ABSTRACT

While our understanding of high pressure spark discharges (i.e. short duration electrical discharges between electrodes in an ambient gas or pressure close to atmospheric pressure) has benefited from computer simulations and numerical modeling, the same cannot be said of high pressure surface discharges. The main reason is that the surface discharge, lacking the cylindrical geometry of a freely expanding spark discharge, is more complex to model. Also, the outcome may not commensurate with the efforts unless the dominant mechanism behind the plasma channel-surface interaction is identified and can also be included in the model in a realistic manner. Of course, surface discharges occur under a wide variety of circumstances and the mechanism that is responsible for bringing the surface into play will not be universal. So in each case, the appropriate mechanism has to be recognized.

In the experiments described here, we obtain a situation where the initiation of the breakdown on an insulator surface does not seem to be dependent on the presence or the absence of the surface. However, the subsequent evolutions of the plasma channel are quite different on the surface and in the absence of the surface. We have been able to compare the two types of discharges under nearly identical condition of electrode geometry and separation, rate of electrical energy input and the ambient gas pressure. For inter-comparison between surfaces, three polymeric materials - namely, Teflon, Plexiglas and Nylon - were selected. The expectation was that the relatively low working temperatures associated with the polymers (in comparison to ceramics) would ensure that the evolution of gas/vapor from the surface, would be large enough to compete with the high pressure ambient air density - even at the low electrical energy input in our experiments - and yield observable differences. This has been borne out.

The electrical characteristics of the discharges were recorded with a time resolution of a few nanoseconds. The expansion of the plasma channel were recorded by imaging it using an Image-intensified Charge-coupled device (ICCD) camera. The evolution parallel and perpendicular to the surface were recorded with a time resolution of tens of nanoseconds. This was done by gating the exposure at different time delays from the initiation of discharge in a series of discharges. The expansion, cylindrically symmetric, of a free spark (i.e. in the absence of any surface) is seen to be similar

to published results and also consistent with existing theoretical models. The expansion of a discharge on a surface is asymmetric - the expansion being faster along the surface than that of perpendicular to it.

To understand the observation, a qualitative model involving the absorption of photons emitted from the plasma, by the surface layers and their rapid heating to high temperatures leading to vaporization has been explored. The measured values of the photon intensity from the initially formed channel have been shown to be adequate to heat the top layers of the polymer surfaces for significant evolution of vapor molecules from the surfaces.

The light emission from the discharges have also been analyzed spectroscopically with $\sim 2\ A^o$ resolution in the 3000-6000 A^o wavelength range using a spectrometer/ICCD based optical multichannel analyzer system. The plasma parameters - electron temperature T_e and density n_e have been calculated from the above data. The enhanced radiation from all the surface spark discharges in comparison to the free spark discharges has been argued to be due to the higher n_e obtained.

Whether the observed differences between free and surface spark discharges and the differences among the discharges on the different surfaces studied could all be explained on the basis of the proposed qualitative model can be answered only be a full fledged numerical model or simulation. However, we believe that this experiment has yielded sufficient data for such a comparison. The proposed model also provides a basis for incorporating the optical and thermal properties of the surface into existing simulations of free spark discharges and thus extending them to the surface spark discharges.