# Carbonization by Irradiation of Microwave

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## Introduction

Microwave is a electromagnetic wave with wave length of cm unit. The frequency range from 300MHz to 300GHz. In most countries, 2.45GHz is used for heating. The principles of heating by microwave are dipole rotation, ionic conduction, and dielectric heating generated by internally interaction among the intermediates. The material with permanent dipole is heated by dipole rather than by ionic conduction. Lorenson et al. [1] studied the effect of particle size of carbon on microwave heat treatment and on subsequent crystallite growth.

This work contains measurements of the dielectric properties of carbon powder and the growth of Lc[002] for both conventional and microwave processing.

## Experimental

A residue from the ethylate process, pyrolysis fuel oil (PFO) (Table 1) was condensated in the presence of $Br_2$ at 280℃ and followed by carbonizations at 600, 700, 800, 900, and 1000℃. The product yield and carbonization yield (at 600℃) of the reaction product were 41% and 71% respectively. The carbon materials were granulized in a attrition mill. Some of the carbon powder was deposited in a quartz tube of diameter 30mm and followed by irradiations of microwave (2.45GHz) under an inert gas of nitrogen or argon for 30 minutes. The microstructure of the carbon powder was characterized by scanning electron microscope. The total width at half-maximum was used to determine Lc[002] from $Lc=K\lambda/\beta\cos\theta$ where K is constant (1), $\lambda$ is the wavelength of the incident radiation in Å, $\theta$ is Bragg reflection angle, $\beta$ is the width of the peak in radians.

The some % of Teflon powder was dispersed in carbon powder and the mixture was moulded in a disk form and followed by measuring capacitance. The dielectric constant was calculated on the basis of the disk dimensions and the capacitance measured.

## Results and Discussion

X-ray diffraction curves of the sample heat treated at 900℃ were illustrated in Fig. 1. The peak intensity of [002] plane increased with microwave irradiation in $N_2$ and further in Ar atmosphere. The Ar heated the sample more effectively than $N_2$, which would be correlated with a larger value of dielectric constant for more effective heating ( $\varepsilon_{r,Ar} = 1.53$; $\varepsilon_{r,N_2} = 1.454$).

Fig. 2. shows that microwave irradiation and traditional heat treatment effect on the Lc[002] value. Though the heat treatment by both method increased the Lc[002] value, microwave is more effective in comparisons with traditional heat treatment. Exceptionally, the sample carbonized at 600℃ was not significantly affected by microwave irradiation, however, for the carbonized samples at higher temperature, the Lc value increased by microwave irradiation in $N_2$ further in Ar atmosphere. The effective carbonization seems to be very much dependent upon the dielectric constants of both sample and atmosphere (Table 2).

The higher energy generation in Ar atmosphere was understood by the formation of the glare in the process of microwave irradiation.

## Reference

1. Lorenson CP, Patterson MCL, Risto G, Kimber R, Mat. Res. Soc. Symp. Proc., 1992;269:129.

Table 1. Some properties of the PFO.

| | SP[1] (℃) | Elemental Analysis (wt. %) | | | C/H ratio | fa[2] | Carbon yield (%) |
|---|---|---|---|---|---|---|---|
| | | C | H | N | | | |
| PFO | 40℃ | 92.62 | 7.37 | 0.07 | 1.04 | 0.71 | 22 |

1) Softening point

2) fa, aromaticity determined by Brown-Lander method

3) $\frac{wt.\ of\ carbonized\ PFO\ at\ 600℃}{wt.\ of\ PFO} \times 100$

Table 2. Dielectric constant of the samples carbonized at various conditions.

| | | Heat treatment temperature (℃) | | | |
|---|---|---|---|---|---|
| | | 700 | 900 | 1000 | Graphite |
| Dielectric constant $\varepsilon_r$ | control | - | 1.493 | 1.487 | - |
| | $N_2$ | 1.523 | 1.468 | 1.535 | 1.568 |
| | Ar | 1.464 | 1.885 | 1.580 | - |

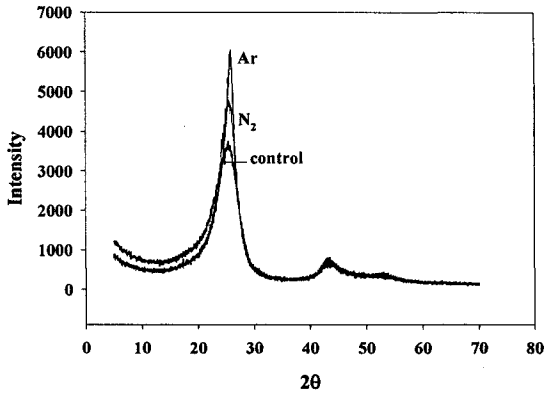


Fig. 1. X-ray diffraction curves of the carbon powder heat treatment at 900℃.

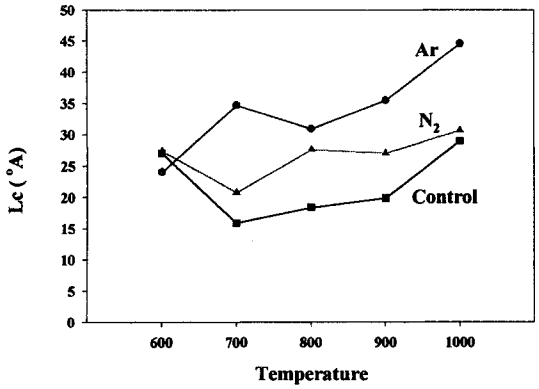


Fig. 2. Heat treatment temperautre vs. Lc[002] value.