Preparatory experiments for future functionalized detector for transactinide homolog experiments

A.S. Kirkland,[1,2] A.M. Bukowski,[1,2] T.L.M. Cook,[1,3] J.R. Garcia,[1,2] I.W. Haynes,[1,2] J.A. Mildon,[1,2] C.M. Sehring,[1,2] P.E. Smith,[1,2] J.K. Tung,[1,2] and C.M. Folden III,[1,2]

[1]*Cyclotron Institute, Texas A&M University, College Station, Texas 77843*

[2]*Department of Chemistry, Texas A&M University, College Station, Texas 77843*

[3]*Department of Nuclear Engineering, Texas A&M University, College Station, Texas77843*

Transactinide elements ($Z \geq 104$) are difficult to chemically characterize, due to their short half-lives and low production cross sections. Typically, chemical characterization is done by thermal- or isothermal-chromatography. These techniques study the adsorption of the element of interest on either a silicon dioxide column or a detector array with silicon detectors, from which an adsorption enthalpy can be measured [1-3]. Recent advancements have focused on coating Si detectors with Au. This technique was applied to the study of Nh on Au-coated Si detectors, but unfortunately it sorbed too strongly on Au to measure the adsorption enthalpy [2, 3].

The range of surfaces that adsorption enthalpies can be studied on has been expanded at Texas A&M University. Au-coated Si detectors can be coated with self-assembled monolayers (SAMs), which are organic molecules that have self-assembly properties. A large variety of terminal groups are available to study the adsorption enthalpy of transactinide elements. SAMs are ideal for SHE chemistry experiments, with desirable properties such as having high surface coverage, a thickness of approximately 1 nm, and surface stability of at least one month [4, 5].

Lighter homolog studies with Ir and Rh have been performed at Texas A&M, with promising results [4, 5]. Current research is focused on a new chemical system, studying adsorption of Po [the expected homolog of the superheavy element Lv (Z = 116)] on 1,9-nonanedithiol (NDT), a SAMs with an exposed -SH group. A detector array has been designed called the SAMs Polonium Isotope Detector ARray (SPIDAR), which is a Si-detector array with interchangeable detectors, allowing for the adsorption enthalpy of Po, At and Er to be measured on a variety of surfaces. Testing of the SPIDAR offline using ^{228}Th to produce ^{216}Po ($t_{½}$ = 145 ms) is currently ongoing.

To perform transactinide chemistry experiments, elements of interest must be produced in a nuclear reaction, purified, thermalized and extracted [6]. In December 2024, a preparatory experiment for online experiments with SPIDAR was performed using Al Ghiorso's Gas-filled Ion Equipment (the gas-filled separator AGGIE). A 6.3 MeV/u $40Ar^{11+}$ beam was delivered to the AGGIE target chamber, where fusion-evaporation reactions were performed, including ^{160}Dy(^{40}Ar, xn)$^{195-198}$Po (x = 2-5), ^{165}Ho(^{40}Ar, xn)^{198,199}At (x = 5,6) and ^{118}Sn(^{40}Ar, xn)^{152,153}Er (x = 5,6). The evaporation residues were separated from the primary beam with AGGIE, which was set to a magnetic rigidity of 1.59 T m for Po and At, and 1.27 T m for Er. The products were transmitted through a variable angle degrader (VAD), composed of a thin Mylar sheet that can be rotated, changing the effective thickness of the degrader. The evaporation residues were then sent into the simple Recoil Transfer Chamber (sRTC), which is a chamber filled with 350 torr He, to thermalize the products. The angle on the VAD was changed to control the range of the products in the sRTC. A Si detector was placed in the half-way point of the sRTC funnel in order to optimize the stopping of the evaporation residues at this position before the products are implanted into

the back wall of the funnel. The yield of these products was measured as a function of the total thickness of the VAD and a 2 µm Mylar window placed after the VAD. This range curve was measured in the sRTC both at vacuum and with 350 torr He with a flow rate of 200 sccm. By subtracting these two curves, a gaussian distribution is measured which will determine the optimal stopping thickness of the VAD (Figure 1a-c). This thickness was determined to be 7.1 µm ± 0.3 µm, 6.7 µm ± 0.3 µm and 6.1 µm ± 0.3 µm for Er, At and Po respectively. An experiment is planned for September 2025 to test the SPIDAR in cyclotron-based experiments with Er, At and Po on three surfaces: bare Si, bare Au and NDT.

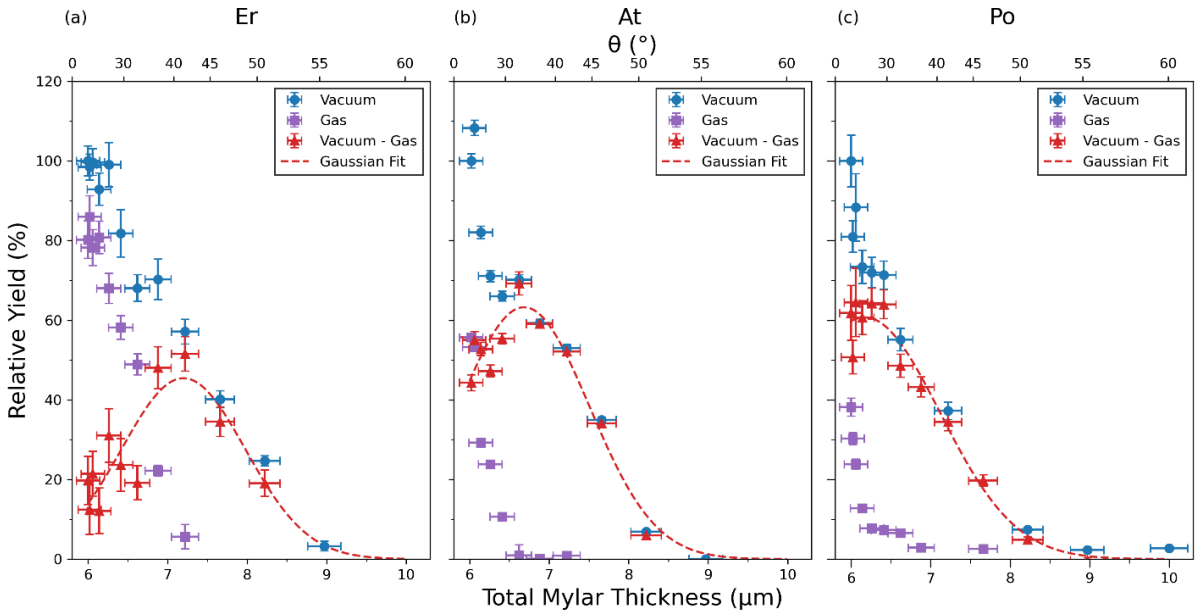

Fig. 1. (a) ^{152,153}Er range analysis, with a gaussian fit to determine the optimal stopping thickness of 7.1 µm ± 0.3 µm. (b) $^{198\text{-}199}$At range analysis, with a gaussian fit to determine the optimal stopping thickness of 6.7 µm ± 0.3 µm. (c) $^{195\text{-}198}$Po range analysis, with a gaussian fit to determine the optimal stopping thickness of 6.1 µm ± 0.3 µm. In all cases, the error bars consist of statistical uncertainty as well as a 5% systematic uncertainty.

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