# Microwave Plasma Reactor Based on Microwave Oven

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**Abstract**— In this paper, a simple compact size microwave plasma reactor (MPR) based on 2.45 GHz 700 W home used microwave oven has been design and constructed for use in laboratory. Main design criteria were low cost and available of parts and components in home country, in order to make it easy to use, to repair, to move and no leak of microwave radiation. This system consist of reactor vessel, mini air pump and solution container with heater. The reactor vessel is made from 800 ml Pyrex beaker with two pipes mounted on the aluminum cover plate of vessel for injection and exhaust gas. The quarter wavelength electrode unit consisting of five tungsten rods is placed on a circular aluminum plate with diameter $\lambda/2$ for used to generating plasma. Currently the microwave plasma reactor built is being used to be microwave plasma chemical vapor deposition system (MPCVD). However, such a system can easily be adapted to serve as surface cleaner of substrate. The fabricated system is used to test the produce carbon nanoparticle from ethanol vapor and treatment of hydrophobic glass by measuring in contact angle with water drops.

## 1. INTRODUCTION

Currently, plasma technologies are being widely used in the field of medical, material, agriculture and environment processing. There are many methods for generating plasma such as by using AC, DC high voltage, radio frequency and method that use microwave. Atmospheric pressure microwave plasma has been developed in this work. The objective of this work was design and constructs a microwave plasma reactor at atmospheric pressure base on 2.45 GHz 700 W home used microwave oven for education and research. Main design criteria were:

- Low cost,
- Using available materials and possible to reproduce,
- Easy to operate and maintenance,
- No leak of microwave radiation,
- Easy to move.

Currently the microwave plasma systems built is being used to plasma treat the glass surface and produce the carbon nanoparticle from vapor ethanol. However, a system can easily be adapted to be microwave plasma CVD in the further.

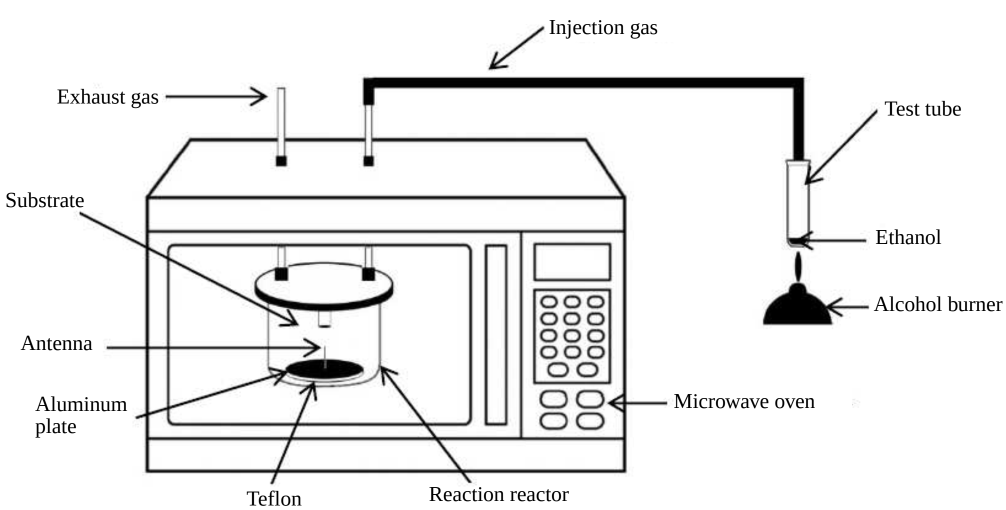



Figure 1: Configuration of experimental setup.

## 2. EXPERIMENTAL SETUP AND METHOD

The experimental setup is shown in Figure 1. The system includes a microwave oven, plasma reactor, mini air pump and solution container with heater.

The length of receiving antenna or electrode ($L$) can be calculated by using the following formula.

$$L = \frac{C}{4f\sqrt{\mu_r \varepsilon_r}}$$

where, $c$ is the speed of electromagnetic wave is ($2.997 \times 10^8$ m/s), $f$ is the frequency of microwave (2.45 GHz), $\mu_r$ and $\varepsilon_r$ are relative permittivity and permeability of the medium (air), respectively. When the relative permittivity and permeability of air equal 1, approximately, so the length of antenna is about 30 mm. Figure 3 is shown the arrangement of an electrode for investigation of efficiency of plasma generating.


Figure 2: Photo of microwave reactor.

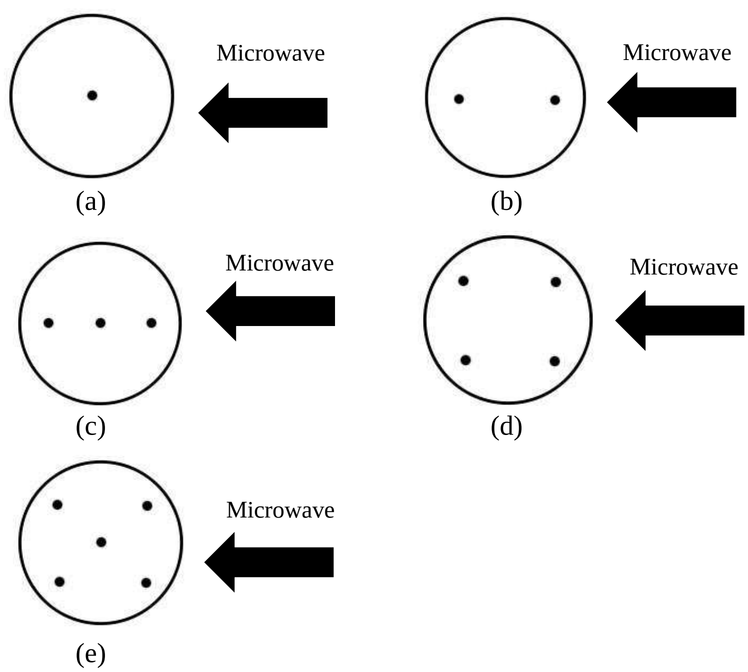



Figure 3: Arrangement of an electrode.

Figure 4 is a photograph of it generating plasma in ethanol vapor with one electrode. The electrode is placed on a circular aluminum plate with diameter 80 mm and install on a Teflon base so that the reactor vessel will not be damaged by the heat when the plasma is being generated. The substrate is place in position at 30 mm above the tip of electrode.

## 3. RESULTS

During plasma process, the carbon particles are deposited at the surface of the glass substrate. Figure 5 shows a SEM image of carbon nanoparticle on the substrate.

Figure 6 is an example of surface modified with the plasma and the change in hydrophobicity of the surface was investigated. The water contact angle on untreated glass plate was 41.7° whereas it reduced to zero after 60 seconds of treatment.

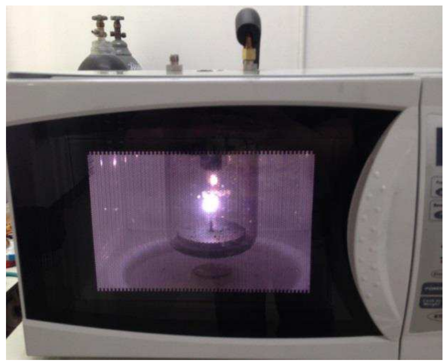
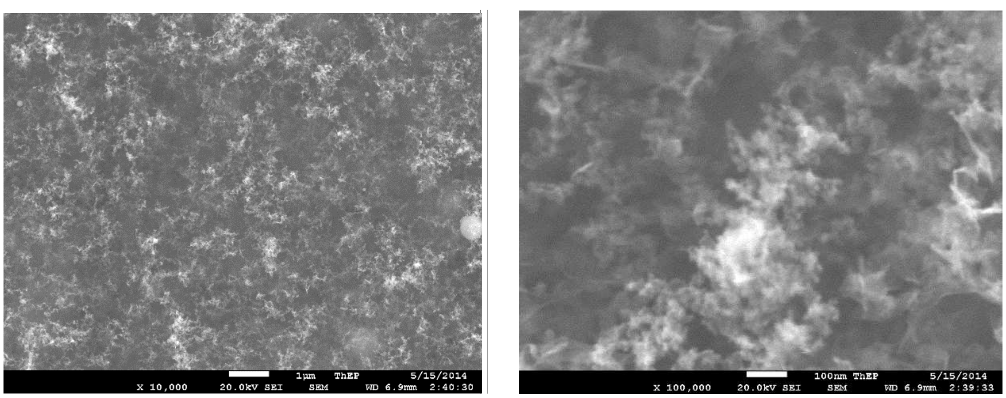
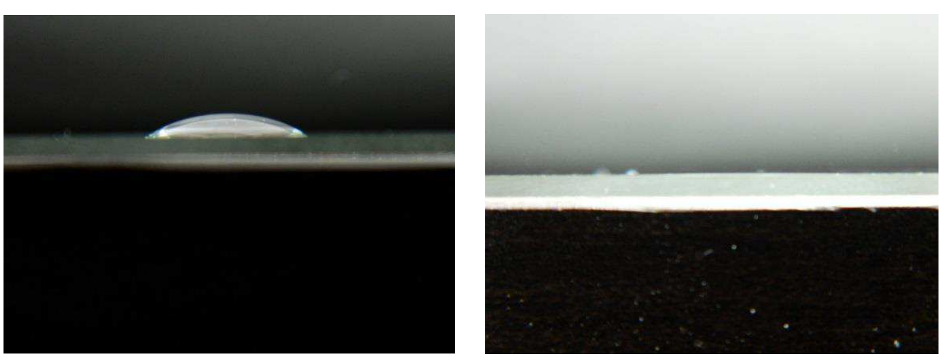


Figure 4: Photograph of plasma generation in ethanol vapor.




×10000 ×100000

Figure 5: SEM photograph of the film created.



(a) (b)

Figure 6: Image of water drop on untreated and plasma treated glass plate sample. (a) Before treatment. (b) After treatment.

## 4. CONCLUSIONS

In this research a method for generating plasma inside a plasma reactor base on microwave oven was investigated and an electrode suitable for generating plasma was fabricated. By using experiments in decomposing ethanol using plasma and through detailed investigation into the length of the electrode used, it was confirmed that the quarter wavelength was optimal for the generation of plasma. It is possible to increase the efficiency of decomposing ethanol by increasing the number of electrodes. Tests were conducted into creating carbon nanoparticles by using these electrodes in reactor vessel. We were found that at 5 electrodes, the efficiency of plasma generation bester than 1, 2, 3 and 4 electrodes. Carbon nanoparticles were successfully created inside reactor vessel by using the vapor from ethanol. For an example of surface modified with the plasma and the change in hydrophobicity of the surface was investigated. The water contact angle on untreated glass plate was more than 40° whereas it reduced to zero after 60 seconds of treatment.

## ACKNOWLEDGMENT

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## REFERENCES

1. Nomura, S., et al., "Production of hydrogen in a conventional microwave oven," *J. Appl. Phys.*, Vol. 106, 073306, 2009.
2. Nomura, S., et al., "Simultaneous production of hydrogen and carbon nanotubes in a conventional microwave oven," *International Symposium on Plasma Chemistry (ISPC19)*, 65, 2009.
3. Khongkrapan, P., et al., "Thermochemical conversion of waste papers to fuel gas in a microwave plasma reactor," *Journal of Clean Energy Technologies*, Vol. 1, No. 2, Apr. 2013.
4. Khongkrapan, P., et al., "Fuel gas and char from pyrolysis of waste paper in a microwave plasma reactor," *International Journal of Energy and Environment*, Vol. 4, No. 6, 969–974, 2013.
5. Toyota, H., et al., "A practical electrode for microwave plasma processes," *International Journal of Materials Science and Applications*, Vol. 2, No. 3, 83–88, 2103.