Microwave Breakdown due to Heating of an Irradiated Metal Sphere

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Microwave gas breakdown is a dangerous failure mechanism for rf equipment working at high power levels [1]. The breakdown results in a region of conducting gas with deleterious effects ranging from noise to the melting of parts of the system. For this reason it is necessary to calculate the threshold electric field, above which breakdown is possible. This analysis is usually done while neglecting the influence of local heating of the gas. This might result in a threshold value which is too high, since heating of a gas lowers the gas density, resulting in higher average electron energies, leading to a lower threshold.

Experiments [2] have shown that small conductive protrusions (screws, filings etc.) might undergo heating to several hundred Celsius, heat the gas and initiate local breakdown.

In order to further the understanding of the main mechanisms of such heating-breakdown scenarios we have analysed the heating and influence on the breakdown threshold of a conducting metal sphere irradiated by a homogeneous electromagnetic wave in the microwave range. The great benefit of this system being that there is an analytical solution for the electromagnetic problem and that the properties of heat conduction and convection from the sphere surface are well known.

Our results show that there are three distinct breakdown thresholds corresponding to breakdown in the ambient field, breakdown close to the sphere due to the local field enhancement, and breakdown close to the sphere after heating. The most interesting quantity is the ratio between the second and third threshold, for it characterizes the influence of the metal sphere on the breakdown problem. For small sphere radii the influence is shown to be negligible, whereas for large radii the lowering of the breakdown threshold might be up to an order of magnitude and the resulting sphere temperature several hundred degrees Celsius.

References