Effects of background-gas composition on phenol decomposition by pulsed-discharge plasma above a water surface

HARUKI SHIOTA*, HIDEYUKI ITABASHI*, KOHKI SATOH* and HIDENORI ITOH*
*Division of Information and Electronic Engineering, Graduate school of Engineering, Muroran Institute of Technology, 27-1 Mizumoto, Muroran 050-8585, Japan

1. INTRODUCTION

- Background
  - Water pollution by persistent organic pollutants and volatile chlorinated organic compounds is a serious problem.
  - Species having high oxidation potential, such as OH, O₂ and H₂O₂ can be produced when pulsed-discharge plasma is generated above or in water.
  - Since these species have potential to decompose the pollutants, effective water purification by those species can be expected.

- Recent work of water purification by pulsed discharge
  - More than 80% of phenol decomposes by pulsed-discharge plasma generated above a phenol aqueous solution are investigated in detail.
  - OH radicals and O₂ can initiate the decomposition of phenol.
  - The decomposition process of phenol by OH radicals and O₂ is estimated.

- Objective
  - In this work, minutely investigate by-products, decomposed by pulsed-discharge plasma above a phenol aqueous solution when Ar, O₂, and Ar-O₂ mixture, are used as a background gas.
  - We deduce the decomposition processes of phenol from the by-products.
  - We investigate the effects of background gas composition on phenol decomposition.

2. EXPERIMENTAL APPARATUS

3. RESULTS & DISCUSSION

(1) Decomposition of phenol when O₂ is used as a background gas

In O₂

- It is found that formic acid, maleic anhydride, succinic anhydride, CO, dihydroxyethylfuran-2,5-dione, catechol and hydroquinone are produced in the phenol aqueous solution by the plasma exposure.
- It is found that CO₂ and CO are produced from phenol and that O₂ are produced from the background gas.

Inferred absorbance spectra of the off-gas from the discharge chamber

Estimated decomposition process in the present work

(2) Decomposition of phenol when Ar is used as a background gas

In Ar

- It is found that catechol, hydroquinone and 4-hydroxy-2-cyclohexene-1-one are produced from phenol by the plasma exposure.

Inferred absorbance spectra of the off-gas from the discharge chamber

Estimated decomposition process in the present work

(3) The concentrations of O₂ and by-products as functions of mixture ratio of Ar-0₂

- Concentrations of O₂ and by-products produced by the cleavage of a benzene ring in figure (a) increase with the increase of O₂ mixture ratio.
- When O₂ is not produced in figure (a), no by-product is produced in figure (a). Therefore, O₂ can cleave a benzene ring of phenol by 1,3-dipolar addition reaction, but OH radical cannot.
- By-products in figure (b) decrease rapidly by the mixture of Ar into Ar₂ so that the decomposition process of phenol can be dramatically changed by O₂ mixture.

4. CONCLUSIONS

We have investigated the decomposition process of phenol by exposure of pulsed-discharge plasma, when background gas composition is changed.

- When O₂ is used as a background gas, phenol is decomposed into 4,6-dihydroxy-2,4-hexadienoic acid by 1,3-dipolar addition reaction with O₂, and then 4,6-dihydroxy-2,4-hexadienoic acid can be produced.
- 4,6-dihydroxy-2,4-hexadienoic acid is decomposed into two fragments, which contain two and four carbon atoms respectively, maleic acid and succinic acid, by 1,3-dipolar addition reaction with O₂.
- O₂ is not detected in this work, but it is reported that formic acid, CO₂ and CO are produced by the decomposition of oxalic acid as shown in reactions(15). Therefore, oxalic acid can be produced by phenol decomposition.

Water treatment techniques using a pulsed discharge have attracted attention.

References