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Federal University of Santa Catarina
Graduate Program in Engineering and Mechanical Sciences

Plasmas and electrical discharges in gases

(ECM410054)

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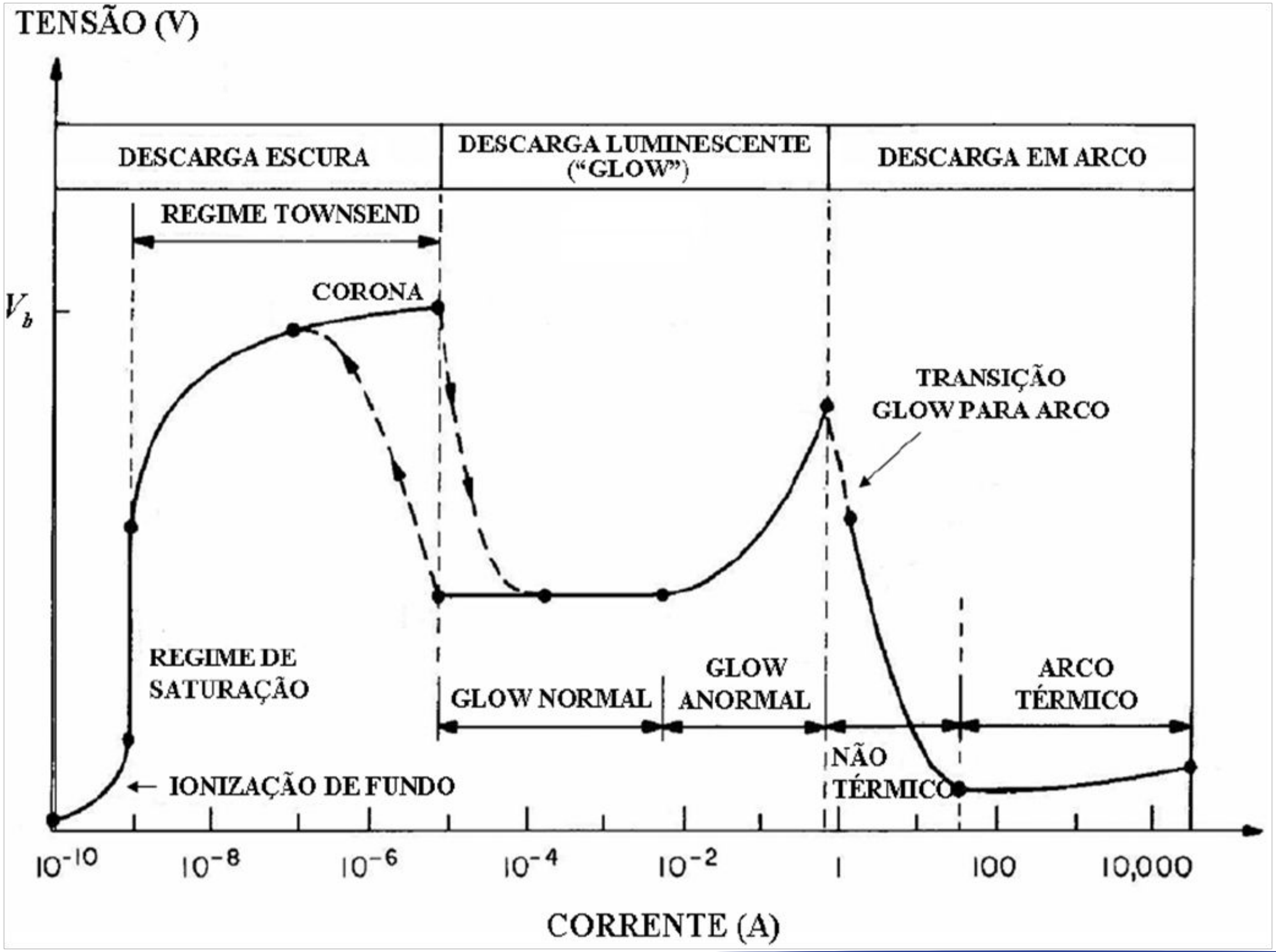
SUMMARY
Plasmas and electrical discharge in gases

- Kinetic theory of gases
- Atomic structure
- Ionization
- Deionization
- Electron emission
- ~~Behavior of charged particles in a gas in electric fields of low E/p~~
- Behavior of charged particles in a gas in electric fields of high E/p
- Glow discharges
- Plasmas

CHARGED PARTICLES IN HIGH E/p

The current-voltage relation



CHARGED PARTICLES IN HIGH E/p
Coefficient of ionization by electron collision

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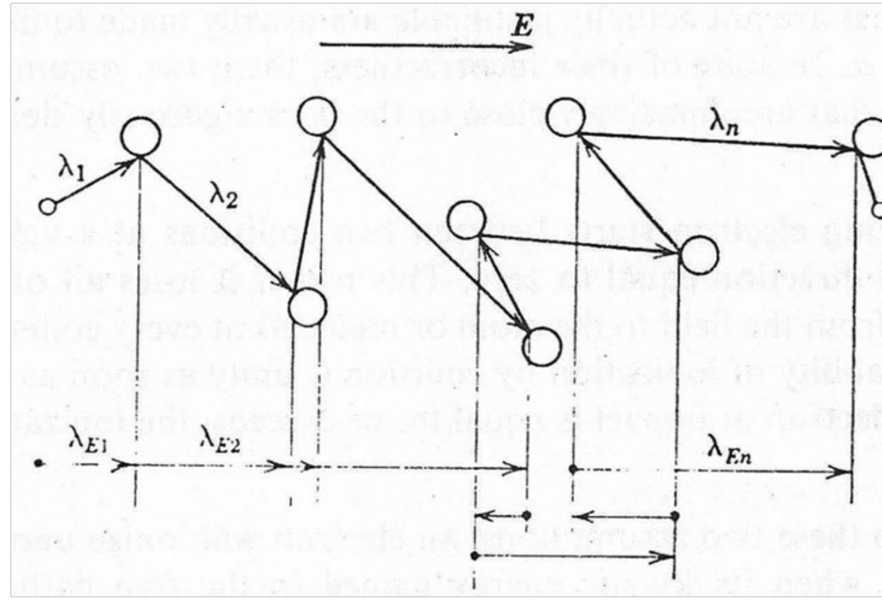
The general condition for gas ionization is:

$$eE\lambda_i \geq eV_i$$

where λ_i and V_i are the free path in the direction of the electric field and the potential of ionization, respectively. Then,

$$\lambda_i \geq \frac{V_i}{E}$$



The number of free paths n with length equal to or greater than x is given by:

$$n = n_0 \exp\left(-\frac{x}{\lambda}\right)$$

where n_0 is the total number of free paths and λ the gas mean free path (where $\lambda = 1/n_0$). Replacing x by λ_i we get the number of ionizing collisions α in the direction of the electric field:

First Townsend coefficient

$$\alpha = n_0 \exp\left(-\frac{V_i}{\lambda E}\right) = \frac{1}{\lambda} \exp\left(-\frac{V_i}{\lambda E}\right)$$

CHARGED PARTICLES IN HIGH E/p
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where $1/\lambda = Ap$:

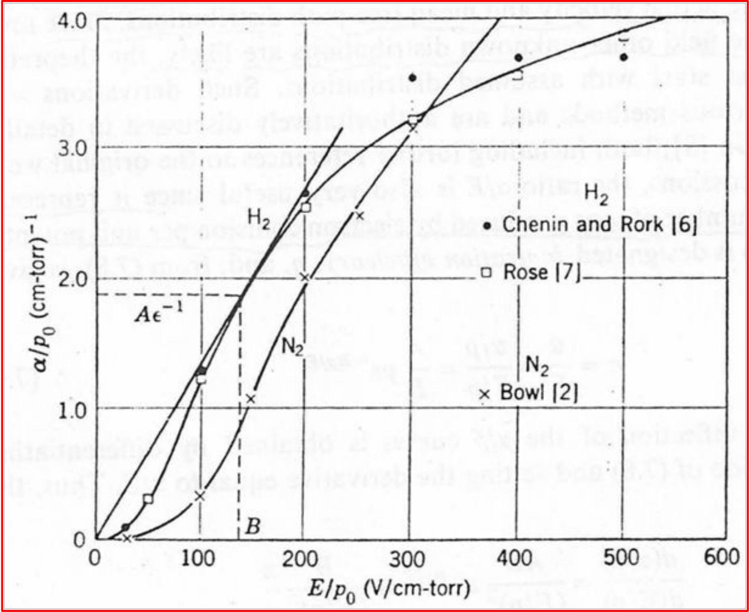
$$\alpha = \frac{1}{\lambda}\exp\left(-\frac{V_i}{\lambda E}\right) = Ap\exp\left(-\frac{AV_i p}{E}\right) = Ap\exp\left(-\frac{Bp}{E}\right)$$

that can also be written in the form ($B = AV_i$):

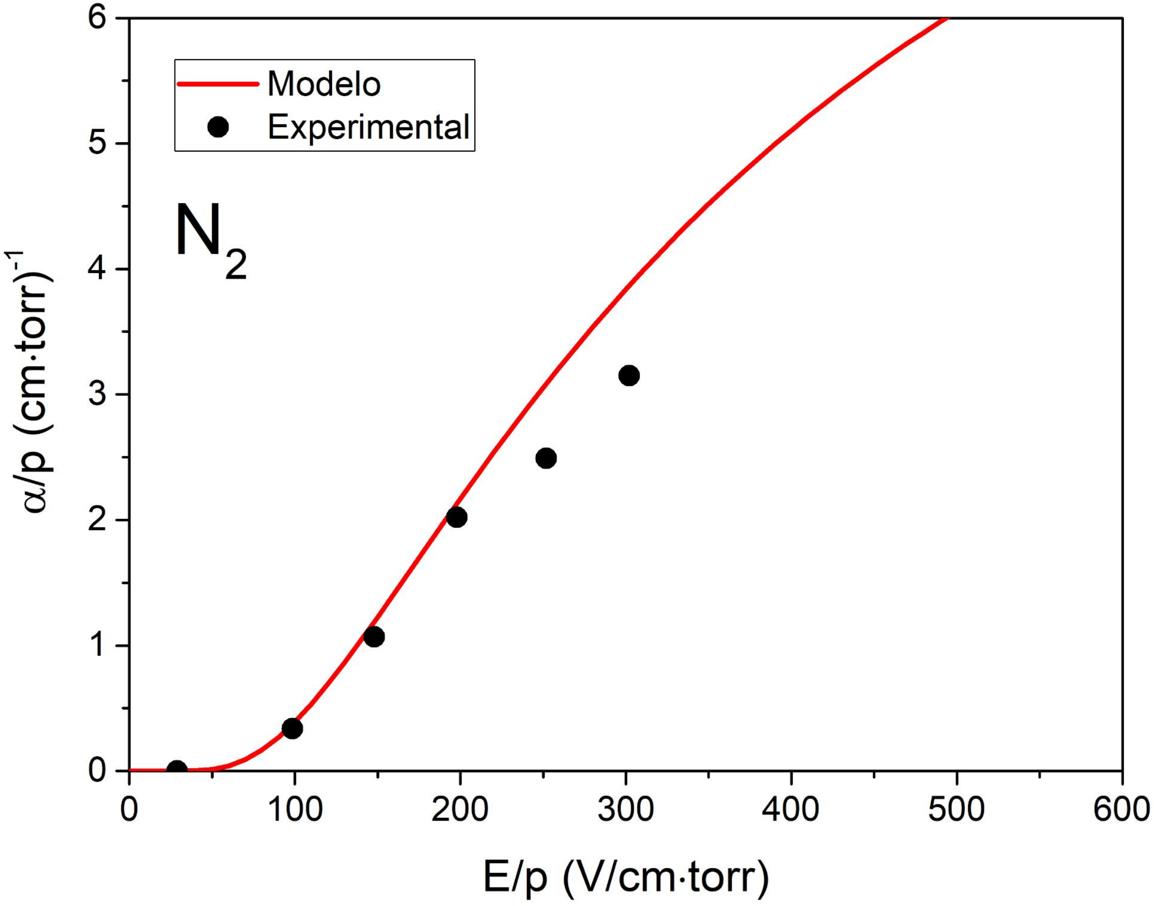
$$\frac{\alpha}{p} = A\exp\left(-\frac{B}{E/p}\right)$$

where A and B are constants for each specific gas.

Gas	A ionizations/cm-torr	B V/cm-torr	E/p Validity Range V/cm-torr
Air	15	365	100–800
N_2	12	342	100–600
H_2	5.1	138.8	20–600
He	3	34	20–150
Ne	4	100	100–400
A	14	180	100–600
Kr	17	240	100–1000
Xe	26	350	200–800



CHARGED PARTICLES IN HIGH E/p
Coefficient of ionization by electron collision



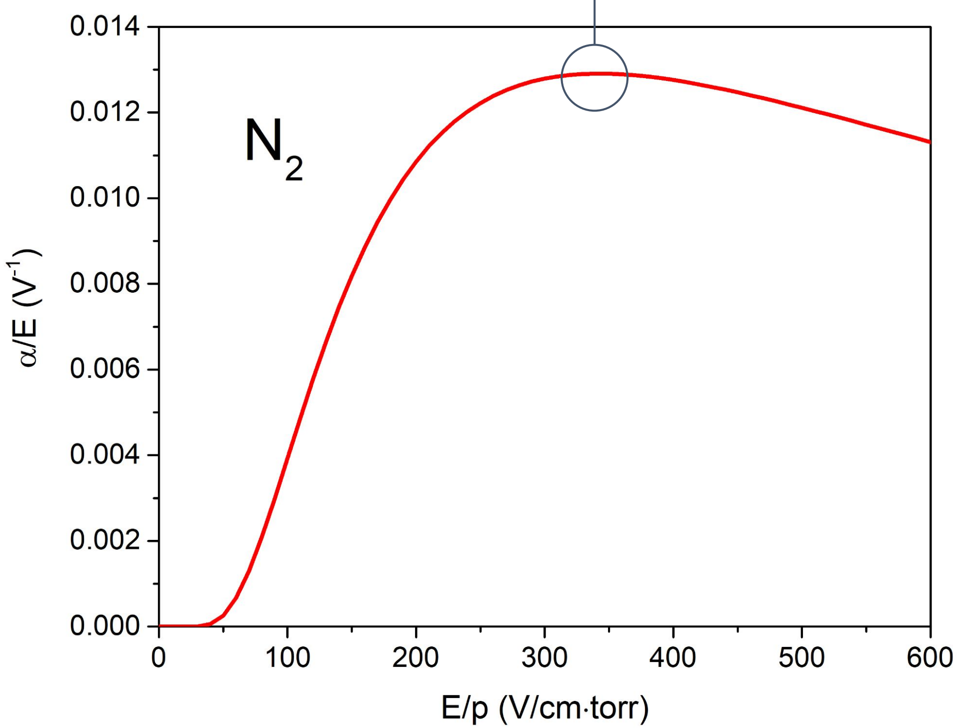
$$\frac{\alpha}{p} = A \exp\left(-\frac{B}{E/p}\right)$$

A = 12 ionizations/cm·torr
B = 342 V/cm·torr

CHARGED PARTICLES IN HIGH E/p
Ionization efficiency

The ionization efficiency η (ionizations per unit potential drop) is defined as:

$$\eta = \frac{\alpha}{E} = \frac{A}{E/p} \exp\left(-\frac{B}{E/p}\right)$$



$$\boxed{\frac{d\eta}{d(E/p)} = 0 \ \therefore \ \frac{E}{p} = 342 \text{ V/cm} \cdot \text{torr}}$$

For a given gas, the maximum point is given by:

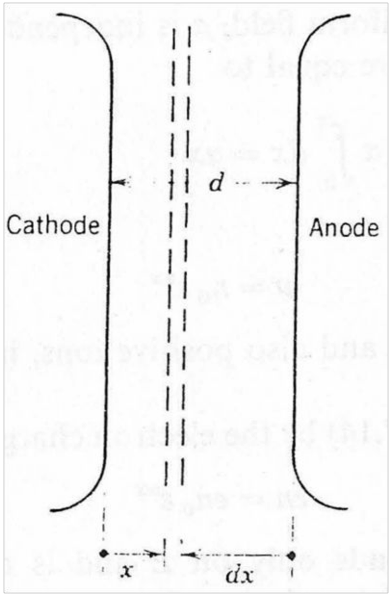
$$\frac{d\eta}{d(E/p)} = 0 \ \therefore \ \left(\frac{E}{p}\right)_{\text{critical}} = B$$

CHARGED PARTICLES IN HIGH E/p
Determination of α

The number electrons produced is given by:

$$dn = \alpha n dx \ \therefore \ n(x) = n_0 \exp(\alpha x)$$

where n_0 is the density of electrons leaving the anode (primary electrons). Rewritten the above equation, we get the current flowing between the electrodes:



$$\boxed{i(x) = i_0 \exp(\alpha x)}$$

Curve	E(kV/cm)
1	36
2	32
3	30
4	28
5	26
6	24
7	22
8	20

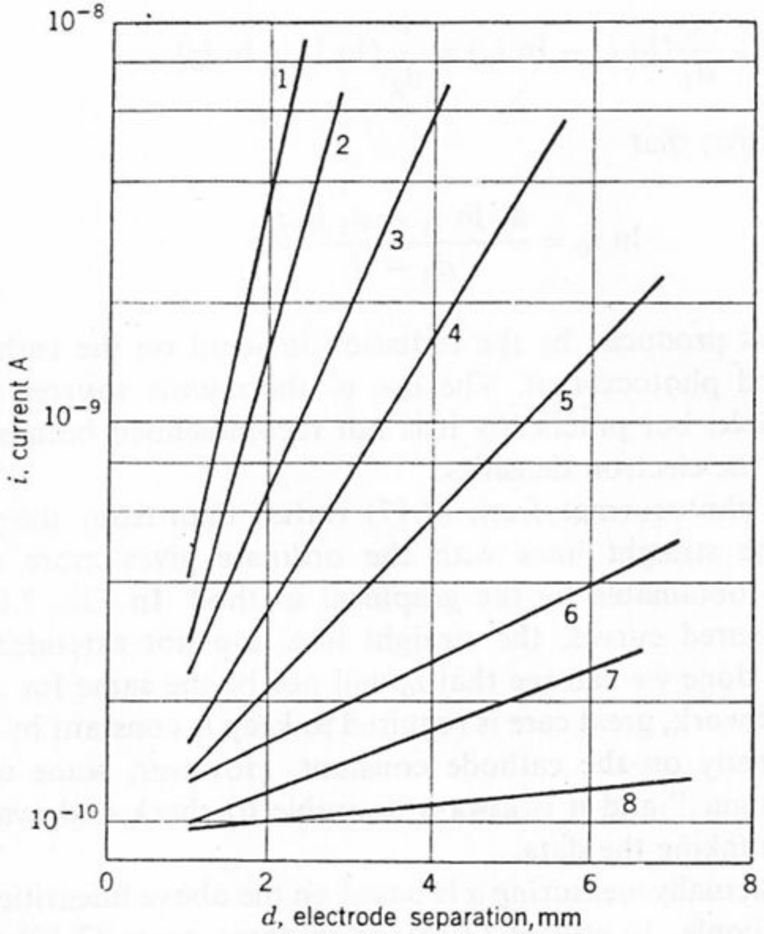


Fig. 7.6 The current i as a function of gap distance d at different values of E/p in contaminated air at $p = 747$ torr [6].

ELECTRON EMISSION
Reading

- Chapter 7 - E. Nasser, Fundamentals of Gaseous Ionization and Plasma Electronics (pages 188-201).

See you next topic!

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