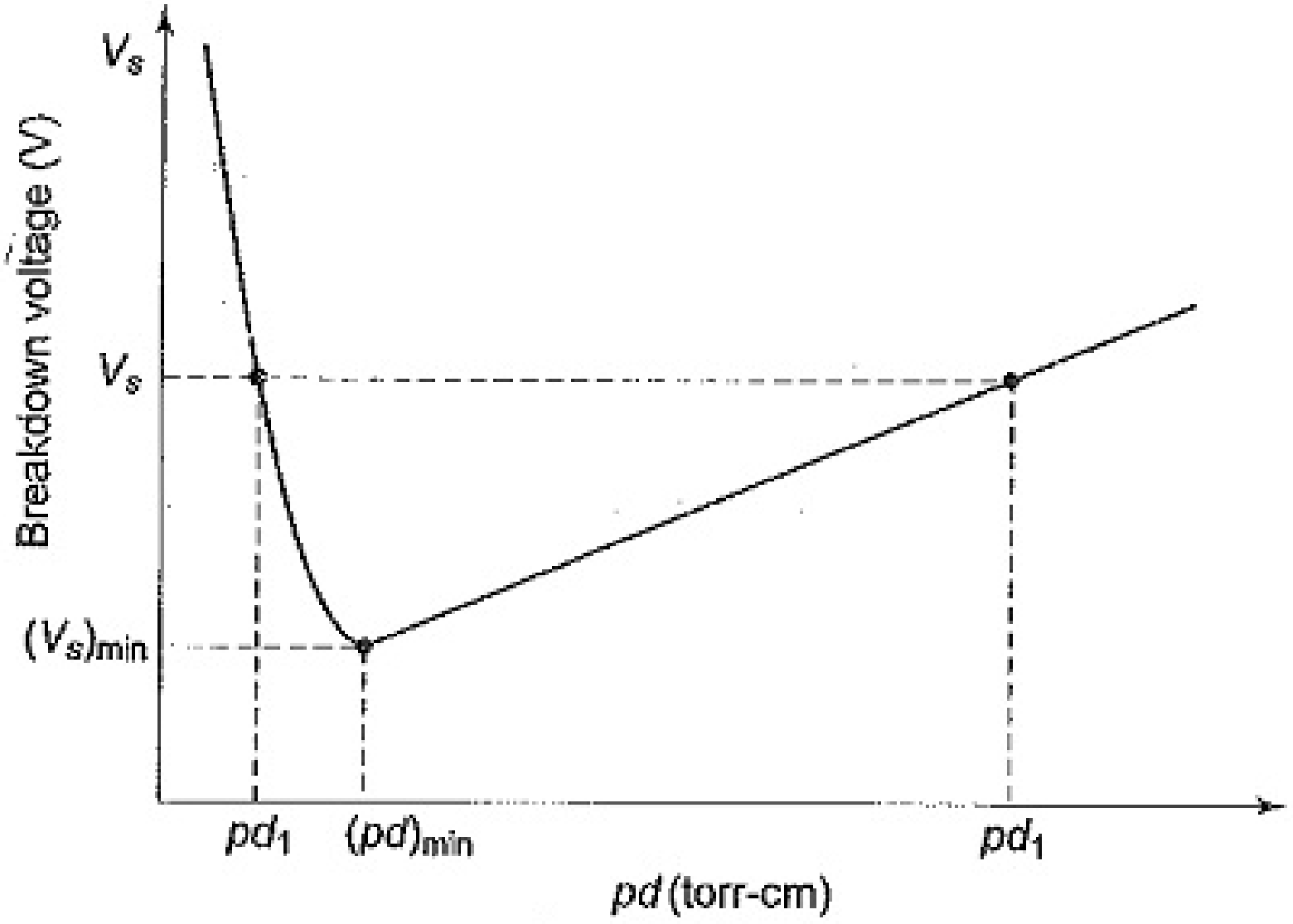
Formation of Plasma at laboratory, Plasma diagnostics and Application of Plasma in Semiconductor Industry

Paschen's Law



Breakdown in non-uniform field and Corona Discharges

If the field is non-uniform, an increase in voltage will first cause a localized discharge in the gas to appear at points with the highest electric field intensity, namely at sharp points or where the electrodes are curved or on transmission line conductors. This form of discharge is called a corona discharge and can be observed as a bluish luminance. This phenomena is always accompanied by a hissing noise, and the air surrounding the corona region becomes converted to ozone. Corona is responsible for considerable power loss in transmission lines and also gives rise to radio interference.

It represents a local region where the air (or other fluid) has undergone electrical breakdown and become conductive, allowing charge to continuously leak off the conductor into the air. A corona occurs at locations where the strength of the electric field (potential gradient) around a conductor exceeds the dielectric strength of the air.

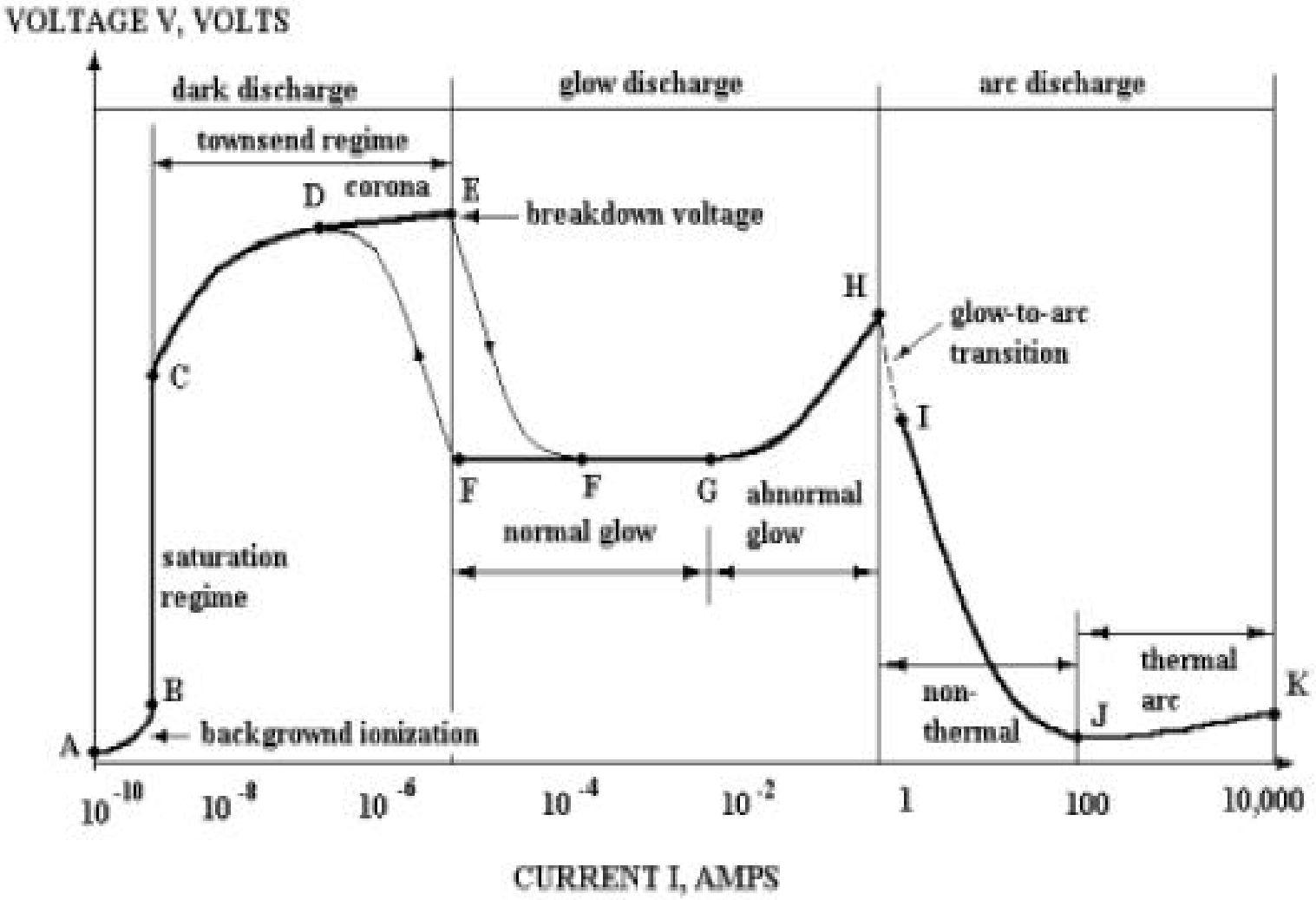
Glow Discharge(low-current, high-voltage discharge.)

A glow discharge is characterized by a diffused luminous glow. The color of the glow discharge depends on the cathode materials and the gas used. The glow discharge covers the cathode partly and the space between the cathode and the anode will have intermediate dark and bright regions.

Arc Discharge(a high-current, low-voltage discharge)

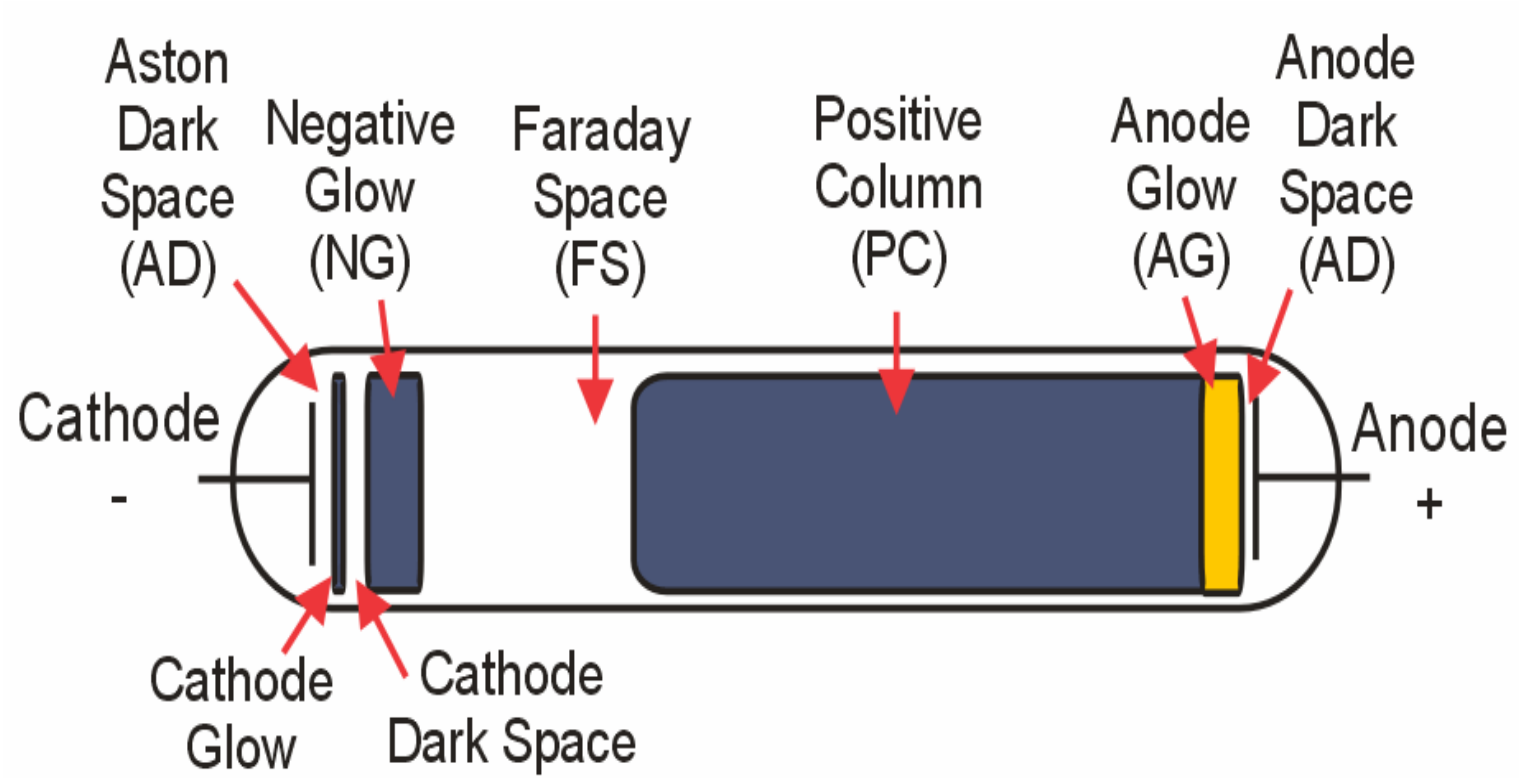
If the current in the gap is increased to about 1 A or more, the voltage across the gap suddenly reduces to a few volts (20-50 V). The discharge becomes very luminous and noisy (region EG).

Post Breakdown Phenomena:



Voltage-Current Characteristics of DC glow discharge plasma

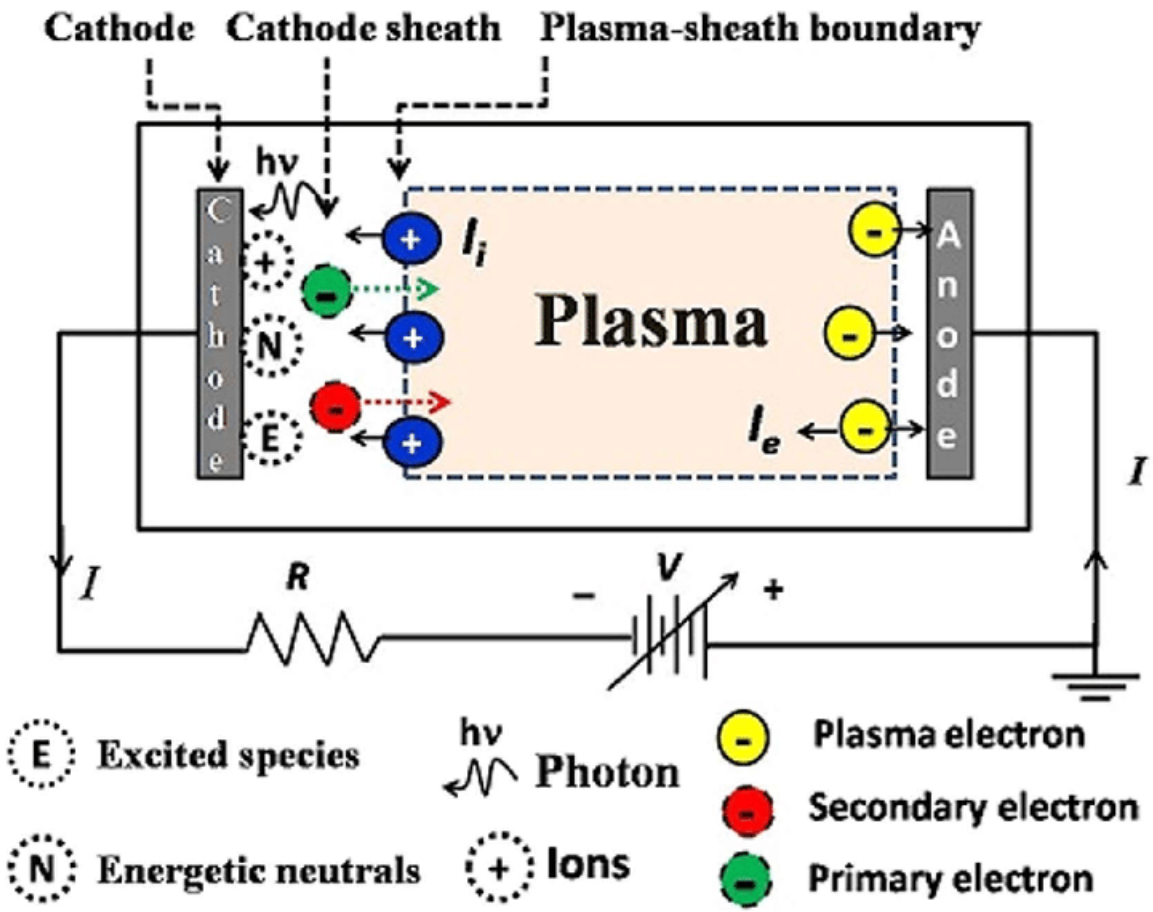
Different regions of Glow Discharge plasma:



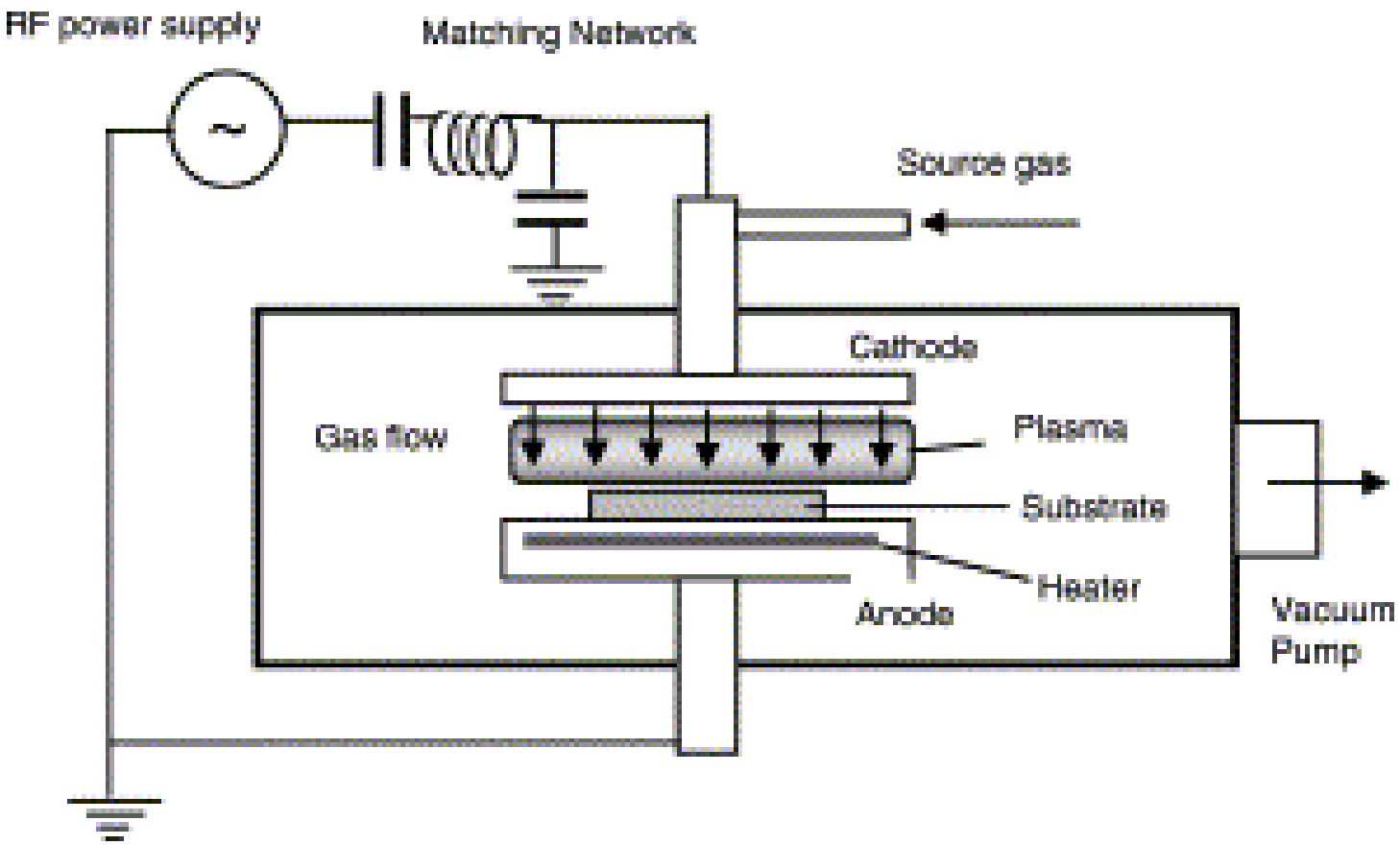
Typical characteristics of a normal glow discharge plasma

Different variants to glow discharge plasmas:

DC Plasma:



RF Plasma


RF power supply
Matching Network
Source gas
Cathode
Gas flow
Plasma
Substrate
Heater
Anode
Vacuum
Pump

AC vs DC discharge

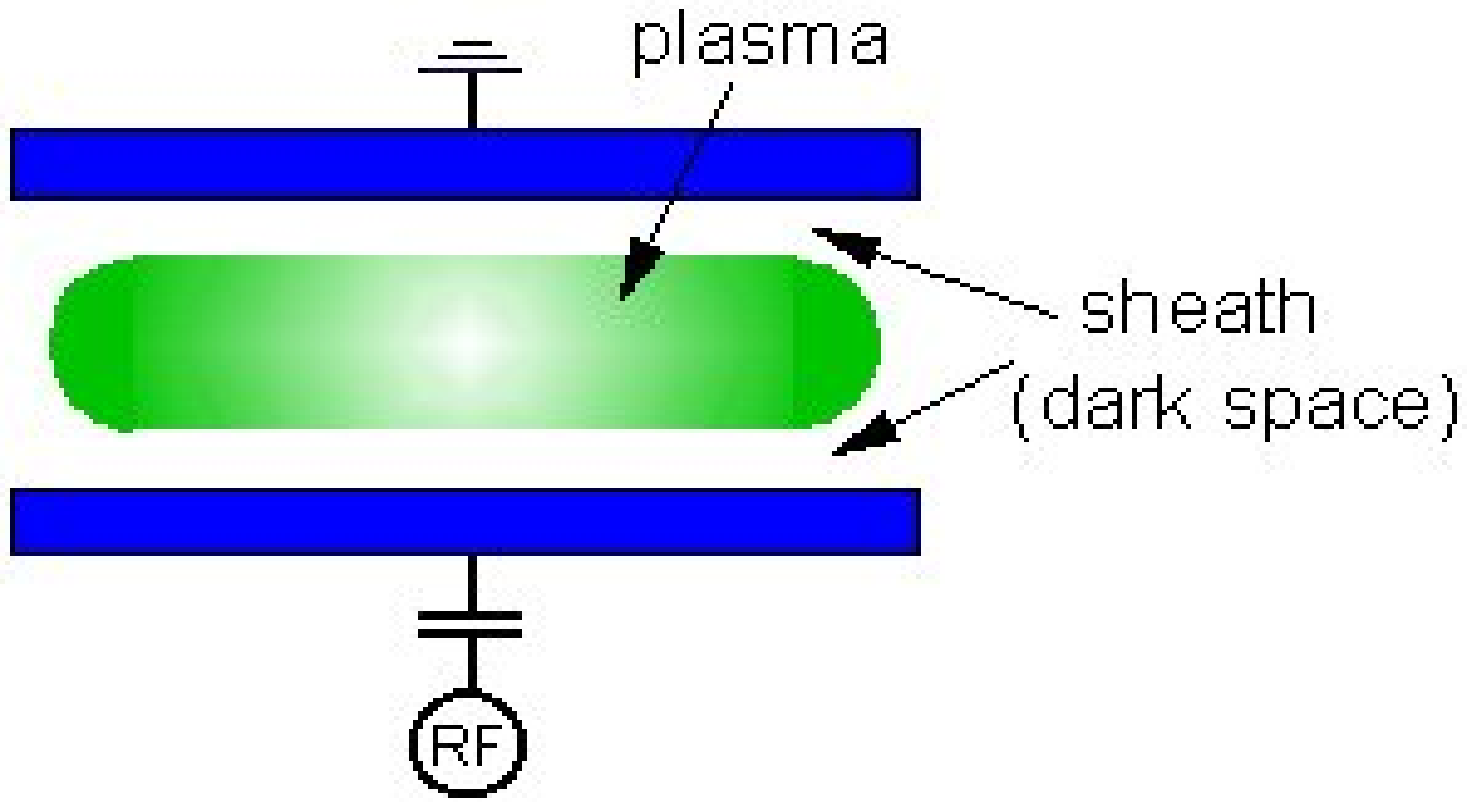
AC discharges are preferred over DC-driven discharges. In a DC discharge, charged particles from the plasma can accumulate on the substrate surface causing unwanted charging effects. By alternating the direction of the current flow sufficiently rapidly, these charging effects can be reduced. At RF frequencies this alternation is sufficiently rapid to almost completely eliminate charging effects, so allowing insulating materials (such as SiO_2, Al_2O_3, etc), to be processed. One problem, however, is that these frequencies are precisely those used for short wave radio communication, in say taxis, police cars, aircraft, etc! So to avoid interfering with these, the US Federal Communications Committee has decreed that certain frequencies (13.56 MHz, and 2.45 GHz) are to be set aside for plasma generation

Applications of glow discharges and related plasmas:

Glow discharges and related plasmas are used in a large number of application fields. The most important application is probably in the microelectronics industry and in materials technology, for surface treatment, etching of surfaces (e.g., for the fabrication of integrated circuits), deposition of thin protective coatings, plasma polymerisation, plasma modification of polymers and other surfaces.
The exciting and light emitting character of discharge plasmas is also used for several interesting applications, such as in the light industry (e.g., fluorescence lamps, neon advertisements), as gas lasers, and as flat plasma display panels for the new generation of flat, large area television screens.
Because a lot of chemical reactions take place in the plasma, several types of discharges (mainly atmospheric pressure glow discharges and dielectric barrier discharges) find also increasing interest for environmental applications (e.g., the destruction of volatile organic compounds) and biomedical applications (e.g., the sterilisation of materials).

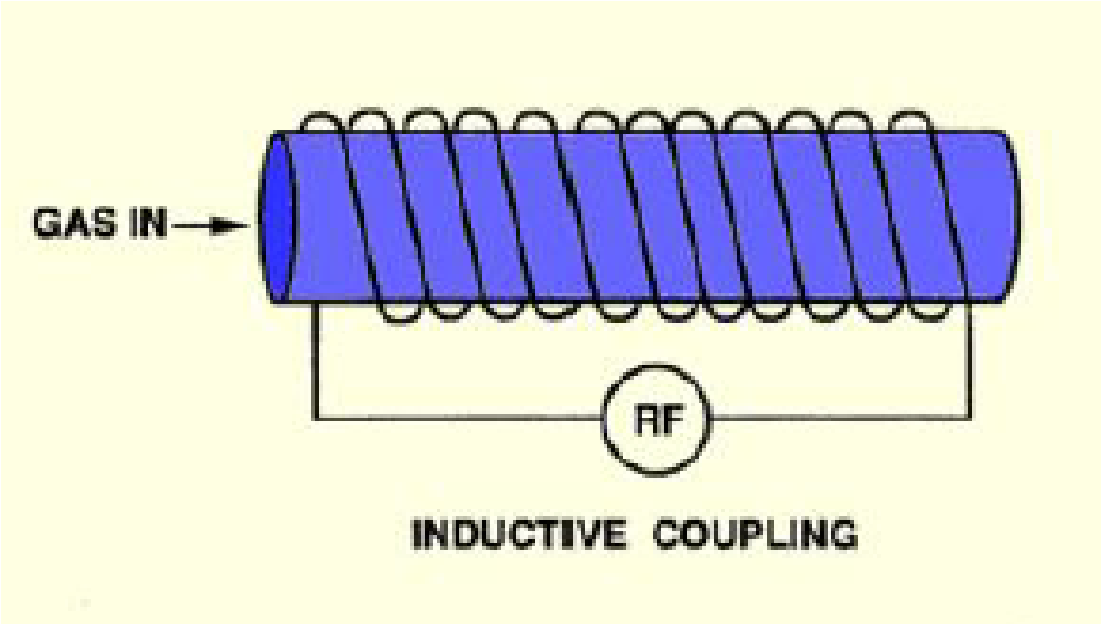
Capacitively coupled plasma:

A capacitively coupled plasma (CCP) is one of the most common types of industrial plasma sources. It essentially consists of two metal electrodes separated by a small distance, placed in a reactor.



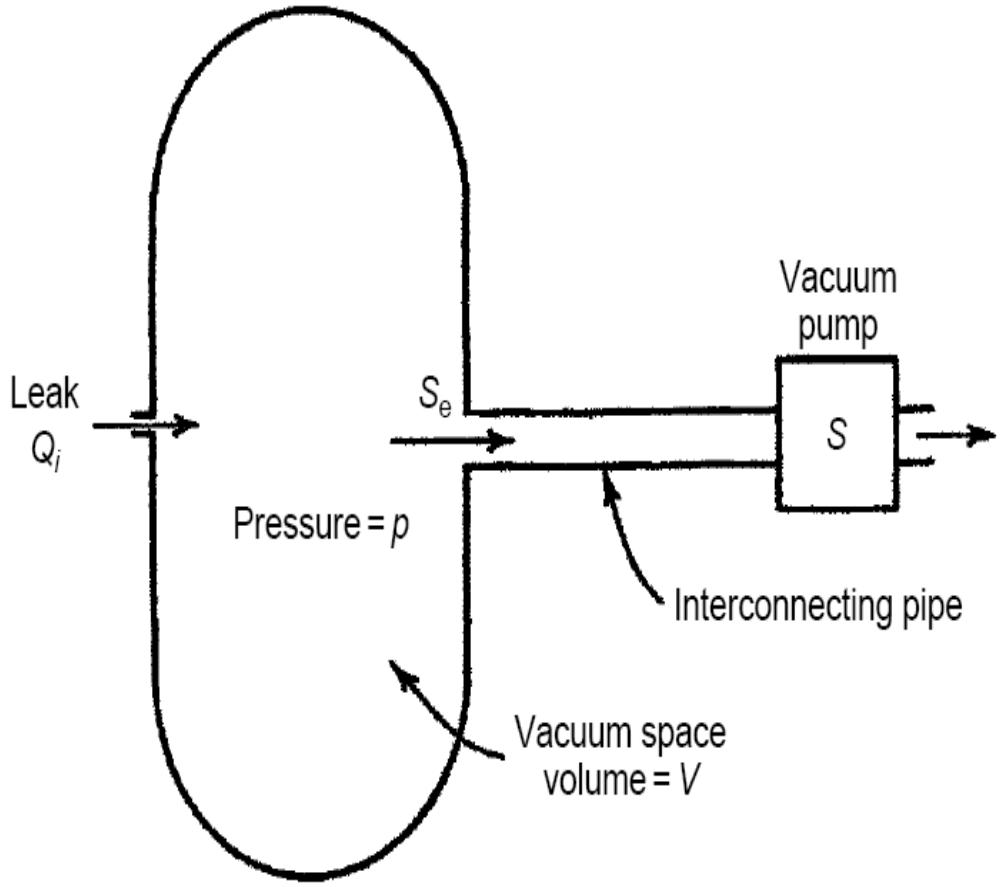
Inductively coupled plasma:

An inductively coupled plasma (ICP) is a type of plasma source in which the energy is supplied by electrical currents which are produced by electromagnetic induction, that is, by time-varying magnetic fields.

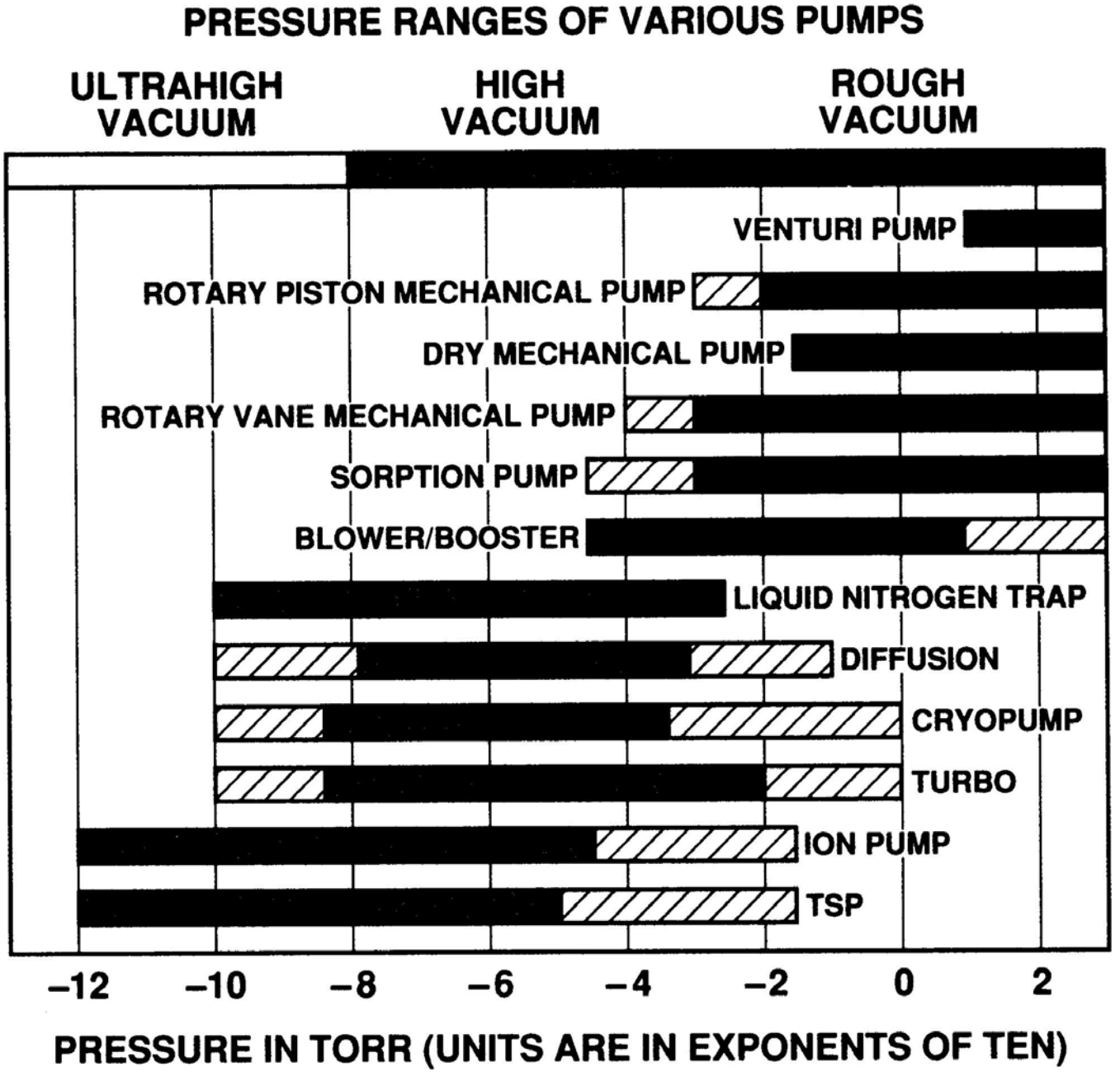


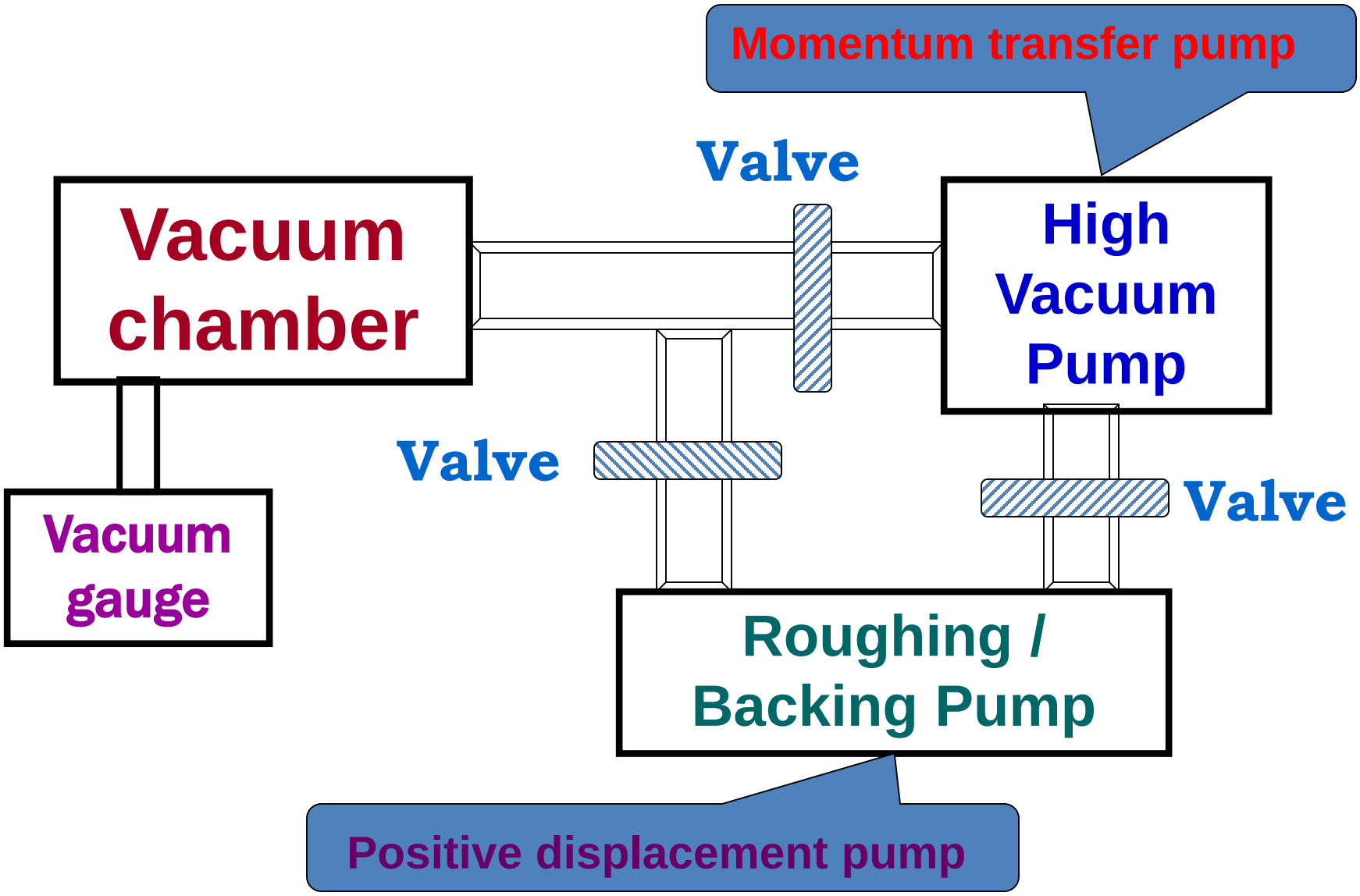
Basic requirement for a plasma deposition chamber

A VACUUM CHAMBER



The simplest vacuum system consists of a vacuum chamber, an interconnecting tube and a vacuum pump which produces a pressure gradient along the tube


PRESSURE RANGES OF VARIOUS PUMPS
ULTRAHIGH VACUUM
HIGH VACUUM
ROUGH VACUUM
VENTURI PUMP
ROTARY PISTON MECHANICAL PUMP
DRY MECHANICAL PUMP
ROTARY VANE MECHANICAL PUMP
SORPTION PUMP
BLOWER/BOOSTER
LIQUID NITROGEN TRAP
DIFFUSION
CRYOPUMP
TURBO
ION PUMP
TSP
–12
–10
–8
–6
–4
–2
0
2
PRESSURE IN TORR (UNITS ARE IN EXPONENTS OF TEN)



Schematic diagram of two stage pumping system