Dielectric Barrier Discharge (DBD)

The discharge, which occurs between two electrodes where at least one of the electrodes is "covered" by a dielectric, is called Dielectric Barrier Discharge. Since there isn't Sparks noisy in this discharge. Consequently, this discharge is called sometimes "Silent Discharge". Note that the DBD discharge generates also noise, but less strong than the Spark Discharge. This discharge has a long history. It's first introduced by Siemens in 1857 to create ozone for tap water treatment. Thanks to the simplicity of this device and the produced plasma characteristics, there are a lot of industrial applications.

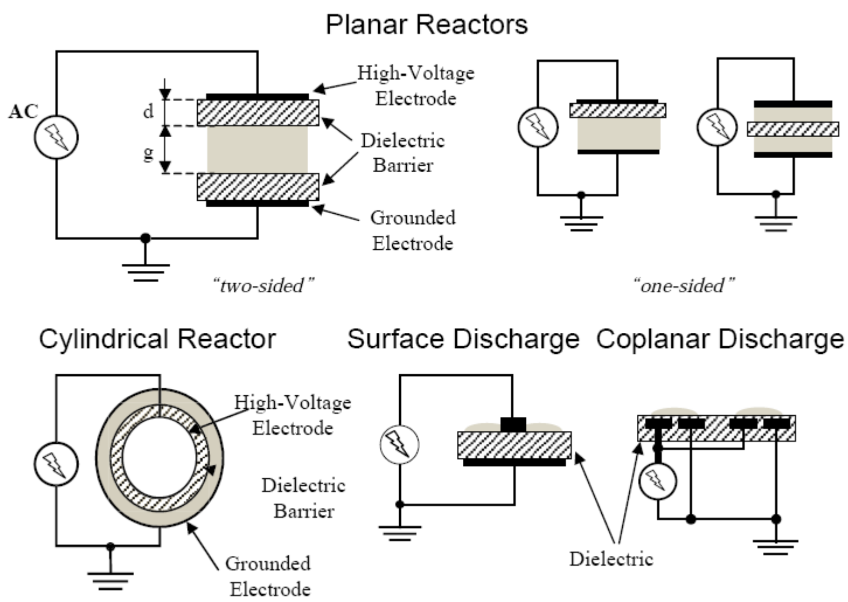
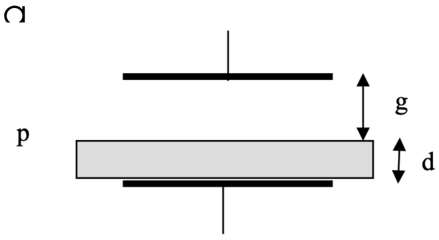


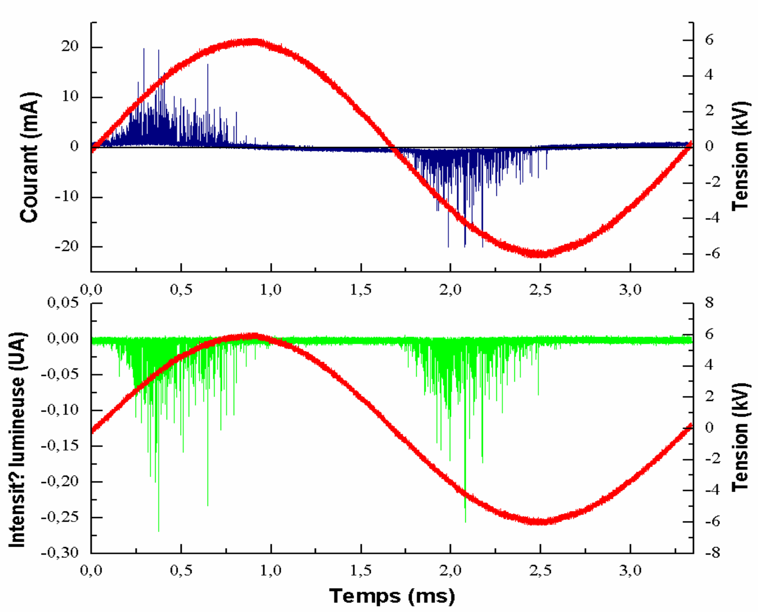
Fig. 2. Typical electrode arrangements of barrier discharges.

Let's study the setup (plane-plane) showed in Figure below, when a voltage U is applied, the electric field in gas will be calculated as following



$$U = U_g + U_d = gE_g + dE_d = gE_g\left(1 + \frac{d}{g}\frac{\varepsilon_g}{\varepsilon_d}\right)$$, while e is the permittivity.

So, if U high enough, Eg can be sufficient high to produce a stronger electronic avalanche and then a streamer and finally an ionized channel.



Typical voltage and current curves (top), typical voltage and light curves. The current corresponding to each micro-discharge (filament) is a very fast pulse of the order of 100 ns and with a low amplitude, less than 100 mA.

Power measurement

Volumic DBD:

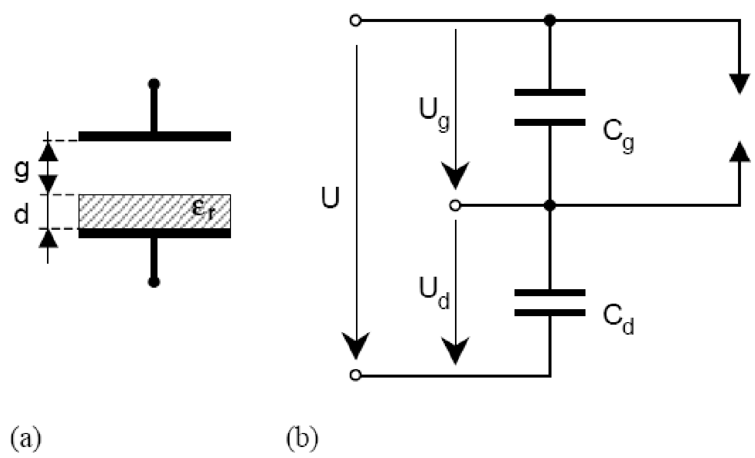


Fig. 3. One-sided BD configuration (a) and the equivalent circuit (b). $C = \frac{C_d C_g}{C_d + C_g} = \frac{C_g}{1 + C_g/C_d} = \frac{C_g}{1 + d/(\varepsilon_r g)}$.

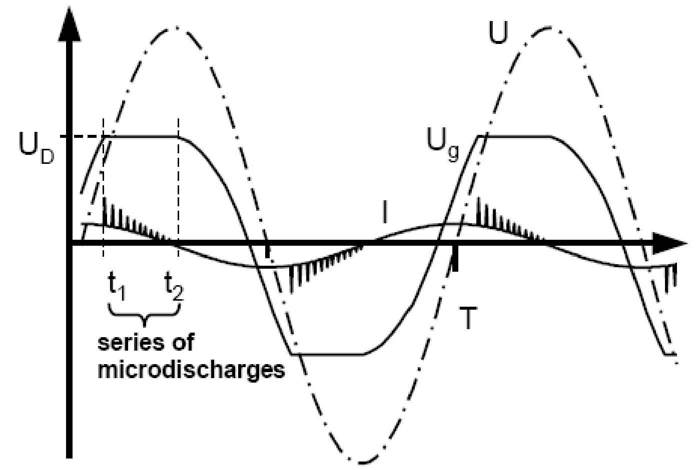


Fig. 4. Schematic picture of the feeding voltage $U(t)$ and discharge current $I(t)$.

When the breakdown voltage of the gas space is reached, microdischarges occur that start to charge the capacitance of the dielectric C, while the discharge voltage U_D remains constant.

The well-known so-called Manley's formula: $P = 4 f C_d U_D \left(\hat{U} - \left(\frac{C_d + C_g}{C_d} \right) U_D \right)$

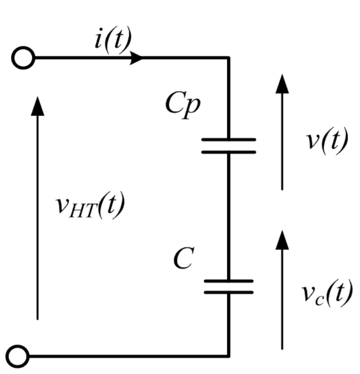
As U_D cannot be measured directly, other methods are often used.

Instantaneous power: $p(t) = v(t) * i(t)$

Mean power: $P = \frac{1}{T}\int_0^T p(t)dt = \frac{1}{T}\int_0^T v(t) * i(t)dt$

This method imposes a precise measure of current.

Another method called "Lissajous method" is often used to measure the Power.



$$P = \frac{1}{T}\int_0^T v_{DBD}(t) * i_{DBD}(t)dt \approx \frac{1}{T}\int_0^T v_{HT}(t) * i_{DBD}(t)dt = \frac{1}{T}\int_0^T v_{HT}(t) * \frac{dq_C(t)}{dt} dt = \frac{1}{T}\int_0^T v_{HT} * C du_C$$

(Cp is the equivalent capacity of the DBD configuration, and C>>Cp)

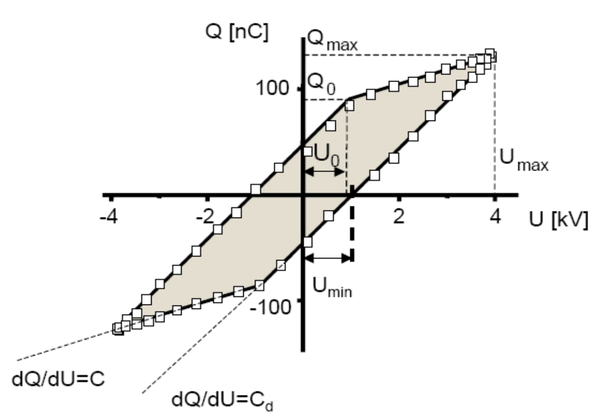


Fig. 7. An Q–U-oscillographic presentation (Lissajous figure).

$$E_{el} = \oint U(t)\,dQ = C_{meas} \oint U(t)\,dU_{meas}$$
$$= 4C_d \frac{1}{1 + C_g/C_d} U_{min}(U_{max} - U_{min})$$
$$= 2(U_{max} Q_0 - Q_{max} U_0) \equiv \text{AREA of } (Q - U) \text{ diagram}$$