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THE OAK RIDGE LOW-TEMPERATURE NEUTRON IRRADIATION FACILITY

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THE OAK RIDGE LOW-TEMPERATURE NEUTRON IRRADIATION FACILITY

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ABSTRACT

The Low-Temperature Neutron Irradiation Facility (LTNIF) is now operating in the Bulk Shielding Reactor at Oak Ridge National Laboratory. This facility, which is sponsored by the Division of Materials Sciences of the United States Department of Energy, provides high radiation intensities ($\sim 2 \times 10^{17}$ n/m²s, $E > 0.1$ MeV) and special environmental and testing conditions (irradiation temperatures from 4 K to 800 K). Sample transfer at 4 K is possible. This user facility is available for qualified experiments at no cost to users. A general description and major specifications of LTNIF are presented, along with the results of performance tests. The hardware and other considerations required to perform experiments in LTNIF are described.

INTRODUCTION

Construction has recently been completed of the Low-Temperature Neutron Irradiation Facility (LTNIF) at the Bulk Shielding Reactor (BSR) in the Oak Ridge National Laboratory (ORNL). The Division of Materials Sciences, Office of Basic Energy Sciences of the U.S. Department of Energy authorized the establishment of the LTNIF to advance the progress of scientific and technological research on radiation effects. This facility is available for qualified experiments at no cost to users.

The LTNIF provides a combination of high radiation intensities and special environmental and testing conditions that have not previously been attainable. Irradiations and post irradiation tests can be carried out at temperatures between 3.2 K and 400 K. An auxiliary Ambient Temperature Irradiation Facility (ATNIF) affords the means to carry out irradiations at the ambient pool temperature of 310 K and higher (up to a maximum of 800 K). A large flux of fast neutrons (2×10^{17} n/m²s, $E > 0.1$ MeV), along with thermal neutrons (2×10^{17} n/m²s) and a gamma-ray intensity of 0.3 W/g (in aluminum) are currently available in the LTNIF. (The gamma-ray intensity is 0.6 W/g in the ATNIF.) Construction of radiation modifiers is planned to meet the needs of

users for modified fast neutron spectra, thermal neutrons, or gamma rays. This facility is expected to be useful for studies of radiation effects in a wide variety of materials.

BULK SHEILDING REACTOR

The core of the BSR consists of a rectangular array of square fuel elements resting on a grid plate, which is suspended in an open pool of demineralized water. The suspension assembly is movable to almost any location in the 6 x 12 m pool. The exposed core is fully accessible on three faces. The BSR is dedicated to the operation of the LTNIF, and it can be operated for indefinite periods at any power up to 2 MW.

Three special features of the BSR will aid LTNIF and ATNIF experimenters. First, the fuel loading provides sufficient excess reactivity to permit restarting after any operating history because xenon poisoning does not limit frequent on-off reactor operations. As a result certain experiments that would be impossible at many other reactors can be done routinely at the BSR. Second, the open pool permits location of storage and auxiliary test facilities for radioactive specimens conveniently close to the irradiation cryostat. Both ambient-temperature and cryogenic facilities are available, and they make use of pool water for biological shielding. The auxiliary cryogenic test facility dimensionally duplicates the test chamber in the irradiation cryostat so that test assemblies will be interchangeable between the two locations. Extended postirradiation testing can be carried out in the auxiliary facility permitting use of the irradiation cryostat by another user. Third, radiation modifiers may be moved easily into and out of position between the fixed cryostat and a core face. It is expected that irradiations with highly thermalized neutrons and other modified spectra will be of interest to experimenters.

IRRADIATION CRYOSTAT

The LTNIF irradiation cryostat is shown in a cutaway drawing in figure 1. Specimens are suspended inside the 37-mm-diameter cylindrical sample chamber for irradiation. Cooling is provided by helium circulating down through the liquid helium supply tube and up through the sample chamber in a natural, two-phase convection loop. The parallelepiped vacuum jacket surrounding the irradiation section of the cryostat nests inside a U-shaped gamma-ray shield, which rests on the grid plate in place of a missing fuel element. In the figure the core has been moved away from the cryostat for clarity. Above the irradiation section a 197-mm-diameter experiment access tube nested inside the annular liquid helium heat exchanger comprises a low temperature test chamber for in situ testing of irradiated specimens. Because the test chamber is outside the irradiation zone, specimens can be irradiated to high fluences and then tested in the absence of nuclear heating, using unirradiated test devices that may be sensitive to radiation (e.g., a superconducting magnet). Liquid nitrogen and liquid helium are delivered through cryopipes to the respective heat exchangers located in the annular space outside the experiment access tube. The closed cycle refrigeration system supplying the liquid helium heat exchanger is capable of cooling to temperatures as low as 3.2 K. The results of tests of the refrigeration capacity in the sample chamber are

Figure 1. The irradiation cryostat with external surfaces cut away to reveal the cryogenic heat exchangers, the experiment access tube and parts of the convection-loop tubing. Broken lines to the reactor core indicate motion necessary to engage the core with the irradiation cryostat.

shown in figure 2. There the temperature of the warmest spot in the sample chamber is plotted versus the electrically simulated nuclear heat load. The electrical heat is indicated on the top scale and the corresponding experiment mass on the bottom scale. At zero experiment mass there is nuclear heating of 40 W in the cryostat. Although the heat generation rate of 0.34 W/g assumed in figure 2 has not yet been measured, the calculations that gave this number

Figure 2. Performance test results showing steady-state temperatures versus electrically simulated nuclear heat (top scale) or the equivalent experiment mass (bottom scale) assuming a nuclear heating rate of 0.34 W/g at full reactor power.

are believed reliable since similar calculations agreed accurately with the measured value in the ATNIF at the LTNIF core position.

AUXILIARY EQUIPMENT

Although the design and construction of experiments are primarily the responsibility of the user, certain auxiliary equipment is on hand and available for experimenters' use. A computer based, on-line data acquisition system is provided with hard-wired electrical terminals available at the cryostat top. Data can be tabulated, plotted, or transmitted to a distant computer over telephone lines for later analysis. Provisions are available for transfer of irradiated specimens at 4.2 K into the user's test device or into vessels for shipment to other laboratories. Temporary storage at 4.2 K or 308 K of radioactive samples or experiment assemblies is available in the BSR pool. Short term storage is often essential to allow decay of short lived radioactive isotopes that may be present. A 12 T superconducting magnet is on hand and will soon be mounted for use either in a poolside experiment dewar or in the test section of the irradiation cryostat. A 200 kV electron microscope is being procured, and a liquid helium stage and transfer device to move specimens from the irradiation cryostat into the microscope without warmup is under design. After completion of this microscope facility it will be possible to obtain direct microscopic structural information about radiation induced defects and their thermal annealing as it occurs in the microscope.

REQUIREMENTS FOR EXPERIMENTS

The difficulty of carrying out experiments will vary greatly depending upon their complexity. The first experiments should be as simple as reasonable; for example, cryogenic irradiation with the specimens being tested at room temperature in the user's laboratory. The LTNIF staff will suspend the user's specimens in an aluminum wire basket for the irradiation, remove them and store them for the user in such experiments. When in situ testing is desired, the user will need to construct a test assembly that can be suspended in the test chamber and a coaxial nesting specimen holder that can be lowered to the irradiation zone for irradiation and raised to the test chamber for testing. Consultation with the LTNIF staff will be required for proper design of experiment and test assemblies. The LTNIF staff will also assist users in planning for low temperature transfer to cryostats in other major facilities (e.g., for characterization of irradiated samples by neutron diffraction). All experiment proposals must be reviewed both for scientific merit (by a user's committee) and for reactor safety (by ORNL staff members). A proposal must include a brief description of the basis for the experiment and certain crucial technical details. Proposal forms are available on request. Prospective users should contact one of the authors.

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