victoria, Canada
P. Kunz[2], A. Mjos[2], J. Wong[2], L. Lambert[2], TRIUMF, Vancouver, Canada
P. Fouquet-Métivier[2,3], [3]Ecole Nationale Supérieure de Chimie de Montpellier, Montpellier, France

Abstract

TRIUMF has the objective of producing radioactive isotope beams (RIB) using the ISOL method. Radioactive isotopes are used in experiments in different areas of science. At the TRIUMF-ISAC facility, a 500 MeV proton driver beam impinges onto different targets and induces nuclear reactions in them. The isotopes obtained in this way then diffuse out of the target material before they are ionized and extracted to form an isotope beam. Targets of uranium carbide with excess of graphite (UC_x) are the most requested targets at TRIUMF. ARIEL, TRIUMF's flagship project, aims at increasing the radioactive isotope production capabilities to satisfy the growing demand of radioactive isotopes. The current production method of UC_x targest does not have the means to supply enough UC_x targets to satisfy ARIEL's demand, therefore, a new method for efficient UCx target material synthesis is being developed.

INTRODUCTION

TRIUMF, Canada's particle accelerator centre, delivers RIB to experiments in nuclear physics, nuclear astrophysics, nuclear medicine, and material science. To expand its scientific capabilities, TRIUMF is developing the Advance Rare IsotopE Laboratory (ARIEL) project. ARIEL will triple TRIUMF's RIB capabilities [1].

UC_x is the reference target material for ISOL worldwide. At TRIUMF, these targets are made of a stack of up to 400 D-shaped discs of 19 mm diameter ~0.4 mm thickness. Each foil is made of an UC_x layer on a graphite foil [2].

The ISAC UC_x targets are produced in a two-step process. In the first step of the process, uranium dicarbide (UC_2) is synthesized through vacuum-based carbothermal reduction of UO_2. In the second step, the obtained UC_2 is mixed with excess graphite and cast on a graphite foil, from that cast D-shaped discs are manufactured and then they are syntered under vacuum at 2000°C.

The current method to produce one UC_x target for online operations requires approximately ten weeks. Such rate of production does not allow the development of new materials to fulfill the requirements of the future facility, neither it can satisfy the upcoming target demand of 30 targets per year, expected in the ARIEL era. Therefore, a new 1-step production method has been proposed.

* marla@triumf.ca

1-STEP CASTING METHOD

The current UC_x target production method consists of casting a slurry made of solvents, binders, UO_2, and graphite powder, this cast is then heated up in vacuum to synthesize UC_2 (Eq. 1) by carbothermal reduction [2].

$$UO_2 + 4C \rightarrow UC_2 + 2CO \quad (1)$$

The obtained UC_2 is mixed with 10 wt% graphite excess, solvents and binders to form a slurry, that is casted to a graphite foil. Then, discs are cut from that cast and loaded in a tantalum container to be sintered and conditioned [2].

The new production method consists of forming a slurry with UO_2, solvents, binders, and enough graphite powder not only to synthesize UC_2 but also to have graphite in excess within the first production step (Eq. 2).

$$UO_2 + 4.5C \rightarrow UC_2 + 0.5C + 2CO \quad (2)$$

This slurry is then casted on a graphite foil, from which discs are manufactured, loaded to a container, and inserted into a vacuum oven for carbothermal reduction and conditioning at the same time [3]. The carbothermal reduction of the materials is done in a furnace under vacuum inside of a resistively heated tantalum container. During the carbothermal reduction, CO is released (Eq. 2), as well as water and other solvents in the cast. The CO and the solvents increase the pressure in the chamber.

The pumping system of the furnace consists of a roughing pump and a turbomolecular pump. A convectron gauge and a bayard-alpert pirani gauge measure the pressure in the furnace. To protect the integrity of the turbomolecular pump, when the vacuum reaches 0.05 mTorr the system automatically trips off the heating current and the material starts to cool down. To keep the vacuum under this limit, the current has to be slowly applied to the material to allow the pumping system to extract the gas and vapor released such that the vacuum stays under the threshold of 0.05 mTorr.

In order to apply faster current rates and to accelerate the carbothermal reduction, the vacuum limit of 5×10^{-2} mTorr was changed to 500 mTorr, and the pumping system was bypassed in order to only pump with the roughing pump avoiding the overtheating of the turbomolecular pump.

Using the roughing and turbomolecular pump, the system can reach 5×10^{-4} mTorr. When bypassing the turbomolecular pump, the system is limited to 1.3 mTorr, so instead of having a difference in vacuum of 4 orders of magnitude to work with, the difference is only 2 orders of magnitude.

A small batch of 35 discs, manufactured using the 1-step casting method, was submitted to carbothermal reduction

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPML131

under vacuum with the turbomolecular pump bypassed. At around 100 A, water and other solvents in the cast start evaporating, at that stage the vacuum in the furnace reached 36 mTorr and the roughing pump did not have the capacity to achieve lower vacuum even after the carbothermal reduction was complete at 520 A (Fig. 1). The carbothermal reduction took 3 hours to complete, the pressure reduction indicates the end of the process.

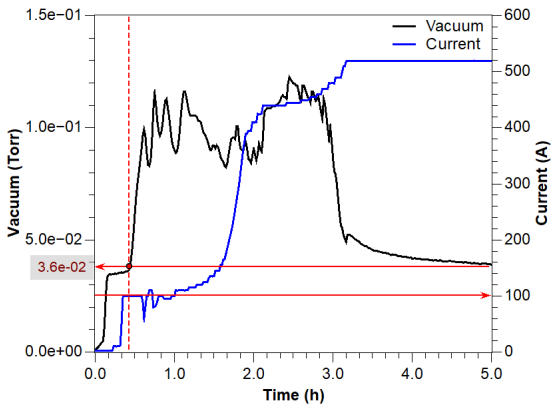

Figure 1: Carbothermal reduction increased pressure in the vacuum system as a function of time of 35 discs manufactured with the 1-step casting method using bypassed system (no turbomolecular pump). When the material started releasing vapor at 100 A, the roughing pump deliver a vacuum of 3.6×10^{-2} Torr.

Another small batch of 35 discs was submitted to carbothermal reduction but in this test, the vacuum limits were set to 0.1 mTorr instead of 500 mTorr, and the turbomolecular pump was not bypassed. The carbothermal reduction process took around 3 hrs for this test as well and the turbomolecular pump did not overheat.

A next step will be to perform the carbothermal reduction of a small batch of 35 discs, without bypassing the turbomolecular pump and using a vacuum limit of 500 mTorr, such that we have a difference in vacuum of 4 orders of magnitude to increase the current at faster rates and speed up the carbothermal reduction. The temperature of the turbomolecular pump must be measured to monitor the potential overheating and avoid a consequent failure of the pump.

CONCLUSIONS

A new method to ramp-up the production rate of UC_x targets have been proposed and a test was performed. The test consisted of manufacturing 35 discs using the 1-step casting method, and submitting them to carbothermal reduction under vacuum, this already corresponds to a significant speed-up, but more is desired. The vacuum system was backed by a roughing pump and the turbomolecular pump was bypassed. The carbothermal reduction had a duration of 3 hours.

ACKNOWLEDGMENT

TRIUMF receives federal funding via a contribution agreement with the National Research Council of Canada. ARIEL is funded by the Canada Foundation for Innovation (CFI), the Provinces of AB, BC, MA, ON, QC, and TRIUMF. AG and MC acknowledge additional support from NSERC. MC acknowledges Aaron Schmidt for his technical support. The TRIUMF scintillator group and the entire ISAC controls group are acknowledged for their technical support.

REFERENCES

[1] J. Dilling et. al., "ARIEL overview", *Hyperfine Interactions*, vol. 225, 2014, 253-262, doi 10.1007/s10751-013-0906-6

[2] P. Kunz et al., "Composite uranium carbide targets at TRIUMF: Development and characterization with SEM, XRD, XRF and L-edge densitometry", *Journal of Nuclear Materials*, vol. 440, Apr. 2013, 110-116, doi.org/10.1016/j.jnucmat.2013.04.065

[3] A. Gottberg, "Target materials for exotic ISOL beams", *Nuclear Instruments and Methods in Physics Research*, B, vol. 376, Feb. 2016, 8-15, doi.org/10.1016/j.nimb.2016.01.020