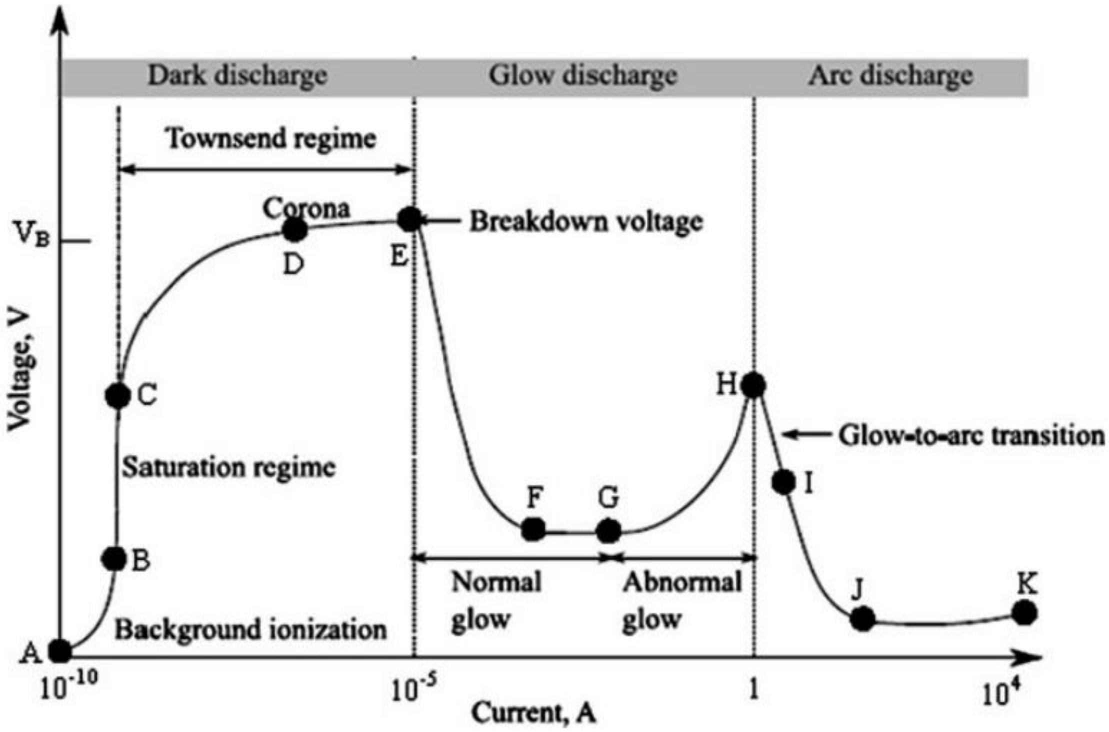
2-The I–V Characteristic of Electrical Discharge

The first part of the characteristic is caused by charges produced by background ionization of the gas either by environmental stray radiation or by photoelectric effect at the cathode surface due to UV radiation. At low voltage, whatever electrons available may be accelerated towards the anode to constitute to the current. If no ionizing collision by electron can occur due to the low potential (and low electric field), the maximum current that can be obtained is determined by the total number of initial electrons available. This current is in the region below nano-ampere and it increases with applied potential. It reaches a saturation value corresponding to the maximum number of electrons available.

With increasing applied potential, the electrons may be accelerated to energy above the excitation and ionization thresholds and these processes will then take place. New charge particles, both ions and electrons, will be produced by ionization and this gives rise to an increase in the discharge current. The potential is further increased to reach the breakdown voltage, the discharge current will increase exponentially and then breakdown will occur and an electrical discharge is formed. This electrical breakdown will occur at potential VB given by (fig.1). The region of the I–V curve before breakdown is often referred to as the dark discharge region. It is subdivided into the background current region, the Townsend region, and the corona region. A corona discharge is maintained by controlling the current at the micro amperes region. The voltage drop across the discharge tube when the discharge is in the dark discharge region is roughly equal to the applied potential.



I–V characteristic of electrical discharge

After breakdown, the discharge will try to draw infinite current from the power supply so it is essential to have a current limiting resistor RL in series between the source and the discharge. The type of discharge that is obtained will depend on the magnitude of the discharge current, which is controlled by the combined effect of the limiting resistor RL and the plasma impedance. Ideally, the plasma resistance is negligible compared to RL after breakdown. This means that the voltage drop across the discharge tube will be zero and the full voltage will be developed across RL. However, when RL is adjusted to limit the current to be in the region of mA. This is the normal glow discharge region and the voltage across the electrodes is called glow voltage, V_g. The normal glow region may be extended down to 10^{-5} A when the current is reduced gradually from mA.

On the other hand, when the current is further increased to beyond 100 mA, the voltage across the electrodes will not remain constant but will increase. The glow discharge is said to become abnormal. When the current is increased to greater than 1 A, the voltage across the electrodes suddenly drops to lower than the glow voltage and the discharge has changed into the arc discharge. As a summary, the three types of discharge that can be obtained by controlling the current are

$$10^{-7} - 10^{-5}\ \text{A} \Rightarrow \text{Corona discharge}$$
$$10^{-5} - 1\ \text{A} \Rightarrow \text{Glow discharge}$$
$$> 1\ \text{A} \Rightarrow \text{Arc discharge}$$

Corona discharge

After breakdown, if the discharge current can be controlled at the level of several µA, a corona discharge will be obtained. The potential drop across the electrodes is still the same as the applied voltage. Corona discharge can also be obtained in situation where electrical breakdown voltage has not been reached but the electric field between the electrodes is not uniform. A particular situation is when the high voltage electrode (can be either anode or cathode) has a sharp profile, such as in the form of a needle or thin wire. In this case the electric field at the sharp point is sufficiently high (>30 kV/cm) that the electrons may be accelerated to high enough energy to produce ionizing collision leading to breakdown within a close distance from the sharp point. The distance from the sharp point within which electrical breakdown can occur is called the effective distance of corona discharge.