IMPROVED PERFORMANCE OF TiC-COATED GRAPHITE LIMITERS BY SURFACE TEXTURING

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TiC-coated graphite limiters are currently in wide use as tokamak limiters. These limiters usually suffer a groove type of damage caused by plasma disruptions. A surface texturing treatment is described that reduces the occurrence of this type of damage.

1. INTRODUCTION

TiC-coated graphite limiters are currently being used as limiters in several operating tokamaks including ISX-B, Doublet III and TFTR. These limiters have generally performed well, improving tokamak operation and surviving extended operation times without extensive coating damage.¹⁻³ In most cases, however, tokamak exposure has lead to some localized coating damage, namely coating melt in areas of excessive thermal loading and local coating spallation in other areas.

The most extensive experience with TiC-coated graphite limiters has been gained in ISX-B and Doublet III, where these limiters have served as the primary machine limiters for over three years.¹⁻³ These limiters are normally prepared by machining the Poco graphite substrate to the desired shape, surface finished with fine emery cloth to remove machining damage, and then rubbed with a lint-free cloth prior to the loading into the furnace for the chemical vapor deposition of the TiC. When prepared in

this manner, the limiters have a smooth, shiny appearance after coating.

When exposed to neutral beam heated discharges in ISX-B or to high power ohmic discharges in Doublet III and Alcator C, these limiters suffer two types of damage--namely, areas of coating melt accompanied often by surface cracks in the graphite and more general areas of narrow, roughly parallel regions of coating spall resembling grooves cut into the coating. These grooves do not always extend to the graphite, often being contained completely within the coating.

FIGURE 1

The TiC-coated graphite surface after the texturing treatment.

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FIGURE 2

A cross-section view of the textured surface.

This groove damage is believed to occur early in the limiter exposure and not worsen with exposure. A spallation damage such as this requires a high stress level which is most likely caused by the severe thermal stresses that are generated in the coating during plasma disruptions.^{4,5}

2. SURFACE TEXTURING TREATMENTS

If the key to reducing the groove type of damage lies in reducing the long range (i.e., ~ 1 cm) thermal stresses in the coating, then two possible methods to achieve this would be: (1) precrack the coating before tokamak exposure; or (2) modulate the surface on a scale smaller than the groove spacing. In this study, two methods of modulating the surface were used. First, the graphite surface was roughened before coating by bead blasting the graphite substrate with a very coarse (G-16) grit. This rough surface was then coated with the normal 20 μ m thick TiC coating before insertion as the primary outer limiter in ISX-B. A series of still photographs and high speed movies were taken of this limiter⁶ during both

ohmic-heated and beam-heated discharges. After an exposure of several months amounting to over 4,000 discharges, this limiter was removed and examined. While it still displayed the small melt region typical of these mushroom-shaped limiters in ISX-B, it exhibited none of the groove-type damage. The limiter had, however, exhibited a more general loss of coating particles, apparently from sharp protrusions of the original roughened surface. This loss of coating particles was particularly noticeable early in the limiter exposure period during major plasma disruption.

To try and reduce the particle ejection problem while still avoiding the groove formation, a surface texturing treatment was applied by gritblasting the graphite substrate with a very fine (G-80) grit with the graphite masked by a 20 mesh (i.e., approximately 8 wires per cm of 0.2 mm diameter) stainless steel screen. The regions shielded by the screen were not eroded while the central regions were removed. The use of a fine grit kept the eroded regions microscopically smooth. A typical textured surface is shown in Figures 1 and 2.

Limiters with their surfaces textured in this manner are currently being exposed in ISX-B and in Doublet III. While none of these limiters have been removed to allow detailed analysis, visual inspection has not detected any large occurrence of the groove damage.

In summary, a surface texturing treatment has been developed that is believed to reduce the typical groove type of coating damage while avoiding the introduction of coating particles caused by a normal surface roughening treatment. Tokamak tests are currently being conducted to confirm the usefulness of this technique.

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