Role of the Oarai Branch as a Facility open for University Researchers in Utilization of Research Reactors

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ABSTRACT

The Oarai Branch of Institute for Materials Research in Tohoku University has been acting as a coordinator for university researchers' utilizing fission reactors for their fundamental studies, under the close collaboration and cooperation with Japan Atomic Energy Agency (JAEA). Related research fields extend into a variety of topics. The paper will report present status of university related research activities utilizing fission reactors, Japan Materials Testing Reactors (JMTR), a sodium-cooled high flux fast reactor of JOYO, Helium cooled High Temperature Engineering Test Reactor (HTTR), and Japan Research Reactor 3 (JRR-3). Along with these domestic research reactors, the Oarai Branch is acting as an important interface to utilize reactors overseas through international collaborations. The High Flux Isotope Reactor (HFIR) in Oak Ridge National Laboratory in the USA and the Belgium Reactor 2 (BR-2) of SCK/CEN in Belgium are the most important research reactors overseas. For utilization of research reactors for fundamental studies, some irradiation technologies and intimate linkage between reactors and post irradiation facilities(PIFs) are needed to develop. Typical Examples are prompt transportation of irradiated specimens to PIFs, development advanced analyzing instruments with an ability of handling radioactive materials, such as a highly sensitive gamma ray spectrometer and nano-structural analyzing systems. Also, it is essential to control irradiation conditions such as a temperature, independently from a reactor operational mode and to monitor irradiation conditions and some property changes of materials under irradiation in-situ. The paper will report scheme of controlling irradiation conditions of JMTR and show some examples of in-situ measurements of property changes of materials under irradiation.

I. Introduction

Research reactors incarnate invaluable a theater for materials irradiation, from fundamental points of views, namely, its relatively homogeneous flux distributions, long and stable operations, controllability of irradiation atmospheres, and an electronic-excitation-and-nuclear-displacement ratio relevant to actual application conditions. In the meantime, researches utilizing fission reactors are expensive and time&manpower consuming, which could be affordable only for a long-term and large scale project. The Oarai Branch of Institute for Materials Research in Tohoku University (Hereafter denoted as the Oarai Branch) has been acting as a coordinator for university researchers' utilizing fission reactors for their fundamental studies, under the close collaboration with Japan Atomic Energy Institute(JAEA) (coalition of former Japan Atomic Energy Research Institute(JAERI) and Japan Power Reactor and Nuclear Fuel Cycle Development Corporation (PNC)). Related research fields extend into a variety of topics such as a cosmological and geological age estimation, detection of a trace amount of actinide elements in highly pure semi-conductors, medical application of radioisotopes, and developments of materials for advanced reactors including a next generation fission reactors and nuclear fusion reactors. The paper will report present status of university-related research activities utilizing reactors.

II. Roles of the Oarai Branch of IMR in utilizing research reactors

A variety of researchers in universities have a variety of interests in utilizing research reactors. University researchers of about 2000-3000 man days are visiting the Oarai Branch to carry out their own research projects. A general scheme of relationship among visiting researchers, the Oarai Branch and the reactor related organizations (mainly JAEA) is shown in Fig. 1. Reactors which the Oarai Branch is coordinating on are Japan Materials Testing Reactors (JMTR), a fast reactor JOYO, helium-gas cooled High Temperature Engineering Test Reactor (HTTR), and Japan Research Reactor 3 (JRR-3), whose neutron fluxes are shown in Fig. 2 in relation with other research reactors in the world. Among them, three major reactors, JMTR, JOYO and HTTR are located in the JAEA-Oarai and interactive utilization of these three reactors are enjoyable.

JMTR is the light water cooled tank-type reactor of 50MW power, whose maximum fast neutron flux is about $1x10^{18}n/m^2s$. It runs 5-6 cycles of 30 days operation in a year. JMTR has just shut down on the 1st, August, 2006 due for refurbishment, and it is planned to restart its operation in another 4 years. JOYO is a sodium cooled fast reactor of 140MW, whose maximum fast neutron flux is about $4x10^{19}n/m^2s$ and maximum operation period is about 200 days in a year. HTTR is a high temperature helium gas cooled graphite reactor whose fast neutron flux is about $1x10^{16}n/m^2s$.

In a framework of international collaborations, the Oarai Branch is playing a role in utilizing foreign reactors, namely, High Flux Isotope Reactor (HFIR) of Oak Ridge National Laboratory in the USA and Belgium Reactor 2 (BR-2) in SCK/CEN in Belgium. These two reactors are complementary to the domestic reactors, namely, that HFIR has a very high thermal flux and that BR-2 has its unique water-cooled irradiation loops of MISTRAL and CALLISTO.

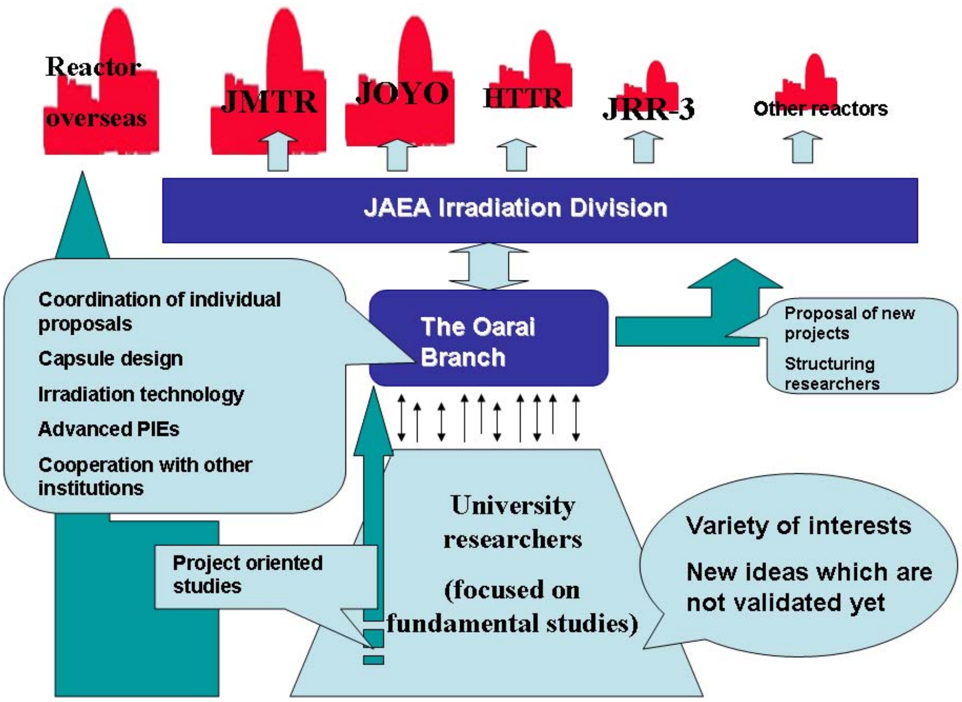

Figure 1 Relationship among the Oarai Branch, university researchers and research reactors mainly operated by the JAEA

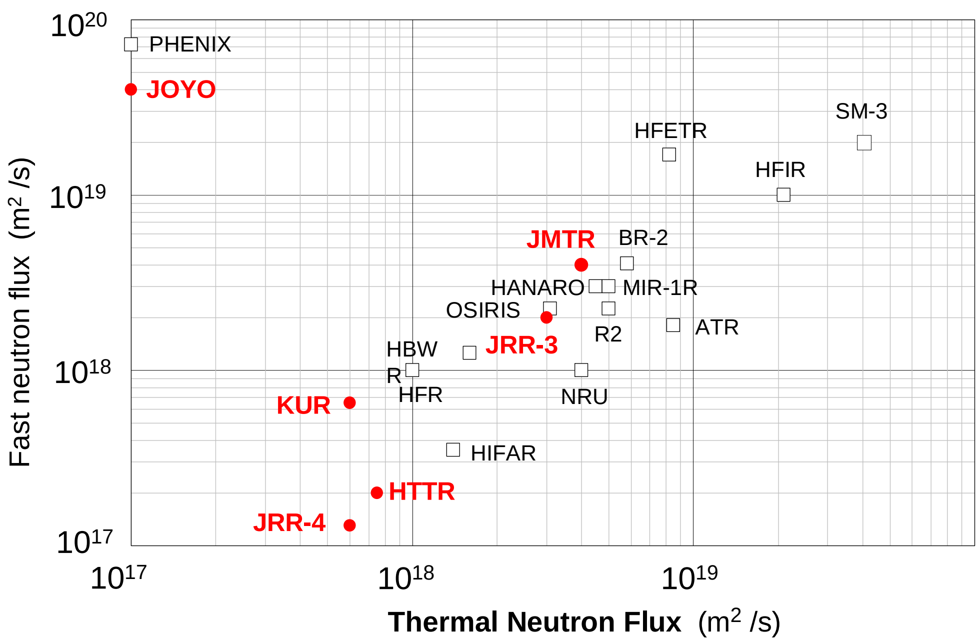

Figure 2 Research reactors utilized by the Oarai Branch along with other research reactors in the world. (red is reactors in Japan)

III. Irradiation studies in the Oarai Branch

For utilization of research reactors for fundamental studies, some irradiation techniques and intimate linkages between reactors and post irradiation facilities(PIFs) are needed to develop. The JAEA is planning to establish a comprehensive framework for advanced reactor-irradiation-studies in the Oarai area, as tentatively shown in Fig. 3. In this framework, the Oarai Branch is planning to play an unique role not only for convenience of university researchers but also for some large-scale national projects which will be managed mainly by the JAEA. Typical Examples are prompt transportation of irradiated specimens to PIFs, and prompt implementation of post irradiation examinations (PIEs). Shortening of an iteration period from specimen preparation to implementation of PIEs is essential for the university researchers, where education of post-graduate students in a defined period is one among major targets. To realize this, legitimate and prompt transfer of irradiated specimens from the JAEA to the Oarai Branch is established with needed software and hardware. Examples will be a development of shuttle irradiation rig for the JOYO irradiation.

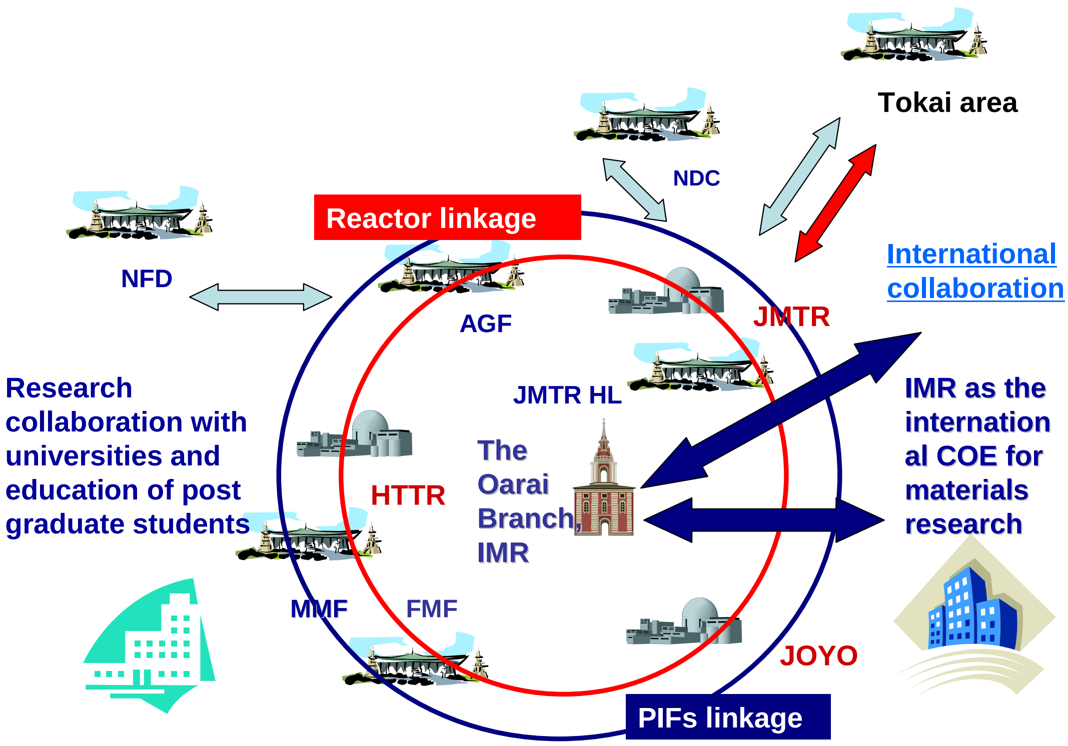

Figure 3 Oarai area as the center of excellence for reactor irradiation studies.

Other roles which the Oarai Branch tries to take an initiative are development advanced analyzing instruments for studies of nano-scale evolution of radiation induced microstructural changes and development of advanced irradiation techniques. Figure 4 depicts PIE activities for nano-structural analysis of irradiated materials in the Oarai Branch. Advanced positron annihilation systems and a three dimensional atom probe system are major players there.

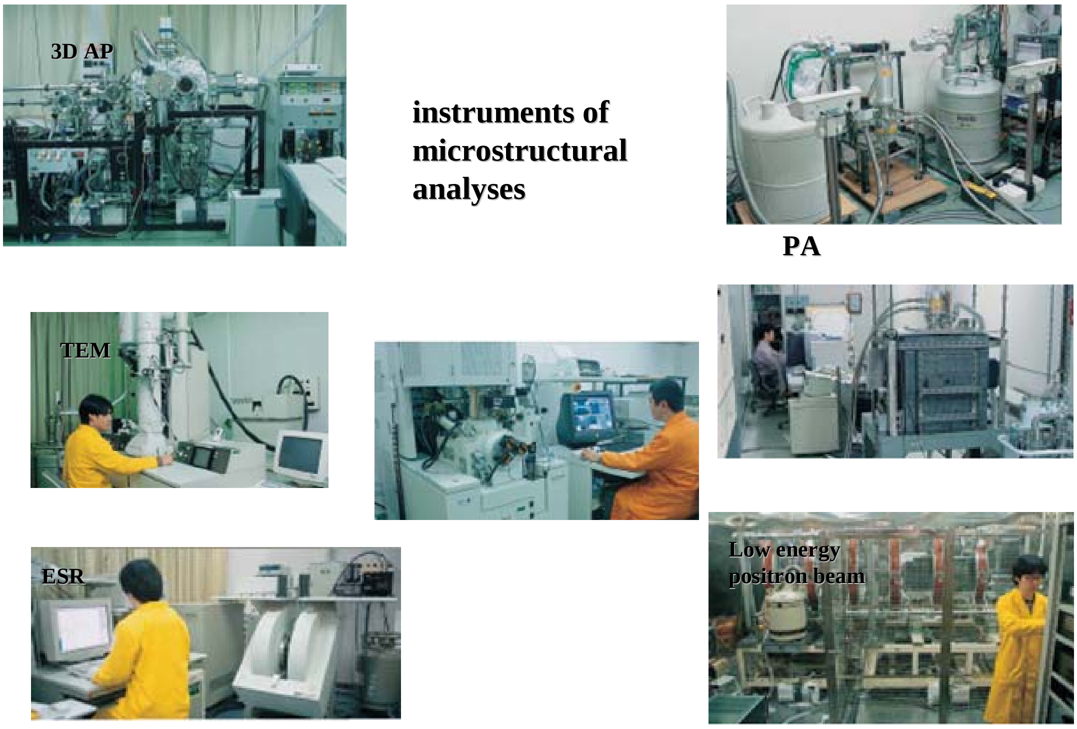

Figure 4 Nano structural analyses instruments for PIEs in the Oarai Branch

Finally, it is essential for fundamental studies of university researchers to control irradiation conditions such as a temperature and an atmosphere, independently of a reactor operating mode and to monitor irradiation conditions and some property changes of materials under irradiation in-situ. Figure 5 shows a history of irradiation rigs for JMTR. By 1980s, no-instrumented rigs were dominant for simple irradiation of materials with possible neutron fluences. In late 1980s, it was seriously recognized through accumulated studies that well controlled reactor irradiation is inevitable to make reactor irradiation compatible with advanced material science. Since then, specially designed irradiation rigs were developed as shown in Fig. 5.

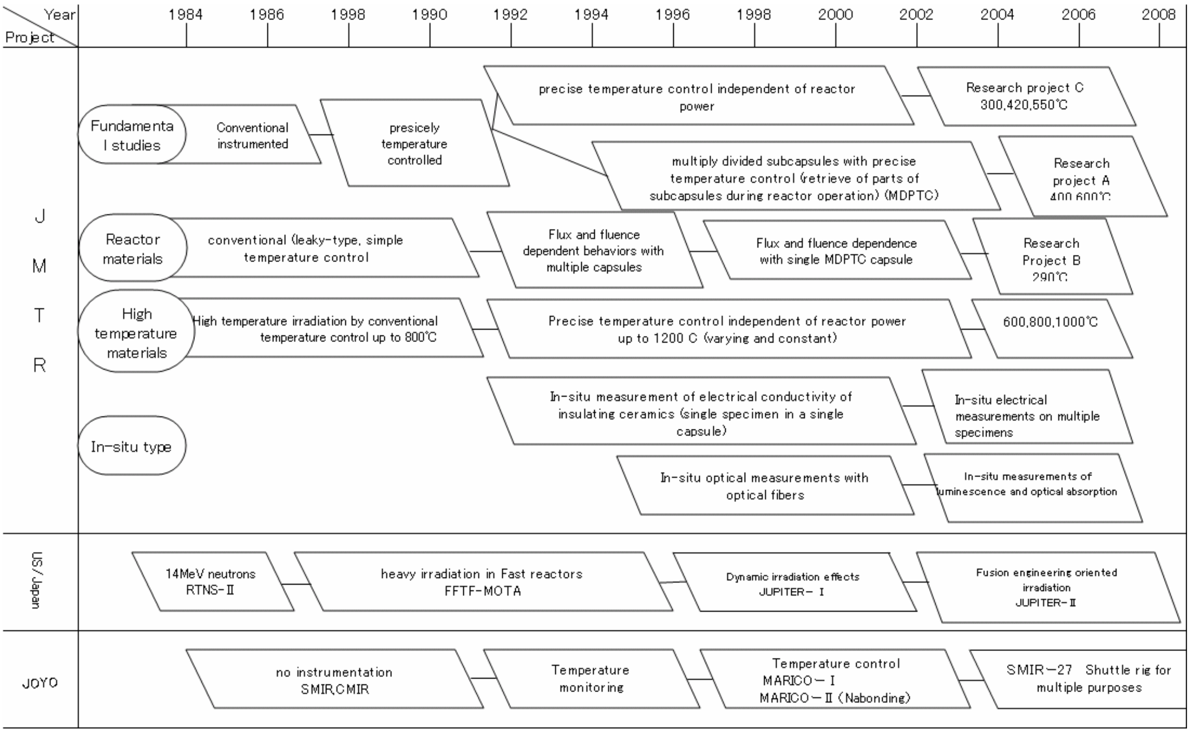

Figure 5 History of development of irradiation rigs

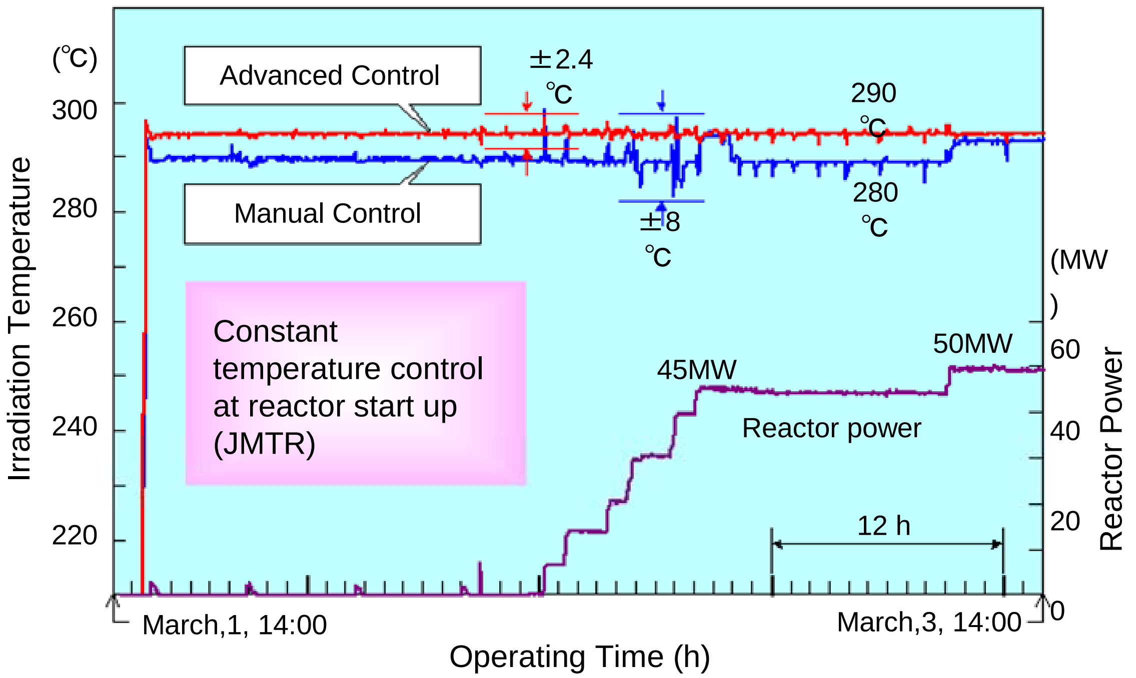

Figure 6 Temperature control being independent of reactor operation mode in JMTR

One among most important topics is a temperature control being independent of a reactor operation mode. Usually, temperatures of irradiated specimens were determined by a nuclear heating (a gamma-ray dose rate), which is dependent of a reactor power. So, an irradiation temperature will vary when a reactor power vary, especially at transient periods of reactor operations such as a startup and a shutdown. It was clearly revealed that the variation of irradiation temperature will result in very complicated evolution of radiation induced microstructures, which could not be rationally understood from fundamental points of views. Figure 6 shows one example of temperature control realized in JMTR at a reactor startup. A similar temperature control rig was developed also for the high flux fast reactor JOYO.

Other irradiation parameters to be controlled will be a neutron flux and a fluence. To do so, usually multiple irradiation rigs in multiple irradiation positions are needed, which are very expensive and time consuming. Figure 7 shows multiply-divided multiple temperatures rig for JMTR irradiation. Some divided subcapsules were drawn out of the reactor core regions during JMTR operation and each subcapsules were independently temperature controlled by independent electric heaters.

In-situ measurements of some properties of irradiated materials under reactor irradiation will be another topic. Electrical and optical measurements were realized in JMTR as shown in Fig. 8&9, where radiation induced electrical conductivity of ceramic insulators were systematically measured and radiation induced luminescence from ceramics was measured through radiation resistant optical fibers during JMTR irradiation.

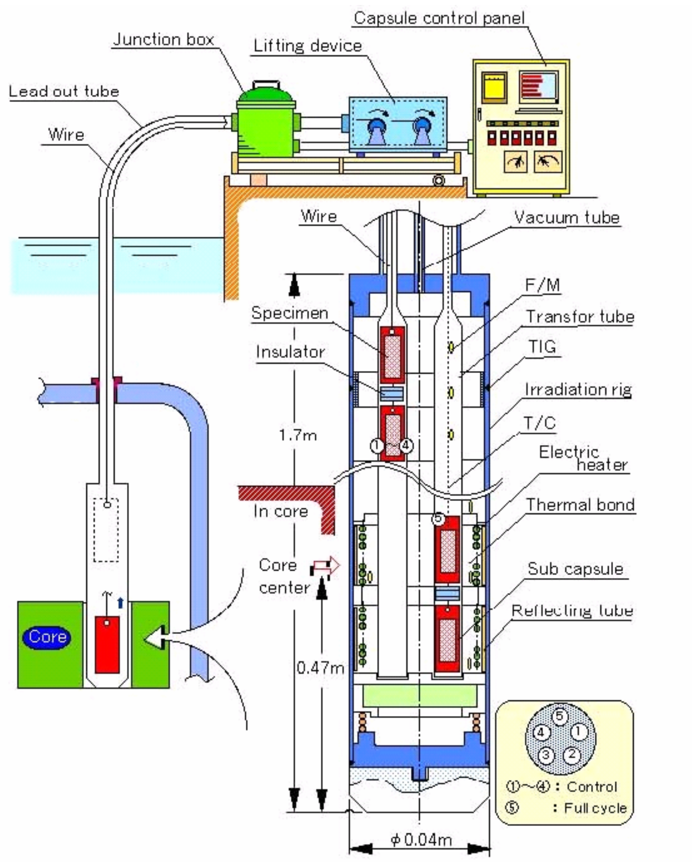

Figure 7 Schematic structure of mutiple divided multiple temperature control rig for JMTR

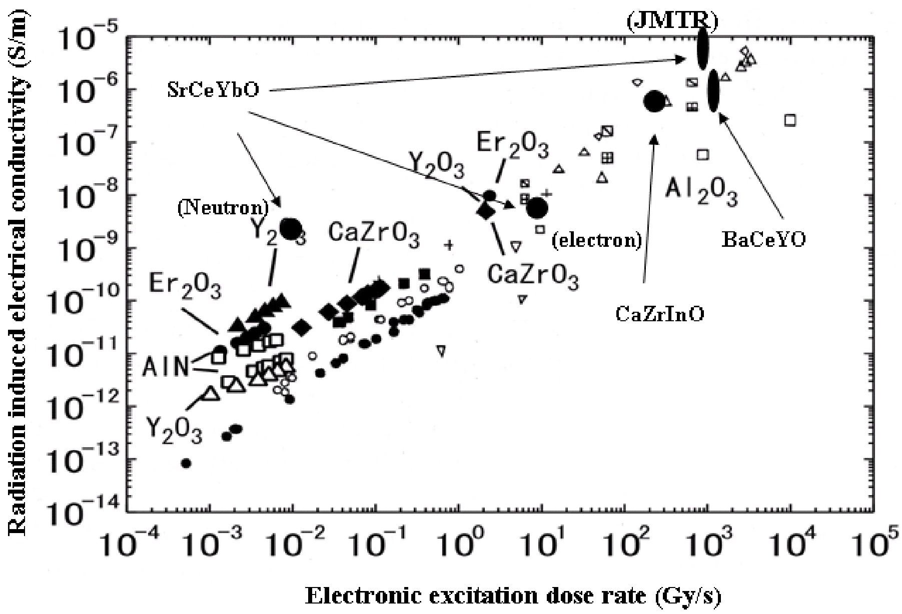

Figure 8 In-situ measurements of electrical conductivity of ceramics during JMTR irradiation with other data measured different irradiation sources.

Figure 9 Optical measurements in a reactor core region under JMTR irradiation

IV Summaries

The paper described the present status of reactor irradiation for materials studies carried out in the Oarai Branch of Institute for Materials Research in Tohoku University, which is executed under a close collaboration with the JAEA-Oarai. To utilize research reactors for fundamental studies in universities, several technical and administrative problems must be resolved. Especially, the studies utilizing research reactors must catch up with rapidly advancing material science and other related sciences. The Oarai Branch has been working to improve quality of reactor irradiations with specially designed irradiation rigs and to improve relationships with a reactor operating organization, the JAEA. The JAEA-Oarai is planning to establish it as an international center of excellence for reactor irradiation issues. The Oarai Branch is planning to play a limited but a specialized role there.

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