Development of electroplating Bismuth onto Aluminum target frames

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Electroplating is the process in which an electric current causes a chemical reaction and the subsequent deposition of metals onto a substrateand a graphical example of electrolysis process is shown in Fig. 1. We aim to find the optimal conditions for plating bismuth metal onto an aluminum frame for subsequent irradiation with alpha particles to produce astatine-211. This process of electrodeposition of bismuth onto the target frames should result in flat and evenly distributed targets, which are desirable characteristics for a target. Beginning in Fall 2024, the electrodeposition and analysis of thick bismuth films, a study by Hatfield et al.3 helped determine that starting conditions were 0.15M bismuth dissolved in 15M nitric acid, 1.4M glycerol, 0.33M tartaric acid, and 1.2M potassium hydroxide.

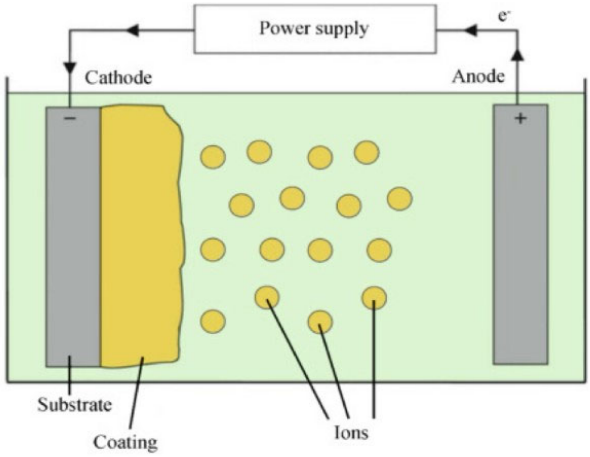

Fig. 1. Graphical figure of example of electrolysis process [2].

Four trials were run over the course of the semester, the results are listed in Table I. It was discovered that the pH affects the solution. If the pH is above 0.2, then a white precipitate forms that is a

Table I. The amount of Bi, power, and current used, the time of the run, and the amount of Bi deposited successfully with each trial during fall 2024.

Trial	Bi (g)	Power/Current	Time	Bismuth deposition
1	2.2g	2.2 volts/0.01amps	20 hrs	1.059g
2	1.0268g	2.1 volts/0.01amps	18 hrs	0.7748g
3	1.00146g	3.3 volts/0.01amps	20 min	0.06504g
4	0.46g	2.2 volts/0.01amps	40 min	0.02815g

bismuth nitrate salt. In the Spring 2025 semester, rather than using bismuth pellets dissolved in nitric acid, 1M bismuth (III) nitrate pentahydrate was used. The rest of the chemicals remained the same. The result of five trials can be seen in Table II.

Table II. The amount of Bi, power, and current used, the time of the run, and the amount of Bi deposited successfully with each trial during spring 2025.

Trial	$Bi(NO_3)_3$ (g)	Power/Current	Time	Bismuth deposition
1	0.71865g	2.1 volts/0.01amps	19 hrs	0.03424g
2	4.81276g	2.0 volts/0.01amps	2 hrs	0.04298g
3	4.62633g	2.0 volts/0.01amps	20 hrs	0.01474g
4	4.76058g	2.0 volts/0.01amps	20 hrs	0.08927g
5	4.95162g	3.8 volts/0.70 amps	7 hrs	1.22442g

Many different methods were tried, such as only using 1M Bi(NO3)3, in trials 2 and 3 following the electroplating procedures of Ye *et al.*4 However, this resulted in a white film formation on the target, so the original method was used in the remaining trials. It was observed that after switching to the TAMU cyclotron, circular target frames had less bismuth deposited onto the frames. It was found that the current of 10mAmps was for the smaller square targets and needed to be increased for these larger targets. In trial 5, the power was doubled to 3.8 volts, and the current was held at 0.7 Amps. This resulted in 1.22g of bismuth being deposited, which is closer to the target goal. It was noticed that the bismuth piled up instead of being plated evenly across the target. This could be due to the very high current and the design of a horizontal electrolysis cell. To achieve a more optimum, even plating, Dr. Claus Müller-Gatermann of Argonne National Laboratory was reached out to for advice. Based on his suggestions, the current will be tested at no more than 100mAmps (0.1Amps). The electrolysis cell will also be changed from a horizontal cell to a vertical one that places the target on the bottom with a glass cylinder holding the solution and a platinum wire running through it as the anode. This setup will also allow for agitation of the solution with a quartz sonicator or another stirrer.

[1] The editors of Encyclopaedia Britannica. Electroplating. *Encyclopædia Britannica*; 2019.

[2] Hasan Mohammad Nazha; A. Darwich, Szávai Szabolcs, G. Bognar; Coating Materials for Artificial Knee Joint Components. Elsevier eBooks 2024, 579–591. DOI:10.1016/b978-0-323-90597-8.00031-1

[3] K.O.Hatfield, E. Dervishi, D. Johnson, C. Clark, N. Brown, G.C. Kidman, D.J. Williams, D.E. Hooks, Electrodeposition and Analysis of Thick Bismuth Films.Scientific Reports **13** (1) (2023), DOI: 10.1038/s41598-023-28042-z

[4] T. Ye, Y. Qin, W. Liu, L. Xia, J. Liao, J. Yang, T. Lan, Y. Yang, N. Liu, F.A. Li, Separation and Purification Technology **330**, 125284 (2024); DOI:10.1016/j.seppur.2023.125284