Preparation of oxygen-vacant TiO$_2$–x and activated carbon fiber composite using a single-step thermal plasma method for low-concentration elemental mercury removal

Hsing-Cheng Hsi$^{a,*}$, Cheng-Yen Tsai$^b$

$^a$Institute of Environmental Engineering and Management, National Taipei University of Technology, No. 1, Sec. 3, Chung-Hsiao E. Rd., Taipei 106, Taiwan

$^b$Graduate Institute of Engineering Science and Technology, National Kaohsiung First University of Science and Technology, No. 2, Jhuoyue Rd., Nanzih, Kaohsiung 811, Taiwan

**Highlights**

- TiO$_2$–x/ACF composites were developed via a N$_2$/Ar/He thermal plasma system.
- TiO$_2$–x had a size within 10–40 nm and a mixture of anatase and rutile phases.
- TiO$_2$–x/ACF composites had a greater Hg removal under UV than VL irradiation.
- Presence of O$_2$ enhanced the Hg removal of TiO$_2$–x/ACF.
- Moisture reduced Hg removal performance of TiO$_2$–x/ACF.

**Graphical Abstract**

TiO$_2$–x/ACF composites were synthesized using N$_2$/He/Ar thermal plasma. Hg$^0$ removal by the TiO$_2$–x/ACF was enhanced by light radiation and O$_2$, but reduced by competitive adsorption from moisture.

**Abstract**

Oxygen-vacant TiO$_2$ (TiO$_2$–x) nanoparticles and TiO$_2$–x/activated carbon fiber (ACF) composites were developed via a N$_2$/Ar/He thermal plasma system. The TiO$_2$–x nanoparticles and TiO$_2$–x/ACF composites were characterized with TEM, XRD, UV–Vis, ESEM and N$_2$ adsorption isotherms. The removal effectiveness of TiO$_2$–x/ACF for gaseous Hg$^0$ at ppb concentration level and various conditions was subsequently evaluated. The experimental results indicated that the formed TiO$_2$–x nanoparticles had a size within 10–40 nm and a mixture of anatase and rutile phases. The TiO$_2$–x formed at 7% N$_2$ concentration had an evident red-shift in wavelength absorption. The ESEM and N$_2$ adsorption results suggested that the synthesized TiO$_2$–x nanoparticles unevenly deposited on the ACF surface causing a decrease in total and micropore surface areas/volumes. Hg breakthrough tests revealed that TiO$_2$–x/ACF composites had a greater Hg removal under UV or visible-light irradiation than those obtained in the dark condition. The presence of O$_2$ up to 12% greatly enhanced the Hg removal, implying the positive effects of catalytic oxidation. However, moisture reduced Hg removal performance, especially when visible-light irradiation was applied. These results revealed the competitive adsorption between Hg species and H$_2$O and the physisorption nature of Hg species on the light-induced hydrophilic TiO$_2$–x/ACF surface.

© 2012 Elsevier B.V. All rights reserved.