The Consequences of Remnant Surface Charges on Microdischarge Spreading in Dielectric Barrier Discharges

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***Abstract*— Dielectric barrier discharges (DBD's) consist of filamentary microdischarges (10s–100s μm diameter) randomly distributed between the electrodes. Charging of the dielectric terminates the microdischarge by removing voltage from the gap. When the applied voltage changes polarity, the residual dielectric charges from the previous pulse can enhance the gap voltage so that a more intense electron avalanche occurs. In this paper, results from a two-dimensional model of a DBD are used to demonstrate the consequences of dielectric charging on spreading of the microdischarges.**

***Index Terms*—Gas discharge devices, plasma applications.**

DIELECTRIC barrier discharges (DBD's) are widely used as ozone generators and to abate toxic gases [1]. Typically, DBD's use an alternating (sine or square wave) voltage of several kV at 100s Hz to several kHz with one or both electrodes covered by dielectric. Microdischarges are randomly distributed throughout the volume with area densities of 10s to 100s cm^{-2}, lifetimes of 10 to 100 ns, and diameters of 10s–100s μms. The microdischarges are terminated when charge accumulation on the dielectric reduces the gap voltage at the position of the microdischarge to below self sustaining. On the following opposite polarity voltage pulse, the residual charge on the dielectric adds to the applied electric field, thereby enhancing avalanche at those locations.

In this paper, results from a two-dimensional (2-D) model are used to investigate the dynamics of multiple microdischarges operating with remnant charge on the dielectric surface from a previous pulse. The 2-D model, which resolves plasma hydrodynamics parallel to the electrodes, consists of a circuit model, a solution of Boltzmann's equation for the electron energy distribution, a plasma chemistry model, and a hydrodynamics model in which continuity momentum and energy equations for all charged and neutral species are solved. The images shown here were produced by generating HDF files from raw output of the model. The HDF files were transferred to a Macintosh where TIFF files were created using Spyglass Transform (Fortner Research). The TIFF files were assembled into the image using ClarisDraw.

The model was executed for two pulses in a dry air ($N_2/O_2 = 80/20$) DBD with one electrode covered by a 0.5 mm dielectric ($\varepsilon = 25\varepsilon_0$) and a 0.25 cm gas gap. The applied voltage is an alternating square wave 40 ns, 8.5 kV pulses spaced 100s μs apart. The electron density, O^- ion density, and voltage across the gap during and after the second pulse are shown in Fig. 1. Residual charge on the dielectric was produced during the first pulse by a cluster of four closely spaced microdischarges whose locations are indicated by the higher gap voltage in the first voltage frame in Fig. 1. The residual charge produces a 4.8 kV potential which, by itself, is insufficient to generate a microdischarge. On the second inverted voltage pulse, a pair of microdischarges occur adjacent to the first four, as shown in the first electron density frame.

At the beginning of the second pulse (0.8 ns), the gap voltage is uniformly 8.5 kV except where the residual charge increases the voltage to 13.3 kV. Avalanche occurs for the second microdischarges which progressively expand until about 20 ns. As the electron density avalanches, the dielectric charges, removing voltage from the gap until the E/N is below self sustaining. Electron attachment then reduces the current density to the point that the dielectric cannot fully charge. The electron density is then a hollow shell while O^- peaks in the cores of the microdischarge (18.3 ns). As the microdischarges expand, they infringe on regions where the dielectric was previously charged. Since these regions have a larger gap voltage, electron avalanche rapidly occurs and produce "daughter" microdischarges (29.4, 32.9, and 36.6 ns) having larger electron densities than their "parents." The higher current densities for the daughters fully charge the dielectric, thereby fully removing voltage from the gap.

At the end of the second voltage pulse (40 ns), the gap voltage for the first daughter microdischarge is almost zero while the voltage for the younger daughters has collapsed only in the gibbous regions corresponding to the extent of the microdischarges. The O^- density is large in regions where there is a small E/N which promotes dissociative electron attachment but not ionization. At 100 ns electron densities are still substantial for the daughter microdischarges where the dielectric has been fully charged and voltage removed from the gap. The O^- ions dominate in the parent regions due to new residual charge producing a small nonzero E/N.

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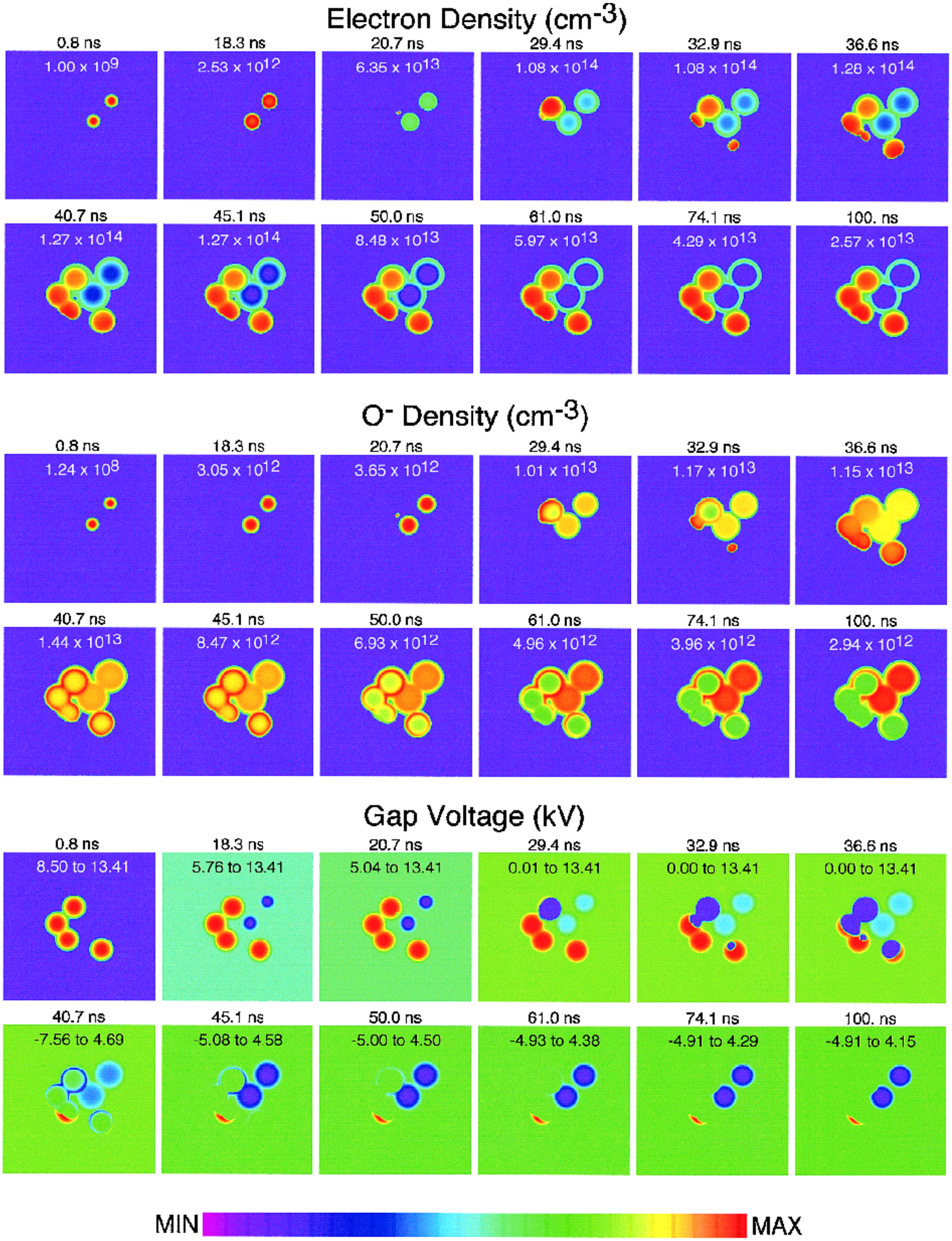

Fig. 1. Electron and O^- densities and gap voltage for various times indicated by each frame. The maximum values of the electron and ion densities are shown in the frame, as is the range of voltage. The dynamic range of the electron density plots is three decades. The O^- density and gap voltage use linear scales.