

IMAGINE A “SELF-CLEANING” WORLD

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*You may say that I'm a dreamer, but I'm not the only one
I hope someday you'll join us, and the world will live as one
- John Lennon, Imagine*

From the *yesterday* decades of *yellow submarines* to bell bottoms to New Kids on the Block, culture has evolved with humans, and technology is no different. Gone will be the need to clean windows *eight days a week*. Glass companies have manufactured “self-cleaning” windows, billed under name brands such as PPG SuncleanTM and Pilkington ActivTM, containing a thin film of titanium dioxide (TiO₂), a photocatalyst which utilizes ultraviolet light on a *good day sunshine* for (a) photocatalytic oxidation (PCO) of adsorbed organic materials, and (b) photo-induced superhydrophilicity (PSH) to assist with water washing of the surface by allowing water to *come together* instead of beading up when it *rains*. Using these two TiO₂ photoreactive properties may minimize the need to send washers outside of big skyscrapers to clean window exteriors, or to remove the bird “mishaps” off Hank Steinbrenner’s luxury box window every time the Boston Red Sox score in the new Yankee Stadium.

Though this *revolutionary* technology is truly amazing, researchers can’t just *let it be*. A field analysis method is needed to characterize the TiO₂ film at initial and continuing times, and various environmental conditions. Furthermore, the creation of these “self-cleaning” surfaces logically leads to consideration of testing potential organic material deposits found in outdoor air.

Work completed by the Ollis research group at Raleigh, NC, focused on using the organic dyes Acid Blue 9 and Reactive Black 5 for visual and quantitative PCO data on Pilkington ActivTM glass¹. The visual results showed a return of aesthetic clarity on the dye-coated ActivTM glass after 1000 min of near-UV illumination (irradiance: 1.4 mW/cm²). Using UV-Vis spectroscopy, our lab quantitatively observed a monotonic decrease in peak absorbance as a function of time. A two-step reaction mechanism was developed to *help(!)* describe the kinetics of dye degradation. The kinetic model indicated that the colored dye forms a colored intermediate before its colorless final product. This model can be applied to characterize the change in TiO₂ kinetics at initial and continuing times. Additionally, *here comes the sun*, solar experiments conducted under variable UV light intensity, relative humidity, and temperature exhibited similar dye decolorization rates compared to work completed in an indoor photoreactor. Our model fit the solar data well even though the UV irradiance varies with time.

Though dyes are a good characterization material, they do not simulate organic pollutants encountered in the atmosphere. Take a walk down *Penny Lane* or enter any industrialized U.S. city, and what you will find besides crime, poverty, obnoxious sport fans, and general *helter skelter*, is the deposition of soot on exterior surfaces (e.g., buildings, statues).

Work completed in our lab systematically studied various TiO₂ and soot thickness to determine their effect on the PCO rate of soot² using a quartz crystal microbalance (QCM). Results of UV-

Vis spectroscopy revealed that our lab could linearly and reproducibly deposit soot using an analytical linear rotor rotating past a hurricane lamp. By changing the amount of soot deposited on top of the TiO₂-coated QCM crystals, experiments revealed a range of behaviors from complete soot mineralization (< 0.7 μm soot thickness), to partial oxidation (1 μm thickness), to minimal soot oxidation (2 μm thickness) caused by soot screening of the incident UV light. Alternatively, varying the TiO₂ thickness did not demonstrate significant changes in the soot destruction rate *because* oxidation of soot in direct contact with TiO₂ is the dominant reaction compared to lateral and remote soot oxidation, and the soot / TiO₂ contact area is independent of TiO₂ thickness. A series / parallel reaction mechanism was successfully constructed and utilized to describe the reaction kinetics of our soot PCO for $t > 1,000$ min. If we *get back* to previous literature^{3,4} for PCO of soot on thick (c.a. 1 μm) TiO₂ films, *we can work it out* that our model⁵ adequately describes their data. Finally our lab illustrated TiO₂ PCO of carbon black, often studied as a model soot, though further tests were needed to elucidate the kinetic reaction mechanism.

While continual development of these novel “self-cleaning” surfaces will transform our *hard day’s night* (and possibly put Windex™ out of business), additional research is required to perfect the TiO₂ thin films. Further experimentation of organic deposits is needed to comprehend fully the applicability of these “self-cleaning” surfaces under realistic conditions. After a *long and winding road*, one can *imagine* how this technology will take us *across the universe*.

The End.

¹ Chin P., Ollis D.F., *Catalysis Today* **2007**, 123 (1), 177-188.

² Chin P., Grant C.S., Ollis D.F., “Quantitative Photocatalyzed Soot Oxidation on Titanium Dioxide”, submitted to *Journal of Catalysis* **2008**.

³ Mills A., Wang J., Crow M., *Chemosphere* **2006**, 64 (6), 1032-1035.

⁴ Lee N.C., Choi W.Y., *Journal of Physical Chemistry B* **2002**, 106 (45), 11818-11822.

⁵ Chin P., Roberts G.W., Ollis D.F., *Industrial & Engineering Chemistry Research* **2007**, 46 (23), 7598-7604.