Phenol decomposition by pulsed-plasma exposure in oxygen and argon atmosphere

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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, O₃, 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 such species can be expected.

Recent work of water purification by pulsed discharge

- Hoheb et al. (1)
  - By-products decomposed by pulsed-discharge plasma generated above a phenol aqueous solution are investigated in detail.
  - OH radicals and O₃ can initiate the decomposition of phenol.
  - The decomposition process of phenol by OH radicals and O₃ is estimated.

Objective

In this work, we minutely investigate by-products, decomposed by pulsed-discharge plasma above a phenol aqueous solution when Ar, O₃, and Ar-O₂ mixtures, 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

- Blanlent (HV) power generator: 110V (11kV, 15kW)
- High-voltage transformer: 110V (11kV, 15kW)
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- Discharge chamber: A cylindrical discharge chamber of 160 mm inner diameter, 180 mm height and 1.1 L volume is made of acrylic resin.
- H.V. power generator: Slator generator
  - A high voltage transformer is used for inverter generation, and applied to the needle electrode.

3. RESULTS & DISCUSSION

3.1 Decomposition of phenol when O₃ is used as a background gas

- Chromatogram of sample liquid after 120 min of plasma exposure
  - Without discharge (15 min)
  - With discharge (15 min)
  - Infrared absorption spectra of off-gas from the discharge chamber

- It is found that formic acid, maleic anhydride, succinic anhydride, 2-hydroxyethyl-2-hydroxyethylene-2,5-dihydroxydurene, catechol and hydroquinone are produced in phenol aqueous solution by the plasma exposure.

- Estimated decomposition process in the present work

- (1) Decomposition of phenol when O₃ is used as a background gas

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

3.2 Decomposition of phenol when Ar is used as a background gas

- Chromatogram of sample liquid after 120 min of plasma exposure

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

3.3 The concentrations of O₃ and by-products as functions of mixture ratio of Ar-O₂

- Concentrations of O₃ and by-products produced by the cleavage of a benzene ring in figure (a) increase with the increase of O₂ mixture ratio.
- When Ar is not produced in figure (a), no by-product is produced in figure (a). Therefore, O₃ can cleave a benzene ring of phenol by 1,3-dipolar addition reaction, but OH radical cannot.
- By-products in figure (b) decrease rapidly with the mixture of O₂ into Ar, 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 the exposure of pulsed-discharge plasma, when background gas composition is changed.
  - When O₃ is used as a background gas, phenol is decomposed into 4,6-dihydroxy-2,4-hexadienedic acid by 1,3-dipolar addition reaction with O₃, and then 4,6-dihydroxy-2,4-hexadienedic acid is decomposed into oxalic acid, maleic acid and succinic acid by O₃. Generally, these products are probably decomposed into CO₂ and CO.
  - When Ar is used as a background gas, 4,6-dihydroxy-2,4-hexadienedic acid is not converted by OH radical. Further, 4,6-dihydroxy-2,4-hexadienedic acid is not converted into catechol and hydroquinone.
  - O₃ can cleave a benzene ring of phenol by 1,3-dipolar addition reaction, but OH radical cannot.
  - The decomposition process of phenol can be dramatically changed by O₂ mixture.