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ORIGINAL RESEARCH ARTICLE **OPEN ACCESS**

EFFECT ON PLASMA PARAMETERS IN A DIELECTRIC BARRIER DISCHARGE REACTOR WITH VOLATILE ORGANIC COMPOUNDS

[1]S. Mohanty, S. P. Das*, [1]G. Sahoo, [1]R. Paikaray, [1]P. S. Das, [2]S. Samantaray, [3]D. S. Patil

[1]Ravenshaw University, Cuttack-753003, Odisha, India
[2]Christ College, Cuttack-753001 Odisha, India
[3]Bhabha Atomic Research Center, Anushakti Nagar, Mumbai-400085, Maharastra, India

*Corresponding author's email: dassmrutiprava@yahoo.in

ABSTRACT
A Dielectric barrier discharge (DBD) device is set up in Ravenshaw University, Cuttack, India to study the plasma assisted destruction of volatile organic pollutants like nitro - benzene and chloro-benzene etc. Plasma parameters like electron density and temperature for argon plasma is measured using spectroscopic technique. The electron temperature of plasma is found to be ~ 1.81 eV for applied voltage 7 kV, MFC at the rate of 1 lit/min and the plasma current is ~ 0.31 mA. When the applied voltage is increased electron temperature as well as electron density increases so also the plasma current showing enhancement of ionization. Volatile organic compound like nitro-benzene on treatment with argon plasma environment inside DBD reactor increases electron temperature in the system and the electron density also increased twice. On the other hand when chlorobenzene is treated with plasma the electron temperature in the system decreases appreciably so also electron density. This indicates the dissociation of chlorine from benzene to neutralize free electrons of argon plasma acting as electron scavenger.

Keywords: DBD, VOC , Nitro-benzene, Chloro-benzene, Electron temperature

INTRODUCTION
Volatile Organic Compounds emitted from different outdoor sources like transportation, paint and office equipment industries are now a matter of regret. These compounds are like different aliphatic and aromatic organic compounds which contain oxygen, nitrogen and sulfur compounds mainly [1]. VOCs are very harmful to the living organisms as well as to the existing environment. Some typical aromatic compounds having different health effects are shown in the Table.1 [2, 3]. VOCs react with nitrogen and sulfur oxides to form photochemical smog and acid rain [4]. Total abatement of VOCs is now a matter of concern as well as to utilize the same in energy conversion. Different abatement technologies like thermal and catalytic incineration, absorption, adsorption, condensation, bio-filtration, membrane separation, ultra-violet oxidation [5-11] and the non-thermal plasma technology [12].

NTP-DBD has its own utility for VOCs decomposition. This can be carried out at low temperature and atmospheric pressure in normal condition at the laboratory [13]. It has significant results in different areas like surface and material processing, biological and decontamination of media, light source, absorption and reflection of electromagnetic radiation with great achievement for the synthesis of nano material [14] and pollution control to energy recovery [15].Working principle of APDBD reactor can be well proven by the determination of basic plasma parameters and their properties which depend on several factors like type of electrodes, type of dielectric materials, power, and concentration of the carrier gases or VOCs and atmospheric conditions like humidity, gas gap distance as well [16-18]. In DBD plasma, electron temperature and electron density like parameters plays important role for their mechanism of ionization process in pure carrier gas with/without VOCs taken. Decomposition of VOCs to different non-toxic materials through these parameters is well understood [19]. To determine electron density and electron temperature, several methods like Langmuir probe, microwave interferometer, Laser Thomson Scattering and optical emission spectroscopy (OES) are used [20].Among those optical emission spectroscopy is the most suitable method. It provides detailed information about plasma parameters, densities of excited atoms, ionization, and dissociation of discharge plasma species [21]. In the present work, these parameters are measured by spectroscopic method for Argon and compared with that in presence of the VOCs. The significant results obtained help to find basic ideas for the decomposition of VOCs.

EXPERIMENTAL

The experimental set up is given in Fig. (1) & (2). The assembly consists of a parallel-DBD reactor with pyrex glass as dielectric materials covered these two electrodes. Two MFCs are connected to the carrier gas and the other to the VOCs gas container which controls the mass flow the above twos. A high voltage AC supply (0-30) kV with frequency 50Hz is applied. At different voltages like 6kV, 7kV and 8kV, emissions of plasmas are measured and analyzed. The electrode gap maintained in 6mm.

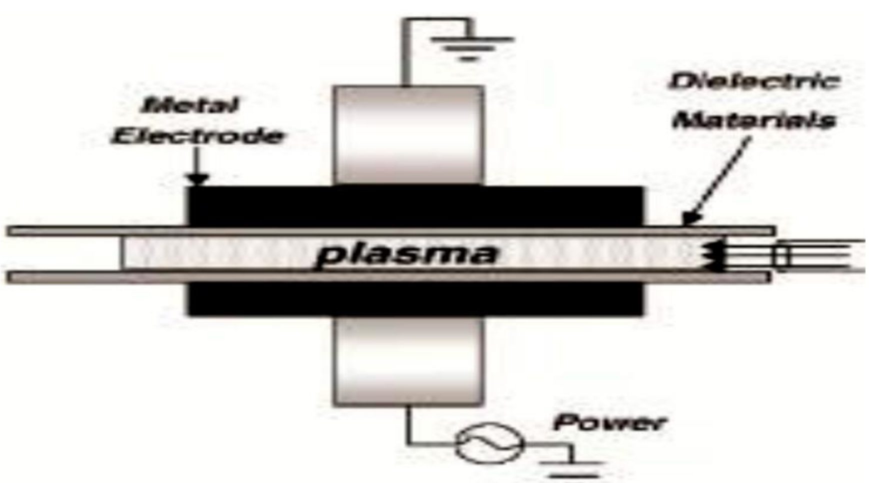

Fig: 1 DBD reactor

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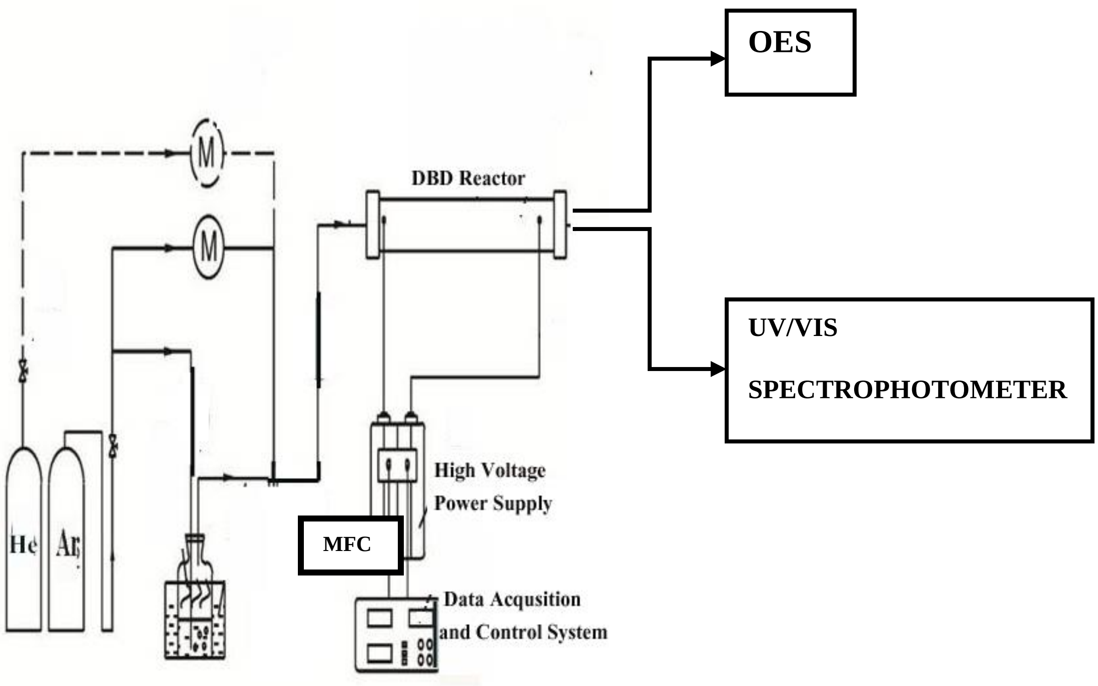

Fig: 2 Experimental Details

Table.1 Typical Aromatic Compounds

VOC type	Health effects	Maximum allowable	Emission source
Benzene	Headache, chest stuffy, paralysis	0.5	Vehicle tail gases, Combustion, etc.
Toluene	Paralysis of nerve center, nausea, muscle weakness	0.3	Vehicle tail gases, Painting industries,
Xylene	Dizziness, paralysis of nerve center	1.5	Painting industries, Vehicle tail gases,
Phenol	Respiratory irritation, stupefaction	0.1	Combustion, Spice
Aniline	Liver and kidney disease	0.5	Aquatic products processing, Leather,etc.
Chlorobenzene	Paralysis of nerve center, headache, dizziness	0.5	Dye, Pharmacy, Leather, Painting
Nitrobenzene	Tinnitus, nausea, shock	0.05	Dye, Pharmacy, Pesticide, etc.
Benzopyrene	Carcinogen, teratogenesis	$0.01\ 9\ 10^{-3}$	Combustion, Vehicle tail gas, tar, etc.

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RESULTS AND DISCUSSION

The break down voltages of different VOCs with He gas as carrier gas are shown below.

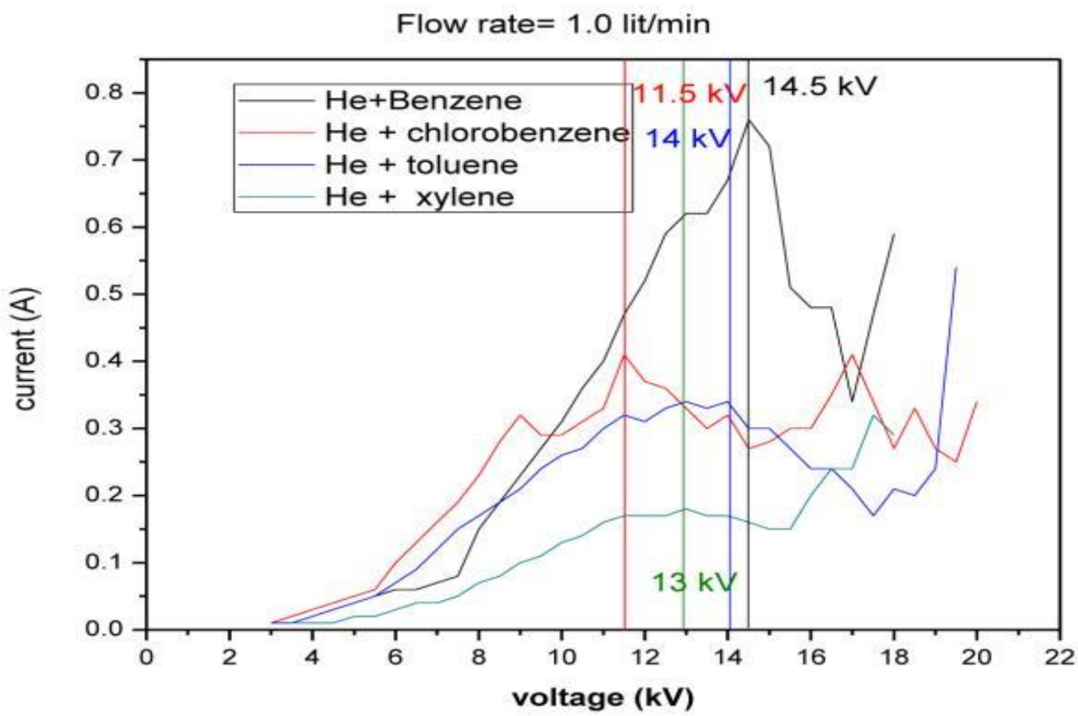

Fig: 3 Breakdown voltages of different VOCs with He as carrier gas.

It is observed that C-Cl bond energy is highest ~399.19 kCal/mole, but its breakdown voltage is 2.7kV, where as benzene is ~390kCal/mole, but dissociates at 3.0kV. The glow region starts at 11.5kV for chlorobenzene where as that of benzene is 14.0kV. This may be because the electron affinity of Cl is appreciable. As soon as the chamber is filled with He plasma, Cl gets detached from chlorobenzene and becomes neutral recombining with free electron in the plasma. For benzene the maximum current drawn is ~ 0.67mA and for chlorobenzene it is lower than benzene i.e. 0.41mA. This may be because the chlorine ions get detached from chlorobenzene by decomposition in DBD reactor. In plasma an ensemble of atoms and/or ions as a whole may be a dynamical process of ionization or recombination. In these processes in addition to direct ionization and recombination, excited levels may play essential role and they affect effective rate of ionization and recombination. Magnitude of ionization flux is proportional to the excited level population. We know spectrum is the finger print of the plasma. Since a spectral line is emitted by excited atoms/ions, its intensity is given by the number density of these atoms/ions. Thus intensity distribution represents population density distribution of atoms/ions over excited levels and ground state.

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Electron Temperature and Density.

The basic parameters of Ar plasma with and without VOCs are measured from the figures 4, 5, 6,7and 8 as well as the data are given in Table 2 and 3.Electron temperature is estimated using the line intensity ratio method.

Ratio of intensities of spectral lines of some element of same degree of ionization/ excitation may be written as

$$I_2/I_1 = (Ag\upsilon)_{2} / (Ag\upsilon)_{1} [\exp (E_1-E_2)/kT] \quad \ldots\ldots\ldots\ldots (1)$$

Hence electron temperature

$$T_e = [\{(E_2-E_1)/k\}/[\ln\{(Ag\upsilon)_2/(Ag\upsilon)_1\}-\ln(I_2/I_1) \ldots\ldots\ldots\ldots \quad (2)$$

$$\text{Electron Density} = \frac{I_a}{I_i} \times \frac{(Ag)_i \lambda_a}{(Ag)_a \lambda_i} \times 2\left(\frac{2\pi mkT_e}{h^2}\right)^{3/2} \times \exp^{-\left[(U-\Delta U)-\frac{(E_a-E_i)}{kT_e}\right]}$$

The electron temperature of Ar plasma is found to be ~ 1.78 eV for applied voltage 7 kV, MFC at the rate of 1 lit/min and the plasma current is ~ 0.31 mA. When the applied voltage is increased electron temperature as well as electron density increases so also the plasma current showing enhancement of ionization.

Table: 2 Te & n_e of Ar in different voltages.

VOLTAGES(kV)	TEMPERATURE(Te)	DENSITY(ne)
6	1.77 eV	$2.05 \times 10^{-22} m^{-3}$
7	1.78 eV	$2.09 \times 10^{-22} m^{-3}$
8	1.82 eV	$2.67 \times 10^{-22} m^{-3}$

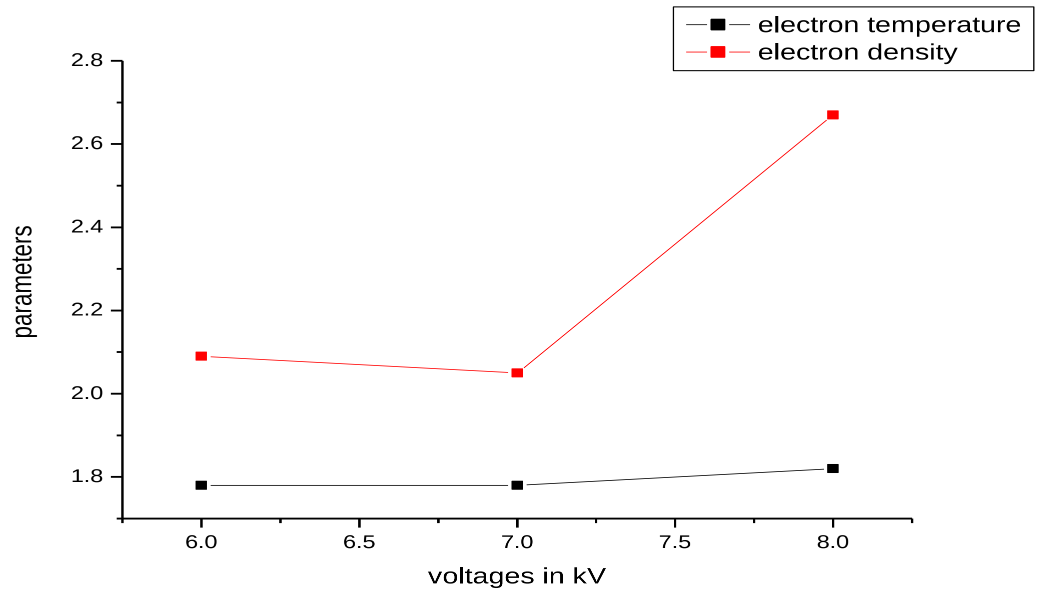

Fig: 4 Te & n_e of Ar in different voltages.

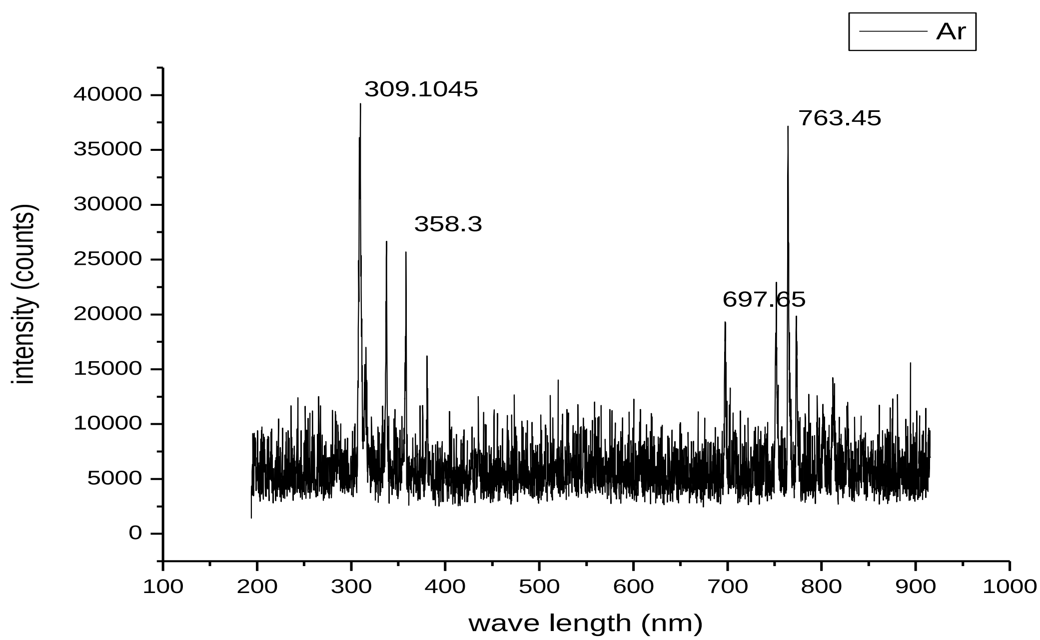

Fig: 5 Different Ar lines

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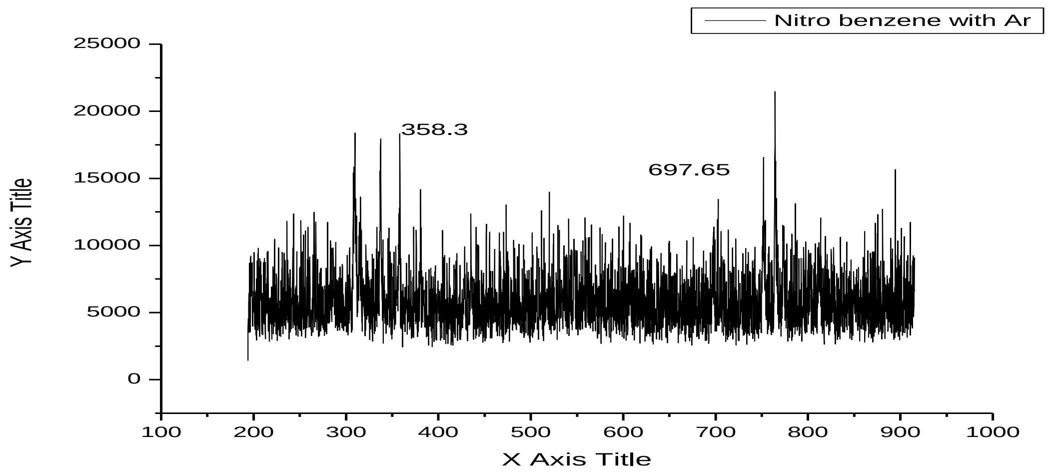

Fig: 6 Different Ar lines in presence of Nitrobenzene.

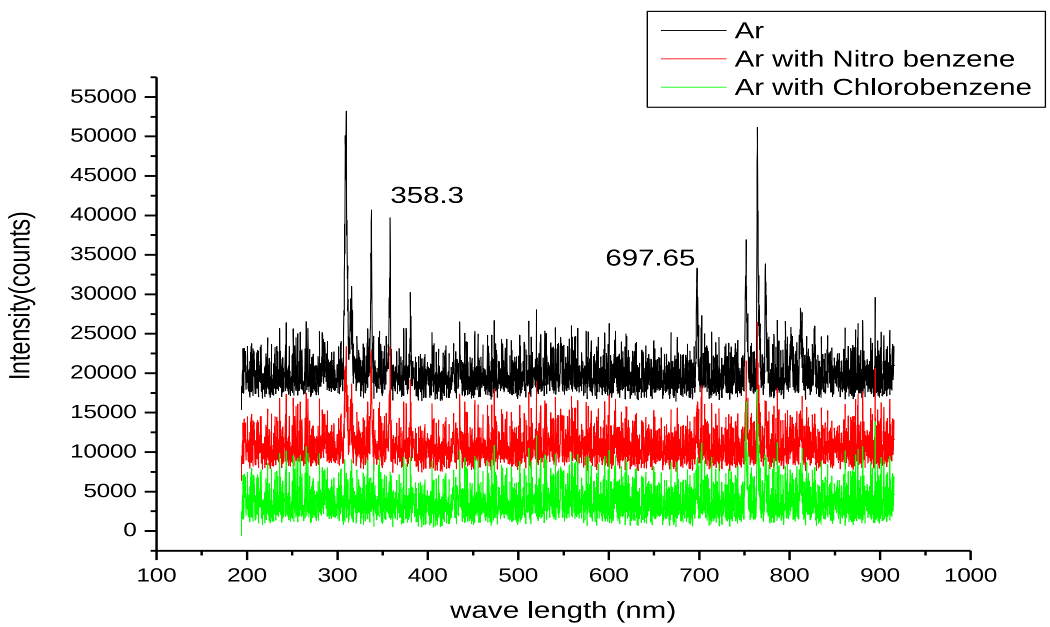

Fig: 7 Comparison of Ar lines presence and absence of VOCs.

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COMPOUNDS	ELECTRON TEMPERATURE	ELECTRON DENSITY
Ar	1.78 eV	$2.53 \times 10^{22}\ m^{-3}$
Nitro benzene with Ar	1.95eV	$5.29 \times 10^{22}\ m^{-3}$
Chloro benzene with Ar	1.64eV	$.92 \times 10^{22}\ m^{-3}$

Table: 3 Comparison of Te & n_e of Ar presence and absence of VOCs.

Volatile organic compound like nitro-benzene on treatment with argon plasma environment inside DBD reactor increases electron temperature in the system and the electron density also increased twice. On the other hand when chlorobenzene is treated with plasma the electron temperature in the system decreases appreciably so also electron density. This indicates chlorobenzene decomposes first due to high electro-negativity of chlorine, which acts as an electron scavenger decreasing electron temperature.

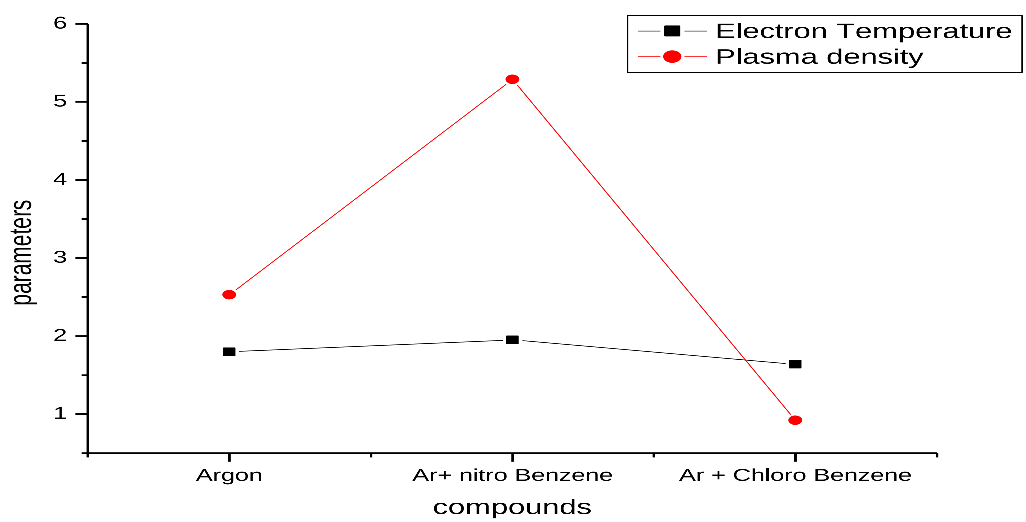

Fig: 8 Comparison of Te & n_e of Ar presence and absence of VOCs.

CONCLUSION

The NTP-DBD is good and cost effective. It shows good results in low frequency condition like at 50Hz. So it can be widely used in industries for the decomposition of different pollutants and pollution is controlled. Also the usable byproducts can fulfill the energy deficiency. DBD-NTP is no doubt one of the greatest green technologies.

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