# Design of air Atmospheric Pressure Diffuse Coplanar Barrier Discharge apparatus

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**Abstract.** In this study, we explored a coplanar barrier discharge apparatus for material modification. The apparatus is introduced and several ways are proposed for fabricating the apparatus. The parameters are optimized and proposed experimentally. The results show the electrode distance and the dielectric layer thickness are very important for the discharge performance. When the electrode distance is 0.5 mm, the dielectric layer thickness is 25   m, the coplanar barrier discharge plasma appears on the device in air at 760 torr.

## Introduction

If an ac voltage (or pulsed voltage) is applied to an electrode system with one or both electrodes covered by a dielectric layer, a dielectric barrier discharges (DBDs) will occur in the gas gap. There are three basic configurations for generating DBDs[1]. The first is the volume discharge (VBD), which is consisted of two parallel plates with the gas gap distance is about several millmeters. A VD device consist of two parallel dielectric plates with electrodes outside fitted. As is shown in Figure 1., the VD is characterized by initiation in a uniform field with fixed gas gap, while SD propagates in a non-uniform field from the surface electrode along the dielectric surface with gas gap unfixed.The second is the surface discharge (SBD), a plane dielectric with an electrode on one surface and a metallic cover on its reverse side. The third is coplanar barrier discharge (CBD), which not only has the advantages of DBD, but also has the advantages of itself, such as the lower spark ignition voltage, easily formation of the discharge, etc. In all the basic configurations the DBDs consist of discharge pulses with a duration of about 10 ns[2]. The discharge can work at about atmospheric pressure. Much work has been done on the DBDs. The volume DBDs are used on a large industrial scale to increase the properties of polymers, films and other materials. It have been tested for atmospheric pressure plasma deposition and have found a number of industrial applications, such as the industrial ozone generation, ultraviolet (UV) or vacuum ultraviolet (VUV) excimer radiation in excimer lamps. But it has some deficiencies for treatment of large area substrates, which can be easily eliminated by using the coplanar barrier discharge structure [3].

The aim of this research was to create a diffuse layer of plasma on a CBD device at atmospheric pressure in air. It is believed that for many surface treatment applications, such a thin surface layer of plasma may be more useful than the other configurations. In this study, we explored a coplanar barrier discharge apparatus. The parameters of the apparatus are optimized and proposed experimentally.

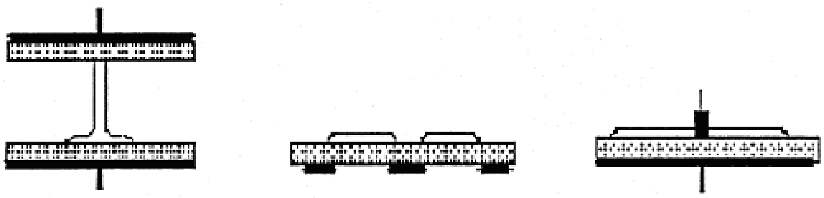

Figure 1. Principle configuration of the VBD, SBD and CBD

## Design of CBD apparatus

Three types of DBD arrangements were developed: volume barrier discharge (VBD), surface barrier discharge (SBD) and coplanar barrier discharge (CBD). Figure 2 shows the coplanar barrier discharge electrode configurations. The electrodes are buried in the dielectric layer [3].

In this paper, we try several ways to make the structure. A proposed method is use anodic aluminum. An aluminum foil is bonding on a glass substrate. Then the aluminum is covered by patterned tar using screen printing to make the electrodes we want. The sample is anodizing in oxalic acid using at about 15 oC. The tar is erased by Acetone and the sample are anodizing at higher temperature until the aluminum doesn't drop much, which shows that the aluminum between the electrodes are eliminated absolutely[4, 5].

Figure 3 shows the SEM picture of the alumina which act as the dielectric in CBD device. The micro tunnel is produced in the anodizing process. The alumina thickness is about 25-45    m.

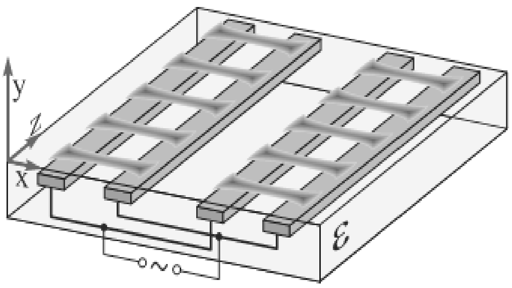


Fig.2. Coplanar barrier discharge electrode configurations

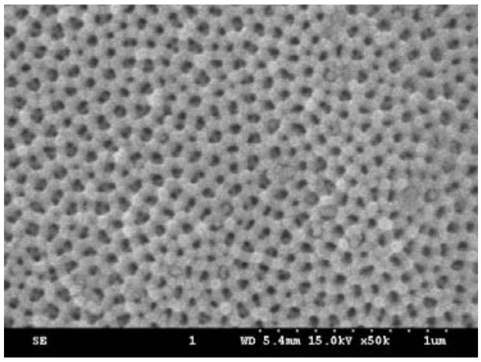


Fig. 3. The power in the dielectric barrier discharge device

By optimizing the parameters of the apparatus, a coplanar barrier discharge apparatus with the better performance is made. The discharge is shown in Figure 4. A thin layer of plasma is produced in neon discharge. To achieve a coplanar barrier discharge plasma sources, the apparatus parameters are optimized experimentally. A uniform plasma layer can be attained by the apparatus in air at atmospheric pressure.

Figure 4. The coplanar barrier discharge process in neon.

## Parameters of the apparatus

**Baking Alumina.**The alumina in the anodizing process acts as the dielectric in the coplanar barrier discharge setup [6-8]. In the anodizing, some residual aluminum in the alumina will influence the device. Figure 3 shows the influence of the alumina baking. The device is excited by 40 kHz pulsed voltage in air at different pressure. The spark ignition voltage increases with the pressure. After baking, the spark ignition voltage decreased obviously.

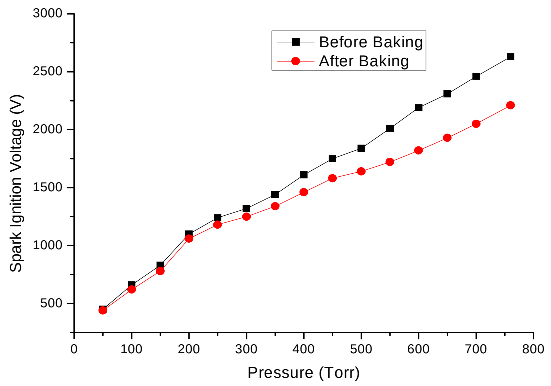


Fig.5. Spark ignition voltage versus pressure

(a) before baking (b)after baking

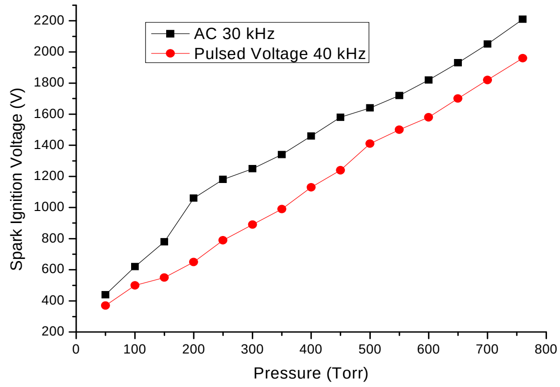


Fig. 6. Spark ignition voltage versus pressure

at different frequencies

Baking treatment helps eliminating the aluminum in the gaps by oxidization, which helps the device endure higher voltage. The heating treatment in the oven is very good for the devices quality. The elimination of the aluminum remainder helps the transportation of the electromagnetic wave, which results in the decreasing of the turn-on voltage.

**The power frequency.**During the coplanar barrier discharge, the breakdown voltage is very important for the device. The higher voltage will increase the ions energy, which results in increasing the device temperature [9-10].

In Figure 6, the spark ignition voltage increases with the pressure at different frequencies. At higher frequency, the spark ignition voltages are much lower than those at lower frequency. The higher frequency will lead to the only acceleration of the electrons. The ions, however, will not be accelerated because of larger masses.

**The alumina thickness.**The alumina acts as the capacitance in the coplanar barrier discharge device [11-12]. The thicker the alumina is, the lower the capacitance is. In the coplanar barrier discharge device circuit, the capacitance is parallel linked with the resistance. The alumina thickness in the device should be optimized.

In Figure 7, the spark ignition voltages change with the pressures at different alumina thicknesses. In 25 m devices, at atmospheric pressure air coplanar barrier discharge, the spark ignition voltage is about 1800 v when the device is excited by 40 kHz pulsed voltage.

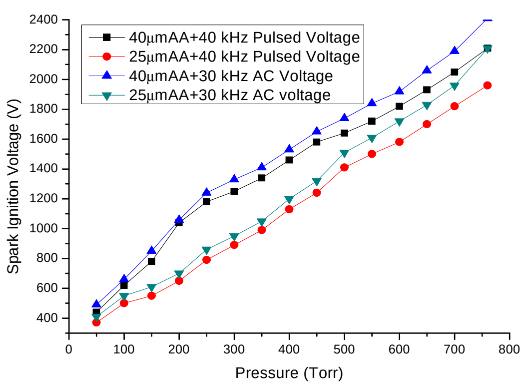


Fig.7. Spark ignition voltage versus pressure
at different alumina thicknesses

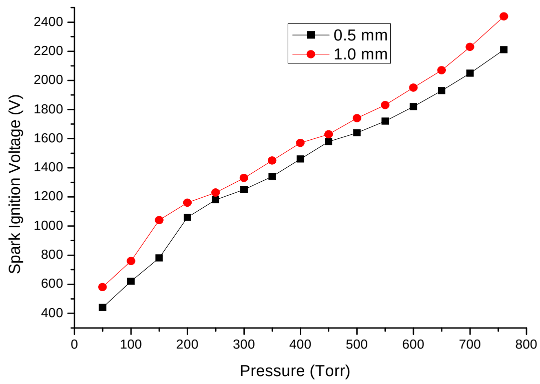


Fig. 8. Spark ignition voltage versus pressure
at different electrode gap distances

**The electrode gap distance.**The electrode gap distance is very important for the device. The nearer the gap distance is, the higher the electric field is, which result in the higher electron energy. From Figure 8, the 0.5 mm gap distance sample performs better than the 1 mm gap distance one. However the gas gap distance can't be minimized any more because of the fabrication arts.

From the results, we know that the two devices with the electrode structure: 0.5-mm-gap-distance sample is the better structure for the atmospheric discharge.

## Conclusion

A coplanar barrier discharge apparatus is designed and fabricated. The device fabricating arts are introduced and the parameters are proposed experimentally. From the experimental results, the parameters are proposed: the electrode gap distance is about 0.5 mm, the alumina thickness is 25 m. By optimizing, the device can work at the atmospheric pressure in air. The higher frequency pulsed power supply is also proposed.

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