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Temperature runaway in a pulsed dielectric barrier discharge reactor

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ABSTRACT

This paper reports on experimental measurements of the gas temperature in a dielectric barrier discharge reactor powered by a high voltage pulsed signal. It is shown that the thermal behavior of the reactor follows a first order model. However, an unexpected runaway phenomenon was observed at a frequency of 300 Hz. A sudden increase in the power source and consequently in reactor temperature which reaches 170 °C is observed. This behavior is discussed in terms of input power variation with temperature, possibly due to a resonance phenomenon.

1. Introduction

Non thermal plasmas which can be generated at atmospheric or lower pressures are in non-equilibrium state so that the gas temperature is considered to be at a temperature only slightly higher than the ambient temperature while electrons temperature is about 10000 K. In these plasmas, free radicals (O°, HO°…) are formed and can be used in many applications such as pollution abatement [1–3], surface treatment [4] or chemical vapor deposition (CVD) [5]. A great deal of experimental, theoretical and numerical works has been conducted so far and helped us to better understand these processes [6]. Whatever the concerned application, gas temperature has a great influence on the electrical parameters and on the nature and production of primary species formed by plasma and must then play an important role.

The increase of temperature leads to modify current and voltage shapes as it has been shown in [7]. Moreover, the increased number of gas collision can cause a large fraction of the input power to be dissipated in gas heating. The measurements have been generally performed by spectroscopic methods which allow the determination of vibrational and rotational molecules temperatures. The direct use of thermocouples in the plasma region is not possible since the electromagnetic environment and the presence of electrons and ionized species can initiate undesirable sparks. In a previous work we have already shown that gas temperature measurements can be achieved by using optical fibers [8]. These very first results have allowed us to calculate the heat transfers and losses with a simple analytical heat conduction model. A lumped heat capacitance model has been presented in [9] for the modeling of the unsteady regime.

According to the work of Okazaki et al. [10] and Liu et al. [11] the use of a pulsed power source seems to be more efficient for volatile organic compound treatment or ozone formation than sinusoidal one. We have therefore used a bipolar pulsed power supply which could produce positive and negative pulsed discharge so that the charges on the dielectric surface accumulated during the first part of the pulse discharge strengthen the electric field induced by the inversion of the polarity, favoring then the plasma formation.

In this work we report for the first time an experimental measurement of the gas temperature in a dielectric barrier discharge (DBD) plasma reactor powered by a bipolar voltage pulse with a frequency ranging from 100 to 300 Hz which corresponds to the range of input energy densities used for VOC elimination [12,13]. In the case of VOC elimination from air many works are published coupling a catalyst to the plasma reactor [13,14], the efficiency of the catalyst increasing when it was heated. In order to reduce the energy expense or to avoid the thermal destruction of the reactor it is necessary to describe how the plasma alone can heat the reactor.

The unsteady electrode and gas temperatures were monitored from the initial time until a steady state was reached. It is shown

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