VACUUM BREAKDOWN MITIGATION

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Introduction. Understanding the breakdown voltage process in vacuum, specifically technology of breakdown mitigation, is important for applications such as accelerators and thermonuclear synthesis. In our work, we present simulation results and our conclusions about crater formation on a material surface due to vacuum arc and plasma heating. Atomic layer deposition (ALD) and irradiation by gas cluster ion beam (GCIB) can be applied to smoothen electrode surfaces; thus reducing the risks of a breakdown.

Materials and methods. Finite Element Method Comsol Multiphysics software was used to simulate and explain the breakdown process in metals (electrodes). We used different geometries (1D, 2D) to simulate heating and cooling during a vacuum arc. ALD is a thin film growth technique by gas phase chemical process. One of the special features of this method is to form molecular and atomic monolayer with no 3D-islands. Irradiation by GCIB is a method of surface processing with beams of molecular/ atomic clusters that ensures smoothness on various kinds of surfaces at the atomic level. These methods will be used to improve breakdown mitigation.

Results and discussion. Vacuum arc is a high current electric discharge, where the discharge generates plasma, evaporating and ionizing electrode material. When the electrode surface is exposed to plasma for even a short period of time, glow regions appear on cathode surface. As a result of the breakdown, craters are formed. Based on our simulation results, we predict that duration of surface heating determine a size of craters and a thickness of molten layer. Longer heating time results in thick molten layer and larger craters; and shorter heating time results in thin molten layer and smaller local craters.

The interaction type, used in Comsol Multiphysics, adds the electromagnetic losses from the electric field as a heat source. In addition, the temperature from the heat transfer in solids interface acts as a thermal load for the solid mechanics interface, causing thermal expansion.

Since ALD and irradiation by GCIB are great means of surface smoothing, we are planning to improve the methods of breakdown mitigation.

Conclusions. We were able to successfully predict and prove the dependence of crater size on duration of surface heating, using Comsol Multiphysics software. Vacuum breakdown is still a complex phenomenon, and it is very challenging for software users to take into account all the parameters of the real process. In addition, preliminary work on ALD and GCIB processing is being implemented at this moment.

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References.

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