Arcs Spark New Interest

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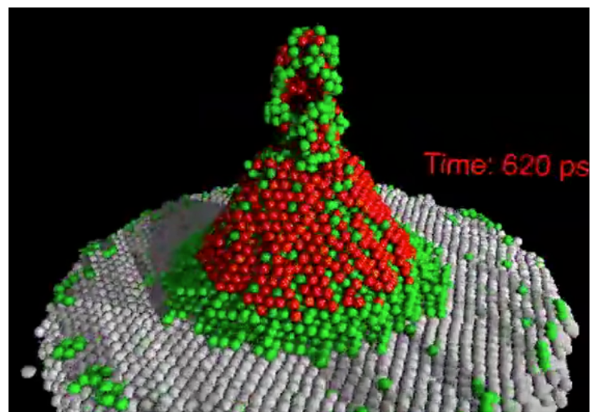
We are developing a self consistent model of vacuum arcs.

Whenever two pieces of metal at different voltages are brought near each other there is a chance there will be an arc between them. An example is the spark that appears when a battery is connected in a circuit or something is plugged into a live socket. Most of the arcs people see are breakdown of the gas between the metal surfaces, but breakdown also occurs in a vacuum, and this vacuum breakdown has not been well understood.

As part of an effort to understand the maximum accelerating field in particle accelerators, we have been modeling the processes involved in vacuum breakdown, a phenomenon that has been studied for almost 110 years, when the mechanism was first identified. We now think we have a new model of this phenomenon and are beginning to understand what is happening in these arcs, and are studying a number of new phenomena associated with them.



Modeling electric fields tearing the surface

In our model, the breakdown arc is triggered by the electric field in the vacuum gap literally tearing the metal apart. The same force that causes "static cling" can be very powerful for high electric fields, particularly at tiny corners, and in cracks where the fields are intensified by the local geometry of the surface. After the metal is torn apart, the fragments should become ionized and form microscopic plasmas that are very dense and cold (for a plasma). Because of the high densities in these plasmas, the surface fields inside the arc quickly become even stronger than they were at breakdown and the arc becomes very damaging to the metal surface over a comparatively large area, eventually leaving a pit that should be visible to the naked eye.

While this model seems to be internally consistent, we are trying to use it to produce predictions that we can experimentally check. We are using molecular dynamics to show what happens at the atomic level when the material is torn apart, plasma modeling codes to show how the plasma initially forms and what its properties are, and electrohydrodynamics to show how the surface of the arc pit is affected. Our results seem generally consistent with existing experimental measurements but we are trying to devise more precise tests.

In principle, understanding the precise causes of electrical breakdown should suggest solutions to the problem that are relevant to fusion reactors and space communications, among other things.

This work has been presented at accelerator conferences for the past few years, as it has been evolving.