Numerical Modelling of Interaction between the Electric Arc and Electrodes

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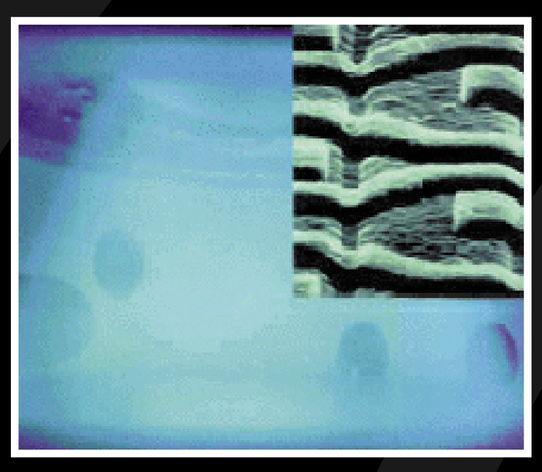
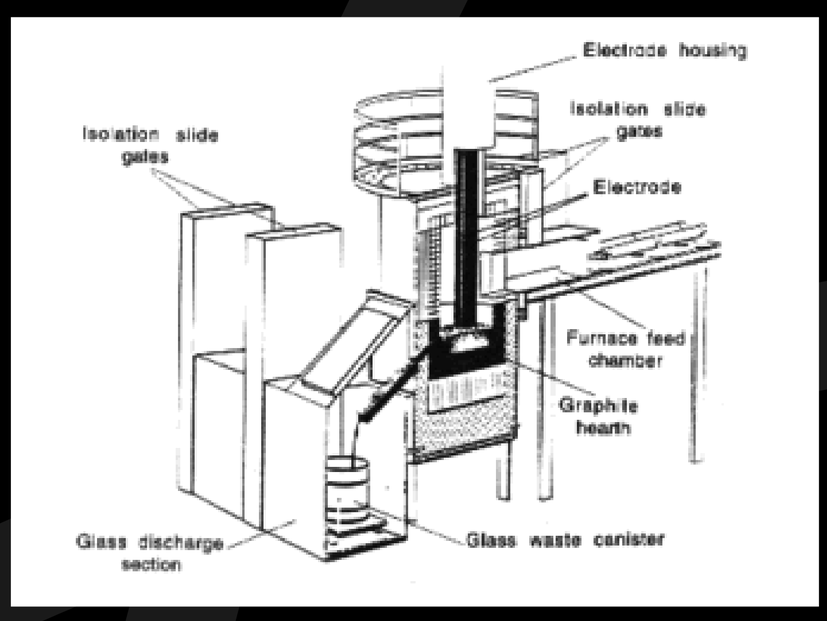
There is a wide spectrum of electric arc applications, as for example in the area of arc welding, development of arc circuit breakers for current interruption and in the lighting industry. In the recent years, the emphasis has swung towards high temperature chemistry and material processing with successful application in plasma etching semicondutors and toxic waste destruction via oxidation.

Arc circuit breaker used in high voltage network

Although theoretical and computational studies have spearheaded many of the advances in arc plasma physics, the understanding of arc behaviour, especially those processes occuring at the electrode region is still poorly understood or remains incomplete. This work is primarily concerned with the arc phenomena associated with low voltage switching devices during the breaking of two current carrying electrical contacts.



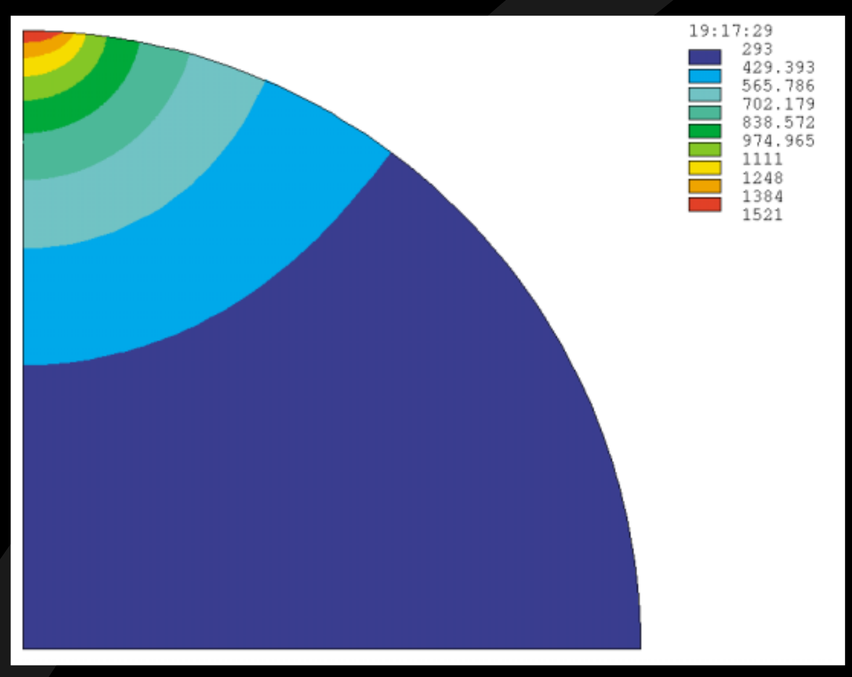
Plasma etching semiconductor



High temperature plasma in arc furnace used in toxic waste destruction

Failure of a contact for whatever reason can have relatively catastrophic consequences.
Arc erosion due to material transfer in the plasma developed between contacts at opening and closure is one of the major mechanisms leading to failure. Even with a macroscopics clean metallic surface, metallic contact

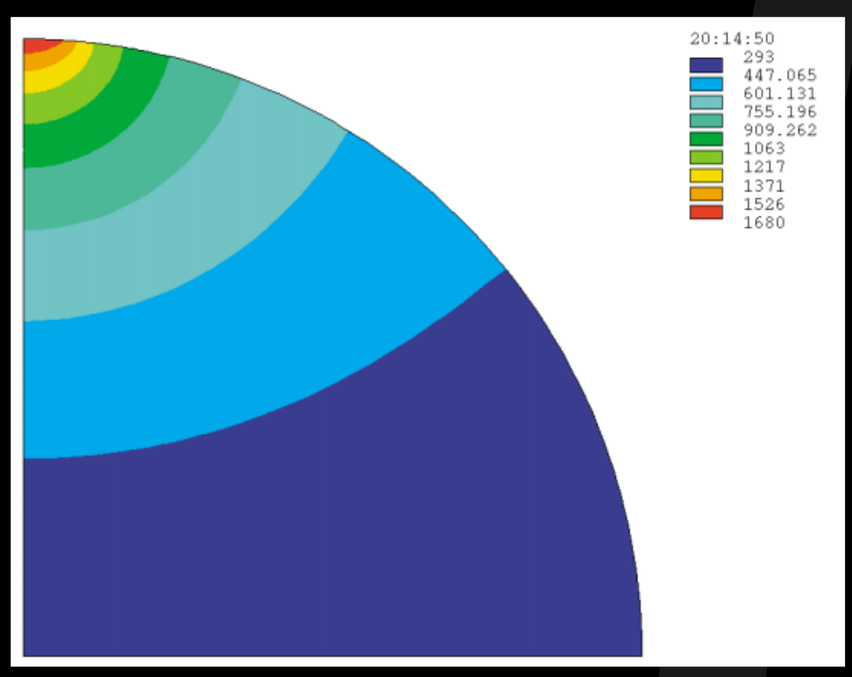
High intensity arc lamp



Electrode temperature after 1ms of arcing with power density of $3x10^9$ W.m^{-2}

occurs only at a small number of asperities. The current flowing through the contact is constricted and the contact point may be heated to a temperature sufficient for the electrode to melt.
Upon the breaking of two contacts, the molten metal is then drawn into a molten metal bridge.
The rupture of this molten metal bridge will generate ions and electrons across the electrode gap.
These electrons and ions provide the necessary charge carriers for developing an arc upon the breaking of two electric contacts.

Much of the progress in arc-electrode interaction has been motivated by the need to understand the erosion process in electrical contact. Some of them attempt to predict erosion using the experimental data such as arc current, arc voltage and current density.
The input arc energy into the electrode is a pre-requisite for this approach. The amount of arc energy flow into electrode surface is very subjective as there is still no quantitative theory to determine it. Therefore there is a growing need to solve the energy balance equation on the cathode surface coupled with the influence of electric arc.
This work has been undertaken to develop a numerical model of interaction between electric arc and electrodes. It is hoped that this model will provide some insight into the arc erosion process through the amount of arc energy fed into the electrical contacts. A full mathematical model based on multi-species, two-temperature Navier-Stokes equations is developed to describe non-equilibrium fluid dynamic effects between two electrodes during switching operation.
A one-dimensional Poisson equation is used to represent the sheath region immediately next to the electrodes.



Electrode temperature after 2ms of arcing with power density of $3x10^9$ W.m^{-2}

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