INTRODUCTION TO LOW TEMPERATURE PLASMAS

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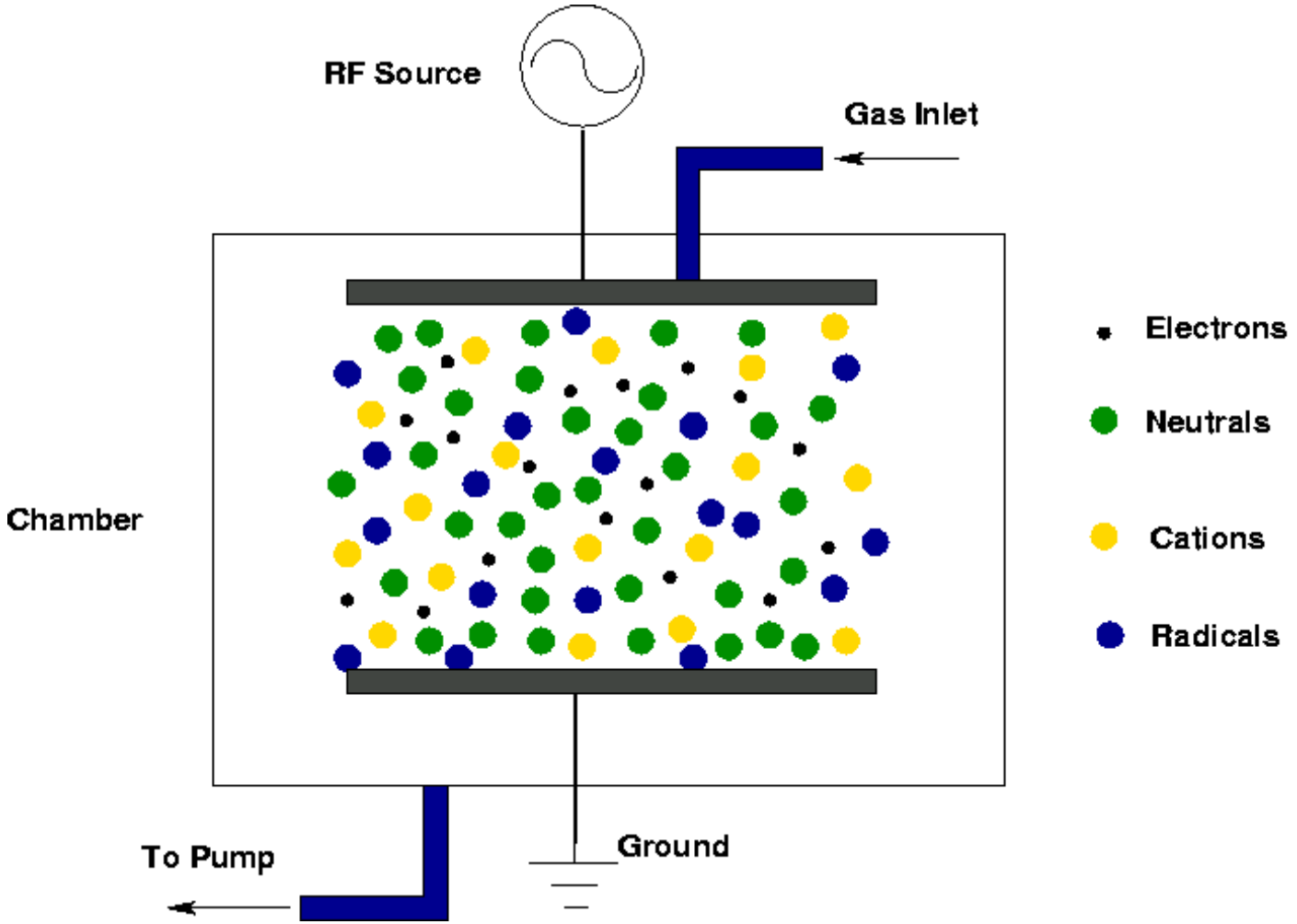
PLASMA – IONIZED GAS



PLASMA – CHARACTERISTICS

1. Quasi-neutrality

2. Collective Behaviour

3. Length scale is far greater than a Debye Length

4. Number density per Debye sphere far greater than ONE.

PLASMA - CLASSIFICATION

High Temperature Plasmas:

Mostly equilibrium plasmas at high pressures.

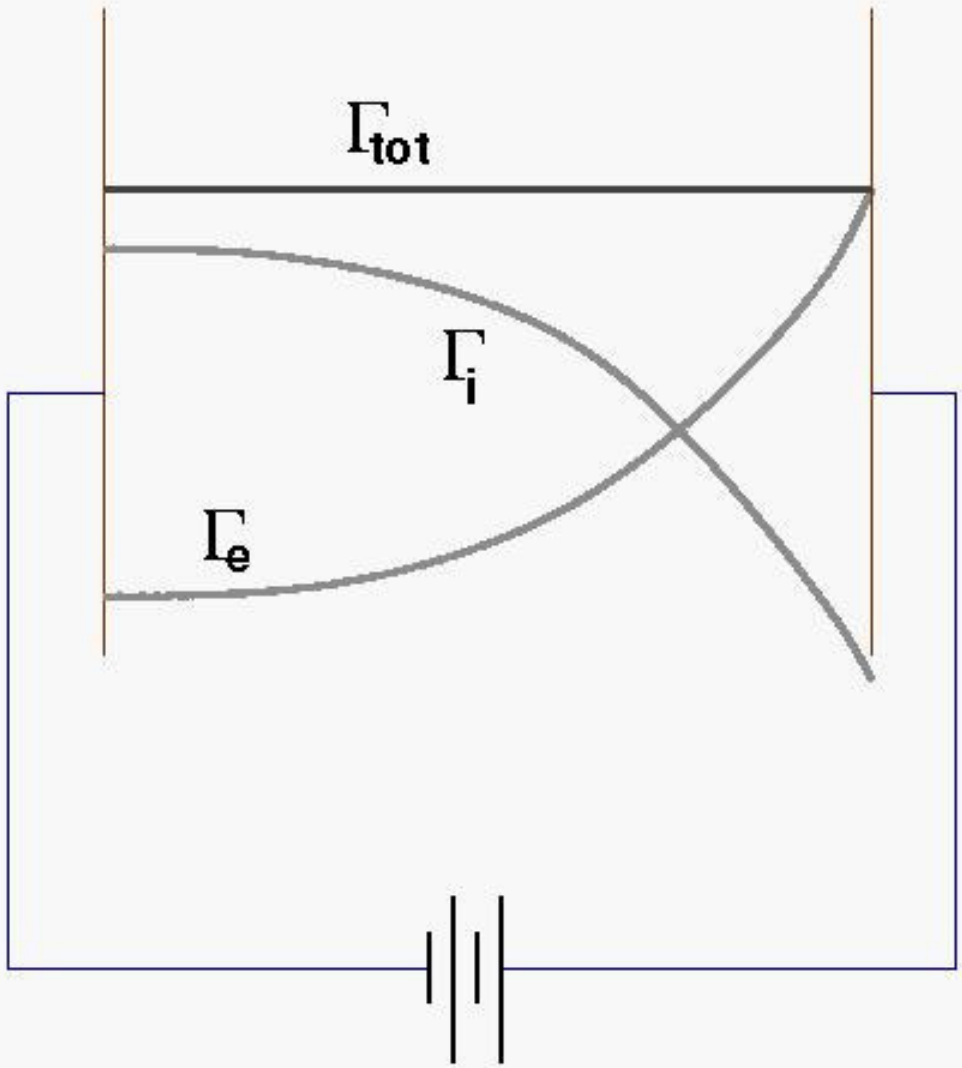
e.g. Arcs, lightning, stars.

Low Temperature Plasmas:

Mostly non-equilibrium plasmas at low pressures.

e.g.; Glow discharges (neon lights), Fluorescent tubes, sputtering plasmas, low temperature deposition plasmas.

PLASMA – TOWNSEND DISCHARGE

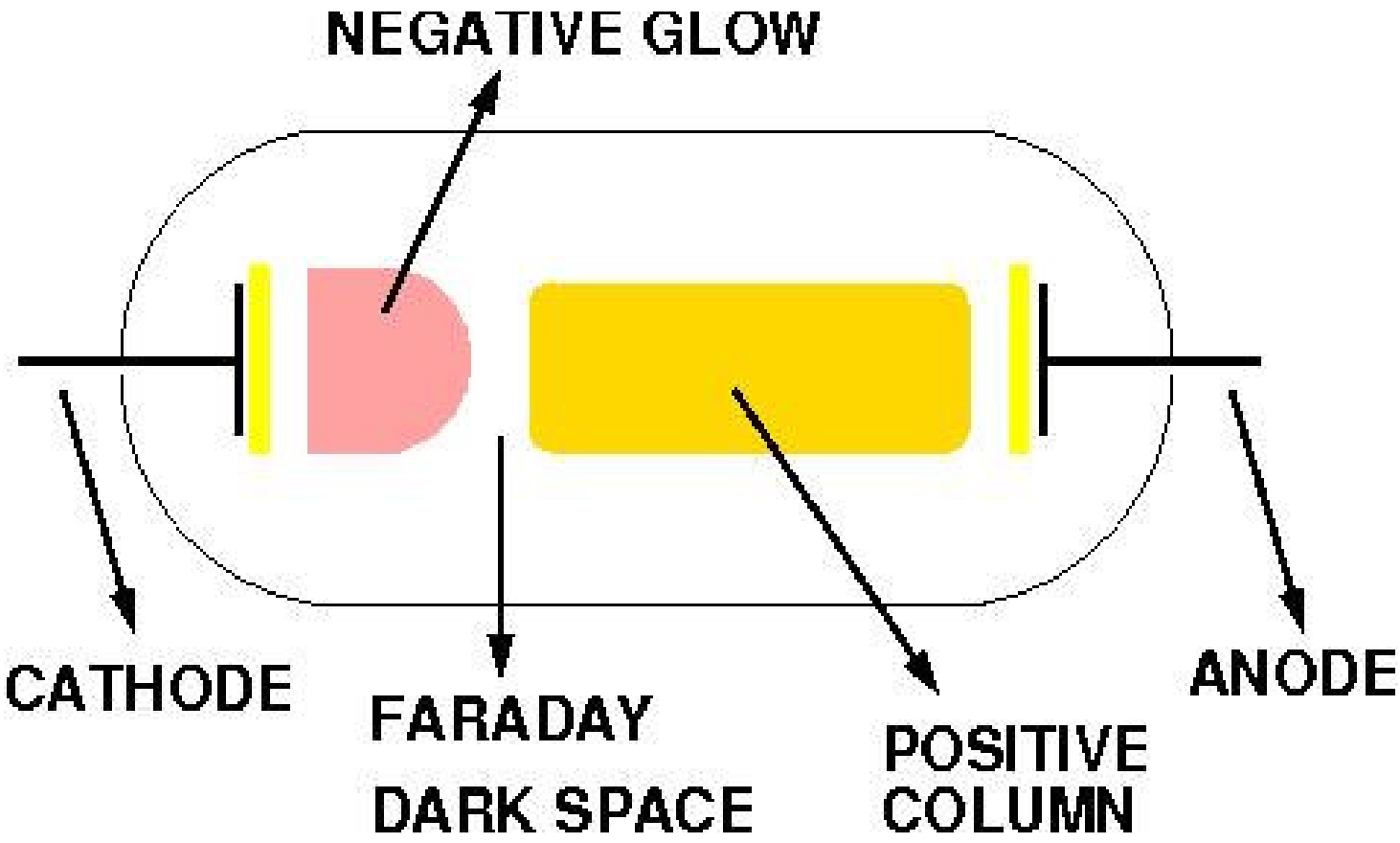


$$\Gamma_{tot} = \Gamma_e + \Gamma_i$$

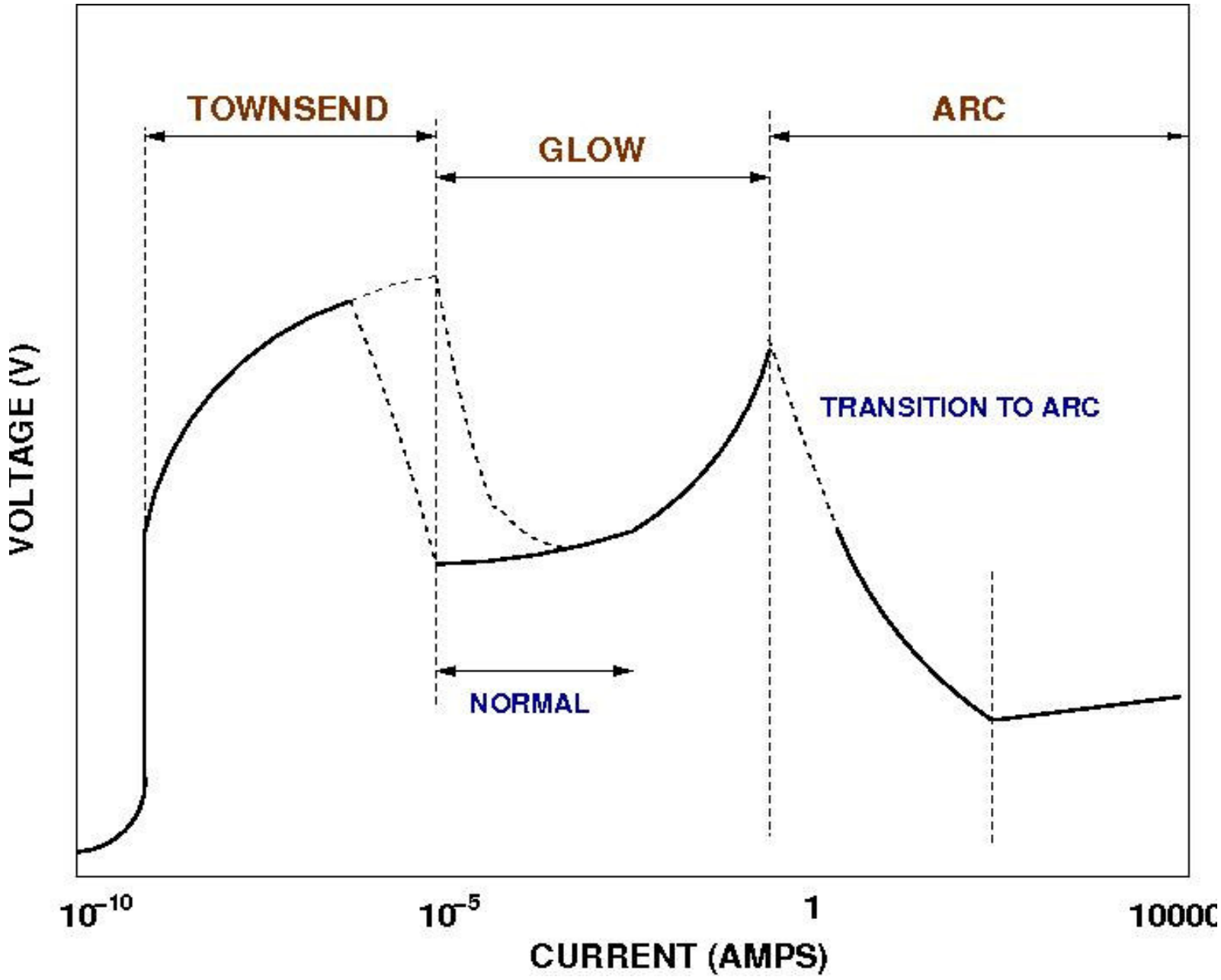
$$\Gamma_e(0) = \gamma_{se}\ \Gamma_i(0)$$

$$1 + 1/\gamma_{se} = \exp\left[\int_0^d \alpha(z)\,dz\right]$$

PLASMA – GLOW DISCHARGE

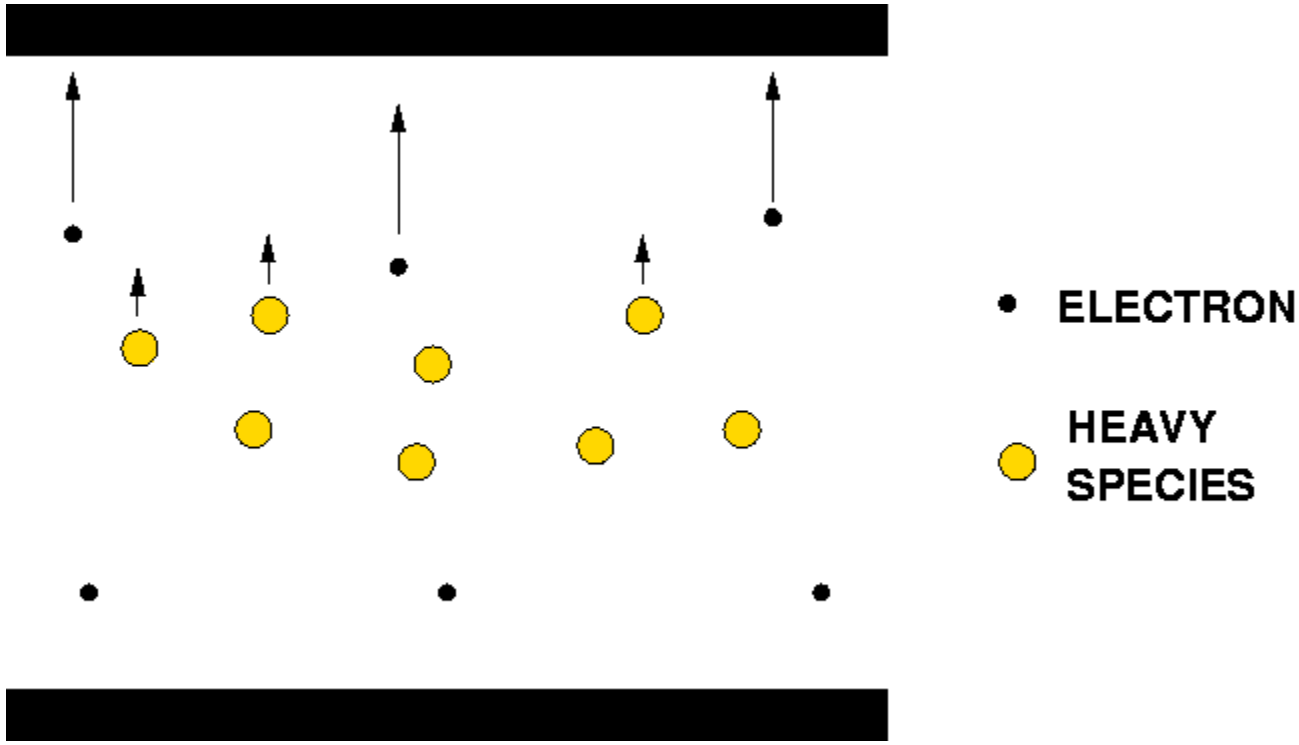


PLASMA: V-I CHARACTERISTIC



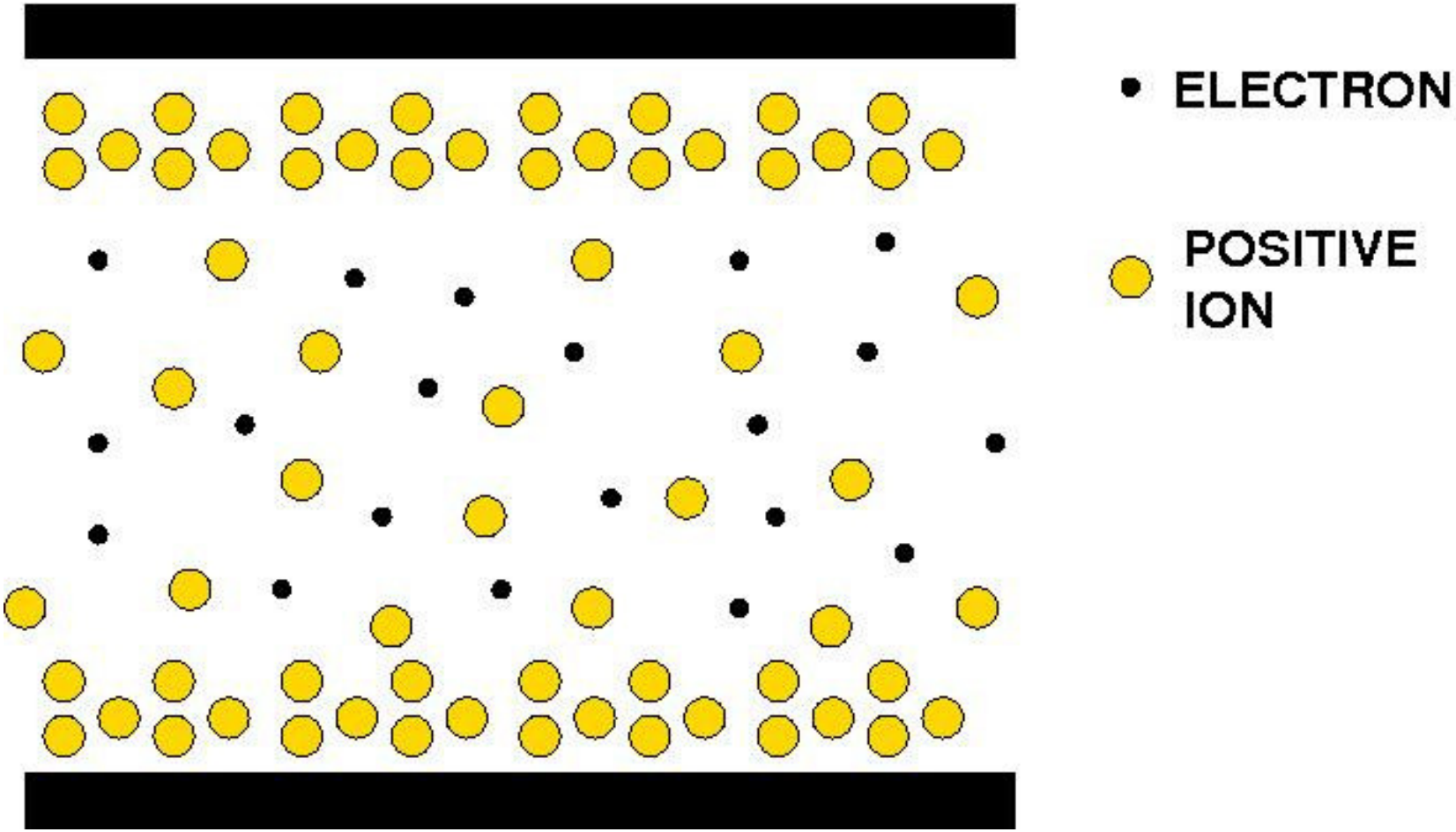
ELECTRONS ARE FAST

Electrons are fast and charge a surface negatively.



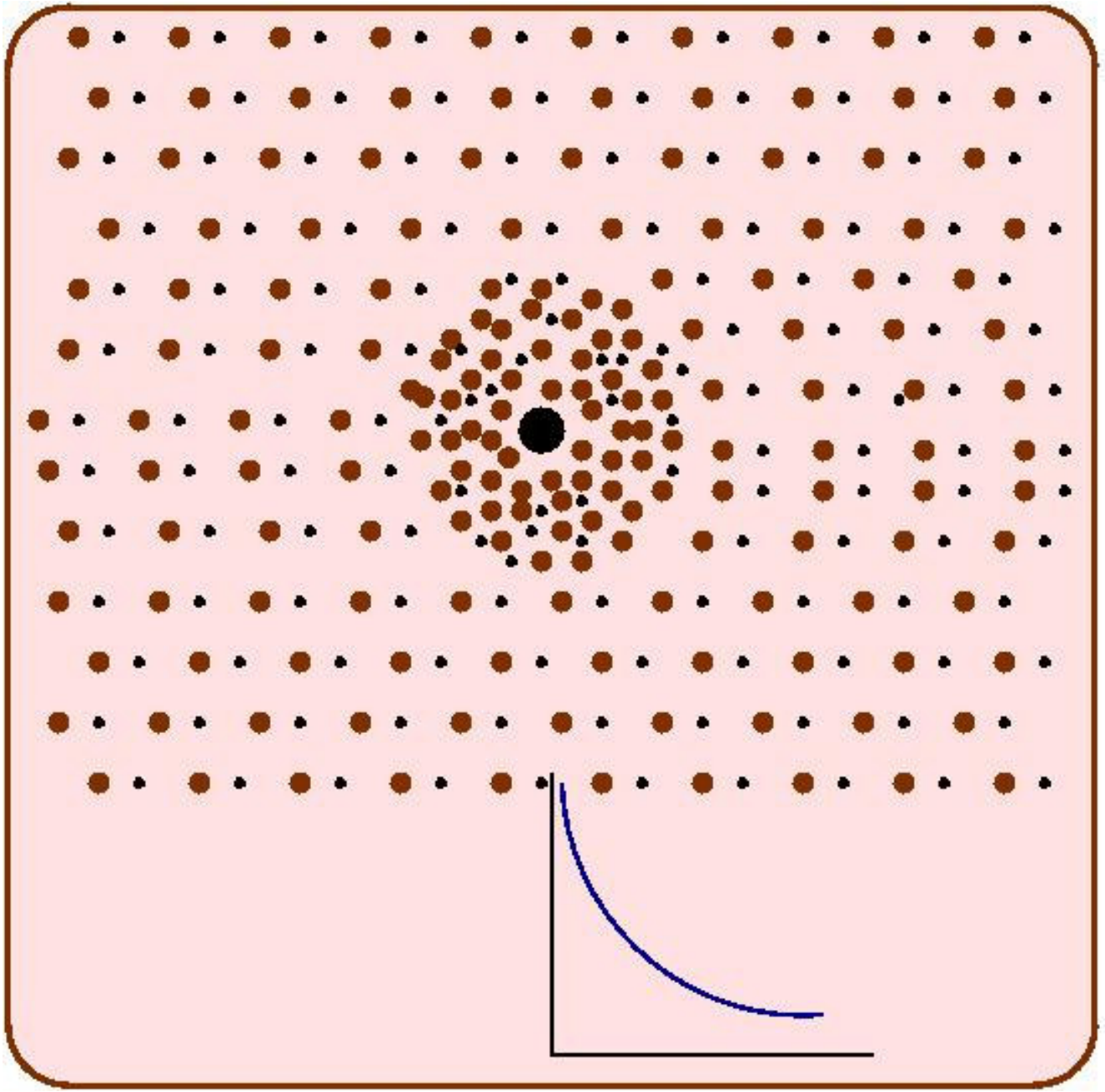
SHEATH FORMATION

A positive space charge sheath forms near any surface.



Sheath is a few **Debye** lengths in thickness.

DEBYE LENGTH



$$\lambda_D = \left(\frac{\varepsilon_o k T_e}{n e^2} \right)^{1/2}$$

RF PLASMAS

DC plasmas cannot be used once the substrate becomes insulating.

We then go for AC to sustain the plasma.

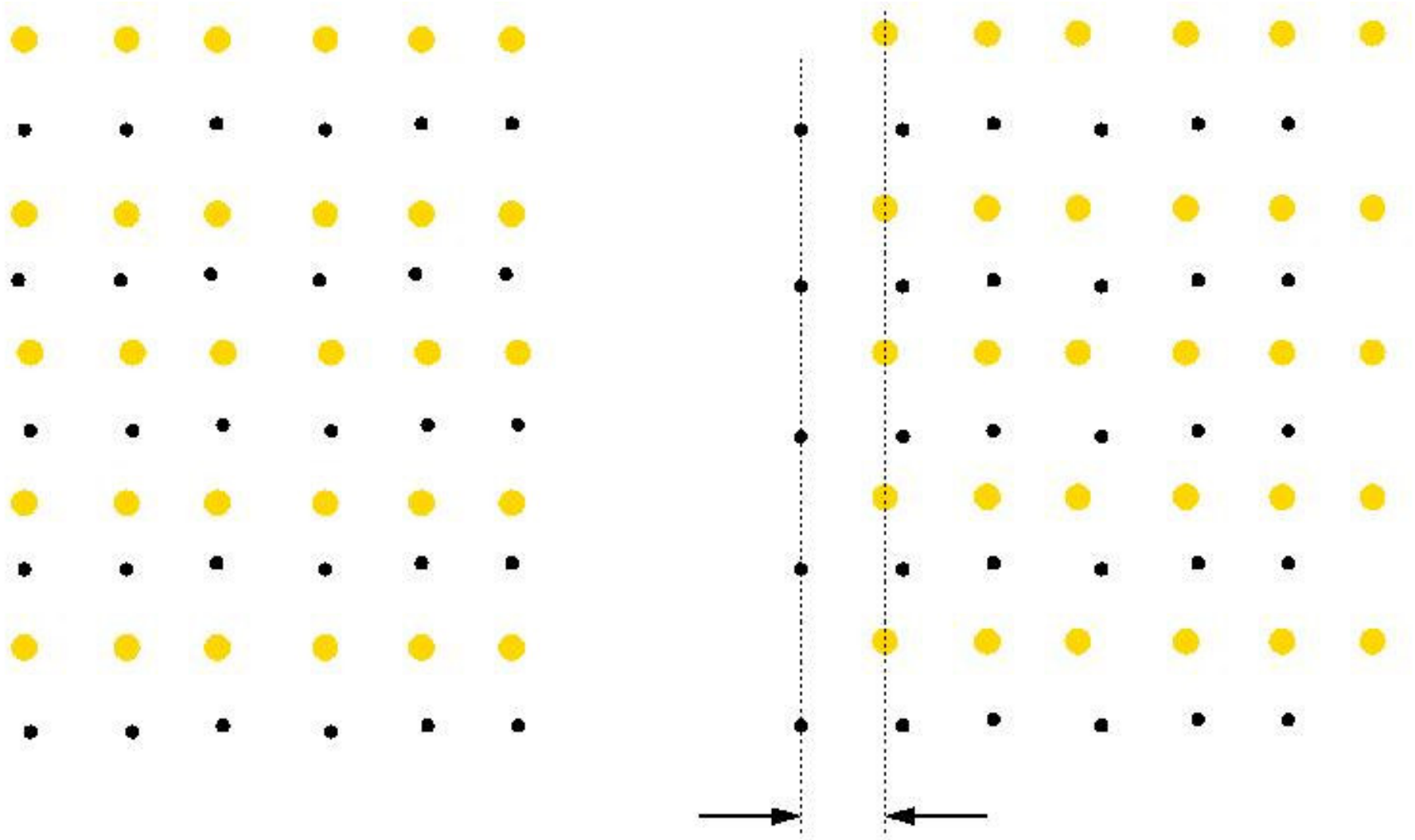
Radio-frequency (RF) plasmas are the most common plasmas seen in operation. The most common frequency used is 13.56 MHz.

RF plasmas are usually coupled using:

1) Capacitive coupling.

2) Inductive coupling.

PLASMA FREQUENCY

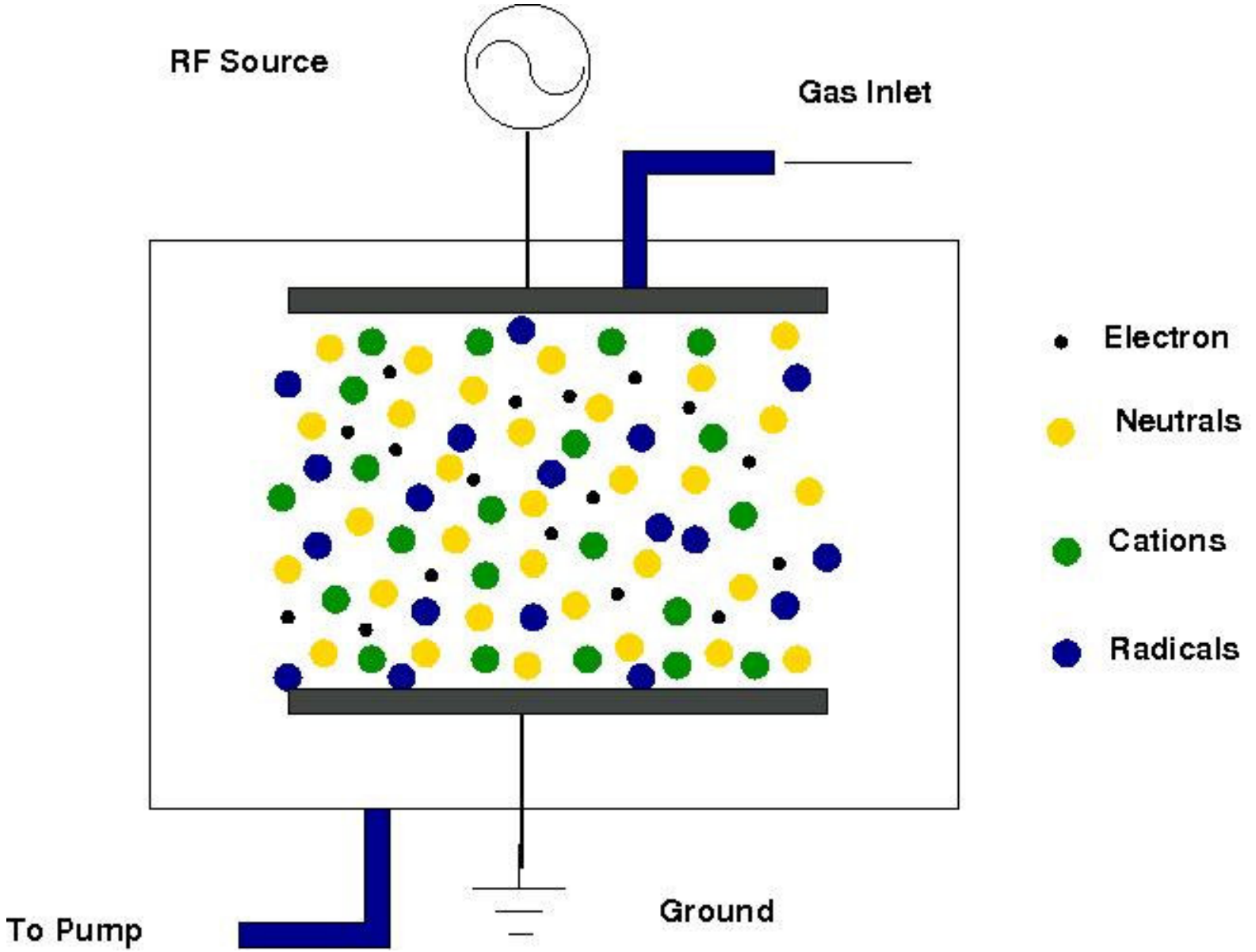


$$\omega_p = \left(\frac{ne^2}{\varepsilon_0 m} \right)^{1/2}$$

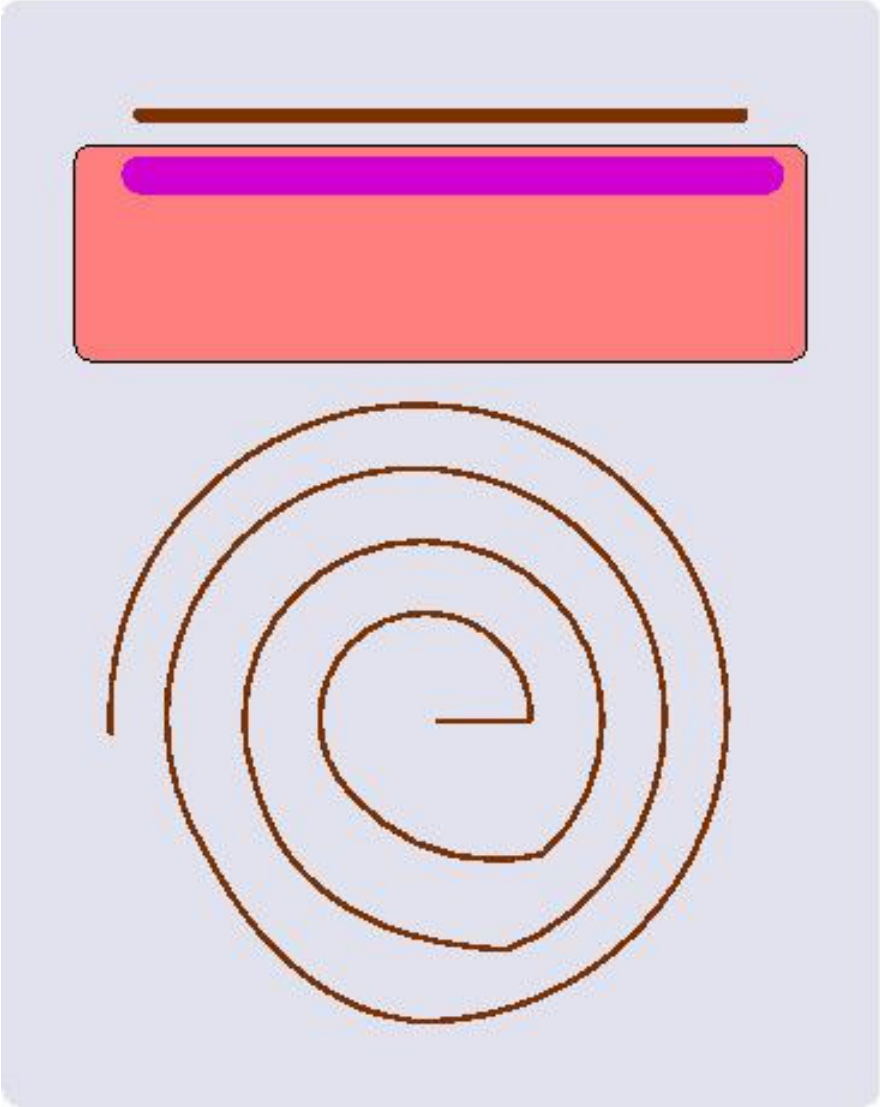
POSITIVE ION

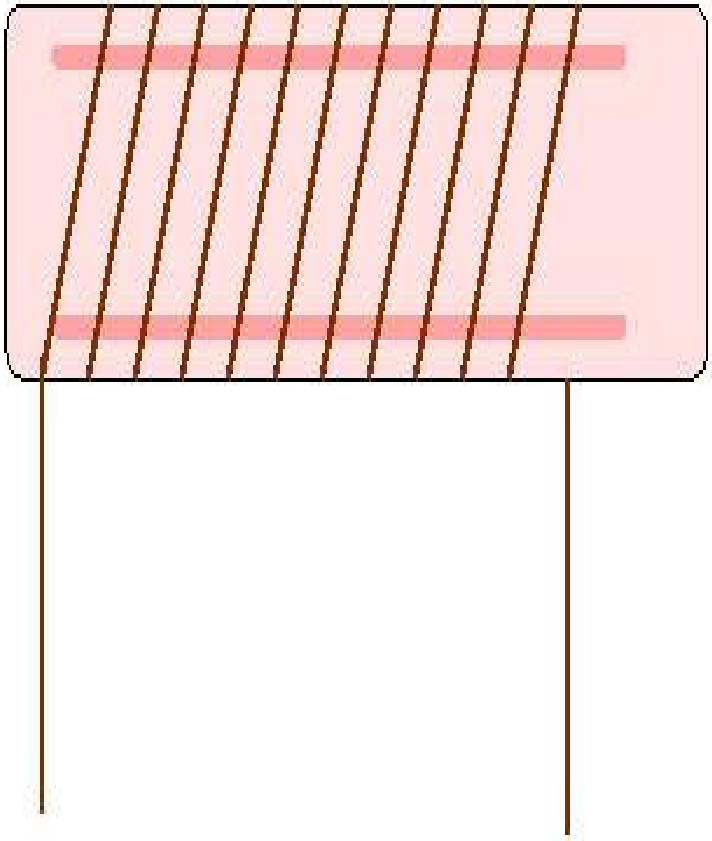
ELECTRON

CAPACITIVE COUPLING

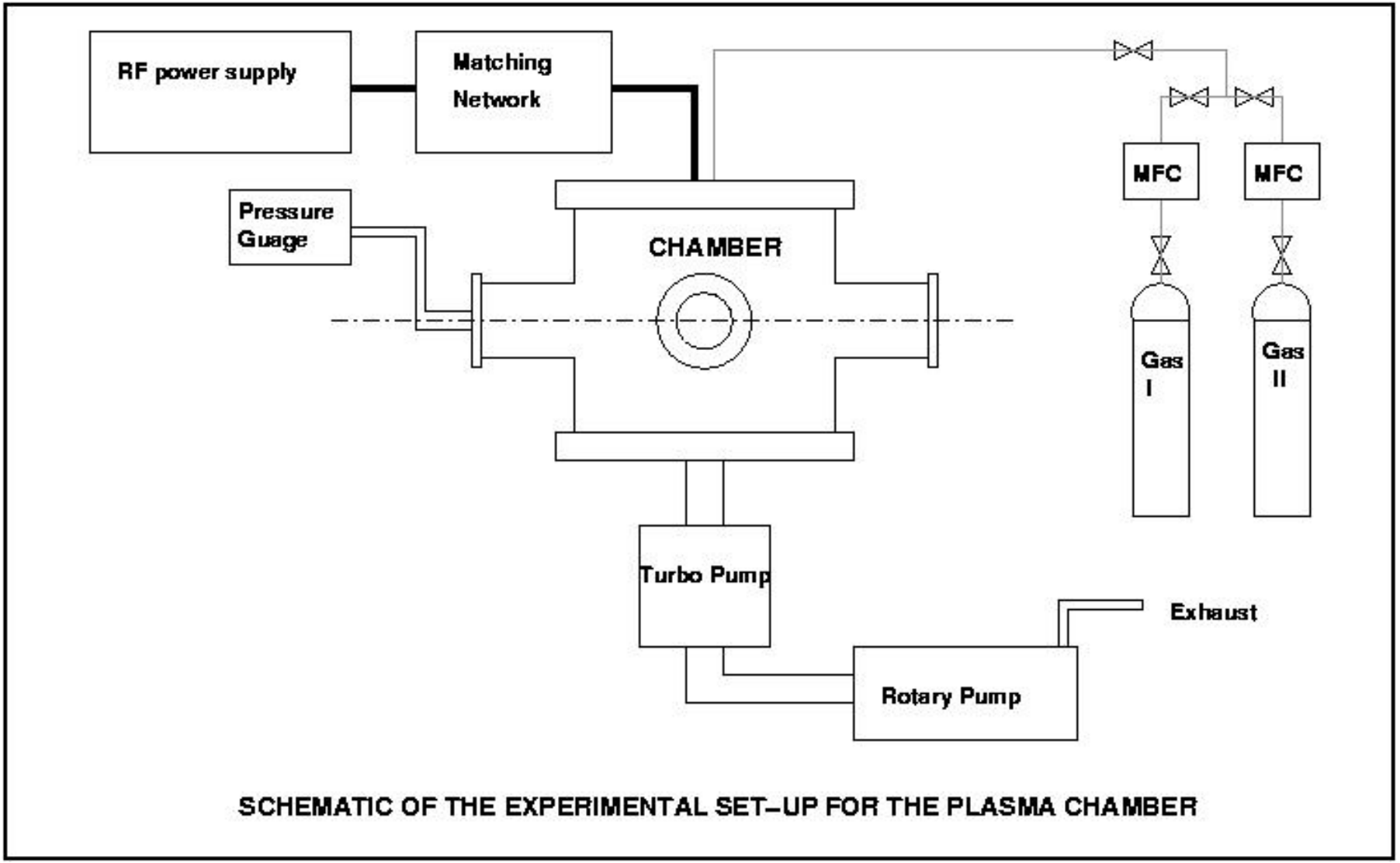


INDUCTIVE COUPLING



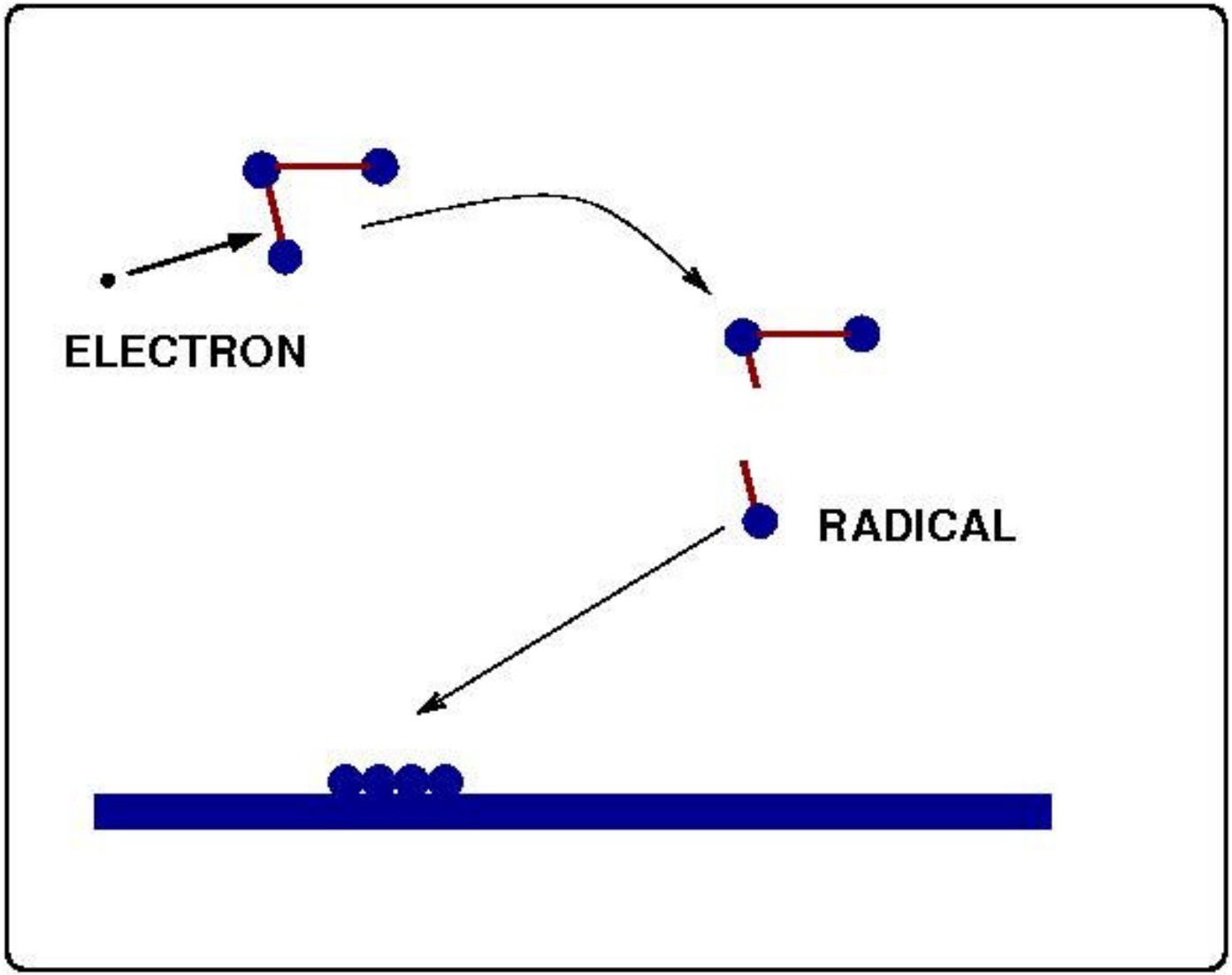


TYPICAL EXPERIMENTAL SET-UP



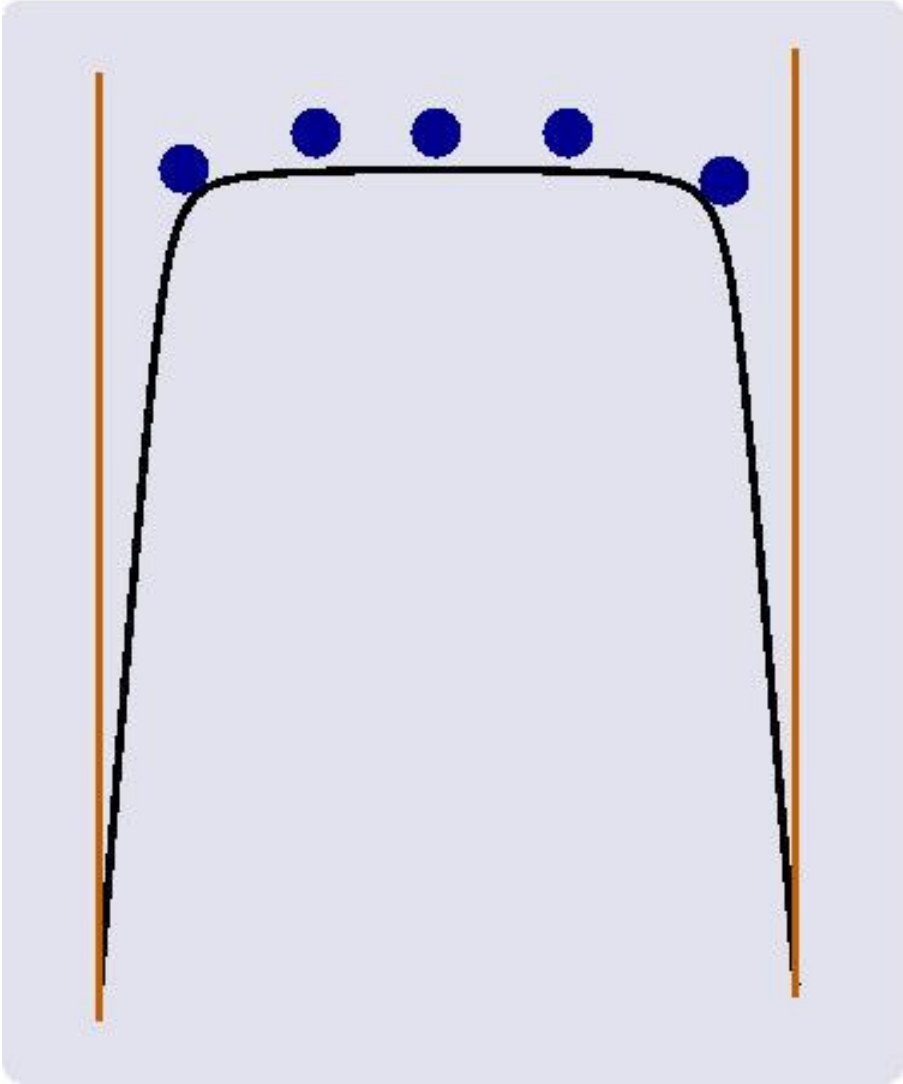
SCHEMATIC OF THE EXPERIMENTAL SET–UP FOR THE PLASMA CHAMBER

DEPOSITION USING PLASMAS



Energetic electrons break bonds and form reactive radicals which react at the substrate.

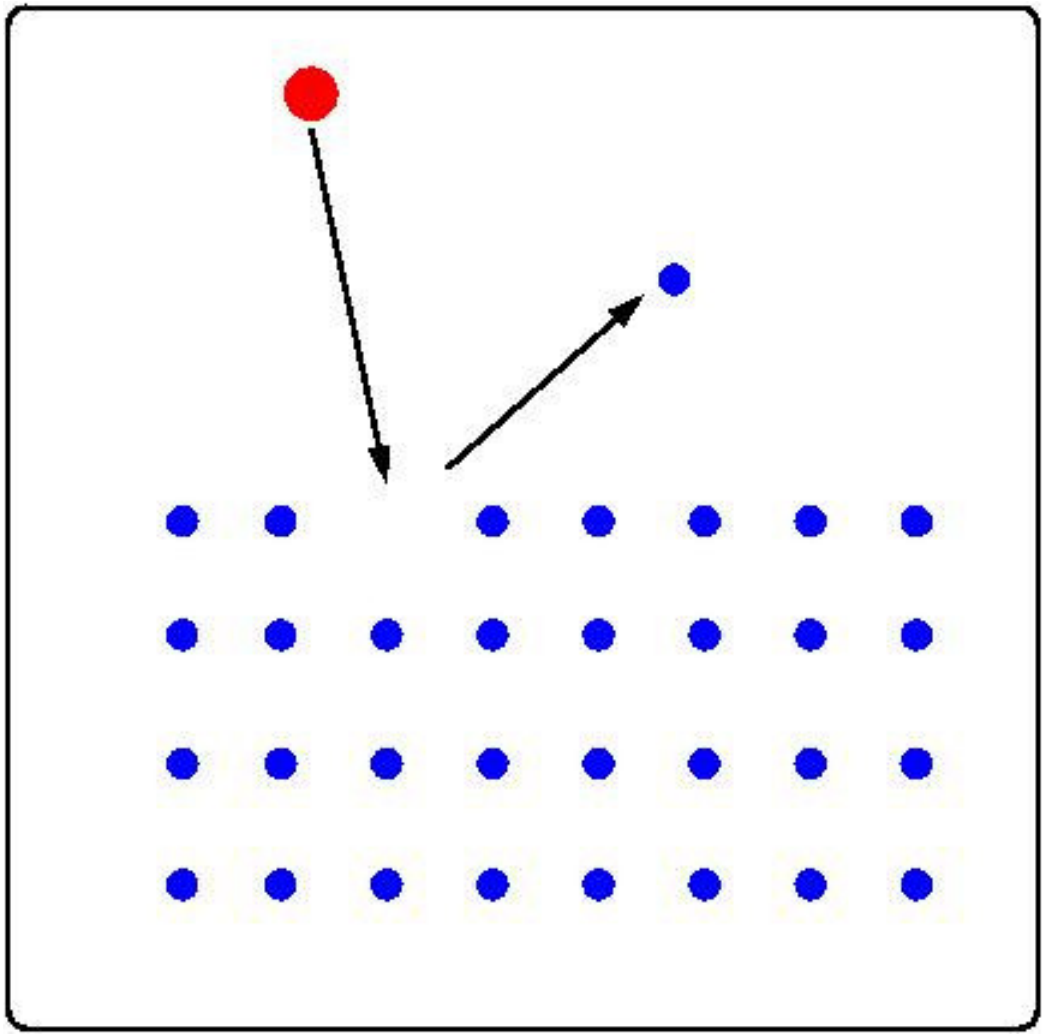
POSITIVE IONS AT THE SHEATH EDGE



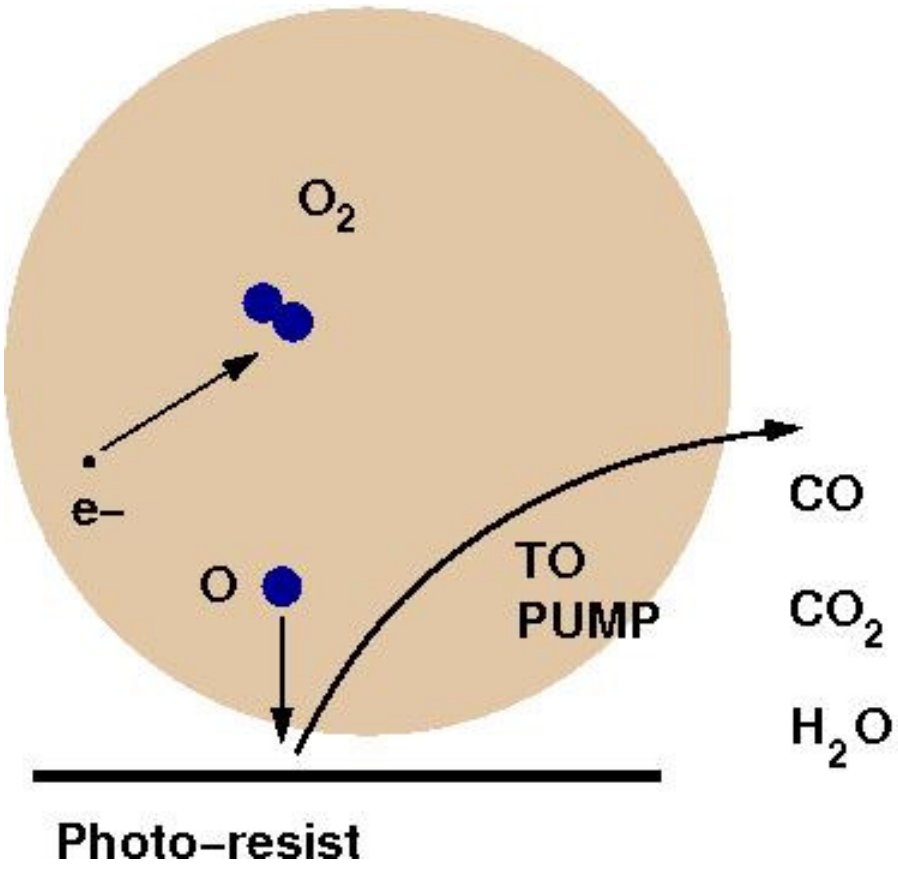
POSITIVE IONS REACHING THE EDGE SEE A STEEP DOWNHILL SLOPE.

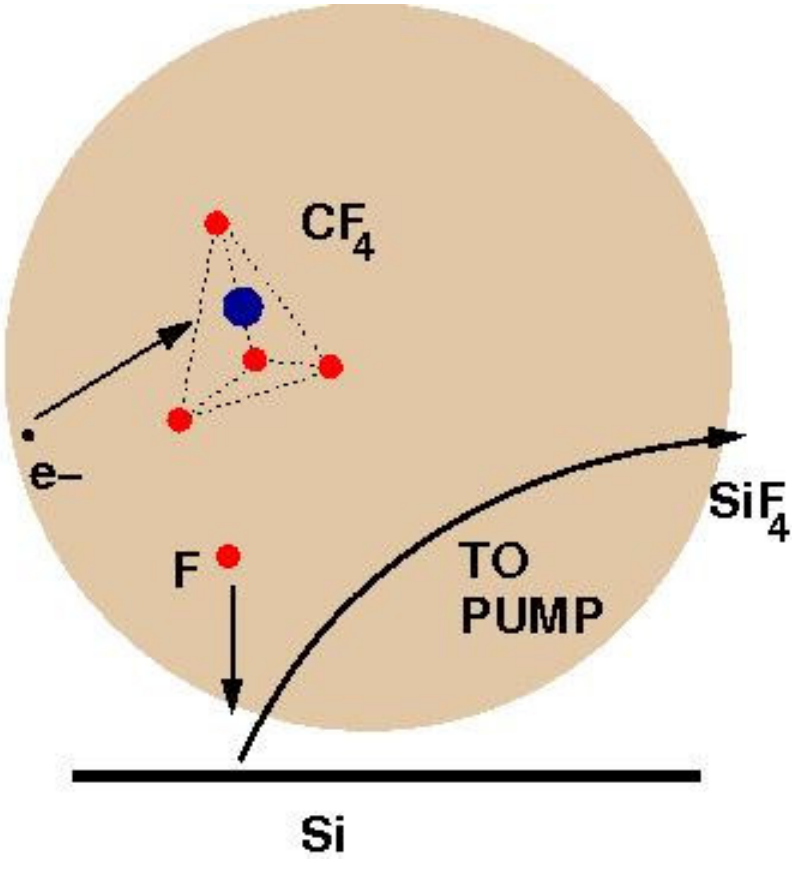
THEY ARE ACCELERATED IN THE SHEATH REGION AND IMPACT THE ELECTRODES WITH HIGH ENERGIES.

SPUTTERING

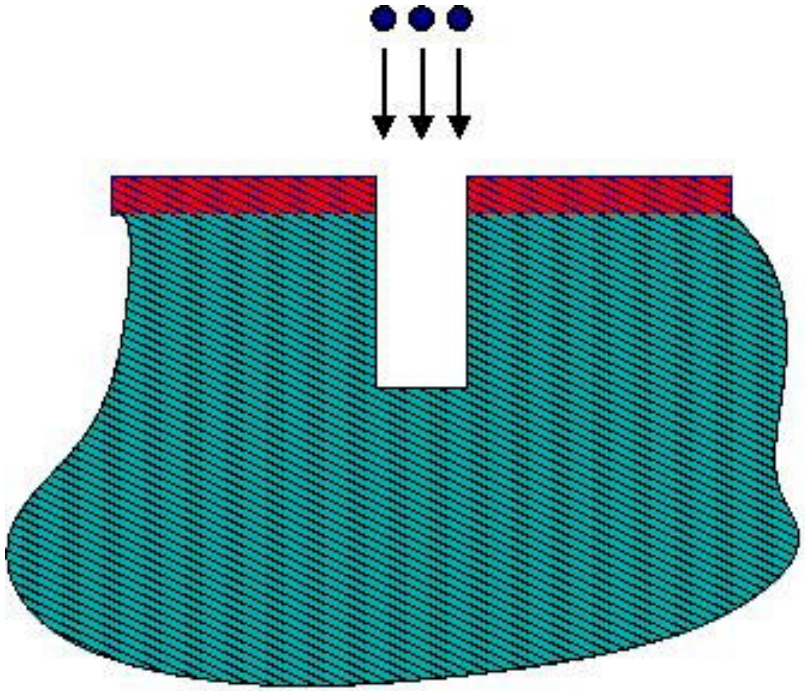


ETCHING

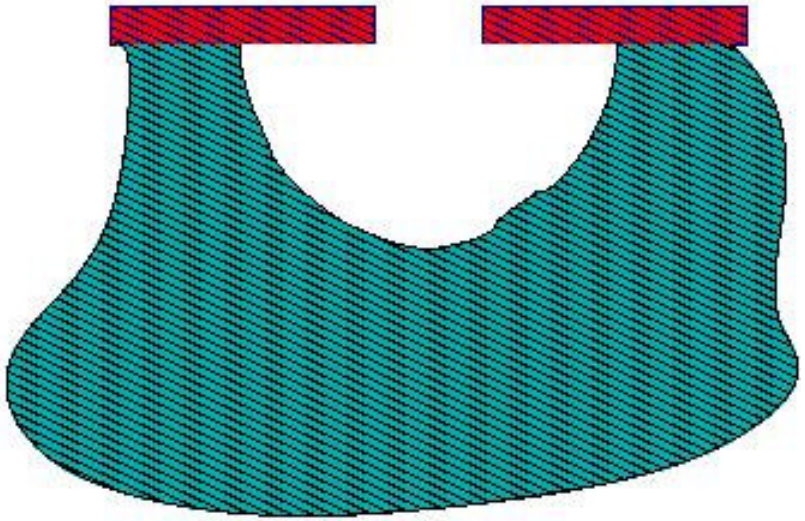




ETCHING - ANISOTROPIC

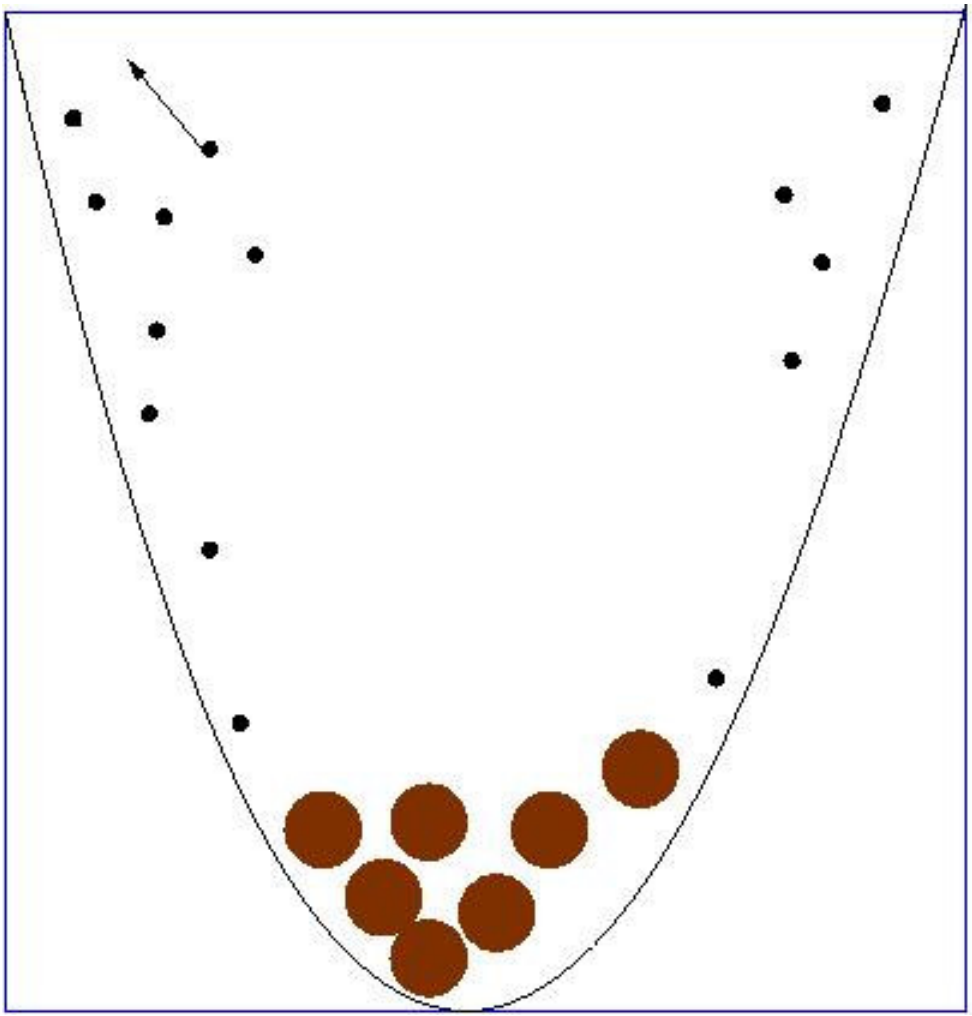


ANISOTROPIC ETCHING



ISOTROPIC ETCHING

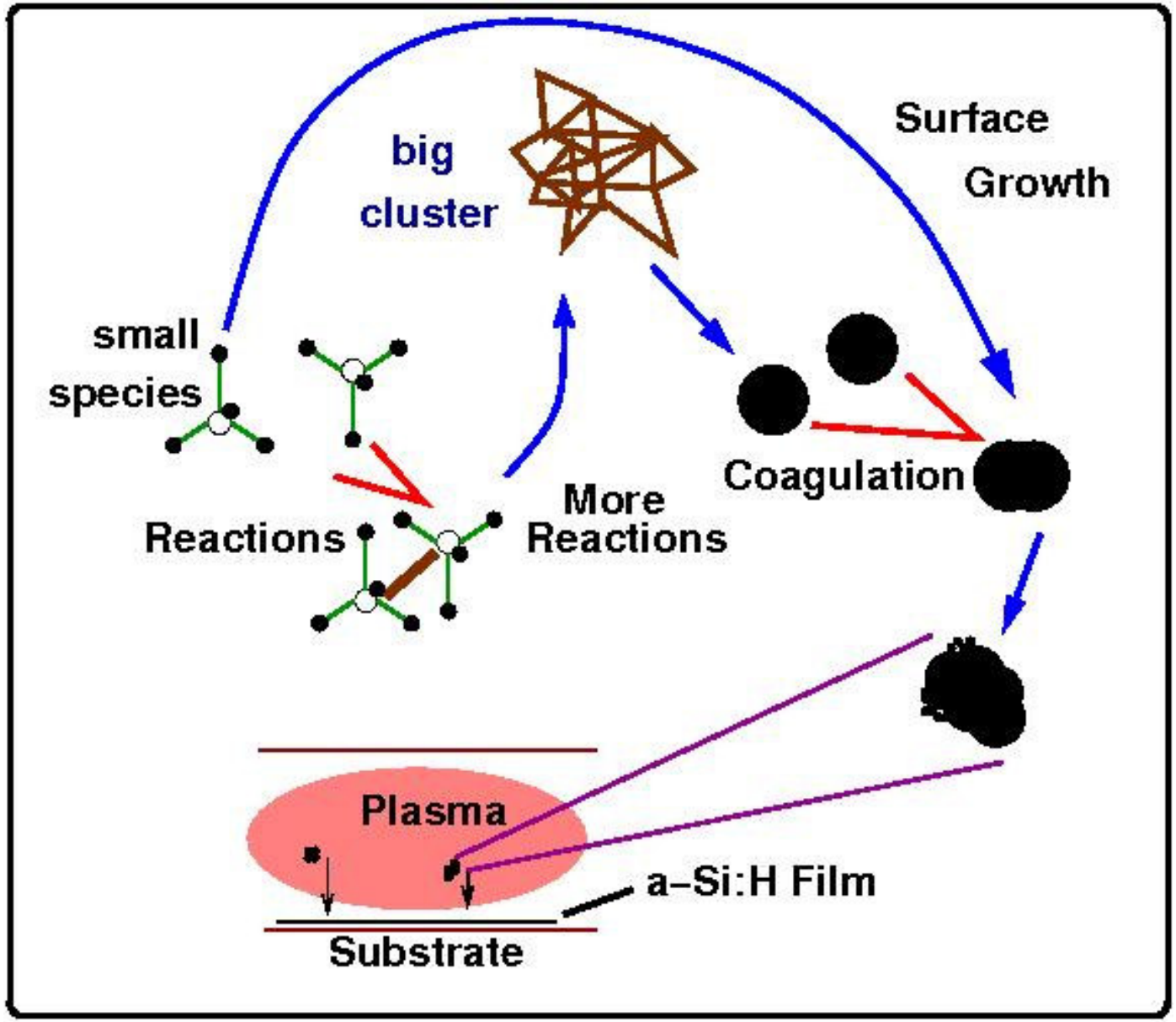
HEAVY NEGATIVE SPECIES ARE TRAPPED



ELECTRON

HEAVY NEGATIVE SPECIES

PARTICLE GENERATION



THANK YOU