Determination of the First Townsend Coefficient in Pure Isobutane

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Abstract. In this work studies of the first Townsend coefficient (α) behavior in isobutane for reduced electric fields ranging from 139Td up to 208Td are presented. Pure isobutane has been widely used in Resistive Plate Chambers (RPCs) and other gaseous detectors because of its excellent timing properties. Regardless of these characteristics, there is a lack of swarm parameters data in the literature for this gas. The measurements were based on the Pulsed Townsend technique. Considering the ratio between the current, measured in avalanche mode, and the primary ionization current, the first Townsend coefficient can be determined. In order to validate the technique, results for nitrogen are also presented.

Keywords: First Townsend coefficient, avalanche regime, isobutane.
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INTRODUCTION

The first Townsend coefficient (α) is a fundamental transport parameter used to describe the charge growth in a detector operating in avalanche mode. Defined as the number of electrons created per unit of length, the first Townsend coefficient depends on the gas nature and on the electric field strength. Beyond its practical applications, this parameter also plays an important role for modeling discharge and for validating electron collision cross-sections [1].

Recently, the experiments in high energy Physics and the development of particle detectors operating in high electric field ranges have motivated the determination of α coefficient in complex molecular gases. In this context, due its timing and quenching properties, isobutane (iC_4H_{10}) has been used in resistive plate chambers (RPCs) and other gaseous detectors [2-3]. However, there is a lack of swarm parameters data in literature for this gas.

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The experimental method used in the present work is based on the pulsed Townsend technique and follows from the relation $\alpha = d^{-1}\ln(I/I_0)$, where d is the gas gap, I is the current in avalanche mode and I_0 the primary ionization current.

In order to validate the technique, the measurements were first performed to nitrogen, which is a widely studied gas. Results concerning signal analysis and studies of electric field uniformity were earlier published and led to changes in anode dimensions, which were performed in the present work [4].

EXPERIMENTAL SETUP

In our configuration parallel electrodes are enclosed in a stainless steel chamber at gas flow regime, under atmospheric pressure. The cathode is made of aluminium (40mm diameter) and the anode consists of a high resistivity ($2.10^{12}\Omega$.cm) glass ($32.5\text{x}32.5\text{mm}^2$). The parallelism procedures are made by the means of three micrometers (189 Mitutoyo®) connected to the anode while the cathode is fixed to a linear positioner (L2241-2 Huntington®), which enables varying the gas gap (Fig.1a). Further details concerning the chamber design are described by P. Fonte *et al*. [5].

Photoelectrons are released from the cathode by the incidence of a fast nitrogen (λ = 337.1nm) pulsed laser (MNL200-LD LTB®) through a quartz window, as shown in Fig.1b. The extracted electrons drift toward the anode under the electric field applied through a high voltage power supply (225-30R Bertan®). This charges movement produces an electric current which is measured by an electrometer (610C Keithley®), directly connected to the cathode.

In the present work the method employed to measure the parameter α is based on the solution of the Townsend equation for uniform electric fields. Considering the ratio between the current measured in avalanche mode (I) and the primary ionization current (I_0), the α coefficient can be determined, since $\alpha = d^{-1}\ln(I/I_0)$, where d is the gas gap.

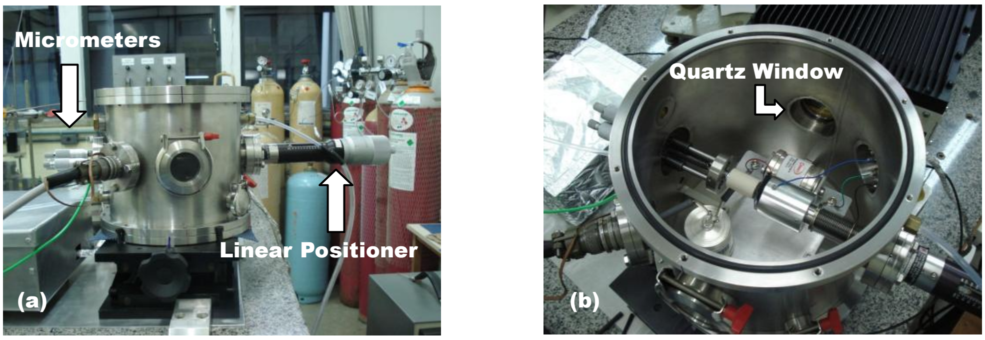

FIGURE 1. (a) Micrometers and linear positioner (b) Laser-chamber configuration.

RESULTS

The first Townsend coefficient was measured for nitrogen and for isobutane as a function of the reduced electric field E/N, where N is the gas density. The results were compared with data from Magboltz 2.7.1 simulation [6] and with data from literature

[7]. Written by S. Biagi, this simulation is based on a Monte-Carlo integration and solves numerically the Boltzmann transport equation.

The electric current was measured as function of the electric field, with a gap between the electrodes of 1.25mm, under atmospheric pressure (Fig. 2). The flat part of the curves corresponds to the primary ionization current, which depends on the laser intensity, and the exponential part corresponds to the current in avalanche regime. The uncertainties were evaluated considering the electrometer instrumental precision. The divergence between Data 1 and 2, for nitrogen, are due to different temperature and pressure. On that account, the α coefficient is normalized to the gas density N.

From these data, α coefficient was determined and since nitrogen is widely studied, measurements of α coefficient were first performed for this gas (Fig.3).

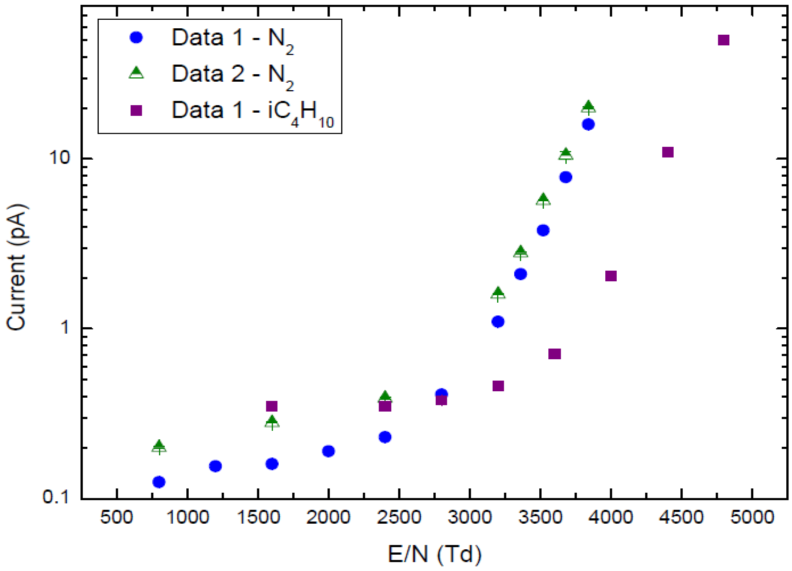

FIGURE 2. Current as function of the electric field for nitrogen and for isobutane.

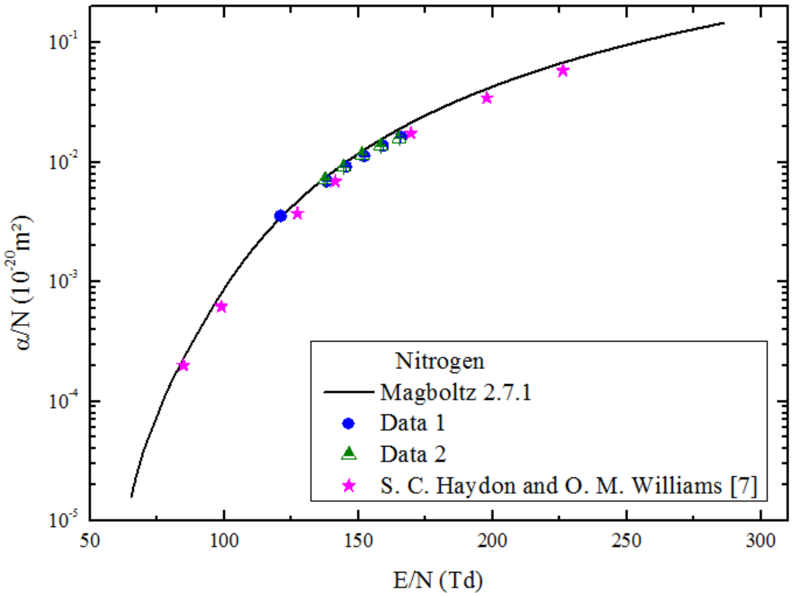

FIGURE 3. : First Townsend coefficient in nitrogen.

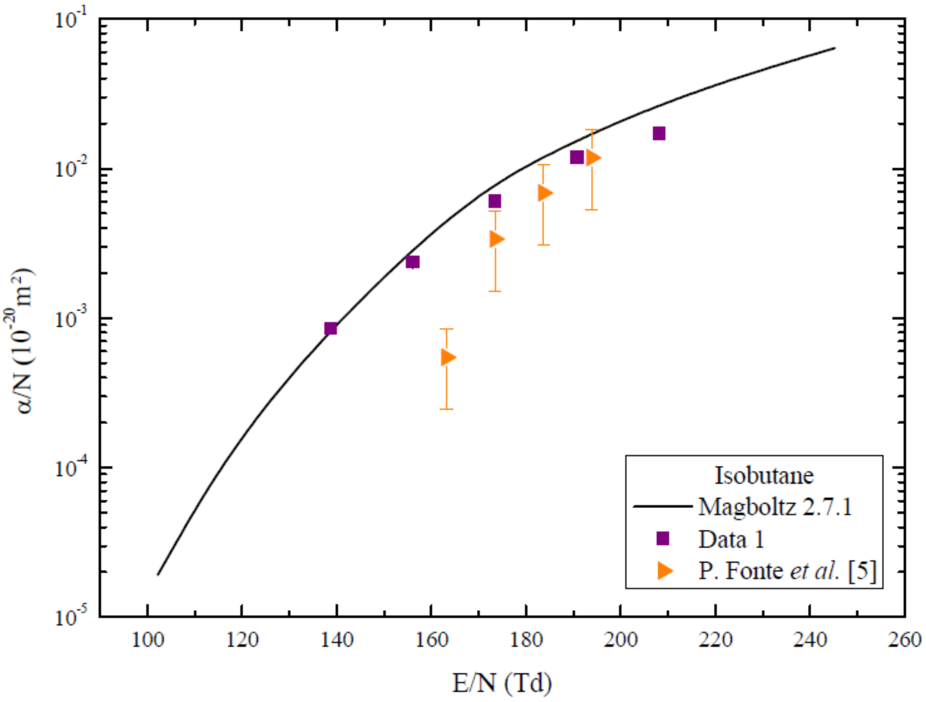

FIGURE 4. : First Townsend coefficient in isobutane.

The good agreement found with nitrogen led us to extend the technique to isobutane (Fig.4). In Fig. 3-4 are also shown results of α/N obtained with Magboltz 2.7.1 code. The results were also compared with data published earlier by the group, which were obtained with a smaller anode and a method based on pulse shape analysis [5] (Fig.4).

CONCLUSIONS

In this work the technique for determining α coefficient was validated by means of measurements with nitrogen. The procedure led to the determination of the first Townsend coefficient in isobutane. The data were compared with those simulated with Magboltz 2.7.1 and with results earlier obtained by the group. This comparison showed that the results behavior is satisfactory in comparison with Magboltz 2.7.1 code and is better than the earlier published data from the group. Nevertheless, in order to extend the reduced electric field range, studies concerning reproducibility for different gas gaps are under way.

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