MEETING REPORTS

SUMMARY OF U.S.–JAPAN WORKSHOP ON DYNAMIC EFFECTS OF IRRADIATION IN CERAMICS, SANTA FE, NEW MEXICO, NOVEMBER 11–14, 1992

The main purposes of this workshop were to exchange technical data, to identify the major current technical issues, and to define a set of jointly conducted experiments that will be recommended for the next U.S.–Japan Monbusho collaboration. The workshop was hosted by E. Farnum [Los Alamos National Laboratory (LANL)] and T. Shikama (Tohoku University). Twenty-three experts in the electrical, optical, and mechanical properties of ceramic materials under irradiation attended the workshop: 5 were from Japanese universities, 1 was from the Japan Atomic Energy Research Institute (JAERI), and 17 were from various U.S. laboratories and universities, including LANL, Oak Ridge National Laboratory (ORNL), Pacific Northwest Laboratories, Naval Research Laboratory (NRL), Idaho National Engineering Laboratory, and the University of Illinois.

Ceramic insulators are increasingly being recognized as critical-path materials for future fusion reactors, including the International Thermonuclear Experimental Reactor (ITER) and the DEMO reactor. The materials research and development needed to provide data on ceramic performance under fusion reactor conditions has not been adequately supported, and therefore, the development of improved materials has not been possible. As a result, very little is known about the ability of ceramic insulators to survive even ITER-like environments. The workshop discussions assessed the state of knowledge of dynamic effects of irradiation in ceramics and identified major technical issues that must be addressed before materials for the next generation of fusion experiments can be recommended. The technical presentations identified electrical and optical failures in potential fusion insulators at fluences far less than anticipated for some ITER applications.

The importance of irradiation-induced electronic excitation to the migration of defects and development of defect structure was brought out by several participants. N. Itoh (Nagoya University) reported that changes in the charge state of point defects alter the mobility of the defect. In KCl, for example, the F-center mobility changes from 0.7 eV with no electron to 1.2 eV with a captured electron. Itoh also pointed out that transient electronic defects, such as self-trapped excitons, cause lattice distortion and associated volume expansion. This distortion can affect the mobility of point defects. S. Zinkle (ORNL) showed that the ratio of ionizing to displacive radiation affects dislocation loop formation in several ceramics. These data also support the hypothesis that electronic excitation affects defect motion. Zinkle suggested that since the ionic radius of an interstitial changes with charge state, which in turn depends on the degree of ionization, the diffusivity of interstitials would be expected to depend on amount of ionization. C. Kinoshita (Kyushu University) added that dislocation loops formed during ion irradiation can disappear during subsequent electron irradiation. Thus, the stability of defect aggregates may also depend on the degree of ionization.

A number of experiments were reported that attempted to observe the radiation-induced electrical degradation (RIED) effect first identified by E. Hodgson (CIEMAT). In addition, radiation-induced conductivity (RIC) was measured in these experiments. K. Noda (JAERI) reported that sapphire irradiated with 14-MeV neutrons and almost no gammas showed RIC proportional to flux to the first power, identical to results observed with highly ionizing electron and ion irradiation. E. Farnum and J. Kennedy (LANL) reported preliminary results from spallation neutron irradiation in alumina to 0.03 displacements per atom (dpa) that showed saturating or decreasing conductivity rather than the rapidly increasing conductivity reported with electron or proton irradiation at <0.001 dpa. S. Zinkle also saw no RIED effect during irradiation of alumina with protons and helium ions to 0.05 dpa. For reactor-irradiated alumina, however, T. Shikama (Tohoku University) did observe an increase in conductivity similar to, but less than, the RIED measured by Hodgson. Starting at $\sim$0.2 dpa, the conductivity increased by about one order of magnitude at 1 dpa. A need for increased collaboration on these experiments was identified, along with irradiation to >1 dpa and higher electric fields. It was agreed by all that a set of round-robin materials is needed so that data can be better compared, but specific materials and purchasers were not detailed. The effect of atmosphere inside the capsules was also identified as an important issue.

The effect of irradiation on the optical properties of fusion insulators was reported by several participants. Fluorescence caused by ionization during irradiation was observed to decay rapidly after irradiation with a time constant in the 2- to 100-μs range. T. Tanabe (Osaka University) reported that the fluorescence in silica is a broad peak centered at 800 nm. W. Unruh (LANL) and D. Griscom (NRL) reported on spallation neutron irradiation of pure and OH-doped fiber optics at much higher fluence than has previously been investigated. With increasing irradiation, the absorption increases first in the ultraviolet range (200 nm) and then progresses to longer wavelengths. At very high dose, there was some indication that the absorption decreases in the 200-nm range. There was speculation that the fluoride-doped fiber cladding might be more resistant to the radiation than the core. K. Noda (JAERI) compared the efficiency of generating degradation in optical fibers and found that neutron irradiation is more efficient in inducing absorption than gamma irradiation.

K. Abe (Tohoku University) reported on postirradiation examination of metal-ceramic joints. Thermal expansion coefficient matching is important. One joint of alumina and vanadium alloy survived 60 dpa of fast reactor irradiation.

T. Tanabe (Osaka University) irradiated diagnostic instruments and components with 14-MeV neutron irradiation. He reported that a charge-coupled device camera failed at 2×10^{10} n/cm^2. An irradiated electron multiplier tube produced pulses from the neutrons similar to those from electrons. Tanabe also reported that 14-MeV neutrons are ~100 times more damaging to pulse-counting detectors than an equal absorbed dose of fission neutrons.

Radiation sources suitable for dynamic measurements in both the United States and Japan were discussed. The following were of particular interest:

1. a temperature-controlled materials irradiation facility at Japan's Joyo fast reactor that will be available in 1997
2. a cryogenic facility that is proposed for development at the OKTAVIAN 14-MeV neutron source
3. a proposed upgraded LASREF
4. an instrumented irradiation facility being built at the High-Flux Isotope Reactor (HFIR) that is expected to be operational by the end of 1993.

The sources considered most suitable for future *in situ* experiments are the LASREF spallation radiation source at the Los Alamos Meson Physics Facility at LANL, the Japanese Material Testing Reactor at Oarai, the HFIR at ORNL, and the OKTAVIAN 14-MeV neutron source at Osaka University.

A copy of the proceedings, which includes a summary and presentation viewgraphs, can be obtained from the author.

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SUMMARY OF 7TH U.S.-JAPAN D-^{3}He WORKSHOP, CHAMPAIGN, ILLINOIS, MARCH 16–18, 1993

INTRODUCTION

G. Miley (University of Illinois) hosted this meeting of the U.S.-Japan working group devoted to the physics and application of D-^{3}He for the creation of fusion energy. The 3-day meeting was held at the University of Illinois to discuss the latest analyses, experiments, and applications of advanced fuels and included a tour of the Fusion Studies Laboratory.

SESSION I: L. STEINHAUER

D-^{3}He Tokamak Reactor with Alternating Current Operation

O. Mitarai discussed the use of an inductive alternating current (ac) using D-^{3}He to operate a tokamak reactor to eliminate problems encountered from steady-state operation. The reactor analyzed had a 9.5-m major axis and 2.8-m minor axis and operated at 10 T and a plasma current of 53.6 MA. It was analyzed to operate successfully in the first-stability range using a small current power drive of ~50 kW.

The underlying physics assumptions were first-stability operation with high triangularity and four times L-mode confinement. Fairly aggressive technology assumptions were made, including rectenna conversion of synchrotron radiation energy and a relatively high maximum field of 18 T in the ohmic transformer. Given these conditions, a large auxiliary heating power of nearly 500 MW would be needed during startup. Several ideas were mentioned that might reduce this requirement, including "hot-ion" operations (ion temperature 1.5 to 2 times the electron temperature) or spin polarization of the fields. While some work has been done on spin polarization, no approach is known to achieve hot-ion operation.

Overview of Inertial Electrostatic Confinement and Possible Use for Burning D-^{3}He

G. Miley discussed the origin of inertial electrostatic confinement (IEC), another potential confinement approach for advanced fuels. The operational principles of IEC were described. Ions and electrons are injected into a spherical shell configuration that is designed to trap ions in a potential well to produce high reaction rates in a small core, providing a high-beta confinement approach. The IEC does not require magnets: The combination of the well potential and the inertia of the ions provides the necessary confinement. Beam-beam reactions make IEC well suited for burning D-^{3}He. The experimental studies being conducted at the University of Illinois were described. Neutron production has been achieved, creating interest in IEC as a neutron source. D-^{3}He experiments are planned next. The ultimate goal is a reactor.

Physical Issues in the Design of a D-^{3}He Tokamak Reactor

S. Tanaka discussed the results of a study to consider the feasibility of steady-state burning of D-^{3}He in a tokamak. The analysis is based on confinement in the second-stability regime and a double-null divertor. The conclusions reached were that the tokamak is not suited to burning D-^{3}He, direct conversion from synchrotron radiation is not a candidate, and a first-wall design using water coolant from burning D-^{3}He works well.

Somewhat more conservative technology assumptions were made in this design than in that by Mitarai, specifically, conventional thermal and reasonable wall reflectivity of synchrotron radiation. The more conservative assumptions necessitated the second-stability regime. The assumption of low recycling, which was considered a realistic physics assumption, led to a large requirement on the divertor region volume to handle the heat removal. The conclusion was that a