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Development of Irradiation Techniques for Material Study in JMTR*

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Synopsis

The Oarai Branch has been carrying out the irradiation of materials using the JMTR, for these twenty years. We have made efforts to improve the irradiation conditions and to satisfy the various demands evoked by our users. Here, we describe our efforts to improve the irradiation rigs and the irradiation techniques.

I. Introduction

Since the beginning of the Oarai Branch, Institute for Materials Research, we have been carrying out the irradiation of materials in the JMTR, the JAERI Materials Test Reactor in Oarai Research Establishment of Japan Atomic Energy Research Institute, JAERI. In the initial stage, the purposes of irradiation scattered in wide fields of researches. To satisfy a variety of demands from wide research fields, we developed the irradiation rig which could accommodate a variety of specimens which have much variation in their chemical compositions, configurations and sizes. At that time, the major concern was the total neutron fluences. The control of irradiation temperatures, neutron spectra, etc. was not so seriously demanded.

As time went by, the interests and efforts to the JMTR irradiation have been concentrated mainly on the irradiation effects of nuclear materials. The fundamental study of the irradiation effects as well as the reliable materials irradiation-test has raised their demands to carry out the irradiations under well defined conditions. Also, we still have to accommodate a variety of specimens.

To satisfy the demands mentioned above, we have developed the tailor-made instrumented irradiation rig. Also, we developed some techniques for the in-situ measurements modifying the developed instrumented irradiation rig. Now, we have plans to improve our irradia

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tion conditions. The final goal at present will be the development of a loop-type irradiation facility in the JMTR. The present paper describes the details of the developed irradiation techniques and the present efforts to improve the irradiation conditions.

II. Development of Irradiation Rig

Fig. 1 shows the irradiation rig developed in the initial stage of our irradiation study. The rig was specially designed to accommodate a variety of specimens from university researchers in a variety of research fields. The variation of specimens arises from their chemical compositions, configurations, sizes, etc.. The aluminium-made spacers having a variety of configurations were developed to accommodate such a variety of specimens.

The rig was instrumented only by thermocouples and passive monitors for neutron flux, spectrum, and fluence. No active temperature control was executed. The change of gaps between the spacers and outer wall of the rig and between the spacers and specimens was the only way to change the irradiation temperature. The typical temperature history during the irradiation was depicted in Fig. 2.

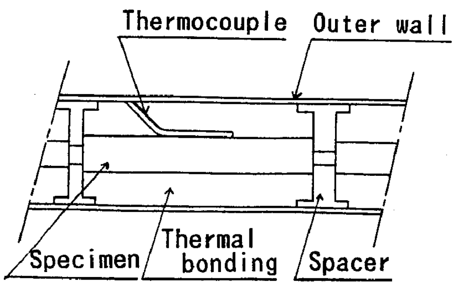


Fig.1 Schema of irradiation rig developed in the initial stage

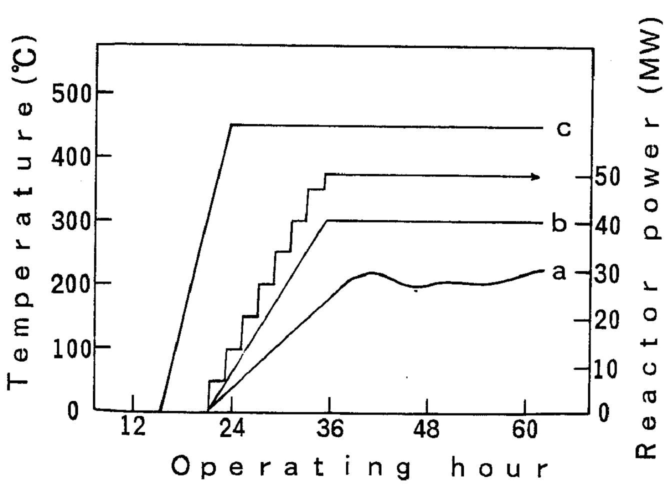


Fig.2 Typical temperature histories
(a) not-instrumented (b) instrumented
(c) instrumented/improved

To respond to the increase of demand for the irradiation temperature control, we developed the instrumented irradiation rig shown in Fig. 3. The temperature can be controlled by changing the gas pressure between the inner and outer walls of the rig and by the electric heater as shown in Fig. 3. By this irradiation rig, we can control the irradiation temperature in the range of 300-800°C.

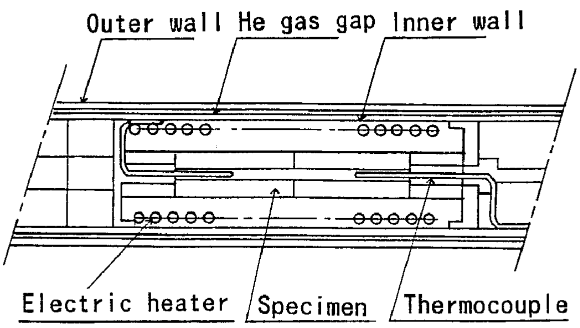


Fig.3 Instrumented irradiation rig

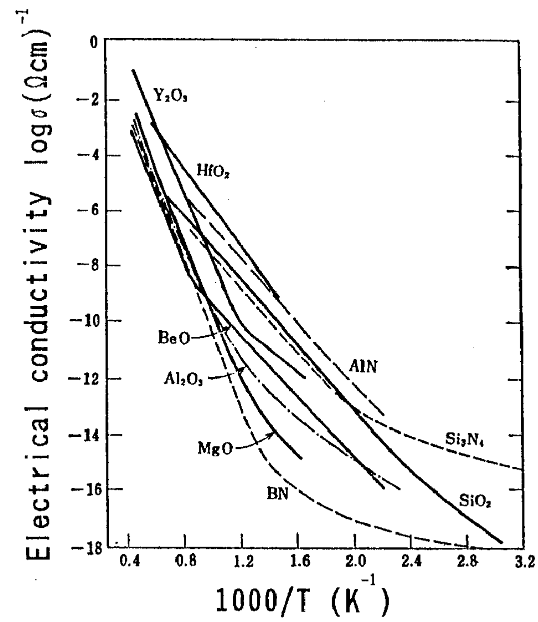


Fig.4 Electrical conductivity of typical ceramic insulators[3)]

The recent experimental results emphasize the importance of the temperature history during irradiation strongly.[1)] By using the irradiation rig mentioned above, we could control the irradiation temperature at our options, in the temperature range of 300-500°C. One example of such temperature control was depicted in Fig. 2 with the conventional temperature control. Also, we schedule to carry out the irradiation with changing the temperatures intentionally and in an as-planned way during the irradiation, by using this irradiation rig.

Here it should be stressed that the realization of the temperature control depicted in Fig. 2 depends strongly on the characteristic of the JMTR and on the capability of the present rig. The specimens should be heated up to the irradiation temperature before the reactor starts to operate. This means that we can not depend on the γ-heating at this stage. We should raise the temperature only by the electric heater and the thermal insulation between the inner and the outer walls of the rig, with the result that we need to install a high-power electric heater. In the case of the liquid metal cooled reactor, the use of electric heater is quite limited due to the difficulty of electrical insulation with a high voltage and a high current.

Also, it is inevitable that the electrical insulation is deteriorated by the irradiation especially at elevated temperature. Also, it will take a longer duration to start up and shut down the reactor in the case of the liquid metal cooled reactor and the power generating reactor due to their safety problems. Here, the JMTR has its advantages. The duration for its start-up is around 12-20hrs and it takes only 0.4-1hr to shut down the JMTR.[2)]

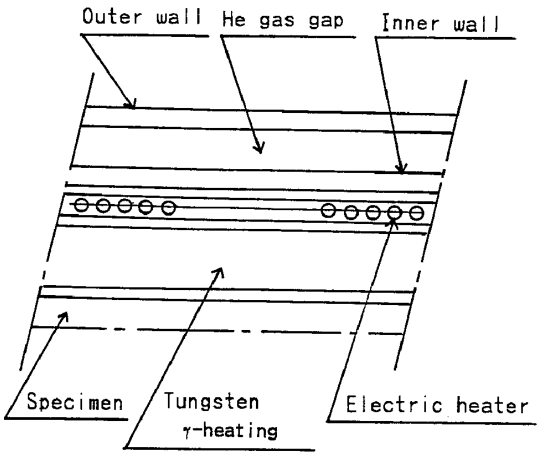


Fig.5 Schema of high temperature irradiation rig

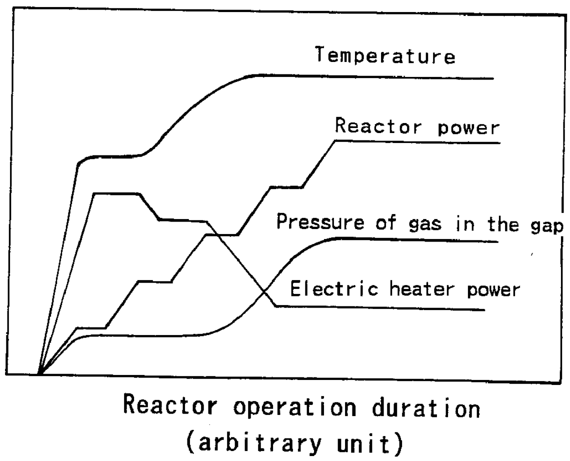


Fig.6 Schema of operation mode and expected temperature history

The recent advance of the study of ceramics and refractory metals renewed the interest in controlled high-temperature irradiation. One of the most serious difficulties to be resolved are the development of a sheathed heater which can be used at high temperatures for an appropriate period in the reactor. It is well known that the ceramic insulators increase their electrical conductivity with temperature as shown in Fig 4.[3)] Above 500°C, the alumina, the most popular insulator, decreases its electrical resistivity smaller than $10^{12}\,\Omega\cdot$cm. Also, the phenomenon of so-called radiation induced conductivity decreases the electrical resistivity of ceramic insulators substantially in the reactor. The JMTR internal regulation demands that the sheathed heater should have the resistivity larger than $10^{8}\,\Omega$ to the earth. At present, the available heater can be used only below 500°C.

The effective use of the γ-heating and the tricky control of the thermal insulation between the inner and the outer walls of the rig shown in Fig. 3 are needed to compensate the insufficient heater power. The planned irradiation rig is schematically depicted in Fig. 5. The tricky control of the gas pressure in the gap between the inner and outer walls of the rig are shown in Fig. 6 with the expected temperature history at the reactor start-up.

The low temperature irradiation in the temperature range of 50-250°C is attracting the strong attention, in concerned with the safety issue of the water cooled reactor as well as with the fusion reactor development. The JMTR has a large possibility to realize the controlled low-temperature irradiation, because its coolant temperature is low, namely, about 50-70°C. Now, the JMTR offers us the so-called "leaky-type" uninstrumented capsule for the low temperature irradiation. We plan to develop the new instrumented "leaky-type" rig for the low temperature irradiation in corporation with the Oarai Research Establishment of the JAERI. The point is how to control the temperature as precisely as the concerned researches demand. The electrical heater, the so-called saturated-vapor-pressure technique, and the heat pipe technique are the candidate techniques now surveyed.[4)]

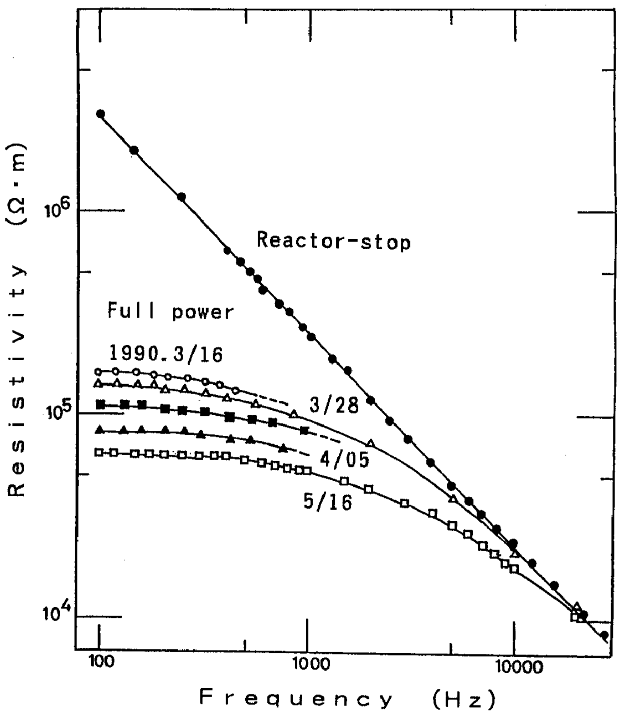
As described above, we have tried and are trying to improve our irradiation techniques to satisfy the demands of researchers. Now, we have a middle-term target for the further improvement of our irradiation conditions. We have just begun to survey the possibility of constructing the loop-type irradiation facility in the JMTR. In the loop, we can control our irradiation conditions independently of the reactor operation modes and of the reactor safety problems. As the first step to realize this middle-term target, we plan to improve the present irradiation rig further.

III. In-situ Measurements

Since the beginning of the irradiation study, it has been pointed out that some phenomena were very important to be observed under the irradiation. The development of nuclear fusion reactor and the advancement of the fundamental study on irradiation effects highlight the importance of in-situ observation of irradiation effects again.

Now, we plan to develop the in-situ measurement techniques. As the first step, we plan to carry out the tests of sensors, such as a optical fiber, piezoelectric sensor, and thermocouples. Also, we have just demonstrated the possibility of execution of the in-situ measurement in the JMTR. Fig. 7 shows the measured AC(alternating current) resistivity of alumina in the reactor.[5)] The resistivity decreases substantially at low frequencies when measured while the reactor is under the operation. Fig. 8 shows the capsule recently developed by improving the previous one, which will be used for the in-situ measurements of electrical properties of irradiated materials in the reactor.

Fig. 7 Resistivity of alumina as a function of AC frequency



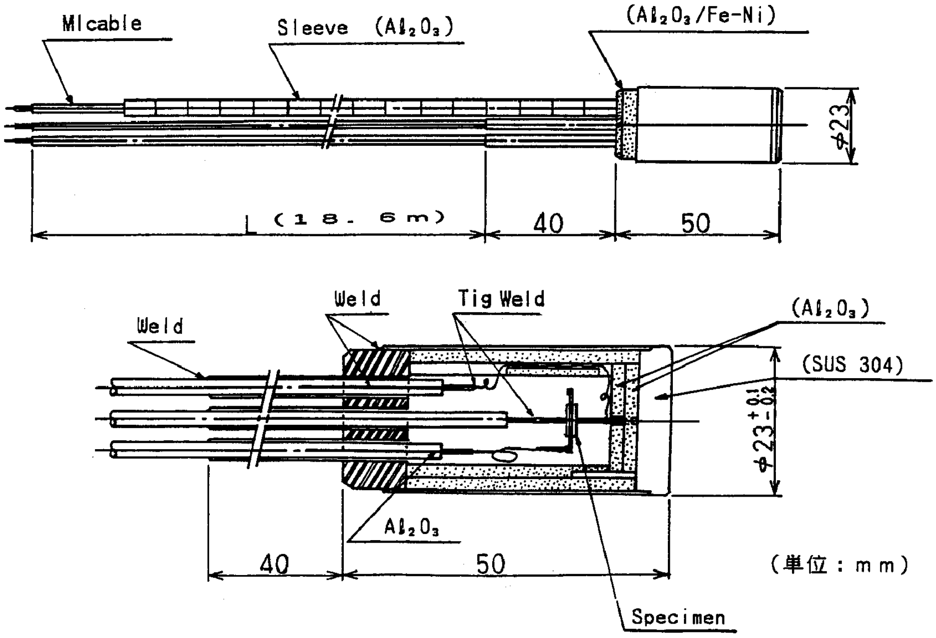


Fig.8 Developed capsule for in-situ measurement of electrical properties

IV. Conclusion

To carry out the well-defined irradiation and to satisfy the variety of demands evoked by researcher in the variety of research fields, we have improved our irradiation techniques mainly by developing the tailored irradiation rigs. Now, we have a middle-term target, the development of the loop-type irradiation facility in the JMTR, to accommodate the continuously changing demands of researchers and the demands of advanced irradiation conditions. The development of the in-situ measurement techniques is one of the recent efforts to extend our capability for the advanced irradiation study.

Acknowledgement

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