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Nanosecond Surface Dielectric Barrier Discharge: Experimental investigation of streamer to filament transition in high-pressure gases

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In high-pressure nanosecond surface dielectric barrier discharges (nSDBD) it is common to observe two different type of streamer development: a diffuse mode and a filamentary mode [1-2]. The transition between these modes was defined as the apparition of 2 to 5 filaments with varying applied voltage. In this study, the effects of photoionisation and electronegativity of the gas mixture on the transition voltage were compared for a wide range of pressures and concentrations. In the positive polarity, it was found that photoionisation played a stabilising role on the diffusive discharge for all studied pressures, while electronegativity appeared to reduce the threshold for transition at lower pressures. In the negative polarity, the photoionisation effect was no longer observable while the filament threshold was lowered for more electronegative mixtures. Fundamental understanding of these processes is of great importance in many applications, most of all in plasma-assisted combustion [3-4].

1. Introduction

A common feature of high-pressure nSDBD is the two different streamer propagation modes that exist depending on the pressure and applied voltage, referred to here as the diffuse mode and the filament mode. For a fixed pressure, the diffuse mode with a diameter of roughly 200-300 μm is usually observed at lower applied voltages. With increasing voltage, filament of roughly 20 μm channels appear for every 4 or 5 diffuse streamer observed. This transition is abrupt, typically taking 1 to 2 ns, and accompanied with a sharp rise of electron density from 10^{15} cm^{-3} to 10^{19} cm^{-3} . A transition point was defined as the voltage for which formation of 2 to 5 filaments is observed in the first 12 ns of the discharge as shown in Figure 1(a).

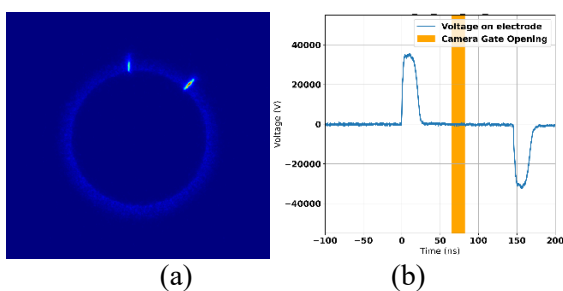


Figure 1:

- (a) ICCD Imaging of the discharge, gate opening of 12 ns
(b) Pulse and reflection with camera gate opening

2. Experimental set-up

In this study, a 20 mm diameter round high-voltage electrode was used. It rests on a 0.3 ± 0.1 mm PVC sheet, held in place on the 50 mm diameter mass electrode by a similarly sized layer of silicon adhesive. Single-shot HV pulses of positive and negative polarities, 20 ns in duration (FWHM), 2 ns rise time and 20-60 kV on HV electrode are

produced by FID Technology pulsers. An example of these pulses is found in Figure 1(b).

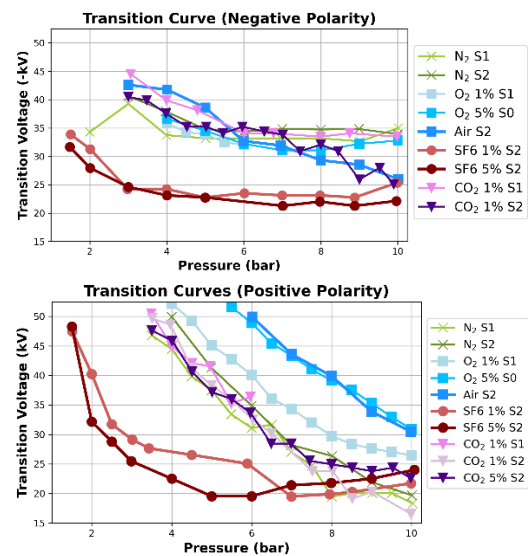


Figure 2: Transition curves in positive and negative polarities for different gas compositions

3. Results

The transition curves obtained for varying gases are shown in Figure 2. Looking first at the positive polarity, the variation of the transition threshold with gas composition is obvious. Using N₂ as the reference, the addition of fractions of O₂ to the mixture appears to increase the transition voltage for a given pressure. This was attributed to photoionisation of the O₂ by electronically excited N₂. For comparison, measurements with CO₂ fractions cannot be differentiated from N₂ transition. As CO₂ cannot be photoionised by the lower energy emissions of N₂, it appears to confirm the stabilising effect that photoionisation plays on the diffuse mode in the positive polarity. This effect does not however

translate in the negative polarity, where all curves are collapsed together.

Finally, looking at the SF₆ fractions, the transition voltage is noticeably lower than all other mixtures. It is of importance to note that in the highest pressures in both polarities, the SF₆ discharges are immediately in filamentary mode, no diffuse mode existing and no discharge lighting before the transition. The trend of transition is somewhat maintained although shifted left, and the addition of even 1% of SF₆ is sufficient to still transition at pressures where, in pure N₂, it would be impossible to get a filament.

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