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The role of alumina coating porosity on the electrical insulation in a weakly ionized plasma atmosphere

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The design of the RFX-mod2 experimental fusion device requires a copper shell close to the plasma to aid in stability and magnetic confinement of the plasma [1,2]. This conductive structure, only 3mm thick, placed around the plasma, must have electrical discontinuities in both the poloidal and toroidal directions, so as to allow the penetration of electromagnetic fields into the plasma region. These gaps are conceived to avoid the formation of net poloidal and toroidal currents in the copper shell during the experiment phases. Furthermore, the shell was designed with an overlapped region at the poloidal gap in order to minimize induced field errors.
The loop voltage, that is the electromotive force induced by external coils which sets up and supports the plasma current, can reach values up to 400 V, during operations in the Reversed Field Pinch magnetic configuration. Besides, if a fast termination occurs, i.e. rapid loss of the plasma magnetic confinement, these values can rapidly rise up to 1.5 kV. Therefore, intense electric fields can be generated between the shell edges, only a few millimetres apart, along the overlapping region. Furthermore, considering that the stabilizing copper shell, placed inside the vacuum chamber, is exposed to low temperature weakly ionized plasma, the formation probability of harmful electric arcs is high.
In order to avoid the formation of arcs, the copper shell will be coated with a ceramic layer made of aluminium oxide (alumina), applied by means of atmospheric plasma spraying.
An experimental apparatus was prepared with the aim of reproducing the conditions expected at the plasma edge close to the copper shell. It consists of a vacuum chamber in which a helium plasma is produced, generated by an incandescent tungsten filament and a DC power supply. The alumina-coated copper samples are polarized, applying a pulsed voltage up to approximately 2 kV. The electrical tightness of the insulating layer and the possible formation of electrical discharges on the alumina surface were verified.
It was observed that in some samples, in which the breakage of the dielectric layer occurred, the thickness of the ceramic layer was less than that required (100 μm) and was characterized by an irregular structure with high porosity and large cavities of tens of microns. Moreover, these cavities generate a network of interconnected fractures forming an almost continuous porosity, thus reducing the effective thickness of the alumina. The electrical insulation has been significantly improved by creating alumina deposits with better compactness and reduced porosity. The latter parameters have been validated for having an effective electrical insulation in the presence of plasma.
In this contribution, we present the electrical insulation performance of alumina coated samples with different thickness and porosity levels. Furthermore, the copper samples with alumina coating were analysed, both in section and on the surface, by means of a scanning electron microscope (SEM).

References
[1] Peruzzo S., et al. "Technological challenges for the design of the RFX-mod2 experiment." Fusion Engineering and Design 146 (2019): 692-696 https://doi.org/10.1016/j.fusengdes.2019.01.057.
[2] Marrelli L. et al. "Upgrades of the RFX-mod reversed field pinch and expected scenario improvements" Nuclear Fusion 59 076027 (2019)

Topic

Applications

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