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A Brief Survey on Treatment of Different Hydrocarbons Pollutants using DBD

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1. Abstract:

At dilute pollutant concentrations less energy than incinerators or other thermal processes is sufficient to treat the pollutants. Non-equilibrium plasma treatment of flue gas can achieve the cracking of such hydrocarbon pollutants present in the gas stream. In general it can be stated that non equilibrium plasmas use most of the discharge energy to produce and accelerate electrons. These electrons generate highly reactive free radicals which can selectively decompose toxic compounds. This can be achieved at low gas temperatures and at atmospheric pressure conditions that are of utmost importance for flue gas or off gas treatment. A prominent feature is the simple scalability from small laboratory reactors to large industrial installations. Industrial applications include ozone generation, pollution control and surface treatment. This work gives idea about the use of non-thermal plasma to reform or dissociate carbon-hydrogen bonds in hydrocarbons to obtain hydrogen and syn gas or to obtain methane as a product or to obtain various lower hydrocarbons from the mixture of volatile organic compounds.

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

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2. Introduction

The emission of volatile organic compounds (VOCs) from industries is an important factor associated with human and environmental health, and has both local and global impacts. Many VOCs are precursors to ozone formed by photochemical reactions leading to increased asthma. Different technologies have been used for controlling VOCs, including adsorption, incineration, condensation and biological treatment. Adsorption is generally cost-effective only for low concentrations of VOCs, whereas incineration and condensation are best used for high VOC concentrations. For air streams with medium to low concentrations of VOCs, biological treatment methods (e.g., biofiltration) have proven to be effective, however biofiltration is only applicable to the treatment of biodegradable Pollutants. An emerging air pollution control technology is non-thermal plasma (NTP) which has the potential to treat high flows for both low (<100 ppmv) to high (>1000 ppmv) concentrations of pollutants.

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

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. Application of DBD:

DBD technologies have an incredible potential 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 CO2 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 industr

Medicine Dielectric barrier discharges were used to generate relatively large volume diffuse plasmas at atmospheric pressure and applied to inactivate bacteria in the mid 1990s. This eventually led to the development of a new field of applications, the biomedical applications of plasmas. This field is now known as plasma medicine.

Water treatment An additional processwhen using chlorine gas for removal of bacteria and organic contaminates in drinking water supplies. Treatment of public swimming baths, aquariums and fish ponds involves the use of ultraviolet radiation produced when a dielectric mixture of xenon gas and glass are used.

Industry A dielectric barrier discharge is one method of plasma treatment of textiles at atmospheric pressure and room temperature. The treatment can be used to modify the surface properties of the textile to improve wettability, improve the absorption of dyes and adhesion, and for sterilization. DBD plasma provides a dry treatment that doesn’t generate waste water or require drying of the fabric after treatment. For textile treatment, a DBD system requires a few kilovolts of alternating current, at between 1 and 100 kilohertz. Voltage is applied to insulated electrodes with a millimetre-size gap through which the textile passes.

5. Survey on Treatment of VOCs:

Feed	Volt.(kV)	Freq.	Flow Rate	Resident Time	discharge gap(mm)	Product	Power
[1]Alcohols	10-30	1-6kHz	60-90sccm	-	1-3	CO+ H_2(100%)	-
H.C.+CO_2	15	4	35	-	1-3	CO+H_2(70%)	-
[2]mix.VOC	-	-	1.5slpm	0.016s	1.34	MEK(50%) benzene(58%) toluene(74%) 3-pentanone(76%) MTBE(80%) ethyl-benzene(81%) n-hexane(90%)	350 J/L
[3]Benzene	10	7.5kHz	100(+/-)5	-	2-6	methane(40%)	-
[4]n-Hexane	6	50kHz	100slpm	-	5	C_2H_5,C_3H_3,C_3H_5 C_3H_7,C_5H_9,H_2,C_3H_6	- -
[5]HCHO	19	60Hz	1.5slpm	6.6s	2.5	H_2O,CO,CO_2	-
[6]Ethane	13	450Hz	0.5-1slpm	-	1.75	H_2,CH_4,C_2H_2	-

Tab. 1 Reforming VOCs in DBD Reactor Data and parameters

In the design of DBD the inner electrode made up of stainless steel with controlled roughness and quartz tube with 25 mm diameter is outer electrode which is grounded. The process parameters, applied voltage and operational frequency respectively, are very important to control the process. The roughness of surface sustains the discharge, so controlled roughness is also very important for optimization of process.

The outer design of reactor made up of cylindrical quartz tube, 9mminner diameter, 266 mm length, 3.5 mm thick, fitted with an aluminum cylindrical sleeve 5 cm long. and 3.2 mm thick inner electrode is centred in it and connected to high voltage power supply which is made up of stainless steel rod of 6.32mmO.D. and 40 cm long. All VOCs are at same operation parameters to determine how treatment performance was affected by the nature of pollutant. Large hydrogen molecules compounds are more reactive and better removal, without effecting the reactor's removal efficiency.

40% methane is produced by disintegrating 50-1100 ppm benzene and remaining trace is transformed into solid mixture of non-volatile hydrocarbons and very small amount of phenol produce which deposited on the surface of dielectric.

Reactor's outer electrode(quartz tube), which is grounded, has 6.5 mm D respectively and inner high voltage wire electrode has 1.5 mm D. total length of ground electrode is 100 mm. By varying parameters, such as temperature, oxygen addition, helium concentration etc, could change the dissociation pattern of hexane to yield olefin product.

In the design of reactor outer electrode, fused silica tube, is surrounded by 120mm high cylindrical mesh (Ç 1 mm) which is connected to power supply. Decomposition of ethane produces major yield of H_2 , CH_4 , C_2H_2 & C_2H_4.

The outer electrode is made up of pyrex glass tube with 3.2 mm diameter and inner electrode is molybdenum rod with 0.24 mm diameter which is covered with glass ball to prevent corona discharge. As the system is powered by 19 KV and gas stream contain 150 ppmv HCHO, and flow rate controlled at 1.5 slpm. The rate of CO (ppmv) will decrease in the product at outlet as the increase of oxygen (by vol.%) in stream gas. Parameters by which destruction of HCHO affected are gas composition, voltage, gas residence time.

6. Conclusion:

In this study, the treatment of selected volatile organic vapors in a DBD-type non-thermal plasma reactor was evaluated. Experiments conducted at the same operating conditions for all VOCs allowed to determine how the treatment performance was affected by the nature of the pollutant. This simple technology proffering one-step and instantaneous chemical conversion of hydrocarbons to lower alkenes is a pointer for the need of its further development in practical lines so that it may emerge as an exploitable green tactic for conversion of typical hydrocarbons to usable/useful products, especially in the context of current global intents on undesirable pollutants' alterations. For methanol and ethanol 100% conversion can be obtained for relatively high flows of reactants. The applied voltage and the operational frequency are also very important parameters for the control of the process. Thus, increasing the voltage always produced an increase in the conversion yields. Decomposes ethane into smaller fragments—the major products of decomposition being H2, CH4, C2H2, and C2H4. The measured total yield of decomposition products is in reasonable agreement with the estimated aggregate yield, based on the simple assumptions employed. Destruction of HCHO molecules can be achieved via direct electron attack or indirect gas-phase radical reaction. HCHO removal efficiencies achieved with DBDs depends on the applied voltage, gas composition, and to a second order effect, gas residence time for the evaluated conditions. The great potential of applying DBD as an alternative technology for removing VOCs with relatively low concentration (down to tens of ppmv) from gas streams has been demonstrated in this study.

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