Evaluation of Decomposition Treatment for Halogenized Compounds Using by Acceleration of Electrons from Carbon Nanotubes

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INTRODUCTION

Halogenized compounds such as polychlorinated biphenyl (PCB), chlorophenols, and dioxins are considered to be the most environmentally hazardous materials. The total amount of PCB that exists in insulation oil in condensers or transformers and has been left unattended is estimated to be approximately six hundred thousand tons. Under the law in Japan, it is obligatory to treat PCB by 2015. Dioxins are mainly produced at 573–873 K during combustion in trash incinerators. The produced dioxins are released as gases into the atmosphere or remain in a very small quantity in the ash as solids. The released dioxins are very harmful to the ecological system as they permeate not only the atmosphere but also the soil and water. There is an urgent demand for the development of technologies to eliminate them.

We had proposed a harmless and high-efficiency decomposition treatment for halogenized compounds by using a carbon nanotube (CNT) electron source [1-4]. In this study, we investigated the decomposition property of sample substances based on the differences in their concentrations using the proposed CNT electron source.

EXPERIMENTAL PROCEDURE

The sample targets were adapted for liquid o-chlorophenol and solid 2,4-dichlorophenol and they comprised a hydroxyl group, chlorine molecules, and a benzene ring; further, the materials derived from dioxins are relatively safe and easier to handle. The test samples were suited to the proposed reduction scheme. o-Chlorophenol or 2,4-dichlorophenol was first coated on silica gel with a typical specific surface area of 650 m²/g. Different concentrations of o-chlorophenol or 2,4-dichlorophenol were obtained by adjusting their amounts for the test targets. It was confirmed that the o-chlorophenol or 2,4-dichlorophenol does not evaporate once coated on silica gel. The coated silica gel was placed in a ceramic reaction cell with an anode at its lower end showed in Fig.1. The cathode of the CNT electron source was located at the upper end of a vacuum chamber that could be evacuated up to 10⁻⁴ Pa. A 1-kV positive DC voltage was applied to the cathode grid. At the anode, a 2-kV positive DC voltage was applied to uniformly irradiate the electrons on the silica gel. The distance between the anode and cathode was 35 mm, and the treatment lasted for a few minutes. After exposure to the electrons from the CNTs, 10 cc of the silica gel from the cell was rinsed in 20 cc of ethanol for 1h with agitation. The solution was then analyzed by gas chromatography (GC); 1µl of the solution was introduced into the analyzer. The minimum detectable concentration, obtained by referring to the instruction manual, was a few ppm. As a reference, a sample solution was prepared using silica gel that was not exposed to the electron source.

RESULTS AND DISCUSSION

The plot of the initial chorophenol concentration as a function of the treatment time using the CNT electron source is shown in Fig. 2. The x and y axes represent the treatment time and the peak intensity obtained by GC, respectively. It was confirmed that the peak intensity corresponding to the chorophenol concentration decreases after a few minutes of treatment. The concentration is reduced to a maximum level of less than 1/1000 after only a few minutes of treatment. The plot of the initial 2,4-dichlorophenol concentration as a function of the treatment time using the CNT electron source is
shown in Fig. 3. As shown in this plot, the peak intensity decreased drastically after a few minutes of treatment, similar to the case in the chlorophenol treatment.

Fig.2 Plot of initial chlorophenol concentration as a function of treatment time for the case in which a CNT electron source is used.

Here, the occurrence of desorption is ascertained by calculating the quantity of heat from the electrons that was emitted by the CNTs to the chlorophenol-coated silica gel. The equation used for this calculation is as follows:

\[ C = 0.24 P t \]  \hspace{1cm} (1)

where \( C \) denotes the quantity of heat; \( P \), injection power; and \( t \), treatment time. \( C \) is calculated as 14.4 cal. In this experiment, the mass and the specific heat of silica gel are 3g and 0.22 (cal/g °K), respectively. Hence, the temperature increase of chlorophenol-coated silica gel is 293K. The boiling point of chlorophenol or 2,4-dichlorophenol is 448–449 K or 483 K, respectively. Therefore, it is clarified that desorption does not occur in this experiment and that both o-chlorophenol and 2,4-dichlorophenol decompose by the deoxidation treatment using electrons. The input energy for 1 g of chlorophenol was 46 J when the injection power was 0.5 W. The input energy was only 1/161 times lower when compared with that for the treatment for barrier discharge. The treatment using CNTs has a high efficiency because the input energy is provided only by the accelerated electrons. The decomposition treatment for halogenized compounds using the CNT electron source is very effective in achieving high-efficiency decomposition in a short duration.

CONCLUSIONS

In summary, a benign and highly efficient decomposition treatment for halogenized compounds that uses an electron source with a CNT has been proposed. It is observed that the amount of chlorophenol decreases significantly by the proposed treatment, which utilizes the electrons from the CNT. The decomposition treatment for halogenized compounds using the CNT electron source is very effective in achieving high-efficiency decomposition in a short duration.

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REFERENCES


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