Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 6-8, 2026

Recent Irradiation Trends of Materials R&D (2020~2025)

Kee-Nam Choo*, Seng-Jae Park, Sung-Woo Yang
Korea Atomic Energy Research Institute 111 Daedeok-daero, 989beon-gil, Yuseong-gu, Daejeon 34057, Korea
**Corresponding author: knchoo@kaeri.re.kr*

1. Introduction

Research reactors (RRs) are fundamental to the progress of both nuclear research and nuclear technology. Especially, RRs have been used effectively for the monitoring of irradiation embrittlement of Nuclear Power Plant (NPP) structural materials. RRs are able to simulate the operational conditions for the testing of new materials for new generation reactors. RRs have played a dominant role in the development, testing and optimization of properties for such new materials.

As the RR testing remains the critical tool for the development, testing and licensing of new nuclear fuel and materials, each country has its own RRs and initiative R&D programs.

Unfortunately, several of the old facilities used by the material R&D programs have been shut down (OSIRIS, JMTR, NRU, HBWR). And new facility programs to cover these closed research reactors have been delayed (ITER, JHR, NRR). Therefore, effective utilization of the existing RRs becomes more important at these days.

HANARO has been actively used for fuel and material irradiation testing to support national R&D projects relevant to nuclear systems [1, 2].

A new research reactor in Gijang is under construction, and is due to start up in 2027. The new research reactor will become the most up-to-date research reactor available in the world and will specialize in radioisotope and NTD production and demonstrations of reactor designs. Therefore, HANARO will specialize more on irradiation research of nuclear fuels and materials. Recent irradiation trends of material R&D at the worldwide RRs will be valuable to the future planning of HANARO.

2. Recent Irradiation Trends of Material R&D (2020～2025)

Figure 1 shows the major worldwide RRs serviced for the material irradiation testing. Among them, OSIRIS, JMTR, NRU and HBWR shut down in 2015, 2016, 2018, and 2018, respectively.

Figure 2 shows the portion of countries published papers concerning on neutron irradiation during recent period (2020~2025).

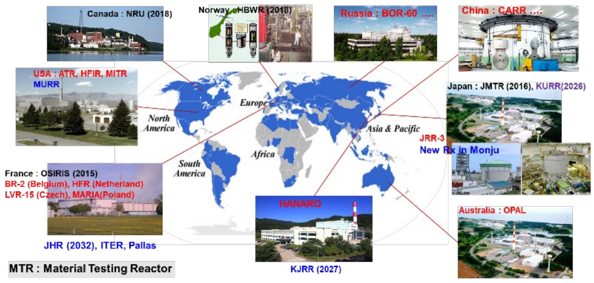

Fig. 1. Worldwide research reactors.

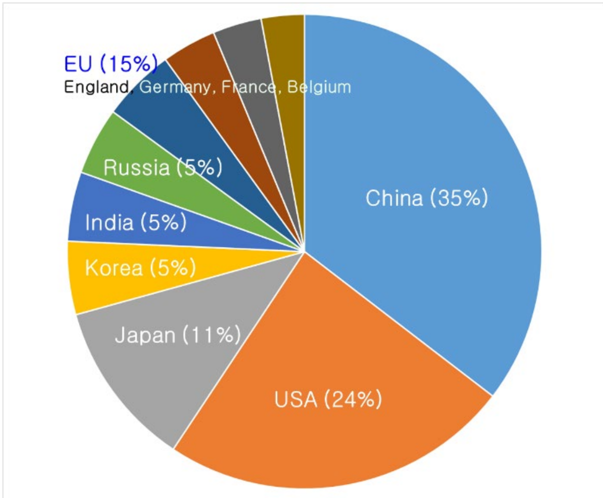

Fig. 2. Published papers on irradiation research.

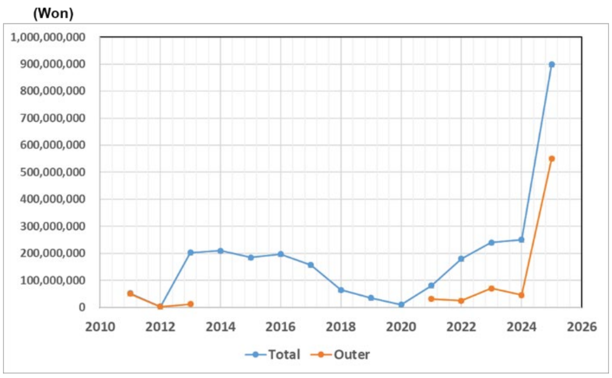

Fig. 3. Trend of HANARO annual irradiation budget by users.

3. Matrial Irradiation in HANARO

HANARO has been actively utilized for the various material irradiation tests requested by numerous users. The user request increased sharply in 2025, as shown in Fig. 3 due to the shut-down of the old research reactors, recent global crisis, and active response to the user requirements.

Table 1. Irradiation research topics of major nuclear countries

Nation	Facility	Research Topics
China	Computer Simulation	- He/neutron damage
		- High entropy alloy (HEA), GaN, SiO2/4H-SiC swelling with MD
		- W defects with MC method
		- Dislocation dynamics (DD)
		- Zr-Nb, SS, SiO2, TCAD simulation
	CSNS	- Single event burnout (SEB) in SiC power MOSFETs
		- S/Dram, High-voltage semiconductor devices (thyristors)
		- Neutron-sensitive microchannel plate (nMCP) for neutron imaging
		- InGaAs p-i-n photodetectors
		- Charge coupled detectors (CCDs)
	CARR	- Irradiation test of fuels and materials, NTD
		- Tritium breeder for ITER & nuclear detectors
	Others	- Be/W/high-entropy alloy/ceramic(HEA/HEC)/ODS for Fusion, MSR
		- Fe/RPV/SS/W/Zr-Nb/Ti/G, SiC/AlN, SiC/C fiber for Nuclear App.
		- PIN diode, 4H-SiC junction barrier Schottky (JBS) diodes in CFBR-II
		- Si/SiC heterojunction detector for Space, RTG, Spintronics
		- 3C/6H-SiC, GaN, BN, ZnO, YBCO conductor, Graphene, Solar cells
		- Diamond/SiPMs/CZT/CMOS Detectors, SPND, Magnet
		- Mo-S-Pb-Ti amorphous films: lubricating materials, Resin/BN
		- $Ge_2Sb_2Te_5$ (GST) memory and data storage technologies
		- Piezoelectric surface acoustic wave (SAW) extreme sensor
		- Alumina/TiAlN Coating, Annealing, Welding, Defect Eng.
		- Al, T extraction in CMRR
		- Plasma-facing material (PFM) in IFMIF
USA	Computer Simulation	- RPV for Life extension, GB segregation
		- Fe/WB/Be by DFT/MD calculations for Fusion
		- Ni-Inconel/Incoloy Heterostructures by MD
	ATR	- Alloy625/690, FeCrAl/ODS ATF cladding, SS316, T91, Zircaloy-2
		- ZrB2 ultra-high temperature ceramic(UHTC), WB for Fusion
		- Graphite for HTR/Annealing, PM-HIP alloys
		- U-Mo/U-Zr/TRISO fuel
	HFIR	- Inconel718/FeCr(Al)/SS304/Ti-MAX, Annealing, Welding Repair
		- SiC ATF cladding, Al-6061, Duplex SS
		- W/Eurofer for Fusion, G/Ta/UPS for advanced NRs
		- Al_2O_3 extreme sensor, silica optical fibers
	MITR	- ZrH_2 Metal hydrides for SMRs
		- T behavior in Fluoride molten salt
		- Corrosion of SiC
	Others	- RPV, HEA, Zry-4 in WSUR, I718, SS 347/304, T91/HT9 in BOR-60
		- Fe-Cr, FeCrAl ATF cladding, Zr-Nb, HEC, U-Si/MOX fuel
		- W/Lithium silicates, T/Li transport for Fusion
		- ABN(Lightweight mat.) for Space, Local chemical ordering (LCO)
		- Dosimeter, SPND, scintillator, Semiconductor Detectors
		- Laser-based inertial fusion energy (IFE) reactor
		- GaN, GaAs, SiC, graphene, AlN, NAND flash in MURR
		- Silica and Sapphire fibers
		- Molten chloride salt in Ohio State University RR (OSURR)

Table 1. Continued

Nation	Facility	Research Topics
EU	JHR (France)	- **ITER** : **Under Construction by 2034**
		- **JHR** : **Under Construction by 2032**
	BR2 (Belgium)	- **RPV, VVER RPV**
		- **Development** of Advanced Technology **Fuel claddings**
		- **Materials for Fusion, SMRs, GEN 3+ and GEN 4**
		- **W, RAFM steel, CuCrZr** for **Fusion**
	HFR (Netherlands)	- **HTR fuel, AGR C creep**
		- **Molten fluoride salt for MSR**
		- **W, Be/TiBe** for **Fusion**
	LVR-2 (Czech)	- **Concrete, SS, F/M(RAFM) steel**
		- **Pb-Li, Be** fatigue for **Fusion**
		- **U Oxide/U-Si fuel**
		- **YBCO and GdBCO/Ag superconductors**
	MARIA (Poland)	- **Graphene** on 4H-SiC **Detector**
		- **Poly-ethylene** gasket for **space**
Japan	JRR-3	- **Fuel/materials of light water/fast breeder/Fusion reactors**
		- **RPV** steel for **APWR**
	KUR	- **Tritium release** behavior of Li_2TiO_3/Li_4SiO_4 for **Fusion**
		- **FLiNaBe blanket material for Fusion**
		- **Optical lenses of ZnSe and ZnS** for **Fusion**
		- **Fe-Cu in RPV**
	Others	- **FeCrAl ODS steel/W** for **future fission/Fusion reactors (in JOYO)**
		- **Be/V/W/F82H steel, Cu oxide/Nb3Sn superconductors for Fusion**
		- **Fluoride molten salts such as FLiBe and FLiNaBe for Fusion**
		- **HEA, SiC, Oxies for APWR/Fusion**
		- **RPV/Recovery, 316SS, Concrete, Zr-Nb, Ti-6Al-4V** alloy in **MARIA**
		- **Zr-based/SiC cladding in HRP**
		- **TRISO fuel/ZrC coating for HTGR in WWR-K reactor**
		- **BGaN, AlN, Si-IGBT, InGaP** solar cell for Detector
		- **Thermoluminescence (TL) materials in KINKI reactor**
		- **Ti-** $LiGaO_2$ **/Eu-doped LiBr scintillator**
		- **Photoluminescence** Er_2O_3**, Diamond sensor**
		- **Graphite for HPHT Condition**

4. Summary

Based on the survey on recent irradiation trends of worldwide materials R&D, we can conclude as follows:
1. Considering the several construction delays of large-scale test facilities such as ITER and JHR, in addition to the new constructions of multi-purpose reactor (MPR) in China, Japan, and Korea, MPR seems to be a major research reactor model. HANARO is the best example of the MPR. The utilization of HANARO is increasing sharply due to worldwide shut-down of old research reactors, global crisis, and active response to the user requirements.
2. HANARO seems to have about 7 years before the start-up of the new large-scale test facilities. During that times it should secure its original utilization plan including a role relocation due to the start-up of new Gijang research reactor.
3. HANARO is recommended to extend its limited utilization (concentrated to fission reactor researches) up to the future reactors including fusion reactor and non-nuclear advanced materials. And it seems to be necessary to cooperate with foreign users, especially with Japanese users using other foreign reactors.

Acknowledgement

This work was supported by the Korea government (MSIT) (1711173832).

References

[1] K. N. Choo et al., Contribution of HANARO Irradiation Technologies to National Nuclear R&D, Nucl. Eng. Technol. 46 (2014) 501-512.
[2] K. N. Choo et al., Development of a High dpa Irradiation Capsule at HANARO up to 10 dpa, Nucl. Eng. Technol. 53 (2021) 344-350.