ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 8, Issue 1, January 2019

Effect on Propane Diffusion Flame Dynamics by Application of Electrostatic field

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Abstract: ***The purpose of this study is to obtain clean exhaust gases from the diffusion flame and get information about the effect of electrostatic field on the change in temperature profile throughout the diffusion flame. The atoms forming the fuel in the diffusion flame are ionized by pyrolysis, and these ions cause a dynamic change of the flame by the electric field. The position of the hot region of the flame and the width of the reaction zone were changed according to the intensity and direction of the electric field. Regardless of the air-fuel mixture ratio, the results showed the same tendency.***

Keywords: **Propane, Flame, Voltage, Polarity, Electric field.**

I. INTRODUCTION

Combustion means the process in which reactants are oxidized through various exothermic chemical reactions after pyrolysis of the fuel. During this process, many positive ions (cation) and negative ions (anion) are generated, and the ions are polarized, so they are affected by the electric field [1]. The dominant ion in the flame of hydrocarbon fuels is cation like CHO^+, $C_3H_3^+$ and $C_2H_3O^+$[2][3]. Concentration of electrons or negative ions such as O_2^- depends on the mixing ratio with air. The maximum ion concentration is observed in the reaction zone before the maximum temperature of the flame [4]. The purpose of this study is to investigate how the ions affect flame dynamics as they react to the direction and intensity of the electric field.

II. METHODS

Figure 1. Shows a schematic diagram of this experiment setup for propane diffusion flame with application of electrostatic field. The diffusion burner made of stainless steel. The diffusion flame is made from an axial propane supply of 0.5 l/min and a dry air supply of 6.25 - 25 l/min at the burner outlet. The flow rates are controlled by MFC (Line Tech M3100V). Ring-type electrode with the applied voltage (– 5 - + 5 kV) from high DC voltage supplier (GLASSMAN HIGH VOLTAGE INC.) is located 25mm height from the burnerto create an electric field. The electric field generated by the electrodes was simulated by using Ansys Maxwell 2D program as shown in Figure 2. The change of the flame dynamics was taken with a Thermal imaging camera (Fluke Ti400).

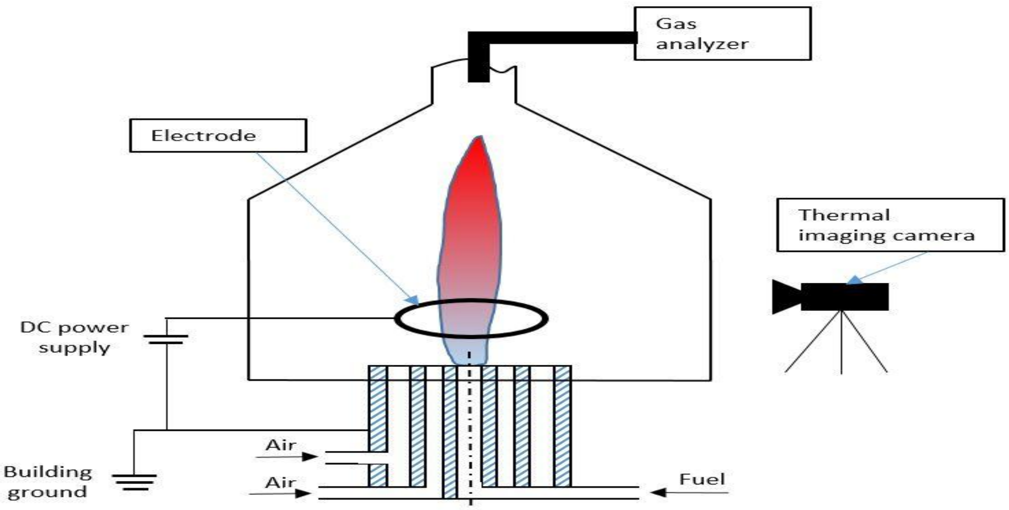

Fig 1. Experimental setup

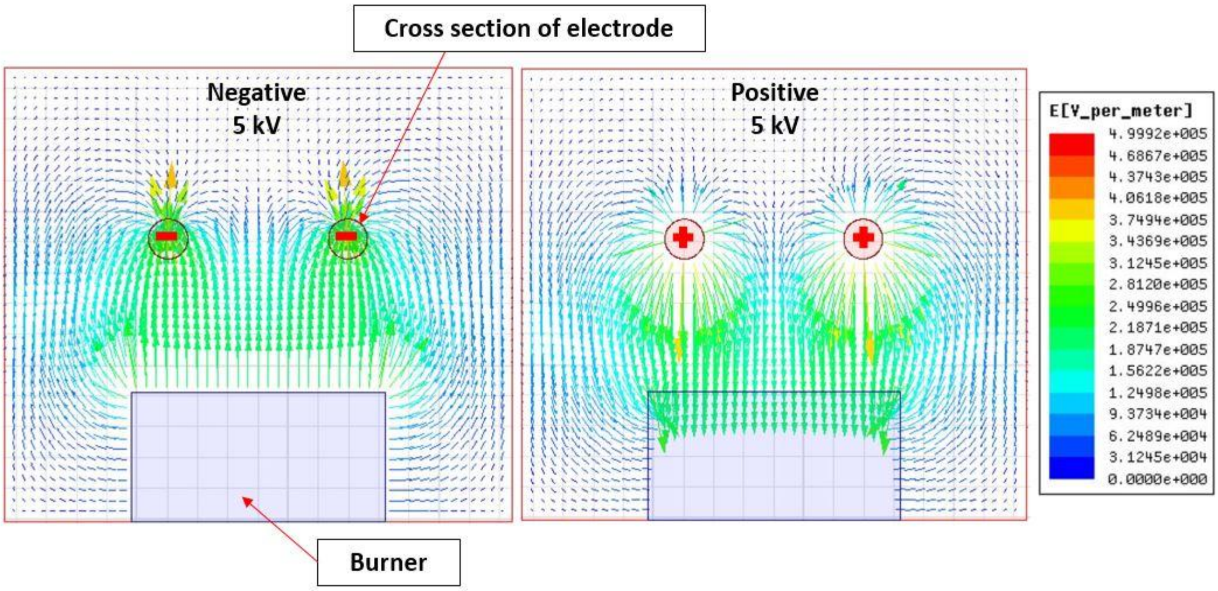

Fig 2. Direction and intensity of the electric field

III. RESULTS

Observing how the entire flame shape changes by applying a voltage to the electrodes, this experiment focuses on two things: lowest position of hot region and reaction zone width. Figure 3 illustrates these points. The reaction zone is where the pyrolyzed cations are formed from the fuel and the reaction begins, which has a great effect on the overall combustion process. The "lowest position of the hot region" is where the reaction zone ends, and where the main diffusion flame burn begins.

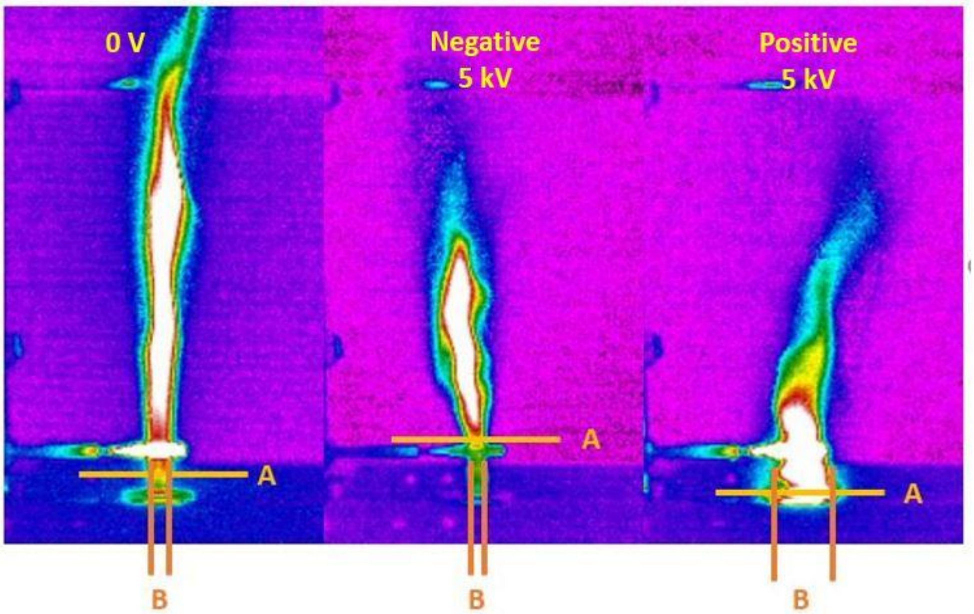

Fig 3. A – Lowest position of hot region, B – reaction zone width

A. Flame Shape and Hot Temperature Region

With the application of the electric field by varying voltage and its polarity, the change of hot temperature region in the flame and the change of flame shape can be observed as seen in Figure 4 and 5.

In all cases in Figure 4, the length of the flame can be seen to be shortened. However, the position of the high-temperature region above 600 degrees is shifted upward from the electrode as the voltage is increased in the

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negative case, and pulled downward in the case of the positive. Since the dominant ion in the flame of a hydrocarbon fuel is a cation, this movement corresponds to the direction of the electric field shown in Figure 2.

If the fuel does not sufficiently combine with oxygen in the reaction zone, the remaining fuel moves along the direction of the flame and burns later, resulting in a longer flame length. In the negative case, as the reaction zone becomes longer as like in Figure 5, the positive ions pyrolyzed from the fuel are better mixed with the anion from the air supplied around the flame than when without electric field. In the positive case, the reaction zone expands laterally and mixes better with supplied air. In both cases, improved complete combustion occurs well as fuel mixes better with air. As the complete combustion is better, the length of the whole flame is shortened.

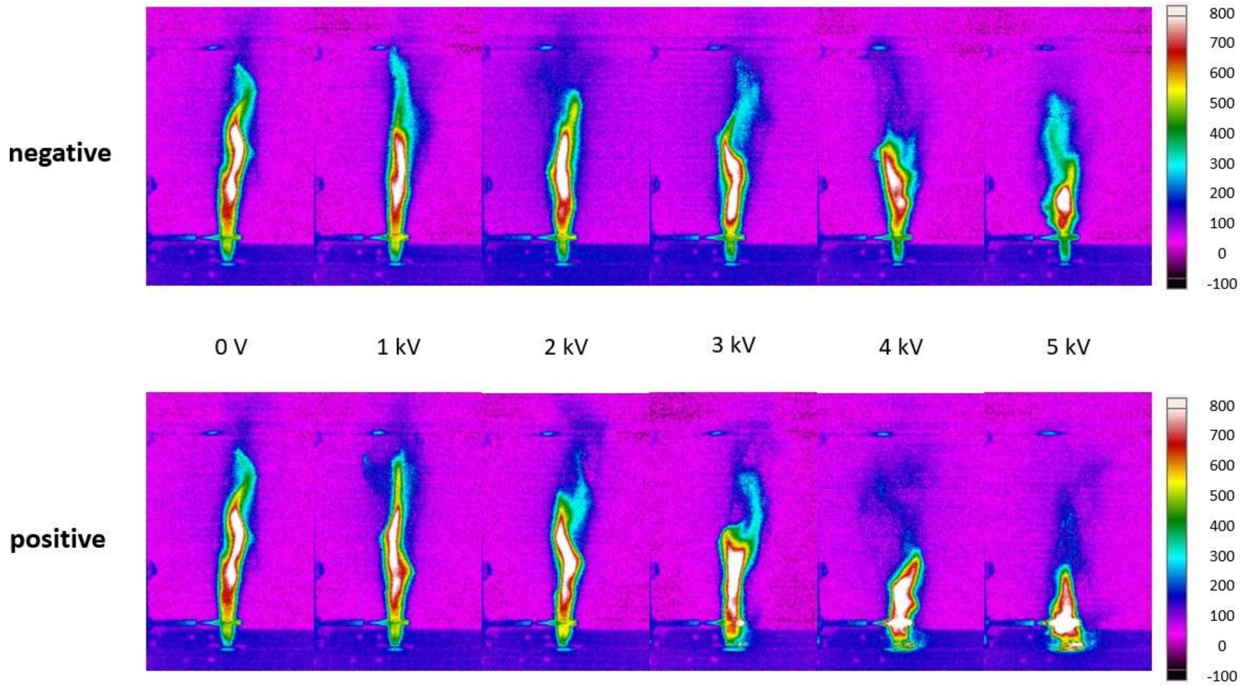

Fig 4.a. Temperature profile for fuel lean case (fuel: 0.5 l/min, air: 25 l/min)

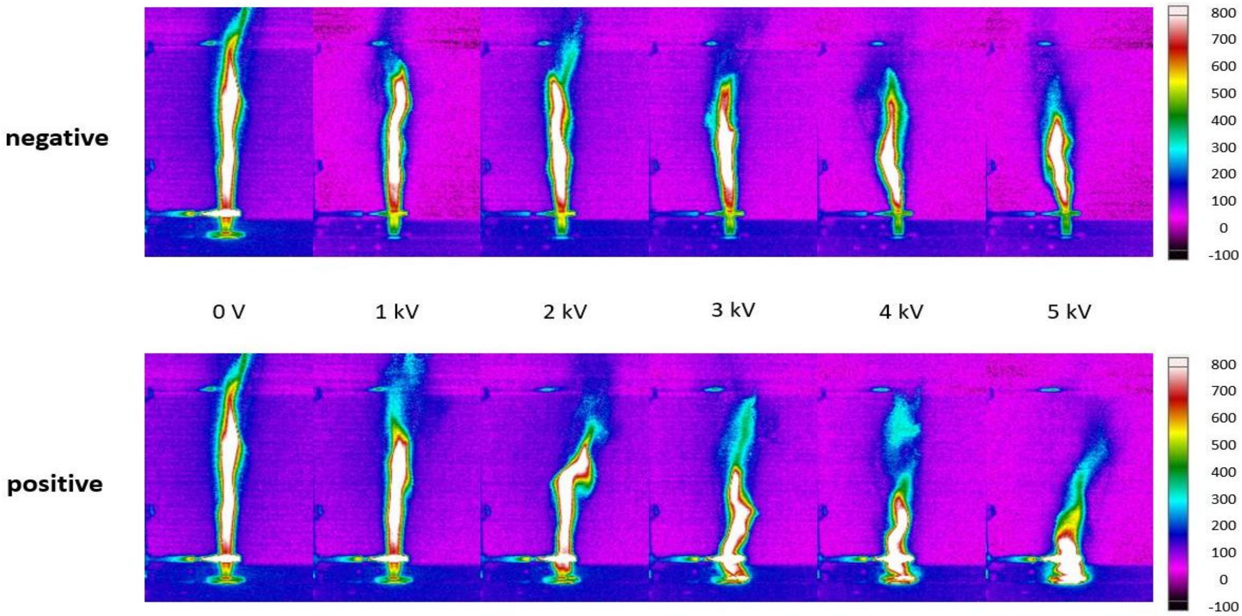

Fig 4.b. Temperature profile for stoichiometry case (fuel: 0.5 l/min, air: 12.5 l/min)

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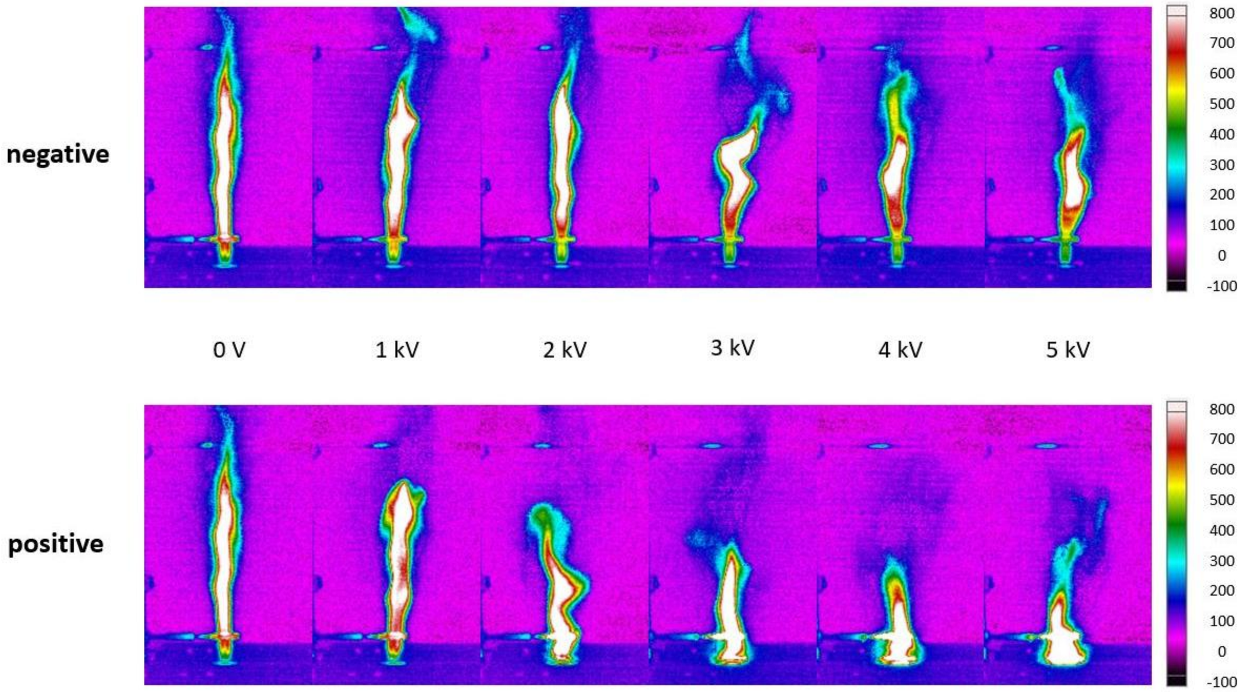

Fig 4.c. Temperature profile for fuel rich case (fuel: 0.5 l/min, air: 6.25 l/min)

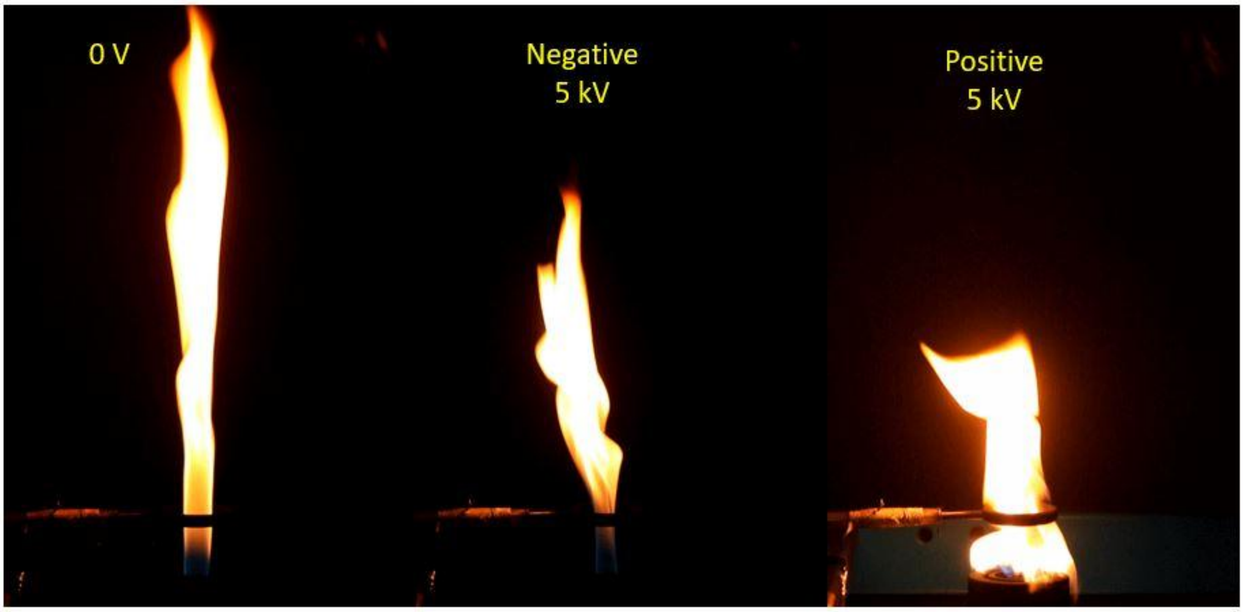

Fig 5. Change of flame shape

B. Reaction Zone Width and Lowest Position of Hot Region

From Figure 6, we can observe that for positive polarity the lowest position of hot region within the flame is gradually getting lower with applied voltage from 0kV to 5kV and change in airflow rate from lean to rich case. When negative polarity was applied to the propane diffusion flame, the lowest position of hot zone is gradually raising up. However, from figure 6, it can be deduced that, for higher voltage case (4kV and above) the effect is least.

In the case of reaction zone width of propane diffusion flame, it was observed that, with applied voltage and polarity, for positive polarity the flame reaction zone width is increasing with increase in voltage (0-5kV) and

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airflow rate (6.25– 25 l/min) from lean to rich case. However, with the application of negative polarity, the opposite trend was observed (Figure 7).

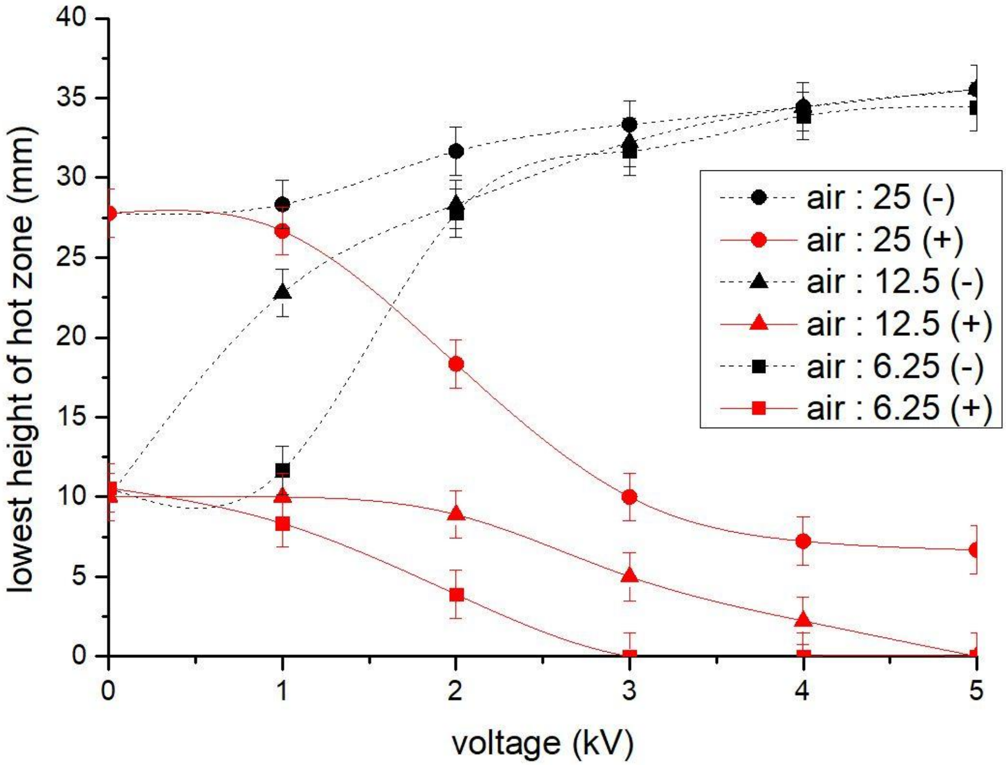

Fig 6. Effect of electric filed on propane diffusion flame hot region

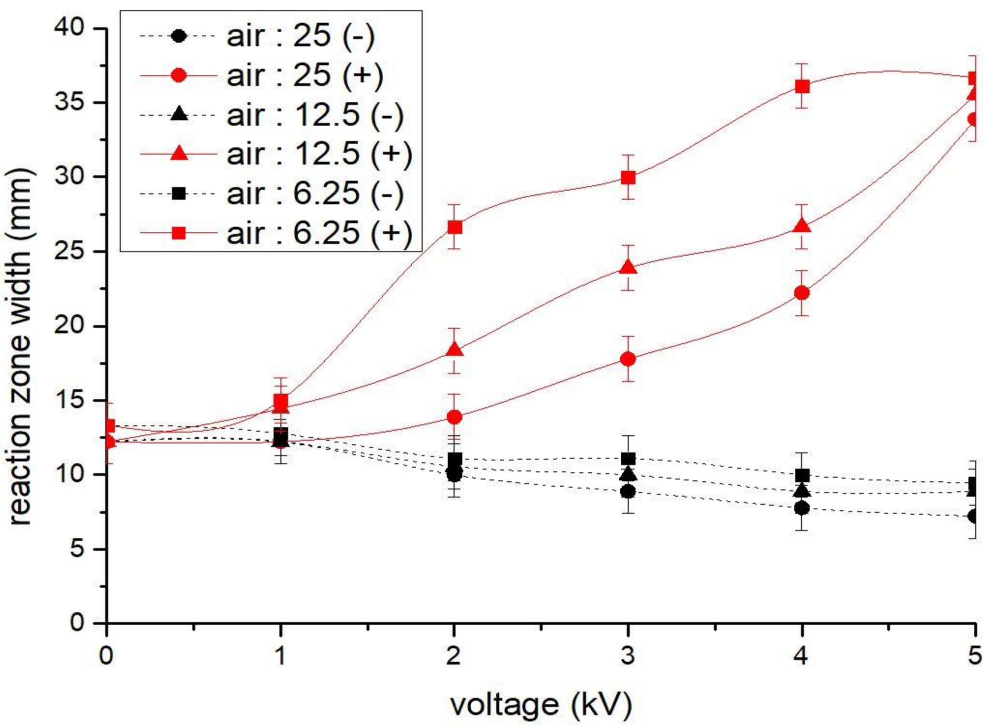

Fig 7. Effect of applied electric field on reaction zone of propane diffusion flame

ACKNOWLEDGEMENT

This research was financially supported by the seed money project of the KUSTAR-KAIST Institute, KAIST, South Korea.

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