

Multi-array Electrode Module for Uranium Electrowinning Applying Automation Concept

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1. Introduction

Pyroprocessing is a dry treatment technology that recovers U and TRU from spent nuclear fuel, utilizing high-temperature molten salt at 500–650°C to recover them electrochemically. Because it is difficult to recover plutonium separately, this process offers excellent proliferation resistance, can significantly reduce the radioactivity of spent nuclear fuel, and can be utilized for fast reactor fuel recycling. Consequently, pyroprocessing is expected to make a major contribution to reducing the required footprint of high-level radioactive waste repositories [1-3].

Designing an electrode module with automation concepts is necessary to facilitate the separation/connection processes for ease of operation. The electrolytic recovery device installed in PRIDE facility contained separated electrowinning, electrowinning, and residual actinide recovery devices, and the size of the devices required for the process was very large due to the arrangement of the reactor and electrode in the circular arrangement. As a way to solve this problem, a system was manufactured that integrates the electrolytic recovery process (electrowinning, electrowinning) so that it can be carried out in one device and reduces the overall size by introducing a multi-array module type electrode. In this study, moving beyond manual operation, we propose multi-array electrolytic recovery electrode module using automation concept. It is intended to improve process integration and operational efficiency.

2. Methods and Results

2.1. Electrode Module Design and Fabrication

An electrolytic recovery electrode module using automation concepts was designed and manufactured. For the linkage between processes, the electrowinning anode and electroreduction cathode were designed with the same structure, and by designing the carbon electrode of the electrowinning and electroreduction process identically, the process device can be simplified. In order to enhance operation efficiency, the additional connection parts were installed on the top of the electrode modules so that it could be transported by the gantry automated handling device, and the upper and lower parts were designed to be separated by simplifying the bonding structure without bolts. Then the separated lower part allows the whole, including the crucible, to be loaded in the distillation process which is a subsequent process.

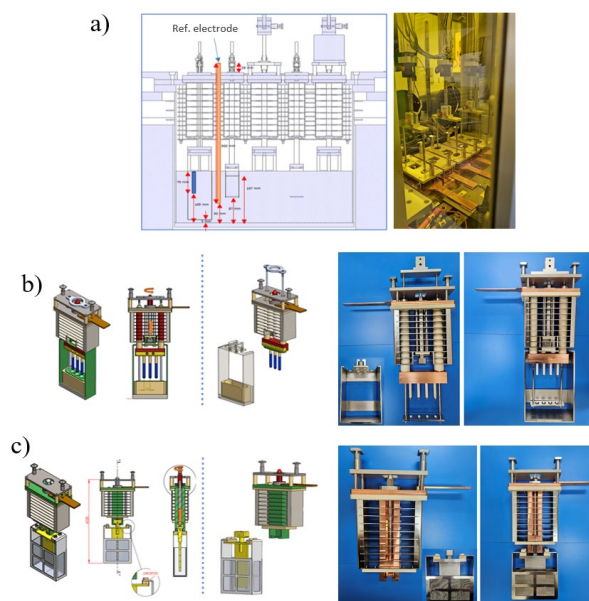


Fig. 1. a) Multi-array electrode concept, Design data and fabricated product of electrode modules (b) cathode and c) anode)

2.2. Electrode Module Performance Test

The performance testing of a multi-array electrode module for uranium recovery, incorporating automated concept was detailed. A single set (1 anode, 1 cathode) configuration was initially used to investigate the U deposition characteristics based on charge input, enabling the establishment of process parameters. The experimental results demonstrated an increasing trend in U dendrite thickness with increasing applied charge following the relationship below (Fig.2.).

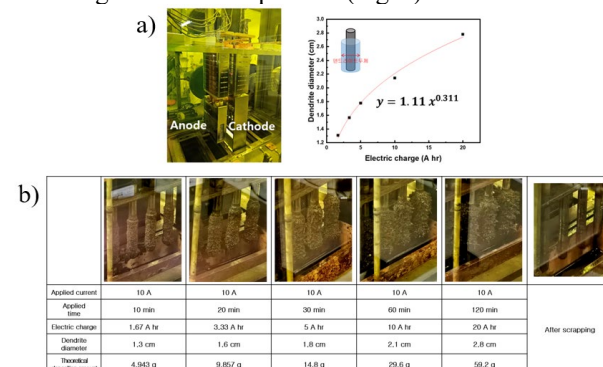


Fig. 2. a) Relationship between U dendrite thickness and charge amount of 1 set electrode module, b) U dendrite thickness according to electric charge

Then, the multi-array module type electrode (2 anodes, 3 cathodes) was implemented for comprehensive performance testing of the electrode module. The test showed a similar trend to the single set experiment. However, excessive uranium dendrite deposition was observed on the centrally located cathode compared to the other two, indicating potential challenges in process optimization. Furthermore, based on the amount of recovered uranium dendrites through electrolyte treatment, we calculated the current efficiency of the electrode module to be 89.9%, indicating satisfactory performance.

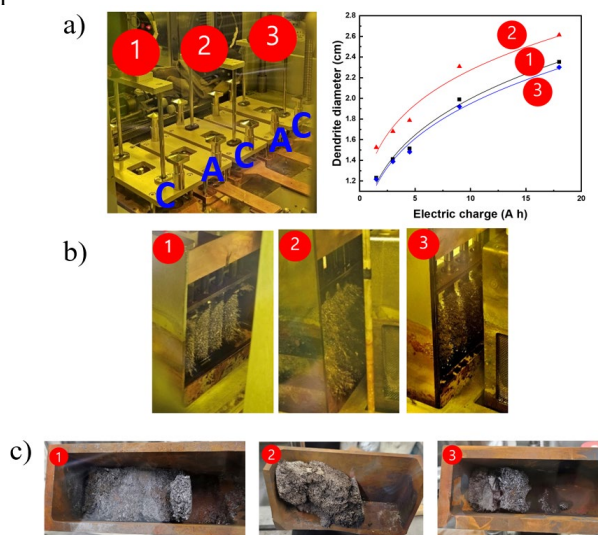


Fig. 3. a) Multi-array electrode modules and U dendrite thickness according to electric charge, b) U dendrite after applying 108 A hr, c) U dendrite after salt distillation

2.3. Areas for Improvement in the Electrode Module

During scraper performance tests, issues such as electrode bending, loose connections of electrodes, and scraper catching on the electrode were encountered. These problems were resolved by modifying the electrode structure, adjusting the connection method between the electrode and copper conductor block, and increasing the size of the scraper holes. Extensive testing confirmed that these modifications effectively addressed the scraper performance concerns.

Moreover, excessive uranium dendrite deposition was observed on the centrally located cathode compared to the other two, indicating potential challenges in process optimization. To solve this problem, it is necessary to stir the salt to enable uniform deposition of U or consider new array of anode and cathode such as C-A-C electrode configuration.

3. Conclusions

A multi-array electrolytic recovery electrode module incorporating automation concepts was designed, fabricated, and performance-tested for uranium electrorefining. The integrated device was simplified, while the bolt-free separable structure and gantry-compatible connection parts enabled automated handling and direct transfer of the lower assembly to the subsequent salt distillation process. Additionally,

configuring the modules in a multi-array arrangement offers the advantages of enhanced scalability and compact installation.

Single-set tests established the process parameters by confirming that U dendrite thickness increases with applied charge, and the multi-array configuration (2 anodes, 3 cathodes) reproduced this trend with a current efficiency of 89.9%, demonstrating satisfactory performance.

Mechanical issues identified during scraper tests, including electrode bending and loose connections, were resolved through structural modifications. However, preferential dendrite deposition on the central cathode remains to be addressed; salt stirring or an alternative electrode arrangement such as a C-A-C configuration will be considered in future work to achieve uniform deposition. These results confirm the feasibility of the automated multi-array electrode module and are expected to contribute to the process integration, footprint reduction, and operational efficiency of pyroprocessing.

REFERENCES

- [1] K. M. Goff, J. C. Wass, K.C. Mardson, *Electrochemical Processing of Used Nuclear Fuel*, Nucl. Eng. and Tech., Vol.43, pp 335-342, 2011.
- [2] M. Iizuka, Y. Sakamura, T. Inoue, *Development of Pyroprocessing and its Future Direction*, Nucl. Eng. and Tech., Vol.40, pp 183-190, 2008.
- [3] K. C. Song, H. Lee, J. M. Hur, J. G. Kim, D. H. Ahn and Y. Z. Cho, *Status of Pyroprocessing Development in Korea*, Nucl. Eng. and Tech., Vol.42, pp 131-144, 2010.