# Research on Small Plasma Devices at University of Malaya

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**Abstract**

In this talk, we describe several small plasma devices that have been developed and researched on in this laboratory since the 1960s. These devices are simple in operation and can be set up with low budget.

## 1. Introduction

Plasma research, particularly experimental research, is often thought to be requiring expensive infrastructures, large investment in human resources and research funding. The experience at the University of Malaya Plasma Research Laboratory [1] where a range of small plasma devices have been developed with nominal funding is described here to illustrate the fact that this is not necessary the case. The small plasma devices to be described here include: the plasma focus [2], the vacuum spark [3], the capillary discharge [4], the glow discharge [5] and the dielectric barrier discharge [6]. These devices can be scaled to manageable size and yet interesting phenomena for both basic research and technological development can be studied.

## 2. The plasma focus

The plasma focus is the only small plasma device that can be operated with electrical input energy of just a few kilojoules (discharge voltage of 10 – 20 kV, discharge current of just over 100 kA) and yet capable of reaching nuclear fusion condition when deuterium is used as the working gas. The plasma obtained typically has electron temperature of the order of 1 – 3 keV and electron density of the order of $10^{18}$ $cm^{-3}$. The device can be used for studying gas dynamics phenomena, shock wave formation and propagation, magnetic compression, plasma instabilities and so on. The plasma formed is also a rich source of various radiations such as neutron, x-ray, electron and ion beams. These lead to an extensive range of diagnostic techniques to be developed thus making the plasma focus an excellent test bed for associated pulsed power technologies.

Fig. 1. The Plasma focus device.

## 3. The vacuum spark

The vacuum spark requires lower electrical input energy as compared to the plasma focus and yet it is capable of producing plasma with electron temperature and density an order of magnitude higher. It is an excellent pulsed x-ray source covering spectral range that is typical of highly ionized metallic plasma such as copper and iron. Recently, our research effort is to scale down the electrical input energy of the vacuum spark from several hundreds joules to few tens of joules. The plasma thus produced is expected to have electron temperature below 100 eV, thus emission spectrum in the EUV region (specifically at 13.5 nm) will be obtained. This EUV source is required by the microelectronic industry for Next Generation Lithography (NGL) at nanometer scale.

Fig. 2. The vacuum spark
device

## 4. The pulsed capillary discharge

The design of the pulsed capillary discharge is similar to that of the vacuum spark, with the inter-electrode spacing replaced by an insulator with a small capillary (diameter of 1 mm or less) along its axis. The material of the capillary is one of the crucial parameter and much studies are needed to understand the characteristics of the plasmas produced with different capillary materials as well as with various operating gases. With input electrical energy of 10's of joules, and by using xenon as the working gas, the repetitively pulsed capillary discharge is being developed as a promising candidate to be utilized as the source for NGL. A fundamentally important area, although technically not within the means of many small laboratories, is to use the pulsed capillary discharge as a pump source for soft x-ray laser.

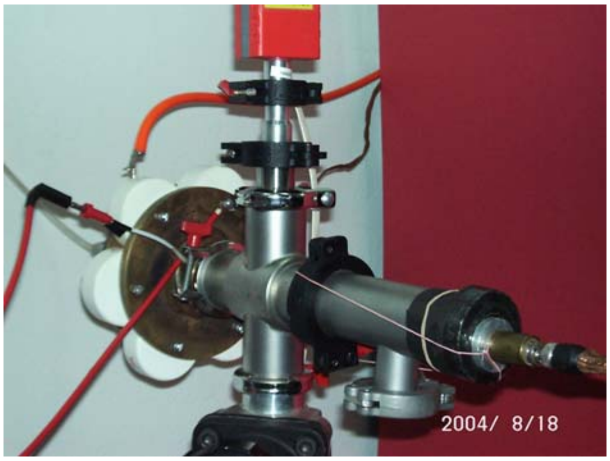


Fig. 3. The pulsed capillary discharge.

## 5. The glow discharge

RF powered glow discharge is widely used in industry for various processes of material surface treatment including cleaning, coating, etching, nitriding and oxidizing. One of the factors that make plasma processing less attractive (hence it is normally employed only when critically necessary) is the high cost required to set up such a system. The RF generator and matching network as well as the vacuum system are expensive. Our emphasis is to explore the possibility of using 50 Hz supply directly from the mains for the production of such types of plasmas. This will effectively reduce the cost of setting up such a system and we believe that this is a promising area of plasma technology development.

Fig. 4 RF inductively coupled glow discharge.

## 6. The dielectric barrier discharge (DBD)

The advantage of this type of discharge, where the electrodes are physically blocked by a dielectric, is that it can be operated with continuously flowing gas at atmospheric pressure. This discharge is capable of producing chemical reactions that will decompose various toxic gases such as $SO_2$, NO and $NO_2$. It can also be used to convert $O_2$ to $O_3$. It can be powered by 50 Hz mains supply. This device has great potential in terms of applications in our daily life such as air filter or freshener as well as for treatment of household water. At a larger scale, it can be used to decompose the hazardous gases in industry exhausts before they are discharged into the environment.

Fig. 5 An ozonizer unit based on the DBD.

## 7. Conclusion

The plasma devices illustrated above are examples of small scale, low cost plasma experiments that can be set up in small laboratory. These devices, although simple in setup and operation, can be used to study many interesting phenomena for both fundamental research and technological development.


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