Front-Sheath of Micro-Plasma Appeared at the Time of Just Starting Breakdown in Gases

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Revised report of the expression associated with the front-sheath in previous presentation “An Estimation of Critical Electron Density at Just Starting Breakdown in Gases Gases “

A Hypothesis for the Appearance of Micro-Plasma at Anode Near Region

Relationship between threshfold field and plasma parameter

$$E^* = \frac{\phi_i}{\lambda_i} = \frac{T_{eV}/e}{\lambda_D}$$

T_{eV} electron temperature in eV

λ_D Debye shielding length

$E \approx 0$ in the plasma column

E^* would be shielded electrically by the polarization of plasma particles. It is best that T_{ev} should be confirmed theoretically by the plasma balance equation. Usually T_{eV} is in the range of several eV.

Critical Electron Density n_e^* at Just Starting Breakdown in Gases

$$\frac{\phi_i}{\lambda_i} = \frac{T_{eV}/e}{\lambda_D}, \qquad \frac{1}{\lambda_D} = \left(\frac{n_e^* e^2}{\varepsilon_0 T_{eV}}\right)^{1/2}$$

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

$$\frac{e\phi_i}{T_{eV}} \approx 5, \quad \phi_i = 10\ \mathrm{V}, \quad \lambda_i = 5\times10^{-4}/P[\mathrm{atm}] \quad \mathrm{cm}$$

$$n_e^* \approx 10^{14}\, p^2 \ \ \mathrm{cm}^{-3} \qquad p \ \text{in atm}$$

Space Charge Density in Front-Sheath and Electron Temperature in Micro-Plasma

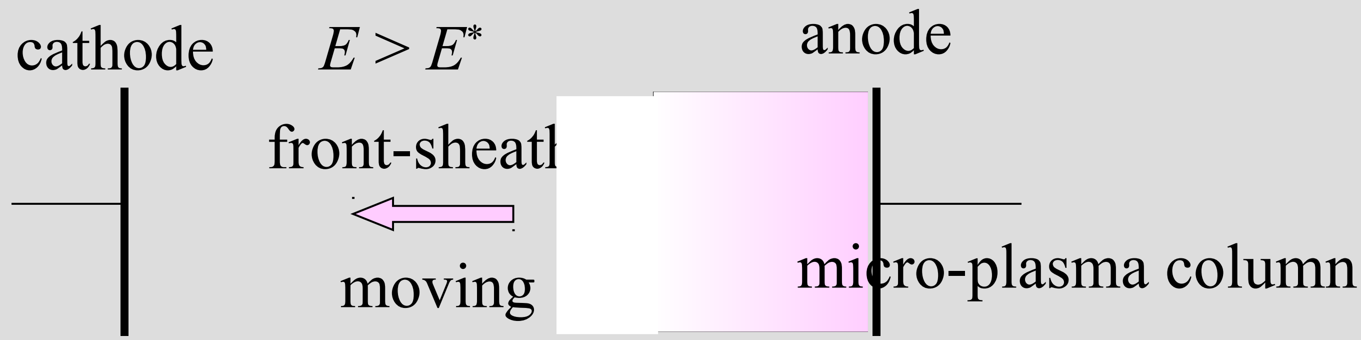
$$n_e^* = \left(\frac{e\phi_i}{T_{eV}}\right)\frac{\varepsilon_0}{e}\frac{\phi_i}{\lambda_i^2}, \quad n_{is} \approx n_e^*\left(1+e^{-1}\right)\left(\frac{1}{2}\right) \approx \left(\frac{2}{3}\right)n_e^*$$

$$\frac{\varepsilon_0}{e}\nabla^2\phi \approx \frac{\varepsilon_0}{e}\frac{\phi_i}{\lambda_i^2} \approx n_i \approx \left(\frac{2}{3}\right)n_e^* \text{ in front - sheath}$$

$$n_e^* = \left(\frac{e\phi_i}{T_{eV}}\right)\frac{\varepsilon_0}{e}\frac{\phi_i}{\lambda_i^2} \approx \left(\frac{e\phi_i}{T_{eV}}\right)\left(\frac{2}{3}\right)n_e^* \quad \Rightarrow \quad \left(\frac{e\phi_i}{T_{eV}}\right) \approx \frac{3}{2}$$

Electron temperature in micro-plasma could be estimated to be $(T_e/e\phi_i)$~(2/3) from mean ion density n_{is} in front sheath

Relationship between Micro-Plasma Column and its Front-Sheath at Starting Breakdown

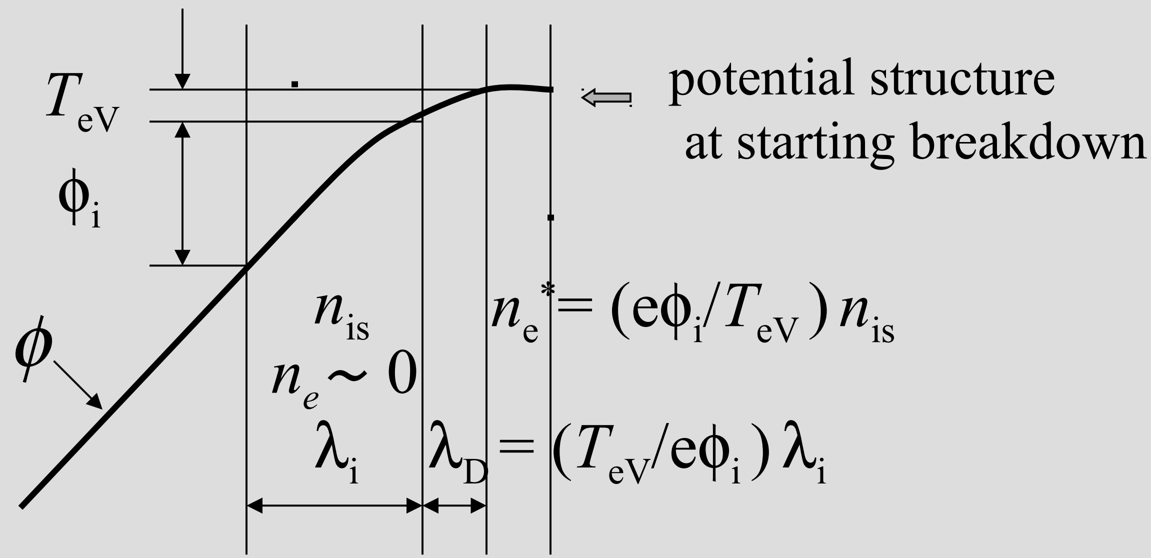


space charge density
in front-sheath

$$n_{is} \approx \frac{2}{3} n_e^*$$

$$\approx \frac{\varepsilon_0}{e} \cdot \frac{\phi_i}{\lambda_i^2} = \left(\frac{T_{eV}}{e\phi_i} \right) n_e^*$$

$$\frac{T_{eV}}{e\phi_i} \approx \frac{2}{3}$$



Summary

Following hypothesis for the appearance of micro-plasma at anode near region, seems to be correct. Breakdown is just starting when the micro-plasma appears at anode near region.

$$E^* = \frac{\phi_i}{\lambda_i} = \frac{T_{eV}/e}{\lambda_D}$$

$E \approx 0$ in the plasma column

E^* is shielded electrically by the polarization of plasma particles

We can estimate the critical electron density and electron temperature at just starting breakdown by using the above formula.

$$n_e^* = \left(\frac{e\phi_i}{T_{eV}}\right)\frac{\varepsilon_0}{e}\frac{\phi_i}{\lambda_i^2} = \left(\frac{e\phi_i}{T_{eV}}\right)\frac{\varepsilon_0}{e}\frac{\phi_i}{\lambda_{i0}^2}\cdot p^2,$$

$$\frac{\varepsilon_0}{e}\nabla^2\phi \approx \frac{\varepsilon_0}{e}\frac{\phi_i}{\lambda_i^2} \approx n_i \approx \left(\frac{2}{3}\right)n_e^* \text{ in front - sheath}$$

$$n_e^* \approx \left(\frac{e\phi_i}{T_{eV}}\right)n_{is}, \quad n_{is} \approx \left(\frac{3}{2}\right)n_e^*, \quad \frac{e\phi_i}{T_{eV}} \approx \frac{3}{2}$$