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MEASUREMENTS OF THE GASEOUS MULTIPLICATION COEFFICIENT IN PURE ISOBUTANE

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ABSTRACT

In this work we present the preliminary studies of the first Townsend coefficient behavior in isobutane for reduced electric fields ranging from 173 Td up to 281 Td by means of signal amplitude analysis. The measurements were based on the Pulsed Townsend technique. The experimental setup consists of two parallel plates housed in a stainless steel chamber at gas flow regime. In our configuration, the primary electrons are produced by irradiating the cathode with a fast nitrogen laser (700 ps pulse duration). In order to validate the technique and to analyze effects of non-uniformity, results for nitrogen are also presented.

1. INTRODUCTION

In the last two decades, due to the increasing demands concerning High Energy Physics, Nuclear Medicine and other Nuclear Applications about gaseous detectors operating at high electric fields, many efforts in radiation and detection have been done about the choice of filling gases that fulfill these requirements [1]. In this context, the determination of electron transport parameters in gases at high electric fields is of great importance for simulation and modeling of discharges, allowing the validation of electron impact cross-sections and detector design. Among various gases, pure isobutane has been widely used in Resistive Plate Chambers (RPCs) and other gaseous detectors because of its excellent timing properties [2,3]. However, there is a lack of swarm parameters data in literature for this gas, mainly at high electric fields.

The transport parameter used to describe the development of avalanche growth is the gaseous multiplication coefficient α (or first Townsend coefficient), which represents the number of electrons created per unit of length along the electric field direction. Although there are established data of multiplication coefficient in literature for several gases, there is an interest in organic gases with complex molecules, such as isobutane [4].

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 (I), measured in avalanche mode, and the primary ionization current (I_0), the effective multiplication coefficient can be determined, since $\alpha = d^{-1}\ln(I/I_0)$, where d is the gap between the electrodes. As the current is related to voltage, these preliminary measurements were carried out by means of signal amplitude analysis.

In order to validate the technique, measurements were first performed for nitrogen, since it is a widely studied gas and there are accurate data available in the literature. Furthermore, these preliminary results permitted to analyze effects of non-uniformity of the electric field and gas impurities contribution.

2. MATERIALS AND METHODS

The experimental setup (Fig 1a) consists of parallel electrodes housed in a stainless steel chamber at gas flow regime, under atmospheric pressure (P = 101 kPa). The cathode is made of aluminium (40 mm diameter) and the anode consists of a high resistivity (2.10^{12} Ω.cm) glass (3 mm thick and 5x5 mm^2). The gas gap could be varied by means of a micrometer linear positioner with 2 μm scale resolution (L2241-2 Huntington®).

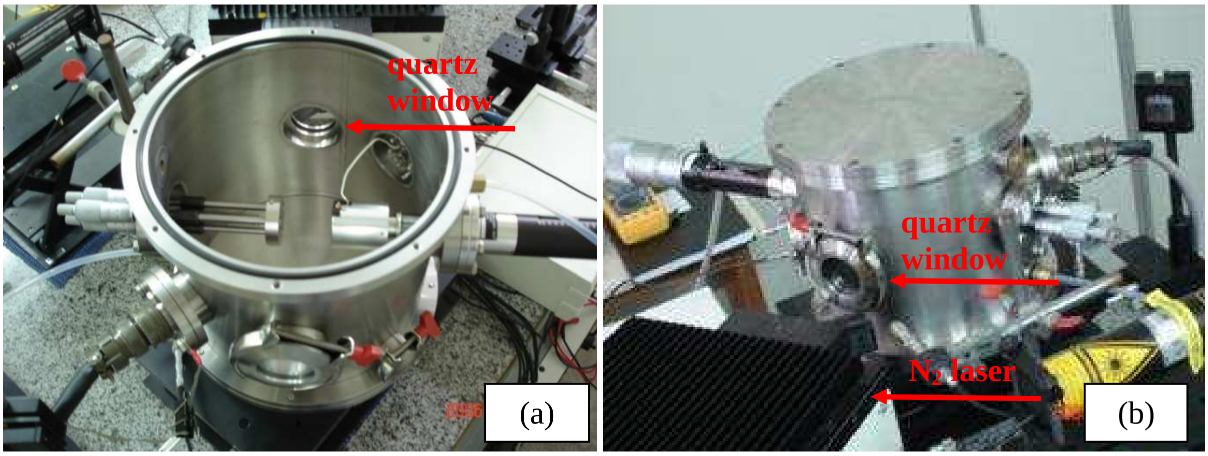

Figure 1. (a) Electrodes inside the chamber (b) Laser-chamber configuration.

Photoelectrons are released from the cathode by the incidence of a fast nitrogen laser (MNL200-LD LTB®) through a quartz window, as shown in Fig.1b. This laser has low divergence, wavelength of λ = 337.1 nm, 700 ps pulse duration and maximum repetition rate of 20 Hz. In order to accelerate the photoelectrons toward the anode, a high voltage power supply (225-30 BERTAN®) was used to create a high electric field. Procedures to ensure the electrodes parallelism and the laser alignment were performed prior to starting each set of measurements.

The signals were fed to a fast amplifier (35.5 dB gain) developed and built at LIP/Portugal [5] and then digitized by a 1 GHz bandwidth oscilloscope (WavePro 7000, LeCroy®). Since the multiplication coefficient depends on parameters such as gas nature, temperature, pressure and electric field, the amplitude dependence on the reduced electric field (E/N, where N is the gas density), was studied. Basically, the multiplication coefficient follows an exponential growth with the reduced electric field.

3. RESULTS

In Fig 2 typical signals obtained for nitrogen and isobutane are presented. As expected, isobutane shows higher amplitude, since, among other molecular characteristics, it has smaller ionization potential (10 eV for isobutane [6] and 14 eV for nitrogen [7]).

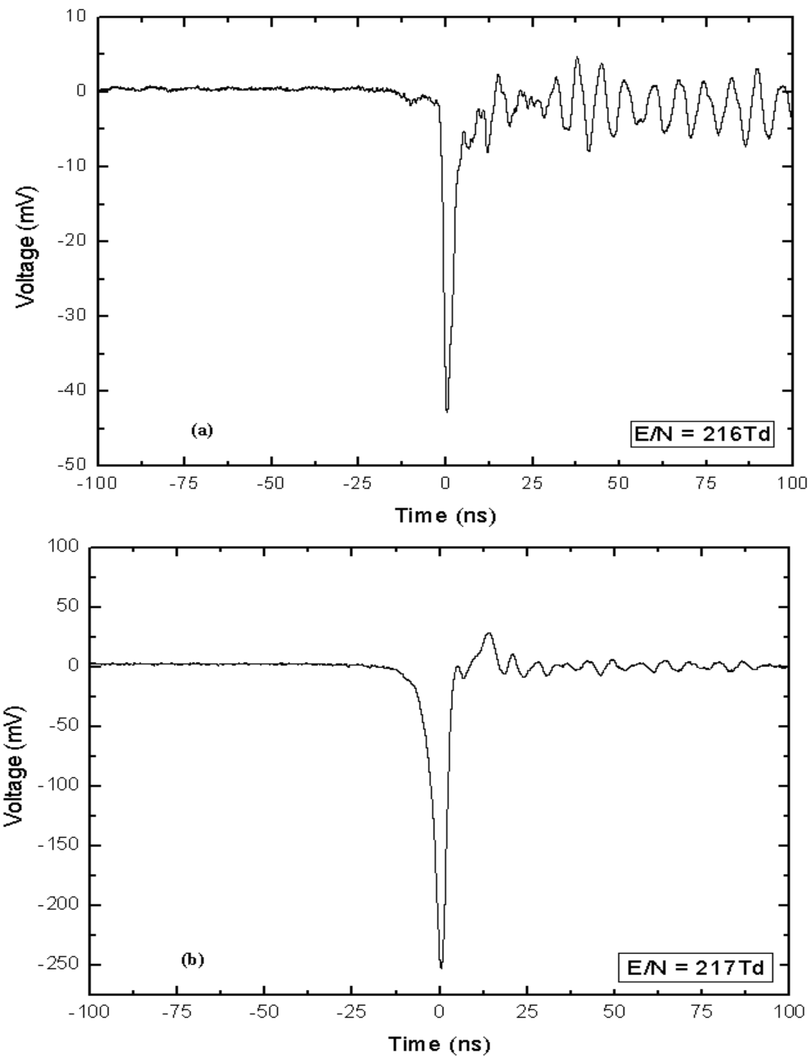

Figure 2. (a) Nitrogen and (b) Isobutane electric signals.

Tables 1 and 2 show the reduced electric field and amplitude values for nitrogen and isobutane, respectively, considering all gaps used and an average number of 30 waveforms.

Table 1. Reduced electric field and signal amplitude for nitrogen.

Gap (mm)	E/N (Td)	Amplitude (mV)
0,5	194	13.80(20)
0,5	216	43.0(6)
1,00	108	5.02 (13)
1,00	119	7.92(13)
1,00	130	9.37(14)
1,00	140	13.62(20)
1,00	151	30.1(4)
1,00	162	34.1(5)
1,00	173	107.0(16)

Table 2. Reduced electric field and signal amplitude for isobutane.

Gap (mm)	E/N (Td)	Amplitude (mV)
0,5	238	29.2(5)
0,5	259	98.6(16)
0,5	281	219(4)
1,00	194	9.89(15)
1,00	205	21.9(4)
1,00	216	58.8(10)
1,00	227	119.8(18)
1,00	238	241.1(4)
1,5	173	12.4(22)
1,5	180	22.2(4)
1,5	187	42.8(22)
1,5	195	76.2(12)
1,5	202	121.0(19)
1,5	209	149.0(29)
1,5	216	234(4)
1,5	217	253(4)
1,75	173	13.7(26)
1,75	179	22.1(6)
1,75	185	46.0(15)
1,75	191	65.4(15)
1,75	198	135(4)
1,75	204	139(4)

The amplitude dependence on the reduced electric field is shown in Fig 3, for nitrogen and isobutane. As mentioned before, since the amplitude is related to the multiplication coefficient, the exponential growth of the signal can be analyzed.

As we can see, for different gas gaps a discontinuous growth in the curves is observed for both gases. This indicates that undesirable non-uniformity effects of the electric field are present due to edge effects on the electrodes, mainly for smaller gas gaps (Fig.3b).

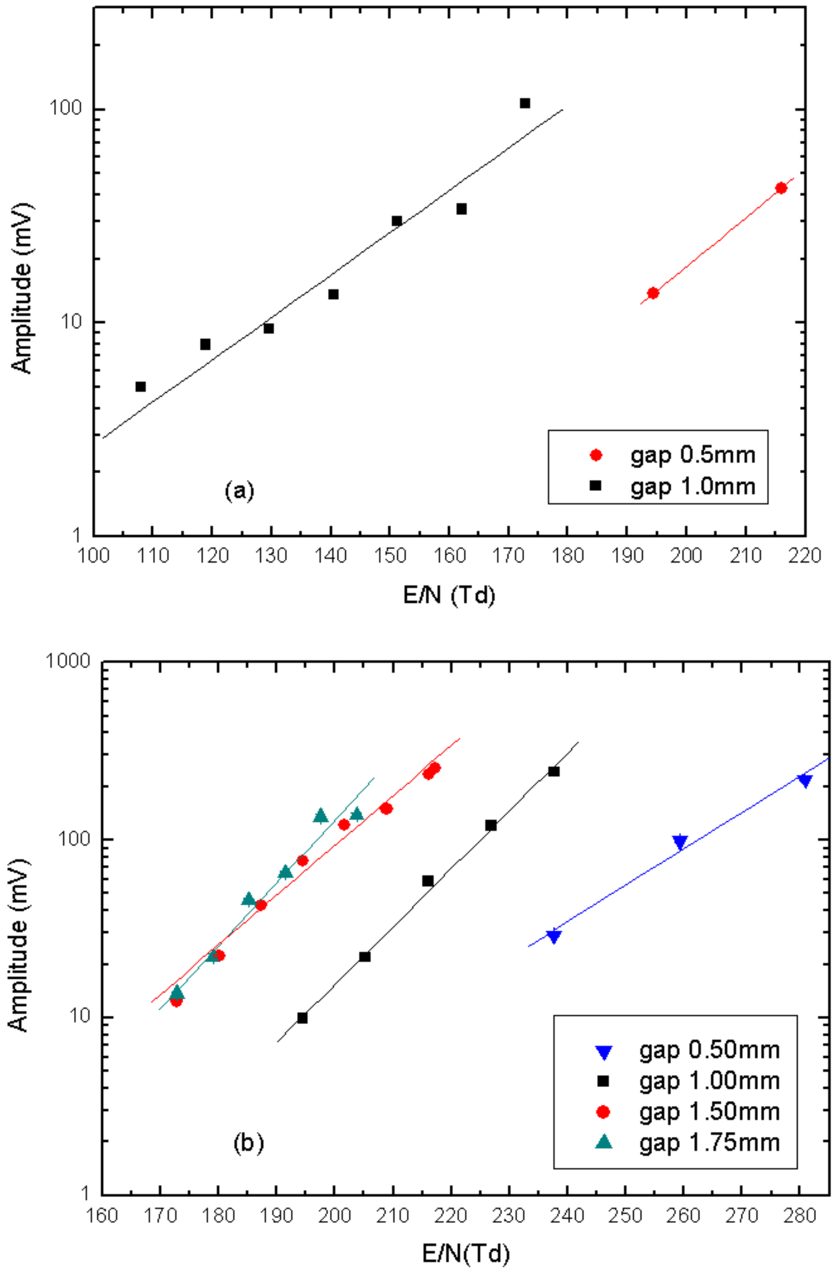

Figure 3. Amplitude versus reduced electric field for (a) nitrogen and (b) isobutane.

4. CONCLUSIONS

In order to validate the technique employed in this work, signals from nitrogen and isobutane for various reduced electric fields values were analyzed. The exponential behavior of the multiplication coefficient was verified by means of amplitude measurements. Also, the influence of non-uniformity effects for different gaps was observed. Since these effects are related to the electrodes dimensions, the forthcoming measurements will be carried out using electrodes with higher area-gap relation.

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