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EROSION TESTS OF MATERIALS BY ENERGETIC PARTICLE BEAMS*

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ABSTRACT

The internal components of magnetic fusion devices must withstand erosion from and high heat flux of energetic plasma particles. The selection of materials for the construction of these components is important to minimize contamination of the plasma. In order to study various materials' comparative resistance to erosion by energetic particles and their ability to withstand high heat flux, water-cooled copper swirl tubes coated or armored with various materials were subjected to bombardment by hydrogen and helium particle beams. Materials tested were graphite, titanium carbide (TiC), chromium, nickel, copper, silver, gold, and aluminum. Details of the experimental arrangement and methods of application or attachment of the materials to the copper swirl tubes are presented. Results including survivability and mass losses are discussed.

INTRODUCTION

A concern for present and future magnetic confinement devices is the lifetime limitation due to thermal fatigue and erosion of the internal components used for plasma heating and impurity control. These components, which include limiters, divertor collector plates, rf launchers, and Faraday shields, must handle high fluxes of energetic particles from the plasma periphery. Depending on the proximity of these components to the plasma, the average continuous heat flux could be 1000 W/cm^2, and the average particle flux could be 10^{19} particles/cm^2·s. During plasma disruptions, transient (~10-ms) heat fluxes of 10 to 100 kW/cm^2 can occur. The design study of FED/INTOR[1] determined that the development of materials and technology for the internal components is one of the critical issues of ongoing fusion research.

The selection of materials for the construction of these components is important in order to minimize contamination of the plasma and degradation of confinement for long time periods. The materials must therefore be very resistant to erosion, thermal shock, and thermal fatigue. Materials with elements having low mass numbers are also desirable. Materials presently being used or suggested include graphite, TiC, Cr, Ni, Al, and Be.

In present short-pulse (<5-s) confinement experiments, the energy lost to the internal components is handled inertially (the mass of the component absorbs the energy from one pulse, which then dissipates slowly to the surroundings by radiation and conduction between pulses). Future experiments with pulse lengths extended to tens of seconds will require active cooling (a coolant flowing through the component). During the development of neutral beam systems[2,3] in the last ten years, it was demonstrated that water-cooled copper swirl tubes could handle high (~7-kW/cm^2) heat flux. Limiters fabricated of swirl tubes have been proposed.[4] Oak Ridge National Laboratory (ORNL) has prime responsibility for the development of rf plasma heating technology for the next-generation fusion devices in the United States. The rf compatibility of materials and geometrical configurations have been and are being studied and have been reported at this meeting.[5] In addition, information about the erosion properties of materials is necessary so that functional rf launchers and Faraday shields can be developed.

Therefore, a study was initiated at ORNL to test various materials' comparative resistance to erosion by energetic particles. The materials were actively cooled by being applied or attached to copper swirl tubes. It is recognized that not only the materials themselves, but also the quality of their adhesion to the swirl tubes, were being tested. The materials tested were graphite, TiC, Cr, Ni, Cu, Ag, Au, and Al. Although copper (uncoated), silver, and gold may not be serious candidates, they were included for comparison.

An Oak Ridge Tokamak (ORMAK) injector[6] was the source of energetic particles with which to bombard the material samples. Beams of hydrogen and helium particles (ions and neutrals) were produced.

SAMPLE PREPARATION

The test samples were prepared using a copper swirl tube substrate. The swirl tubes had an outside diameter of 0.90 cm, a wall thickness of 0.16 cm, and a length of 23.5 cm with a twisted Inconel ribbon inside, as shown in Fig. 1.

All tested materials except copper (uncoated tube) were applied or attached to the copper swirl tubes by electroplat-

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