Influence of Initial Electrons and Electron Multiplication on Formative Time Lag in Gaseous Breakdown

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The formative time lag in the gaseous breakdown strongly depends on the amount of initial electrons and the electron multiplication in the electron avalanche. We discuss their influence on the formative time lag.
In the conventional linear breakdown theory, infinite time is required for starting breakdown. By defining the critical electron density required for starting breakdown, a finite time delay can be obtained. Therefor we can discuss the influence of the initial electrons and the electron multiplication on the time delay, that is the formative time lag.
This is a summary of a part in the previous report titled "A Comment on Formative Time Lag of Gaseous Breakdown".

Condition for shortest Formative Time Lag

The formative time lag is determined by the time when the electron density at the anode near region increases up to the critical density n_e* for starting the breakdown.

If the breakdown starts in the single process of electron avalanche, the formative time lag becomes the shortest time.

In order to start the breakdown in only one electron avalanche, the amount of the initial electrons is required to be the critical density n_{e0}* and then the shortest formative time lag t_{fmis} is given as follows.

$$n_{e0}^{*}=n_e^{*}\exp\left(\frac{-d}{\lambda_i}\right)$$

$$t_{fmin}=\frac{\lambda_i}{v_e}\ln\left(\frac{n_e^{*}}{n_{e0}^{*}}\right)=\frac{\lambda_i}{v_e}\ln\left(\exp\left(\frac{d}{\lambda_i}\right)\right)=\frac{d}{v_e}$$

Where λ_ι. d and v_e are the main ionization length, the gap separation and the electron velocity, respectively.

The shortest formative time lag is achieved when the amount of initial electrons is much large, n_{e0} *>~* n_{e0}**, and essentially depends on the transit time of initial electrons.*

Cf: The critical electron density n_e^* is obtained from the hypothesis of micro-plasma appearance at anode near region and n_e^* is expressed as

$$n_e^{*}\sim\frac{\varepsilon_0}{e}\left(\frac{e\phi_i}{T_{eV}}\right)\frac{\varphi_i}{\lambda_{i0}^{2}}p^{2}$$

Relationship between Formative Time Lag and Initial Electrons under Condition of Electron Multiplication $M=\gamma_p e^{d/\lambda}$ 1/2

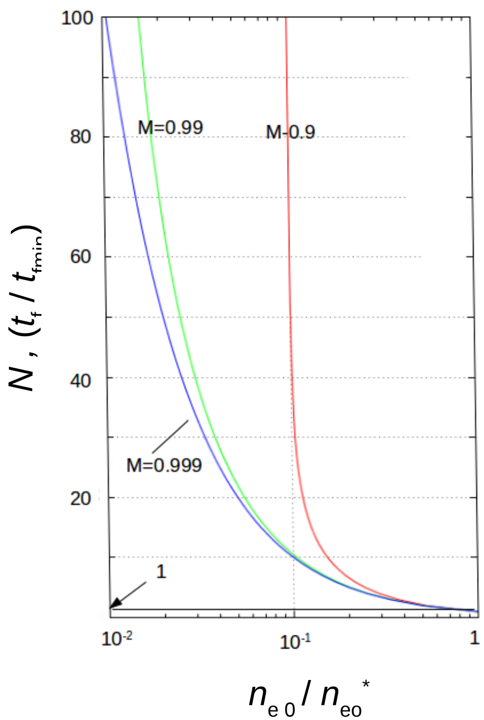
If the breakdown starts after *N* repetition avalanches, the amount of initial electrons n_{e0} is obtained from the following formula.

$$n_e^* = n_{e0}^* e^{\frac{d}{\lambda_i}} = \left(\frac{1-M^N}{1-M}\right) n_{e0} e^{\frac{d}{\lambda_i}}, \qquad M = \gamma_p e^{\frac{d}{\lambda_i}} \leq 1$$

The relationship between n_{e0} and *N* is given by

$$\frac{n_{e0}}{n_{e0}^*} = \left(\frac{1-M}{1-M^N}\right)$$

Following figure shows *N* as a function of n_{e0} in the range of $0.9 < M < 0.999$. When $M = 0.999$ and $n_{eo} \sim 10^{-1} n_{e0}^*$, we find that it appears 10 times of avalanches for starting breakdown. If M = 0.9, the breakdown does not occur in the range of $n_{e0} < 10^{-1} n_{e0}^*$. The breakdown does not occur in the left region of the curve. Where *N* means the ratio of t_f / t_{fmin}.



Relationship between Formative Time Lag and Initial Electrons under Condition of Electron Multiplication $M=\gamma_p e^{d/\lambda}$ 2/2

If the value of *M* is extremely close to unity. (*M*=1 is the self-sustaining condition of Townsend discharge), the equation,

$$\frac{n_{e0}}{n_{e0}^*}=\left(\frac{1-M}{1-M^N}\right)$$

is rewritten as follows by using $M^N \sim (1+\ln(M))N$,

$$N \sim \left(\frac{M-1}{\ln(M)}\right)\left(\frac{n_{e0}}{n_{e0}^*}\right)^{-1}$$

Furthermore, ln(*M*) can be approximated to be ln(*M*)~(*M*-1).
Therefore, *N*, that is the formative time lag, expects to be inversely proportional to n_{eo}.

In order to realize the shorter formative time lag, enough amount of initial electrons and the electron multiplication close to 1 are expected.