

Comparison of Mercury Removal Efficiency from a Simulated Exhaust Gas by Several Types of TiO₂ under Various Light Sources

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A removal efficiency of vapor-phase elemental mercury by TiO₂ irradiated using various light sources was investigated. The effective surface area of TiO₂ for Hg adsorption and UV radiation was increased by packing the adsorption bed with mixture of TiO₂ and glass beads. A rotating-type reactor was specially designed to maximize the photocatalyst's exposure to the light source. For three types of commercially available TiO₂, more than 99% of initial Hg was removed under all the light sources tested except for the blue light still achieving a Hg removal efficiency close to 85%.

Because of the extremely low concentration and high volatility of Hg in coal combustion gases, Hg removal using activated carbon had not been efficient.^{1,2} Previous studies³⁻⁶ showed that a far stronger bond was formed between mercury and TiO₂ under UV irradiation. In this study, removal of elemental mercury in exhaust gas by several types of photo-adsorbent, TiO₂, under various light sources was tested for comparison.

Experimental setup was consisted of three major components: a mercury vapor generator, a photochemical reactor, and an on-line Hg analyzer. A rotating-type reactor was specially designed to maximize the photocatalyst's exposure to the light sources. Also, a mixture of TiO₂ and glass beads was placed inside the reactor to increase the contacting surface area (mercury-adsorbents) and light exposure. A photochemical reaction cell was 10 cm in length, 2.5 cm in diameter, and made of borosilicate glass. Dry, particle-free air (1500 sccm) from a clean air generator (JC-8320C, Jinsol Co., Korea) was supplied to the system as main air. Mercury vapor was introduced to the reactor by passing particle free air at a precisely controlled flow rate (75 sccm) above liquid mercury contained in a temperature controlled gas washing bottle. The mass used was 0.3 g for all three types of TiO₂ tested. The range of Hg inlet concentration was 300–400 µg/m³.

Three different commercially available TiO₂ were used: P25 (anatase:rutile = 80:20, Degussa, Germany), anatase (prepared from STS-01 titania sol, Ishihara, Japan), and rutile (53145-0601, Junsei, Japan). Average particle sizes (literature) and specific surface areas (BET, measured) were 30 nm and 48.8 ± 1.4 m²/g for P25, 7 nm (crystallite) and 375.3 ± 0.7 m²/g for anatase, and 1.5 µm and 3.1 ± 0.2 m²/g for rutile. Removal efficiencies under different light sources were evaluated; UV black light (2 × TLD36w/08, Philips, Netherlands), UV sterilizing light (2 × GB36TB, Philips, Netherlands), fluorescent light (2 × FL40D, Osram-Korea, Korea), and the blue light (2 × FL40B, Wooree Lighting Co., Korea). Figure 1 shows the wavelengths of the light sources. Hg concentration was measured in

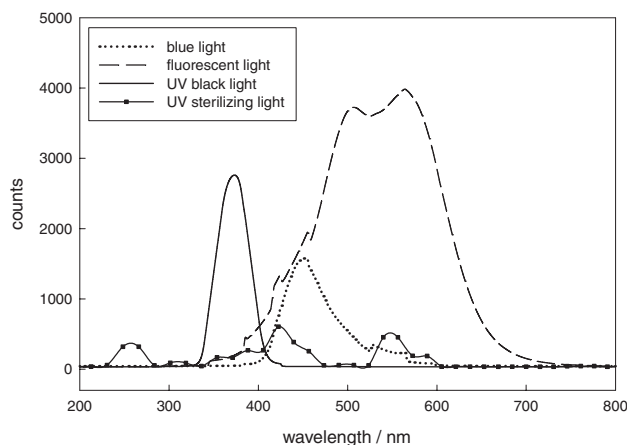


Figure 1. Wavelengths of the light sources tested.

real-time by the on-line Hg analyzer (VM3000, Mercury Instruments, Germany). In addition, the Ontario Hydro Method was used for the collection of total mercury (elemental and oxidized) in the simulated coal combustion gas.⁷⁻⁹

A selected light source was provided only after the analyzer reading had been stabilized, then the outlet Hg concentration was measured.

Figure 2 shows more than 99% Hg removal efficiency for all the light sources except for the blue light whose efficiency was still close to 85%. UV black light with the wavelength of 300–400 nm resulted in a relatively fast reaction than others. Under the conditions tested in this study, physical properties of selected TiO₂ seemed to have less significant effect on their Hg removal efficiencies. For blue light, only rutile form of TiO₂ showed a Hg removal efficiency higher than 99%. It might be from the fact that rutile TiO₂ corresponds better to the light sources with longer wavelengths. Continuous photoactivity was observed for the anatase TiO₂ (with a mercury removal efficiency higher than 99%) for several minutes after the light sources were removed. This behavior was more evident for the light source with significant portion of visible-range wavelength (UV sterilizing light, fluorescent light); the photon (light) seemed to play its role before the succession of cyclic photochemical reaction steps making the catalytic turnover.¹⁰

To verify the fact that mercury was actually adsorbed onto the TiO₂ surface and not simply discharged in different (non-elemental) forms, exhaust gas out of the photochemical reactor was sampled using the Ontario Hydro Method and then analyzed. No mercury was detected when the removal efficiency was almost 100% indicating that mercury was not discharged in the oxidized form but removed by chemisorption onto TiO₂

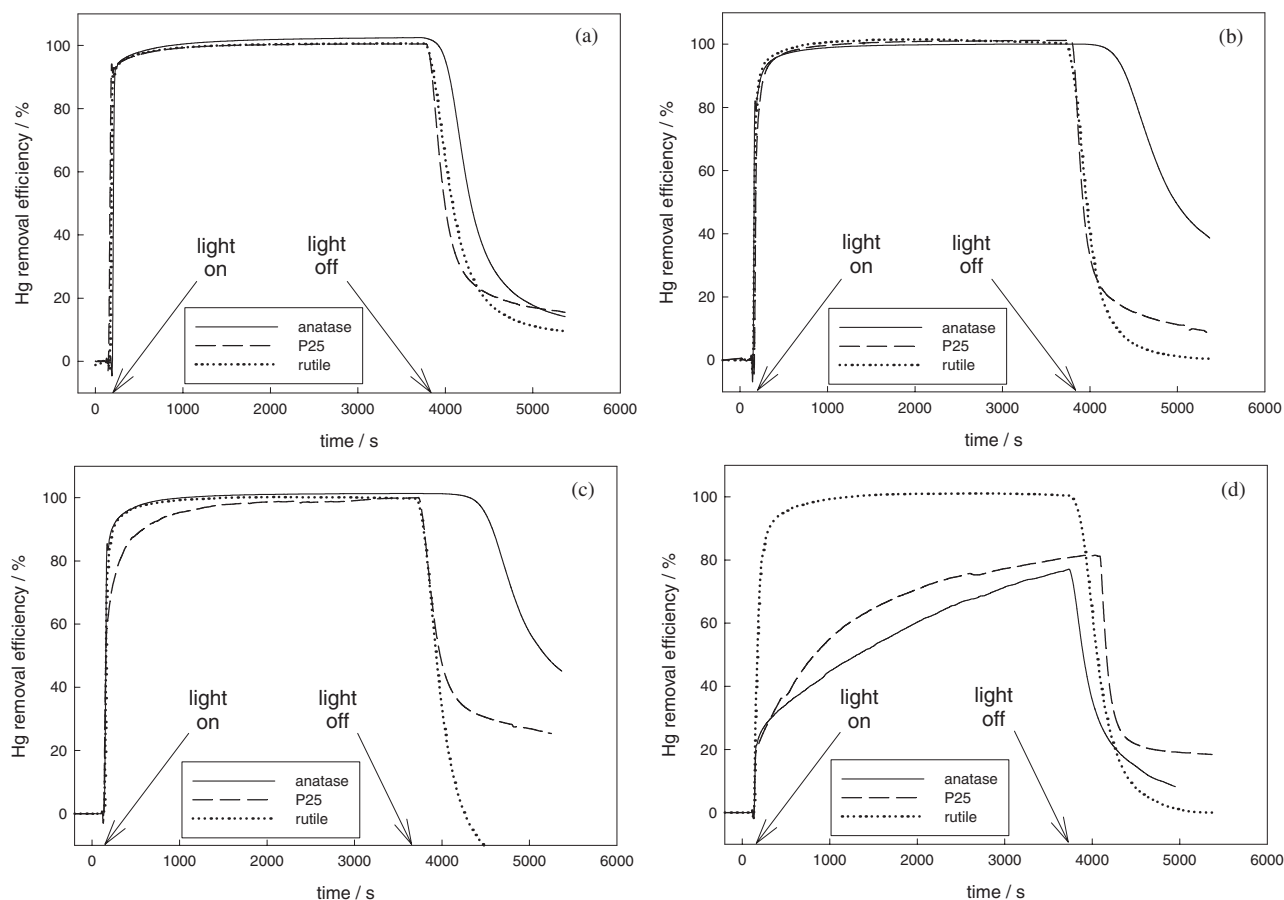


Figure 2. Hg removal efficiency vs. reaction time. (a) UV black light, (b) UV sterilizing light, (c) fluorescent light, and (d) blue light.

surface. XRD result from the previous study^{3,6} also confirmed that mercury was bound as HgO. Breakthrough experiments were performed for TiO₂ (P25) and activated carbon (specific surface area = 1133.6 ± 11.2 m²/g, Kuracool-GW, Kuraray, Japan) under same conditions for comparison. A low-cost, easily-maintainable fluorescent light (2 × 36 W) was selected as a light source. As shown in Table 1, TiO₂ perform far better than activated carbon in maintaining the high-efficiency mercury removal; and using TiO₂ is much more economical than using the activated carbon.

Table 1. Comparison between TiO₂ and activated carbon

	TiO ₂	Activated Carbon
Average time to reach 80% of the initial Hg conc.	≈570 h	≈40 h
Amount of Hg per kilogram of adsorbent	≈68.0 g	≈2.5 g
Average cost per kilogram of adsorbent ^a	≈\$30.0	≈\$8.5
Estimated cost per kilogram of Hg	≈\$440 ^b	≈\$3400

^a Local prices for the adsorbents may vary.

^b Electricity cost is not included: 2 × 36 W for 570 h = ca. \$1.70.

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