*Transactions of the Korean Nuclear Society Autumn Meeting*
*Jeju, Korea, May 18-19, 2023*

# Progress of Strategic Material Irradiation R&Ds with Domestic Facilities toward Future Fusion Neutron Sources Preparation

Dong Won LEE*, Bongki JUNG, Kihyun Lee, Sunghwan YUN, and Seunghyun LEE
*Korea Atomic Energy Research Institute*
*dwlee@kaeri.re.kr*

## 1. Introduction

Korea is developing a fusion energy roadmap to support engineering R&D, including materials, blankets, system engineering, licensing, codes and standards centred on fusion neutron source (FNS) promoting the development of fusion demonstration reactors and fusion reactors by refining the fusion energy roadmap. Various neutron sources are currently being considered, including a 40 MeV accelerator-based neutron resource, an assembly of cyclotron-based neutron resources, and a spherical tokamak-based neutron resource. However, prior research is essential for the construction and operation of such large facilities. Therefore, KAERI is reviewing various existing and proposed neutron sources and focusing on small-scale equipment that can be constructed or assembled in a short period of time: (1) Irradiation test of fusion materials using a heavy ion accelerator: (2) Neutron irradiation tests using a 30 MeV cyclotron-based neutron source: (3) Neutron irradiation tests using the research reactor HANARO under the ITER TBM programme.

## 2. Strategies and previous research

Due to their respective advantages and limitations, a strategy for advancing fusion materials irradiation research is needed that considers ways to induce synergies with ongoing projects. In particular, in the case of materials irradiation testing, the following facilities and ongoing projects should be utilised to advance DB construction and irradiation mechanism research, given the goals pursued by the fusion reactor.

(1) The project to upgrade the heavy ion accelerator facility for ion irradiation tests of fusion and fission materials was newly launched in the current fiscal year. KAHIF heavy ion irradiation tests of the fusion advance programme: Fe ion irradiation tests, high dpa tests using surface irradiation (fine specimen, high dpa effect), and irradiation mechanism studies.

(2) Developed a new cyclotron-based neutron source for neutron radiography in conjunction with the existing 30 MeV cyclotron at KEPRI, which is utilised for radioisotope production. High-energy neutrons, large volume but limited DPA to exploit high-energy neutron effects.

(3) One irradiation test under the ITER TBM programme: thermal neutron, volumetric irradiation (large specimens, substandard), and irradiation up to 3 dpa, which can be used for irradiated DBs, can build higher level irradiated DBs compared to non-irradiated DBs using ARAA of KO RAFM steel.

We are systematically conducting the preliminary research necessary for rational neutron source selection and construction planning. We are continuously introducing the status of these studies through academic conferences of the Nuclear Society, etc., and would like to introduce the progress of our research since the last conference, focusing on (1) and (2).

## 3. KAHIF operation status

KAHIF is a facility capable of accelerating stable heavy ions up to 1 MeV/nucleon through RF linear accelerators, and has successfully irradiated He+ ion beams accelerated to 0.7, 1.2, 1.9, 2.9, and 4.2 MeV in preliminary tests. Recently, through the Nuclear Fusion Leadership Project, it is being improved and operated as an ion irradiation facility for neutron irradiation of fusion materials.

In the first phase (2022-2024), the project will improve the irradiation test facility to investigate simulated fusion environments and conduct He ion beam irradiation for preliminary evaluation, and Phase 2 (2025-2026) will improve the heavy ion irradiation DPA and conduct iron ion beam irradiation experiments to evaluate fusion structural materials.

To date, the purchase and installation preparation of MIVOC for iron ion construction, and He ion tests for preliminary evaluation have been carried out as shown in the figure below; To evaluate the damage to the fusion material, He ion beam was applied to ARAA steel at various temperatures (room temperature, 300 degrees, 550 degrees) with high doses (500, 5000, 50000 appm) so that the degree of damage could be evaluated as shown in Table 1.

Table 1. Specimen distribution according to irradiation environment

| 조사량 / 온도 | 0 | 500 appm | 5,000 appm | 50,000 appm |
|---|---|---|---|---|
| 상온 | | 3-1, 3-2 | 2-1, 2-2 | 1-1, 1-2 |
| 300℃ | 10 | 6-1, 6-2 | 5-1, 5-2 | 4-1, 4-2 |
| 550℃ (400℃) | 11 | 8-1, 8-2 | 7-1, 7-2 | 9-1, 9-2 |

Optimised design of the MIVOC system equipment capable of generating ferrous ions, and purchased and delivered the equipment as shown in Fig. 1. Verified the radiation generated by heavy ion beam using MCNP and its shielding performance, and based on this, reviewed and confirmed that there is no leakage radiation when generating Fe ion beam using the existing shielding configuration, and that the ion beam irradiation is feasible under the existing regulatory license.

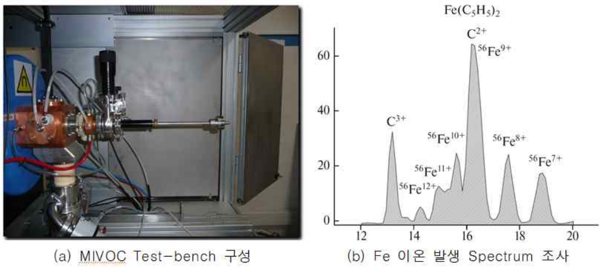


Fig. 1 KAHIF MIVOC test-bench configuration and ion generation rate

### 3. 30MeV CANS development status

The development of the 30MeV cyclotron-based neutron source is progressing as follows according to the project schedule, with full-scale neutron beam production and targeted neutron imaging technology verification scheduled for the second half of this year.

Regarding the production of TMRS, it was carried out as follows: (1) Target assembly design and fabrication for maintenance/replacement and cooling functions completed (2) Completed fabrication and installation of the target system and primary shield (TMRS inner layer) considering the proton beam path, neutron imager location, and shield room structure. (3) Completed fabrication and on-site installation of HDPE+Lead+Casemate combination shield.

Proton beam irradiation tests were conducted in conjunction with TMRS fabrication. (1) Derived proton beam stable withdrawal conditions (currently 30 MeV, 100 uA (up to 125 uA) >36 hours confirmed) (2) Completed beam optical alignment with existing Al window and confirmed >75% proton beam transmittance at the Be target location point.

Neutron productivity verification and imaging technology verification are being prepared. (1) Proton beamline alignment completed and proton beam irradiation performance verified above 90%, the survey condition prior to TMRS installation. (2) Control and signal transmission cable transporter shielding completed and task goal of $10^{12}$ n/s neutron production experiments to be performed. (3) Completed development and fabrication of scintillator-based fast neutron spectrum and yield measurement device. (4) Conduct neutron production experiments and measurement experiments with proton irradiation of aluminium dummy targets

Finally, shielding at target neutron yield conditions, obtaining radiation safety licenses in accordance with license conditions, and facility inspections are planned for the first half of the year. Predicted results of neutron production based on Be targets through MCNP computer simulation and comparison of experimental results have been obtained.

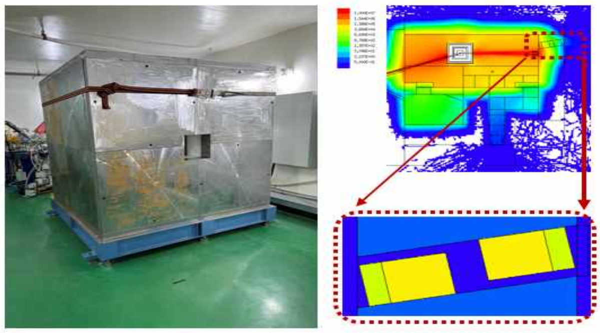

Fig. 2 Constructed TMRS and radiation assessment results

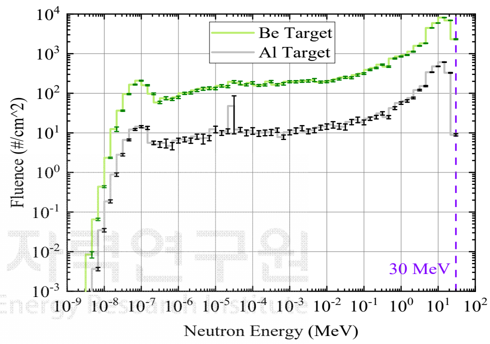


Fig. 3 Estimated neutron production from the constructed neutron source



### 4. Conclusions and Future works

For embodying the KO fusion energy roadmap to reach the DEMO, FNSs to support engineering R&D like material, blanket, system engineering, licensing, code and standard etc. should be developed but we should more focus on the existing facilities and projects for easier and faster R&D and further the FNSs preparation. (1) Linking to preceding and parallel R&Ds for fusion material irradiation tests; DB, mechanism study, experience, expert training etc. (2) R&Ds for preparing (NOT developing) a new CANS type FNSs and basic & long-term R&D for FNS/DEMO/FR. Continuous improvement and utilisation of the facility will support research to achieve the above objectives.

### ACKNOWLEDGMENTS

This work was supported by the KAERI Institutional Program (Project No. 524410-23) and by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (RS-2022-00156272 and RS-2022-00155980).