# Microstrip Line Antenna of micro Plasma Application Modelling and Simulating

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**Abstract -** In this paper, a novel microwave induced plasma (MIP) source based on a microstrip split ring resonator is presented. The plasma microstrip line source can self-start discharges in argon and air with low power requirements over a wide pressure range that includes atmospheric pressure. This advantage makes it possible to drive the plasma source with low-cost off-the-self telecommunication electronics. So, in this work we present the 3D electromagnetic modeling and optimization of a microstrip applied to micro plasma micro-discharge. This study is to determine the maximum coupling power transferred to the plasma, resulting in an efficient plasma source in order to design in the LPGP laboratory. Numerical methods like FEM can be used to study the effect of plasma parameters on the propagation of electromagnetic waves, calculating power coupling, and wave propagation model enabling to determine the wave propagation modes through a microstrip printed circuit. The microwave plasma source consists of a coaxial transmission line (CTLR) operates at 2.45 GHz. Several in this work were studied such as the position and width (the 50-800$\mu m$) of the gap in the circular form of microstrip, the working pressure the microwave power and the gas flow....

**Keywords:**

Microwave plasma, finite elements method (FEM), plasma microstrip micro discharge, coaxial transmission line (CLTR).

## 1. Introduction

In some applications such as bio-MEMS sterilization, small-scale materials processing, micro chemical analysis systems, displays and micro-propulsion, it is desirable to integrate a micro plasma source capable of creating a controlled small-sized discharge. Creating a micro plasma source requires not only scaling down a large-scale plasma but also an understanding of the physics governing the new small-scale discharges. Furthermore, operation of micro plasma sources in small-scale portable devices imposes new constraints on the amount of power and the vacuum levels that can be employed. Operation at atmospheric pressure is particularly interesting for micro plasma sources as it eliminates the need for vacuum pumps. Micro pumps increase the final cost of the system, are inefficient in achieving high vacuum levels, and may reduce the overall system reliability.

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A variety of micro plasma sources with potential use in different applications can be found in recent literature. There still exists, however, the need for a plasma source capable of operating at atmospheric pressure for extended periods of time. In this dissertation a novel microstrip split-ring resonator microwave induced plasma source is presented.

Due to the small dimensions of micro fabricated systems, undesired discharges may occur between nearby features if a device is not carefully designed. In the case of a micro plasma source, however, the discharge is the goal of the device and the design should facilitate gas breakdown in the desired region. Understanding of the factors that control the breakdown in gases is therefore important in designing microwave discharge based on a microstrip systems. [3]

The microwave discharge based on a microstrip systems source is simple to fabricate and the design is very robust. It is fabricated on substrates with high dielectric constant resulting in a compact device. As opposed to other RF and microwave devices, the microwave discharge based on a microstrip source does not required additional circuitry for the matching network. Placing the electronics of the power supply inside the ring structure shall result in no size increase of the final device. Small size and the low-power air-cooled operation at atmospheric pressure make the MSRR-MIP source a well-suited device for portable applications.

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## 2. Governing equations

The distribution of the electromagnetic field is calculated by solving the equation for the electric field E, derived from the laws of Maxwell-Ampere and Faraday [2, 5]:

$$\begin{cases} \vec{\nabla} \times \vec{H} = \sigma \vec{E} + \frac{\partial(\varepsilon \vec{E})}{\partial t} \\ \vec{\nabla} \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t} \end{cases} \qquad (1)$$

E: is the electric field [V/m],
H: is the magnetic field [A/m],
E: is the permittivity [F/m],
μ: is the permeability [H/m] and
σ: is the conductivity of the medium [S/m].

$$\vec{E}(x,y,z,t) = \vec{E}(x,y,z)e^{j\omega t} \qquad (2)$$

$$\vec{H}(x,y,z,t) = \vec{H}(x,y,z)e^{j\omega t} \qquad (3)$$

The two laws can be combined to obtain the electric field wave equation:

$$\vec{\nabla} \times \left({\mu_r}^{-1} \vec{\nabla} \times \vec{E}\right) - {k_0}^2 \left(\varepsilon_r - \frac{j\sigma}{\omega \varepsilon_0}\right) \vec{E} = 0 \qquad (4)$$

Where:
$\mu_r$: Denotes the relative permeability.
j : Tthe imaginary unit.
$\sigma$ : The conductivity.
$\omega$ : The angular frequency.
$\varepsilon_r$ : The relative permeability and
$\varepsilon_0$ : The permittivity of free space.

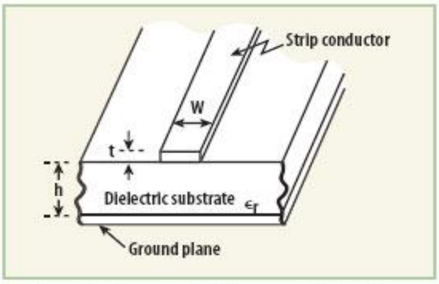


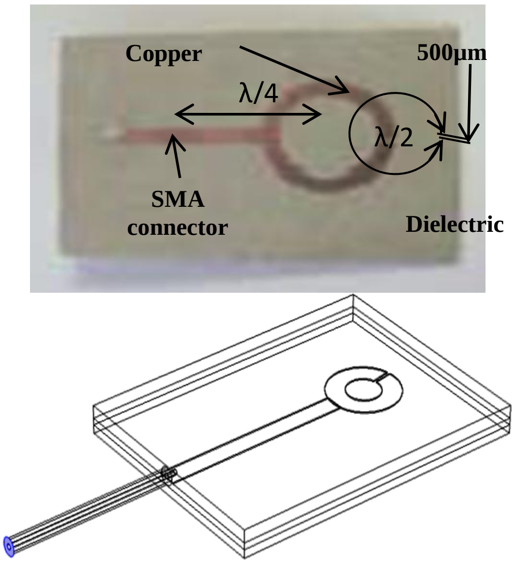
Fig .1 The microstrip line. Cartelistic: brass plate, Teflon dielectric h= 1mm, copper conductor: t = 0.4mm, W = 2mm

An electromagnetic wave propagating in a coaxial cable is characterized by transverse electromagnetic fields (TEM). The power is coupled into the device through a subminiature type A (SMA ) connector that is located at a point where the input to the device is 50 Ω, can be determined by:

$$z_0 = \frac{120\pi}{\sqrt{\varepsilon_e}[(w/d)+1.393+0.667\ln((w/d)+1.444)]} \qquad (5)$$

## 3. Description of the device

A microstrip is constructed with a flat conductor suspended over a ground plane. The conductor and ground plane are separated by a dielectric. The surface microstrip transmission line also has free space (air) as the dielectric above the conductor. This structure can be built in materials other than printed circuit boards, but will always consist of a conductor separated from a ground plane by some dielectric material. The plasma source consists of a microstrip structure, as shown in Fig. 2. The plasma is generated in the small gap of a split-ring resonator.

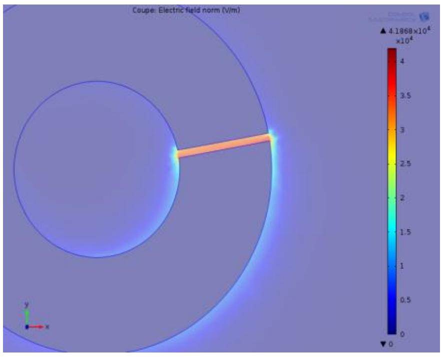


a)
b)
Fig. 2 Shows the: a) Photography and,
b) Geometry of the microstrip.

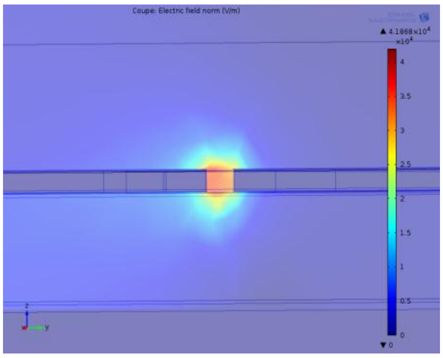
The ring resonator is only half wavelength in circumference (instead of one whole wavelength) and giving the ring geometry and the permittivity ($\varepsilon_r$=2.2) of the dielectric used in this particular design that is shown in Figure 2, there isn't match network necessary to match the impedance of the ring to the power supply.

## 4. Physical principle of operation

The key feature of this design is the electric field concentration that occurs at the gap. Since the voltage at each end of the ring is 180 degrees out of phase, the maximum voltage difference in the device occurs across the - gap where the discharge is to be ignited.



a)



b)

Fig. 3.1 Finite element analysis, a) Electric field in (xy) plane. b) Electric field in (yz) plane perpendicular to the ground plane through the discharge gap.

Figure 3 shows a top view and two cross-sections of the electric field pattern in the half wavelength split-ring resonator. Since a high dielectric constant substrate is used, the electric field is confined around the microstrip lines thereby reducing radiation losses and interactions with other electronic equipment. The electric field pattern along most of the ring is that of a typical microstrip line concentrated between the line and the ground plane with fringing fields at the edges.

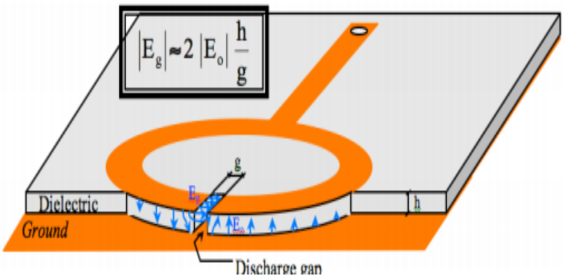


Figure 3.2 Schematic of a Microstrip source showing the electric field in the gap region

Near the gap, however, the fields at each end of the ring interact with each other (section BB''), and instead of going from the line to the ground plane, it jumps directly from one end of the ring to the other. Not only does the electric field vector change direction but it also changes in magnitude. Since the ends of the ring are 180 degrees out of phase, the electric field in the gap ($H_g$) doubles in magnitude relative to that in the microstrip line ($E_o$).

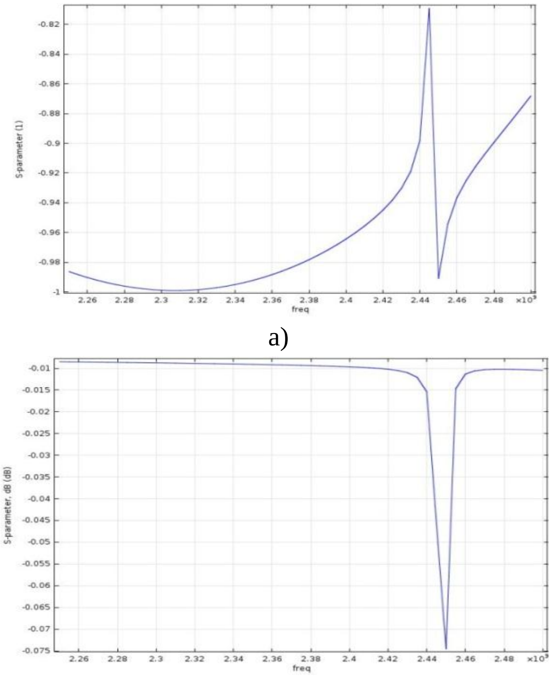
## 5. Result and discussion

The following equation is solved for the electric field vector inside the computational domain. In this section we studied power coupling in terms of frequency.

The actual device closely matches the simulation results in terms of frequency of operation, quality factor, and input impedance. Fig. 3 shows the reflection coefficient of the device (including the SMA connector). From the reflection coefficient, the quality factor of the device can be obtained as:

$$Q = f_c / \Delta f_3 dB \qquad (6)$$

where $f_c$ is the resonant frequency and $\Delta f_3 dB$ the bandwidth where the reflection coefficient increases by 3 $dB$ from its value at resonance [2].



a)

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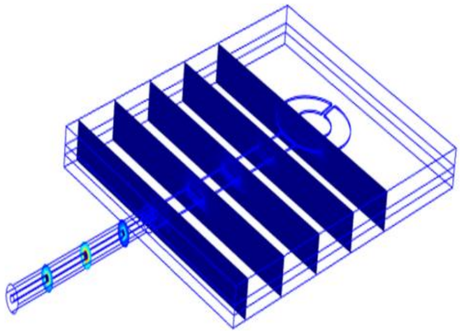
Fig 4 Reflection coefficient S11.



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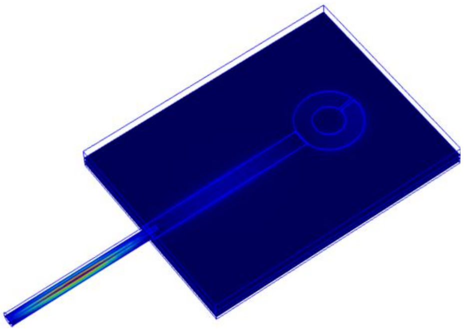
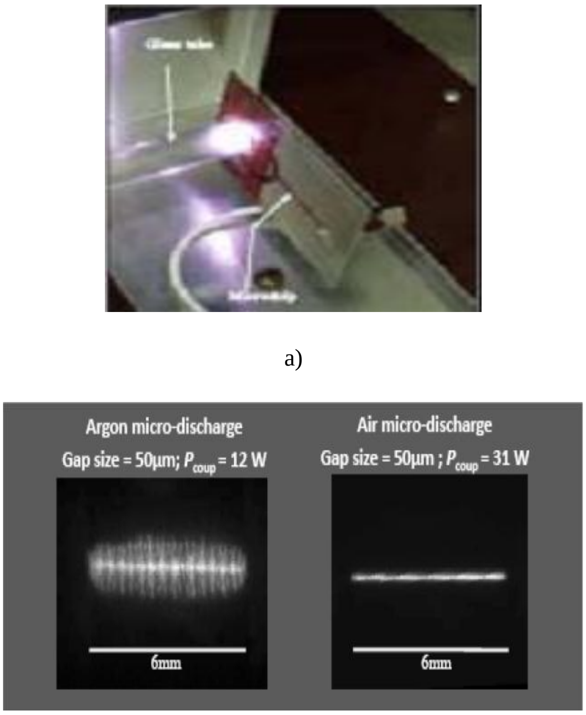


b)

Fig 5: The Electromagnetic waves in xy and yz-planes at different positions.



a)

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Figure 6: Photo of Micro plasma LPGP Orsay (France) 2.45 GHz (camera CCD)

## 6. Conclusion

The electromagnetic (EM) modelling of microwave plasma source is of importance application, as it can contribute to the optimization of these devices. The paper was aimed to optimize the microstrip line at the modeling of a tree-dimensional using a finite element method to solve Maxwell equations and to eliminate the reflecting power for micro-plasma generation in low diameter capillaries to the microwaves source, This work taking advantage of a required and valuable coupling between an experimental and modeling approach. The low-power requirements and the capability of air-cooled operation at atmospheric pressure make the MSRR-MIP source a well-suited device for portable stand-alone systems.

## 7. References

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