Determination of photoionization properties of C_4F_7N – N_2 mixture and their application in streamer simulation

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In the gas-filled electric power equipment, SF_6 gas has been extensively used for its insulating properties [1]. However, due to its high global warming potential, alternatives to SF_6 are being considered. A promising candidate is the C_4F_7N gas and its mixtures, e.g. with CO_2 or N_2, offering high electronegativity, and significantly inhibiting discharge inception and propagation. In a gas, where excited states produce ionizing radiation, the question of photoionization is of interest. The effect of photoionization is significant in some gases, e.g. in air [2]. In contrast, in other gases the ionizing radiation, even if produced, may be quickly absorbed without ionization, e.g in CO_2 [3]. In this work, we study the effect of the photoionizing radiation on the streamer propagation in a nitrogen - C_4F_7N mixture .

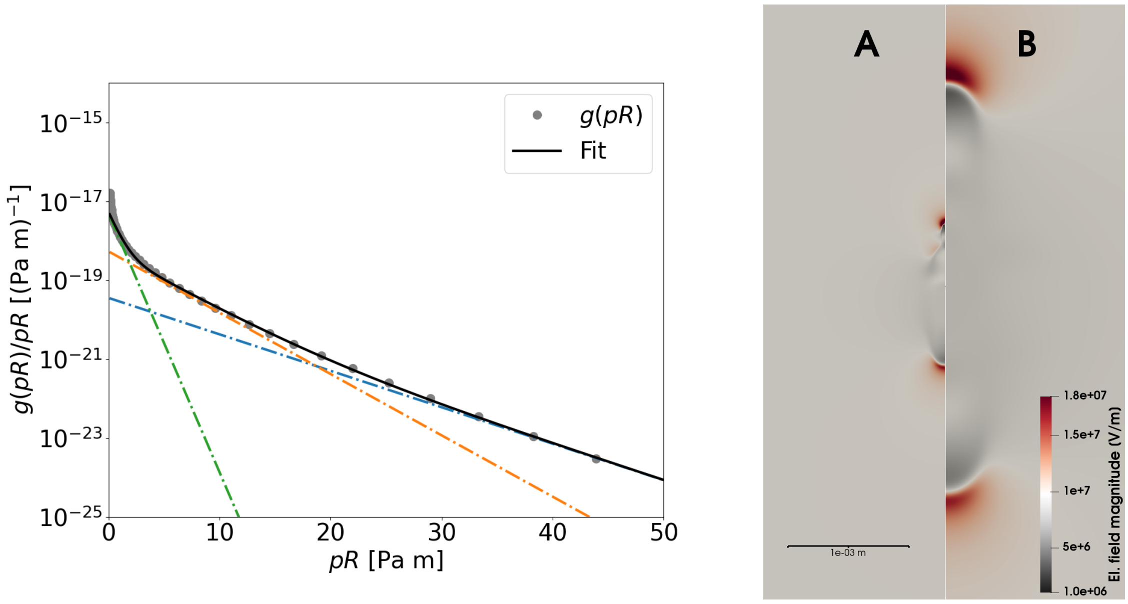

Fig. 1: *Left:* The fit of the photon propagator function for 10% C_4F_7N 90% N_2 mixture. *Right:* Electric field magnitude comparison in axisymmetric streamer simulation of double-headed streamers propagating from a seed charge cloud: (A) without and (B) with photoionization model.

We model the ionizing radiation by a system of screened Poisson's equations as proposed in [2, 4, 5]. The parameters are obtained by the procedure suggested in [6] where the coefficients l_j and A_j are obtained from fitting the function:

$$\frac{g(pR)}{pR} = \sum_j A_j \mathrm{e}^{-l_j pR} \tag{1}$$

where $g(pR)$ is the photon propagator. Based on the experimental data, C_4F_7N in mixture with N_2 may be ionized by the radiation emitted by excited nitrogen states, similarly as oxygen molecules are in nitrogen-oxygen mixtures (e.g., in air).

The input data used in this model were measured for this work. The photoabsorption cross-section of C_4F_7N [7] was measured on the AU-UV beamline of the ASTRID2 synchrotron in Aarhus, Denmark, and the photoionization cross-section [8] was measured on the VUV beamline of the SLS synchrotron in Villigen, Switzerland.

From these data, the photon propagator function is constructed and fitted (see Fig.1 (left)). Radiation from plasma is assumed to originate solely from the excited nitrogen states and is assumed to have the same emission rate as is assumed in the photoionization model for air.

The effect of the inclusion of the photoionization model is shown in fluid dynamics streamer simulation. We compare double-headed streamers modeled in C_4F_7N - N_2 mixture when this photoionization model is used and without it (Fig.1 (right)). The use of photoionization results in a wider streamer channel and faster streamer propagation. As expected, while the negative streamer initiates easily without photoionization, the propagation of the positive streamer is significantly enhanced with the addition of photoionizing radiation.

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