Stroboscopic Images of Streamers Through Air and Over Dielectric Surfaces

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***Abstract*— We study the propagation of streamer discharges through air and along an epoxy rod with an ICCD camera. We use stroboscopic imaging at frequencies up to 110 MHz to visualize discharge evolution and to calculate velocities. Initial results show that surface streamers along a dielectric surface can be up to twice as fast as streamers through bulk air.**

***Index Terms*— Imaging, surface discharges.**

IN HIGH voltage devices, breakdown may occur because discharges seem to move more easily over insulating surfaces than through bulk gas [1]. In this paper, we use stroboscopic imaging to study these surface discharges.

To generate discharges, a positive high voltage pulse between 10 and 17 kV [see Fig. 1(f)] is supplied by a charged capacitor that discharges after a spark gap is triggered to a needle placed 16 cm above a grounded cathode plane. A stainless steel sample holder containing an epoxy rod (4 mm in diameter) is placed on the cathode plane, in such a way that the top of this rod is 6 mm below and 35 mm to the side of the needle. Our experiments were performed in air, at pressures between 40 and 100 mbar.

To image the discharge, we use a LaVision PicoStar HR12 camera system. We send a pulse train of tunable length and frequency to the intensifier. This way, we are able to perform stroboscopic imaging of the discharge. By controlling the number of pulses and the frequency, we are able to control the number of gating cycles and the time between these gates. By measuring the monitor output of the intensifier, we are able to relate the timing of the camera to the voltage pulse [see Fig. 1(f)].

With stroboscopic imaging, we are able to study the spatial and temporal evolution of the discharge in two dimensions. Due to the stochastic behavior of the discharges it is not possible to compare different discharges, and although a streak camera would allow us to study the spatial and temporal evolution of the discharge, this would only yield accurate results for discharges that propagate in a well-defined direction. For the highly nonreproducible discharges that propagate in multiple directions that we are studying, stroboscopic imaging yields the best results.

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Pancheshnyi *et al.* [2] have used the same technique to study streamers, however, in their experiment the number of gating cycles was limited to 6 due to the high velocity of the discharge and the narrow gap. In our experiment, because of the lower discharge velocity and larger gap we can use up to 20 gating cycles, allowing a more detailed study of discharge phenomena like branching and the inception cloud.

Fig. 1(a)–(c) shows the images obtained at 50-MHz intensifier gating. The needle and the contour of the dielectric rod are marked in white. The images clearly show the intermittent pattern caused by the stroboscopic gating. Three parts of the discharge can be distinguished: 1) the inception cloud [3], [4]; 2) the bulk gas streamers; and 3) the surface discharge propagating along the epoxy rod. The number of gating cycles is chosen so that the intensifier has zero gain when the discharge reaches the cathode, to prevent the imaging of secondary streamers.

Information on the inception cloud is relatively hard to derive, since the 3-D morphology of the cloud makes it harder to distinguish the maxima and minima in the intensity. To gain more information, we can reduce the gating frequency and still study the entire discharge [Fig. 1(d)], or we can zoom-in view on this part of the discharge [Fig. 1(e)].

The images show that the surface discharges are faster than the bulk gas streamers. The velocity of bulk gas streamers was determined from the longest streamers, which are assumed to have a small deviation from the vertical image plane. Under the present conditions, we find that surface discharges are typically a factor ~ 2 faster. Bulk gas streamers propagate at around $2 \cdot 10^5$ m/s, compared with $(4–5) \cdot 10^5$ m/s for surface streamers. Inception cloud velocities as low as $\sim 1 \cdot 10^5$ m/s are observed just before the inception cloud breaks up into separate channels.

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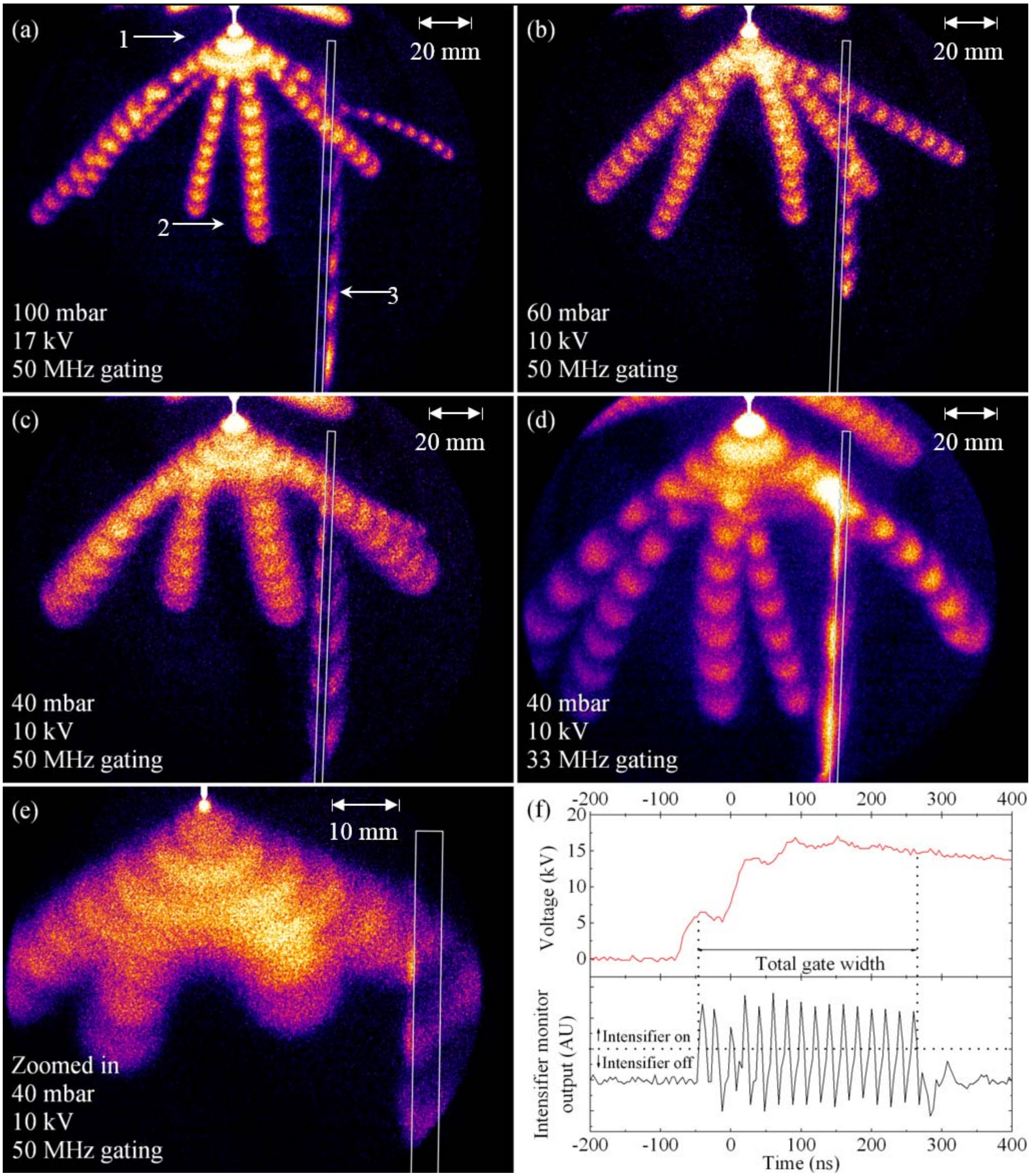

Fig. 1. Stroboscopic images of streamers through air and over dielectric surfaces in air for various pressures and voltages are presented in panels (a)–(e). The anode tip and the dielectric rod are marked in white. The repetition rate of the discharges was 3 Hz. A typical voltage pulse and the monitor output of the intensifier are presented in panel (f). Streamers visible in the top of the image originate from the needle holder. They do not influence the streamer originating from the needle tip to the best of our knowledge.