



Original Article

Electrochemical oxidation of sodium dodecylbenzenesulfonate in Pt anodes with Y₂O₃ particlesJung-Hoon Choi^{a,*}, Byeongwan Lee^{a,b}, Ki-Rak Lee^a, Hyun Woo Kang^a,
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ABSTRACT

The electrochemical oxidation process has been widely studied in the field of wastewater treatment for the decomposition of organic materials through oxidation using ·OH generated on the anode. Pt anode electrodes with high durability and long-term operability have a low oxygen evolution potential, making them unsuitable for electrochemical oxidation processes. Therefore, to apply Pt electrodes that are suitable for long-term operation and large-scale processes, it is necessary to develop a new method for improving the decomposition rate of organic materials. This study introduces a method to improve the decomposition rate of organic materials when using a Pt anode electrode in the electrochemical oxidation process for the treatment of organic decontamination liquid waste. Electrochemical decomposition tests were performed using sodium dodecylbenzenesulfonate (SDBS) as a representative organic material and a Pt mesh as the anode electrode. Y₂O₃ particles were introduced into the electrolytic cell to improve the decomposition rate. The decomposition rate significantly improved from 21% to 99%, and the current efficiency also improved. These results can be applied to the electrochemical oxidation process without additional system modification to enhance the decomposition rate and current efficiency.

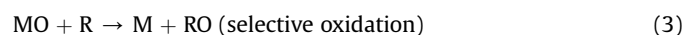
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1. Introduction

The Kori Unit 1 nuclear power plant, the first commercial reactor in South Korea, was permanently shut down in 2017, and is planned to be decommissioned after the cooling period of spent nuclear fuels. Additionally, the designed operating lives of Kori Units 2, 3, and 4 are expected to expire in 2023, 2024, and 2025, respectively [1]. In this regard, the Korea Atomic Energy Research Institute is currently developing technologies for decommissioning nuclear power plants, especially four key technologies: decontamination, remote dismantling, decommissioning waste treatment, and site remediation [2]. Among decommissioning waste treatment processes, modified foam decontamination processes for the removal of radioactive isotopes on contaminated surfaces generate organic decontamination liquid waste, which is mainly composed of surfactants, organic acids, and other reagents [2]. This organic decontamination liquid waste can be treated by incineration;

however, another treatment method should be adopted to meet the safety criteria for the radioactive nuclides in the waste and the public demand for air pollution control.

Recently, electrochemical oxidation processes have been actively studied for wastewater treatment and the oxidation/decomposition of organic materials [3–5]. Fig. 1 shows a scheme of organic material decomposition through an electrochemical oxidation reaction. The oxidation reaction occurs at the anode, which is oxidized by accepting electrons, and is divided into direct oxidation (or selective oxidation) and indirect oxidation (or combustion) after the initial reaction, in which ·OH are generated through water decomposition. The electrode where the selective oxidation reaction occurs is called the active anode, and the organic material decomposition reaction is shown in Equations (1)–(4) [5]:



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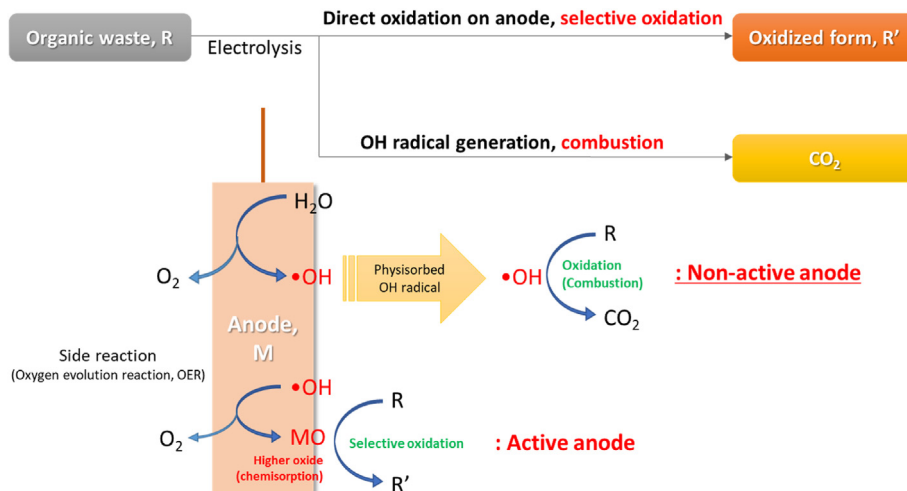
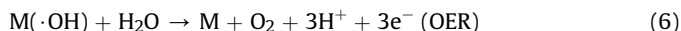
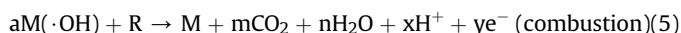


Fig. 1. Scheme of the electrochemical oxidation process.



where the strong interaction between the $\cdot OH$ and electrode (M), the electrode (M) is partially oxidized to form a higher oxide (MO), and the organic material (R) is adsorbed to the electrode (MO) and then selectively oxidized (RO or R'). In addition, the oxygen evolution reaction (OER), wherein oxygen is generated by the oxidation of water, occurs as a side reaction and competes with the selective oxidation reaction of organic materials.

An electrode that cannot form a higher oxide is called a non-active anode, and an organic material reacts with $\cdot OH$ physically adsorbed on the surface because it cannot react with the electrode, resulting in an indirect oxidation reaction. Equations (5) and (6) [5] indicate that the oxidation reaction in an inactive anode is as follows:



where R indicates an organic compound with m carbon atoms; simultaneously, the oxidation reaction by $\cdot OH$ is different from the selective oxidation that occurs in the active anode; the entire organic material is oxidized, and $a = (2m + n)$ oxygen atoms are mineralized into carbon dioxide; therefore, it is called the combustion reaction. The oxidation reaction on the non-active anode also competes with OER.

Therefore, in the organic material decomposition process using electrochemical oxidation, a combustion reaction by $\cdot OH$ should occur to achieve a high decomposition rate, and an anode electrode material showing a high oxygen evolution potential (OEP) should be used to suppress the side reaction.

The electrode material plays an important role in the electrochemical oxidation process, and it is necessary to select an electrode material that exhibits a high stability. Electrochemical oxidation has been mainly studied using electrode materials such as boron-doped diamond (BDD) [6–8], graphite [9], DSA (dimensionally stable anodes such as PbO_2 [10–12], RuO_2 [13], MnO_2 [14], SnO_2 [15]), and Pt [16]. The BDD electrode had a high oxygen evolution potential (OEP) and high stability. However, it is difficult to fabricate large electrodes [11], which limits their application in engineering-scale processes. The most actively studied anode electrode is the PbO_2/Ti electrode [10–12], which exhibits

appropriate corrosion resistance, high conductivity, and electrochemical catalytic activity. However, there is a disadvantage in that the active PbO_2 layer is easily peeled off from the Ti substrate, and thus the activity is lowered [17]. In addition, there is an environmental issue due to the leaching of Pb ions. Meanwhile, the Pt anode electrode, which has high stability and is adaptable for large-scale applications, shows a low OEP, making it appropriate for oxygen evolution applications and not for electrochemical oxidation. Therefore, to apply a Pt electrode that is suitable for long-term operation and large-scale processes, it is necessary to develop a new method for improving the decomposition rate of organic materials.

Based on this background, this study introduces a method to improve the decomposition rate of organic materials when using a Pt anode electrode in the electrochemical oxidation process for the treatment of organic decontamination liquid waste. Electrochemical decomposition tests were performed using sodium dodecylbenzenesulfonate (SDBS) as a representative organic material [18] and a Pt mesh as the anode electrode. To improve the decomposition rate, rare earth particles (Y_2O_3 , CeO_2 , and Nd_2O_3) which have catalytic effect in electrochemical oxidation processes [19] were added to the electrochemical cell, a decomposition test was performed according to the particle amount and electrolysis conditions, and the decomposition rate was evaluated. In addition, an adsorption test of the organic material on the Y_2O_3 particles was conducted to determine the reason for the improvement in the decomposition rate according to the input of Y_2O_3 particles.

2. Experimental

SDBS was of technical grade and purchased from Aldrich. Sodium sulfate was of guaranteed reagent purity (99.0%) and was purchased from Junsei. Yttrium (III), cerium (IV), and neodymium (III) oxides (99.9% purity) were purchased from Alfa Aesar.

SDBS was used as a representative anionic surfactant. A 100 mL solution containing 500 ppm SDBS and 0.1 M Na_2SO_4 was prepared as the simulated organic decontamination liquid waste in consideration of waste water concentration [18]. Linear scanning voltammetry (LSV) and electrochemical oxidation (EO) tests were performed in a conventional three-electrode cell (100 mL for the EO test and 300 mL for the kinetic experiment) using a PARSTAT MC-1000 potentiostat. Platinum with 80 mesh and 8.75 cm² (2.5 cm × 3.5 cm) was used as the anode and cathode, and Ag/AgCl

wire in saturated aqueous KCl solution was used as the reference electrode. The LSV was measured at a scan rate of 2 mV/s in the range of 0.5–2.0 V. EO tests were conducted at constant current densities of 5.7, 11.4, and 17.1 mA/cm². To evaluate the effect of the particles on the decomposition rate during the electrochemical oxidation process, 2 g/L, 10 g/L, or 20 g/L of Y₂O₃, CeO₂, and Nd₂O₃ particles were added to the solution under stirring. The decomposition rate was calculated using Equation (7) as follows:

$$\text{Decomposition rate (\%)} = (COD_t - COD_{t+\Delta t})/COD_t \times 100 \quad (7)$$

where COD_t and $COD_{t+\Delta t}$ indicate the chemical oxygen demand at times t and $t+\Delta t$ (g/dm³), respectively. The chemical oxygen demand (COD) was analyzed by acidic KMnO₄ method using COD meter (COD-60A model, DKK-TOA). Decomposition rates of EO tests were evaluated after 2 h, and for the kinetic experiment, they were evaluated every 30 min for 3 h. Average current efficiency (ACE) was calculated using Equation (8) as follows:

$$\text{ACE (\%)} = [COD_i - COD_f]FV/8It \times 100 \quad (8)$$

where COD_i and COD_f indicate chemical oxygen demands before and after the test, F is the Faraday constant (96,487 C/mol), V is the electrolyte volume (dm³), 8 is the dimensional factor for unit consistency, I is current (A), and t is electrochemical oxidation time (s) [5].

Adsorption tests were conducted using a 100 mL solution containing 500 ppm SDBS and 0.1 M Na₂SO₄ with the addition of 10 g/L of each particle, which was maintained at room temperature for 24 h without stirring. The adsorption rates of SDBS on each particle were obtained using the relationship in Equation (7) by measuring the chemical oxygen demand before and after the adsorption test. The standard deviations of the decomposition rate, adsorption rate, and average current efficiency are presented in all graphs and tables, and all values were within $\pm 2.1\%$. The particle size distributions of the particles were obtained using a particle size analyzer (Mastersizer 3000), and high-resolution images of the particles were obtained using a Hitachi SU8200 field-emission scanning electron microscope (FE-SEM) with an accelerating voltage of 5 kV. Brunauer–Emmett–Teller (BET) surface areas of each particle were measured by 3Flex model of Micromeritics.

3. Results and discussion

In general, Pt electrodes exhibit high durability and are used in various electrochemical fields owing to their ease of commercial-scale electrode manufacturing. However, when the electrochemical oxidation test was performed using a Pt anode, it showed low ·OH generation efficiency owing to the rapid oxygen evolution reaction. The LSV results of the simulant waste solution using a Pt

anode are shown in Fig. 2 (a). The oxygen evolution reaction occurred from about 1.2 V (vs. Ag/AgCl), and from this, the generation efficiency of ·OH essential for decomposition of organic material is expected to be very low due to the low oxygen evolution potential. Therefore, the resulting decomposition rate of the organic materials is predicted to be very low. To overcome this drawback, in this study, particles were introduced into an electrochemical reaction cell to improve the decomposition rate of organic materials. CeO₂, Nd₂O₃, and Y₂O₃ particles were selected as representative particles and, the microstructures and particle size distributions of the particles used in an electrochemical oxidation test were shown in Fig. 3. BET surface area of CeO₂, Nd₂O₃, and Y₂O₃ were 2.14, 11.60, and 5.65 m²/g, respectively. The electrochemical decomposition test was performed by injecting 2 g/L of each particle and 20 g/L of Y₂O₃ into the reaction cell. For comparison, a decomposition test was performed using only the Pt anode without the addition of particles. Fig. 2 (b) shows the potential during the decomposition test for 2 h under a constant current of 5.7 mA/cm². When Nd₂O₃ and CeO₂ were added, the resistance increased, resulting in high potential. However, when 2 g/L of Y₂O₃ was added, the potential was found to be similar to that without particles, and when 20 g/L of Y₂O₃ particles were added, the potential was found to be significantly decreased.

Table 1 and Fig. 4 show the SDBS decomposition rates when the electrochemical decomposition test was conducted by adding the three types of particles. In the case of the Pt anode without particles, the decomposition rate was very low at 7.04%. However, when CeO₂ and Nd₂O₃ particles were introduced, the decomposition rates increased to 22.54% and 21.13%, respectively. In the case of Y₂O₃, the increase in the organic material decomposition rate was the highest among the three particles, with a decomposition rate of 30.99%. In the case of Y₂O₃, which had the highest decomposition rate, it was confirmed that the organic material decomposition rate had increased substantially to 53.52% when the amount of particle was increased to 20 g/L.

To further investigate the effect of the particles on the decomposition rate, Y₂O₃ particles with the highest increase in decomposition rate among these particles were selected, and a kinetic experiment was conducted to determine the decomposition rate of the organic material over time compared to the case where no particles were added. As shown in Figs. 3 and 20 g/L of Y₂O₃ particles having a size distribution of 0.1–10 μm were added in the 300 mL of the simulant waste solution. The test was conducted for 3 h at a constant current of 17.1 mA/cm², and the decomposition rate was evaluated every 30 min. The test results are presented in Table 2 and Fig. 5. It was found that when no particles were added, approximately 0% of the decomposition rate of the organic material was maintained owing to the low radical generation of the Pt anode, where most of the electrons were consumed by the oxygen evolution reaction. However, when Y₂O₃ particles were added, the

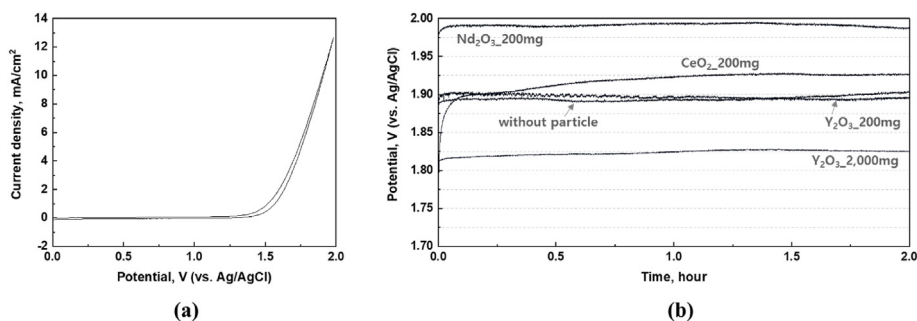


Fig. 2. (a) Linear scanning voltammetry (LSV) of simulant solution and (b) potential during the electrochemical oxidation tests for each particle.

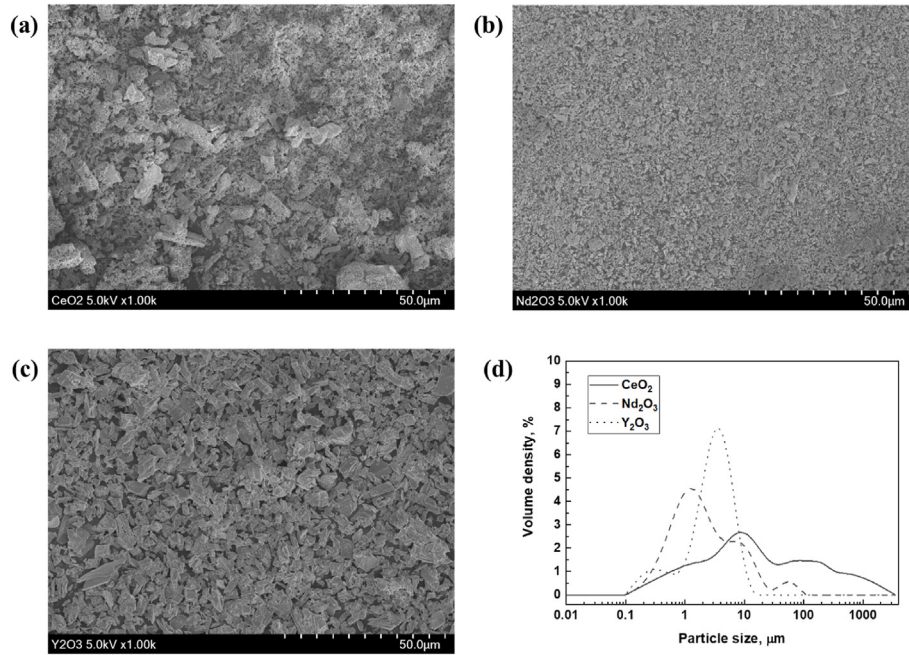


Fig. 3. Scanning electron microscope (SEM) images of (a) CeO₂, (b) Nd₂O₃, (c) Y₂O₃ and (d) particle size distribution.

Table 1
Decomposition rates in the electrochemical oxidation test with addition of each particle.

Particles added	Decomposition rate
Without particle	7.04 ± 1.90%
CeO₂-2 g/L	22.54 ± 1.64%
Nd₂O₃-2 g/L	21.13 ± 1.67%
Y₂O₃-2 g/L	30.99 ± 1.50%
Y₂O₃-20 g/L	53.52 ± 1.14%

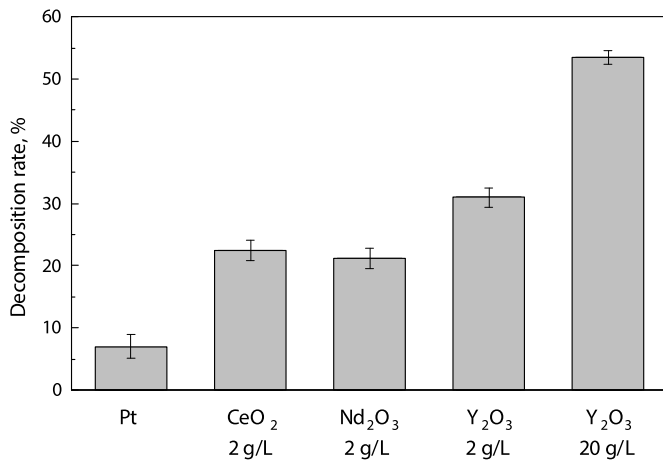


Fig. 4. Decomposition rates in the electrochemical oxidation test with the addition of each particle.

decomposition rate increased by approximately 60% with time. From this, it was found that the decomposition rate of the organic material was greatly improved with time when Y₂O₃ particles were added, even when the Pt anode showed a very low decomposition rate.

Table 2
Decomposition rate in the kinetic experiment with and without Y₂O₃ particles.

Time (h)	Decomposition rate	
	Without particles	With Y ₂ O ₃ particles
0.0	0.00 ± 2.02%	0.00 ± 1.76%
0.5	0.00 ± 2.06%	21.08 ± 1.46%
1.0	4.86 ± 1.94%	36.22 ± 1.24%
1.5	12.43 ± 1.81%	45.95 ± 1.10%
2.0	1.62 ± 1.99%	51.89 ± 1.02%
2.5	1.62 ± 1.99%	55.14 ± 0.97%
3.0	0.00 ± 2.07%	60.54 ± 0.90%

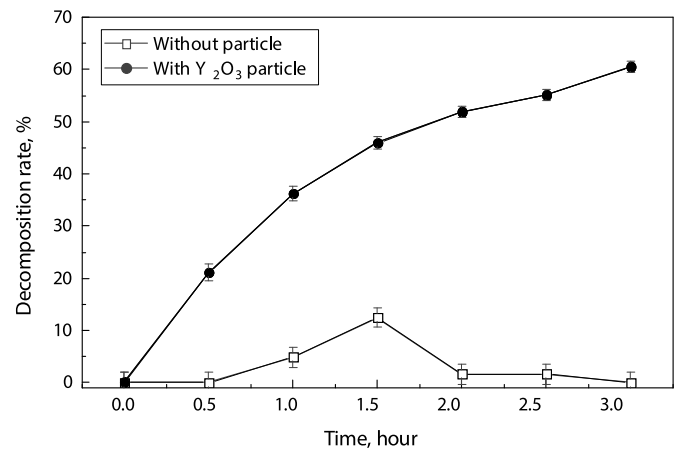


Fig. 5. Decomposition rate in the kinetic experiment with and without Y₂O₃ particles.

To evaluate the decomposition rate according to each variable in the electrochemical oxidation test introducing Y₂O₃ particles, a decomposition test was performed by varying the particle amount and current densities. The decomposition rates were evaluated under various conditions by changing the particle amount to 2 g/L,

10 g/L, and 20 g/L, and the constant current densities were 5.7, 11.4, 17.1 mA/cm². The results are presented in Table 3 and Fig. 6. First, when Y₂O₃ particles were not added, that is, when the oxidation test was conducted using only the Pt anode, the decomposition rate under each constant current condition is shown in Fig. 6 (a). When the current density increased, the decomposition rate showed a tendency to increase, but even at the highest condition of 17.1 mA/cm², a very low decomposition rate of 21.13% was observed. However, when 20 g/L of Y₂O₃ particles were introduced, the decomposition rate improved to 53.52% even at the lowest current density of 5.7 mA/cm². As the current density increased, the decomposition rate increased significantly. At 11.4 mA/cm², the decomposition rate was 97.18%, and at 17.1 mA/cm², the decomposition rate was 99.30%, which was close to complete decomposition. To understand the effect of the particle amount, an electrochemical oxidation test was performed while changing the amount of Y₂O₃ particles to 2 g/L, 10 g/L, and 20 g/L at a fixed current density of 11.4 mA/cm², as shown in Fig. 6 (c). It was observed that the decomposition rate of organic material increased in proportion to the number of particles; in the case of 2 g/L, the decomposition rate was 16.9%, and in the case of 10 g/L, the decomposition rate was 47.89%. When 20 g/L was added, the decomposition rate was very high (97.18%). Therefore, in the present experimental conditions, a decomposition rate close to complete decomposition was achieved when the electrochemical oxidation test was performed under the conditions of 20 g/L Y₂O₃ and 17.1 mA/cm² current density even with a Pt anode. To evaluate the current efficiency under each condition, the average current efficiency was calculated as shown in Table 3 and Fig. 6. If no particles are added, a very low current efficiency of approximately 2–3% is observed, which is considered to be because the anode electrode does not generate ·OH and mostly produces oxygen. However, when particles were added, a current efficiency of 20% or higher could be achieved. When the amount of particles is fixed, the current efficiency tends to decrease as the current density increases as shown in Fig. 6 (b). In particular, the current density of 11.4 mA/cm² showed a high decomposition rate of over 97%, and when the current density was increased to 17.1 mA/cm², the decomposition rate reached over 99%. Therefore, in case of the current density of 17.1 mA/cm², the remaining electrons were consumed for oxygen generation, leading to the decrease of current efficiency. Meanwhile, when the amount of particles was increased under the fixed current density, the current efficiency showed a tendency to gradually increase as shown in Fig. 6 (c). This indicates that the radical generation reaction was enhanced due to the addition of particles. These results show that there is an optimal current density and particle amount that can represent a high

decomposition rate at high current efficiency and further study is required to obtain optimized conditions for organic decontamination liquid waste of a specific concentration.

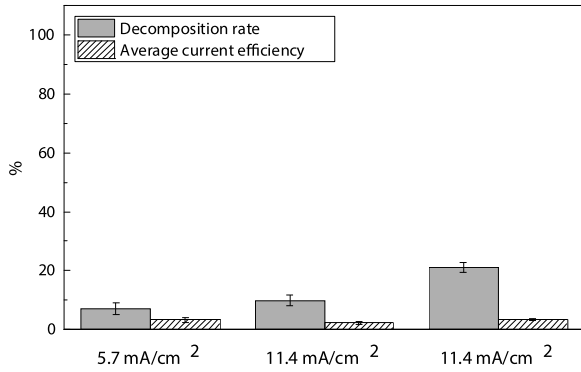
The reason for the increase in the decomposition rate when Y₂O₃ particles were introduced is as follows. One reason for this is that the mass transfer near the electrode surface was physically improved by introducing particles. However, as shown in Fig. 4, there is a difference in the increase in the decomposition rate depending on the type of particle; therefore, it is difficult to explain the increase in the decomposition rate simply by the enhancement of such agitation. Another possible reason is that Y₂O₃ can act as a bed electrode (or particle electrode) [20]. The bed electrode forms a microanode through its own polarization within the particle to locally generate additional ·OH. In addition, bed (or particle) electrode system can produce a higher current than traditional electrode system through charge transfer realized by the collision of particles, thus enhancing the reaction rate [21]. Since current electrochemical oxidation tests were conducted under constant current condition, the potential is expected to decrease if the particle is effective for the charge transfer. As shown in Fig. 2 (b), when particles were added, the potential was found to be different for each particle and decreased in the order of Nd₂O₃, CeO₂, Y₂O₃, and the decomposition rate was increased in the order of decreasing potential (see Fig. 4). Also, to further elucidate the effect of charge transfer promoted by particles, decomposition rates were analyzed under the condition of fixed bed (without stirring of 20 g/L Y₂O₃ particles) and fluidized bed (with stirring of 20 g/L Y₂O₃) using 300 mL solution containing 0.1 M Na₂SO₄ and 500 ppm SDBS, and 5.45 mA/cm² current density as shown in Fig. 7. In the fixed bed, the decomposition rate was found to be very low, however, in the fluidized bed, it was found that the decomposition rate increased significantly. It is considered that the reaction is promoted because the particles collides with the Pt electrodes due to the agitation, thereby promoting charge transfer. Another reason might be originated from an adsorption of the organic materials on the particle surface. To evaluate the adsorption rate of SDBS on each particle, an adsorption test was performed. The SDBS adsorption rates for each particle are presented in Table 4 and Fig. 8. The decomposition rate of each particle in Table 1 has been added to Fig. 8 for comparison with the adsorption rate. The SDBS decomposition rate tended to be proportional to the amount of SDBS adsorbed on each particle. In the case of Y₂O₃ particles showing the highest decomposition rate, the adsorption rate was 26.8%. Therefore, when performing the electrochemical oxidation test using particles, it is considered that adsorption could contribute to the total decomposition rate. In order to figure out the proportion of adsorption rate in the total

Table 3

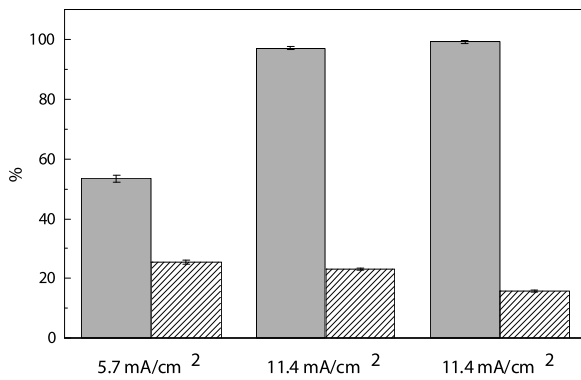
Decomposition rates and average current efficiencies of electrochemical oxidation tests with and without Y₂O₃ particles under various current densities.

Condition: Without particle		
	Decomposition rate	Average current efficiency
5.7 mA/cm ²	7.04 ± 1.90%	3.35 ± 0.89%
11.4 mA/cm ²	9.86 ± 1.86%	2.35 ± 0.44%
17.1 mA/cm ²	21.13 ± 1.67%	3.35 ± 0.28%
Condition: With 20 g/L of Y ₂ O ₃ particle		
	Decomposition rate	Average current efficiency
5.7 mA/cm ²	53.52 ± 1.14%	25.46 ± 0.76%
11.4 mA/cm ²	97.18 ± 0.51%	23.12 ± 0.34%
17.1 mA/cm ²	99.30 ± 0.49%	15.75 ± 0.23%
Condition: 11.4 mA/cm ² with Y ₂ O ₃ particle		
	Decomposition rate	Average current efficiency
Y ₂ O ₃ -2 g/L	16.90 ± 1.74%	4.02 ± 0.43%
Y ₂ O ₃ -10 g/L	47.89 ± 1.23%	11.39 ± 0.39%
Y ₂ O ₃ -20 g/L	97.18 ± 0.51%	23.12 ± 0.34%

(a) Without particle



(b) With 20 g/L of Y₂O₃ particle



(c) 11.4 mA/cm² with Y₂O₃ particle

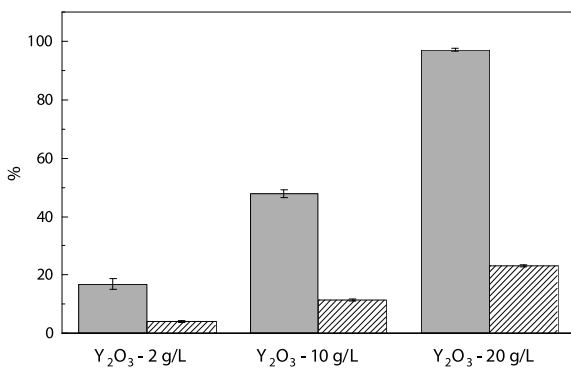


Fig. 6. Decomposition rates and average current efficiencies of electrochemical oxidation tests with and without Y₂O₃ particles under various current densities.

decomposition rate, an additional experiments were conducted according to the scheme shown in Fig. 9 (a). An adsorption rate could be obtained through adsorption test by measurement of

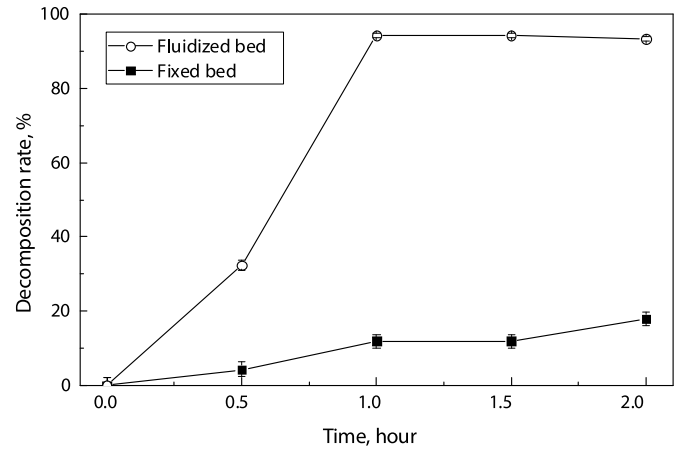


Fig. 7. Comparison of decomposition rate in fixed bed and fluidized bed.

Table 4

Adsorption rates of sodium dodecylbenzenesulfonate (SDBS) on each particle.

	Adsorption rate
CeO ₂	15.49 ± 1.76%
Nd ₂ O ₃	12.68 ± 1.81%
Y ₂ O ₃	26.76 ± 1.57%

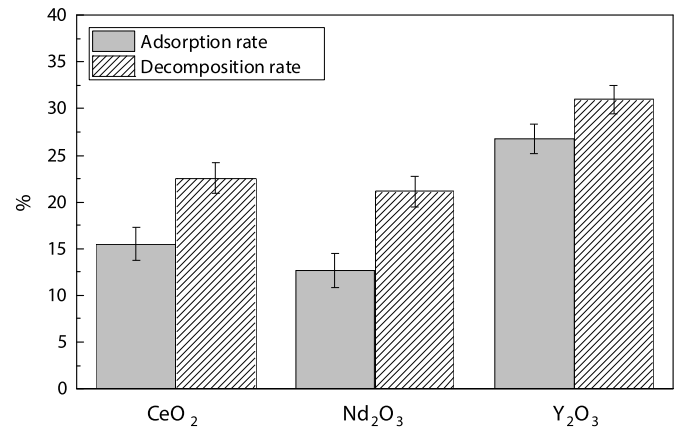
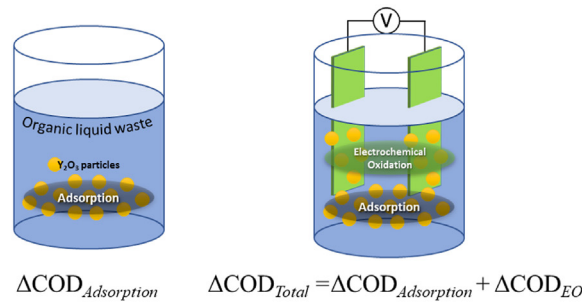


Fig. 8. Adsorption rates of sodium dodecylbenzenesulfonate (SDBS) on each particle.

$\Delta\text{COD}_{\text{Adsorption}}$, and a decomposition rate originated from electrochemical oxidation could be estimated from total decomposition rate and adsorption rate using the relation of “ $\Delta\text{COD}_{\text{EO(} \text{Electrochemical_oxidation)}} = \Delta\text{COD}_{\text{Total}} - \Delta\text{COD}_{\text{Adsorption}}$ ” [22]. The tests were conducted for 2 h using 1000 ppm SDBS and 0.1 M Na₂SO₄ in 300 mL waste water solution and the 20 g/L and 40 g/L of Y₂O₃ particles were added. Electrochemical oxidation was conducted under the current density of 6.25 mA/cm². Fig. 9 (b) shows the contribution to the decomposition rates by adsorption and electrochemical oxidation, respectively. When 20 g/L of Y₂O₃ particle was added to the waste solution, total decomposition rate was found to be 78.0%, where adsorption rate and decomposition rate by electrochemical oxidation were 19.1% and 58.9%, respectively. However, when the amount of Y₂O₃ particle was increased to 40 g/L, total decomposition rate was found to be 90.2%, where adsorption rate and decomposition rate by electrochemical oxidation were 44.5% and 45.7%, respectively. With increase of Y₂O₃ particle, it was found that the proportion of adsorption rate in the total

(a) Method for measurement of decomposition rates by adsorption and electrochemical oxidation



(b) Contribution to the decomposition rates by adsorption and electrochemical oxidation

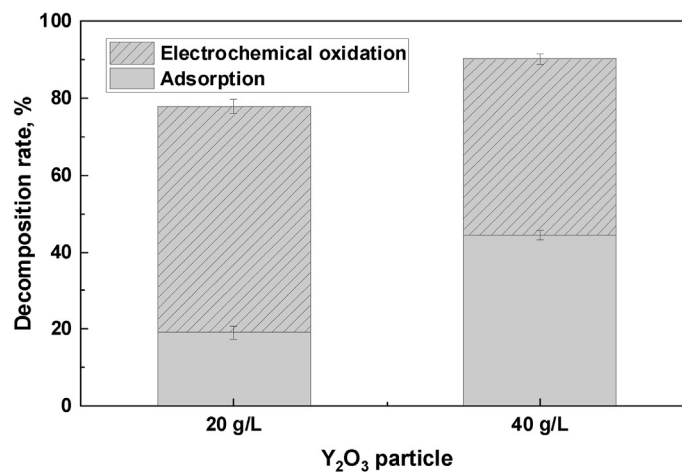


Fig. 9. Measurement of decomposition rates by adsorption and electrochemical oxidation according to the Y₂O₃ particle amount.

decomposition rate was increased, whereas, the decomposition rate originated from electrochemical oxidation was decreased, which indicates that total decomposition rate would be determined by competition between adsorption and electrochemical oxidation and there would be an optimal point to achieve high efficiency for the removal of organic materials. Therefore, it is considered that the above-mentioned various influences acted in combination as the reason for the increase in the decomposition rate when particles were added, and further study on the mechanism is being conducted for the next publication.

4. Conclusion

In this study, using a Pt anode with a very low decomposition rate of organic material in the electrochemical oxidation process for organic waste treatment, electrochemical oxidation tests were performed by adding particles to an electrolytic cell to increase the decomposition rate. Among the CeO₂, Nd₂O₃, and Y₂O₃ particles, the improvement in the decomposition rate was highest when Y₂O₃ particles were added. When the decomposition test was performed using only the Pt anode without the addition of particles, the organic material decomposition rate was 21%; however, when Y₂O₃ particles were introduced into the system, the decomposition rate was significantly improved to 99% and the current efficiency was also improved.

Pt electrodes exhibit high durability and long-term operability, making them suitable for commercial processes; however, their application is limited in electrochemical oxidation processes owing to their low decomposition rate. Our method is advantageous in that it can achieve a high organic material decomposition rate using a Pt electrode system without additional modification. In addition, it can be applied to systems other than the Pt electrode, and when applied to BDD and PbO₂/Ti electrode systems with high decomposition rates, it is expected that a very high decomposition rate of organic material can be achieved with very high current efficiency.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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