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A Brief Review on Atmospheric Non-thermal Plasma Technique - DBD

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1. Abstract:

Dielectric barrier discharge is a typical non-equilibrium high-pressure ac gas discharge. Such devices are beneficial for industrial acceptance, since vacuum systems can be got rid of and devices operated in atmospheric pressure region. DBD is an excellent source of ideal energetic electrons with 1-10 eV and high density. Its unique advantageous is to generate low excited atomic and molecular species, free radicals and excimers with several electron volt energy.[4] In this review paper, the structure, application DBD are discussed. Due to its attractive characteristics, DBD is recently studied for potential industrial applications as an Eco friendly technque. Ozone generators, excimer radiation sources, free radical generation and their applications in pollution control and monitor are also discussed.

Keywords: **Pollution control, Eco friendly technique, Dielectric barrier discharge, Non-equilibrium plasma**.

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2. Introduction

Plasmas can be distinguished into two main groups *i.e.*, the high temperature or fusion plasmas and the so called low temperatures or gas discharges. A typical classification and parameters of different kinds of plasmas is given in table 1. High temperature plasma implies that all species (electrons, ions and neutral species) are in a thermal equilibrium state. Low temperature plasma is further subdivided into thermal plasma, also called quasi-equilibrium plasma, which is in a local thermal equilibrium (LTE) state, and non-thermal plasma (NTP), also called non equilibrium plasma or cold plasma.[1]

Cold plasmas refer to the plasmas where most of the coupled electrical energy is primarily channeled to the electron component of the plasma, thereby producing energetic electrons instead of heating the entire gas stream; while the plasma ions and neutral components remain at or near room temperature. Because the ions and the neutrals remain relatively cold, this characteristic provides the possibility of using cold plasmas for low temperature plasma chemistry and for the treatment of heat sensitive materials including polymers and biological tissues. The remarkable characteristic features of cold plasma that include a strong thermodynamic non-equilibrium nature, Low gas temperature, presence of reactive chemical species and high selectivity offer a tremendous potential to utilize these cold plasma sources in a wide range of applications.

Plasma	State	Example
High temperature plasma (Equilibrium plasma)	$T_e = T_i = T_h$, T_p = 106 K–10^8 K $n_e \geq 10^{20}$ m^{-3}	Laser fusion plasma
Low temperature plasma Thermal Plasma (Quasi – equilibrium plasma)	$T_e \approx T_i \approx T_h$, T_p = 2*10^3 K-3*10^8K $n_e \geq 10^{20}$ m^{-3}	Arc plasma; atmospheric RF discharge
Non- thermal plasma (Non-equilibrium plasma)	T_e » $T_h \approx$ 3*10^2 K–4*10^2 K $n_e \approx 10^{10}$ m^{-3}	Dielectric Barrier Discharge

Table 1: Classification of plasma

3. Dielectric Barrier Discharge:

Dielectric barrier discharge is a specific type of AC discharge, which provides a strong thermodynamic, non-equilibrium plasma at atmospheric pressure, and at moderate gas temperature. It is produced in an arrangement consisting of two electrodes, at least one of which is covered with a dielectric layer placed in their current path between the metal electrodes. The presence of one or more insulating layer on/or between the two powered electrodes is one of the easiest ways to form non-equilibrium atmospheric pressure discharge. In DBDs the electrode and discharge are separated by a dielectric barrier, which eliminates electrode etching and corrosion. DBD cold plasma can be produced in various working mediums through ionization by high frequency and high voltage electric discharge.

4. DBD Structure

The discharge burning between two electrodes, at least one electrode insulated with a dielectric layer can be operated in a wide range of geometrical configurations such as the classical volume discharge, surface discharge, and coplanar discharge. Volume discharges can also have either planar or coaxial arrangements. In planar electrode arrangements, the two electrodes are parallel to each other, and one or two dielectric barriers are always located either (i) on the powered or the ground electrode, or (ii) on both the electrodes, or (iii) in between the two metal electrodes. The electrodes in DBD can also be arranged in a coaxial manner having one electrode inside the other with at least one or two dielectric barriers located either (i) on the outer side of the inner electrode/on the inner side of the outer electrode, or (ii) on both the electrodes facing each other, or (iii) in between the two cylindrical electrodes. Besides the volume discharges, other designs also exist that use either surface or coplanar discharge geometry. Surface discharge device have a thin and long electrode on a dielectric surface and an extended counter-electrode on the reverse side of the dielectric. In this configuration, the discharge gap is not clearly defined and so the discharge propagates along the dielectric surface. There also exist combinations of both volume and surface discharge configuration such as the coplanar used in plasma display panel. The coplanar discharge device is characterized by pairs of long parallel electrodes with opposite polarity, which are embedded With in a dielectric bulk nearby a surface. In addition to these configurations, other variants of DBD are also used in various applications. The typical arrangements of DBD are shown in fig. DBD can exhibit two major discharge modes, either filamentary mode, which is the common form of discharge composed of many microdischarges that are randomly distributed over the electrode surface; or homogenous glow discharge mode, also known as atmospheric pressure glow discharge mode due to similarity with dc glow discharges.[2]

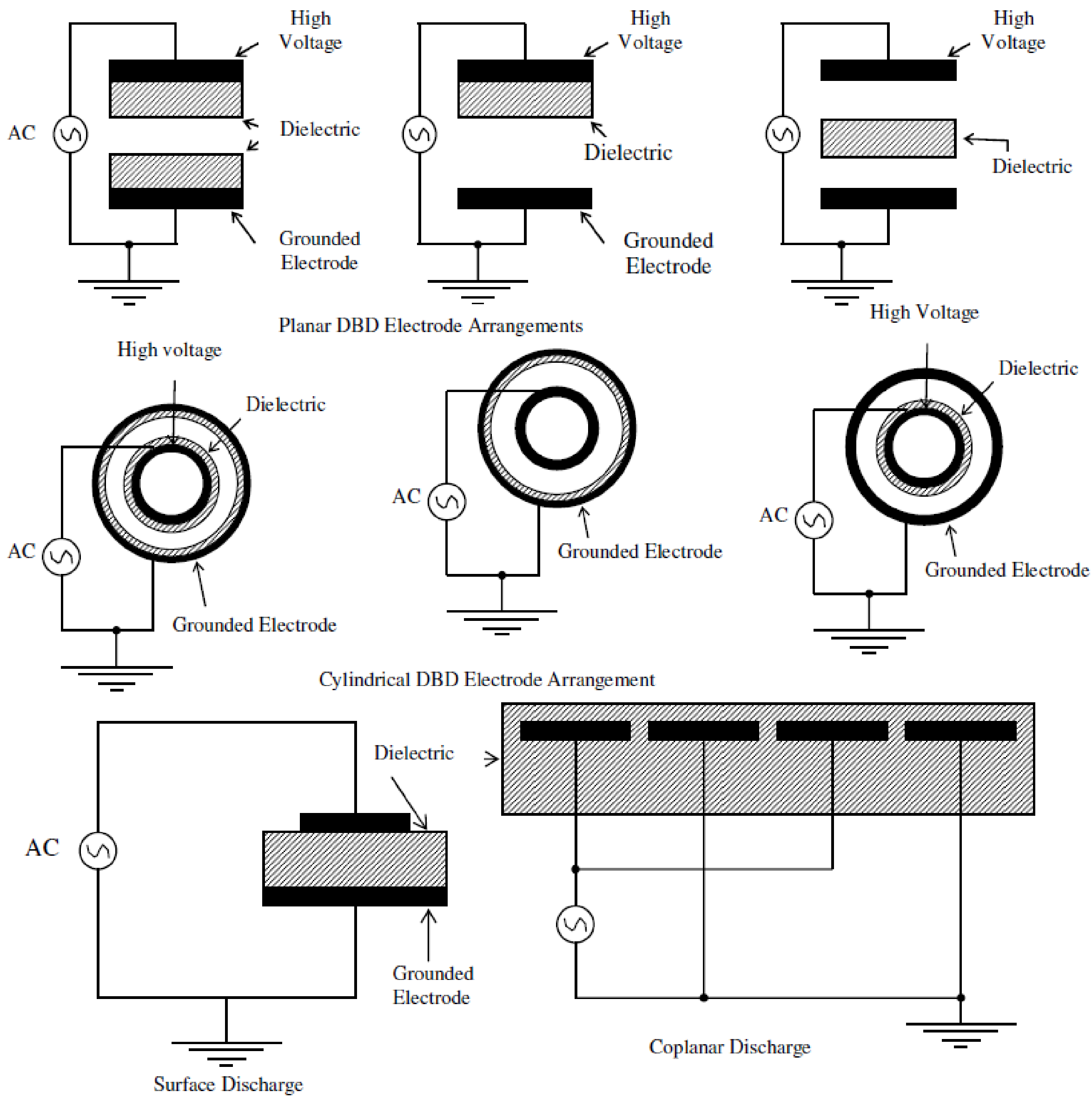

Fig. 1 Different arrangements of DBD

For large scale industrial applications and refineries, Cylindrical arrangement is more suitable then planner arrangement. Cylindrical arrangement also provides no-accumulation inside the reactor, where in planner arrangement its corner provides dead end for passing gases.

5. Application of DBD:

DBD technologies have an incredible potential [50-55] and are widely used in a large number of technical applications. The advantage of DBD over other discharges lies in having the option to work with non-thermal plasma at atmospheric pressure and a comparatively straightforward scale-up to large dimensions. Initially, this technology was utilized for ozone production for the treatment of drinking water. Since then the number of industrial applications of this type of discharge have shown a tremendous growth. Besides ozone synthesis, today the phenomenon of DBD in gases is widely used in the generation of excimer radiation in the UV/VUV spectral regions, surface treatment, in the field of environment protection, for pumping CO_2 lasers, pollution control, various thin film deposition processes, in the textile industry, and more recently in plasma display panel and in several other technological processes in science and industry.

For efficient excimer formation in non-thermal plasma, three conditions need to be satisfied: (1) the bulk gas has to be provided with a large concentration of energetic electrons with energies above the threshold for the metastable formation or ionization; (2) since the formation of excimers is a three-body process, the gas pressure needs to be high, close to atmospheric in order to have sufficiently high rate of three body collisions. The high pressure is needed to ensure that the excimer formation reaction is faster than any quenching processes of the excited precursors; (3) the gas temperature has to be cold since excimers are thermally unstable. These conditions can only be effectively achieved in electron driven high-pressure non thermal plasma processes occurring in DBD plasma.

DBD plasma remediation is concerned several successful laboratory and pilot investigations have been reported in the literature. The destruction of methane (CH_4), butane (C_4H_{10}), propene (C_3H_6), benzene (C_6H_6), toluene (methylbenzene, $C_6H_5CH_3$), styrene (vinylbenzene, $C_6H_5CHCH_2$), xylene (dimethylbenzene, $C_6H_4(CH_3)_2$), formaldehyde (HCHO), acetaldehyde (CH_3CHO), methanol (CH_3OH), propanol (C_3H_7OH) carbon tetrachloride (CCl_4), dichloromethane, trichloroethane (TCA, $C_2H_3Cl_3$), trichloroethylene (TCE, $ClHC=CCl_2$), perchloroethylene (PCE, C_2Cl_4), methylene chloride (CH_2Cl_2), chlorobenzene (C_6H_5Cl), and tetrafluoromethane (CF_4), was investigated.[3]

6. Conclusion:

In the present paper, the unique features of non-thermal plasma have made possible substantial breakthroughs in many growth areas of modern technology and newer applications are continuously emerging, more recently in the vastly growing areas of nanotechnology, which indicate that the non thermal plasma has become an important player in several up-coming technologies. On the other hand, the prospect of using plasmas in numerous industrial applications without the need of any vacuum equipment has been driving the search for methods to generate atmospheric pressure non-thermal plasmas. While there is still more to go in the development and utilization of these plasma sources, no doubt that low temperature atmospheric pressure gas discharge plasma is a promising technology, not only for the future, but also for today's processes and applications. Looking ahead, still many opportunities remain to be harnessed for further research and development in order to meet the demand of various diverse plasma technological applications.

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