Workshop on Passive Photocatalytic Oxidation of Air Pollution

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Passive PCO (Photo-Catalytic Oxidation) — the promise

- Can reduce local air pollutants by 20% to 70%, depending on sunlight levels and wind
- Marginally adds to the cost (e.g., ~20% to the cost of cement)
- Covering 15% of the exposed surfaces of a city like Milan could cut pollution in half
- As a bonus, TiO_2 helps buildings stay white by resisting the pollutants that stain building surfaces

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Can it be done?

- "The question is whether coatings on buildings can treat enough of the atmospheric air to make a difference."
  — M. Sattler, U. Texas at Arlington
- "Catalysts tend to lose their effectiveness over time."
  — H. Liljestrand, U. Texas at Austin

Today's program

- Examine the technology; how does it work?
- What are the potential benefits of air quality improvements?
- Review progress made so far in Europe, Japan, Texas
- Review active air cleaning technology
- Discuss pros and cons of the passive technology
- Outline how California can capture the potential benefits

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Photocatalytic oxidation (PCO)

- TiO_2 particles (anatase phase), size 5-20 nm
- Adsorption of pollutant molecule on surface
- UV photon absorption creates electron-hole pair
- Hole reacts with OH^- group from adsorbed water, forming reactive $OH^\bullet$ radical
- $OH^\bullet$ radical initiates oxidation of pollutant molecule

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PCO illustration

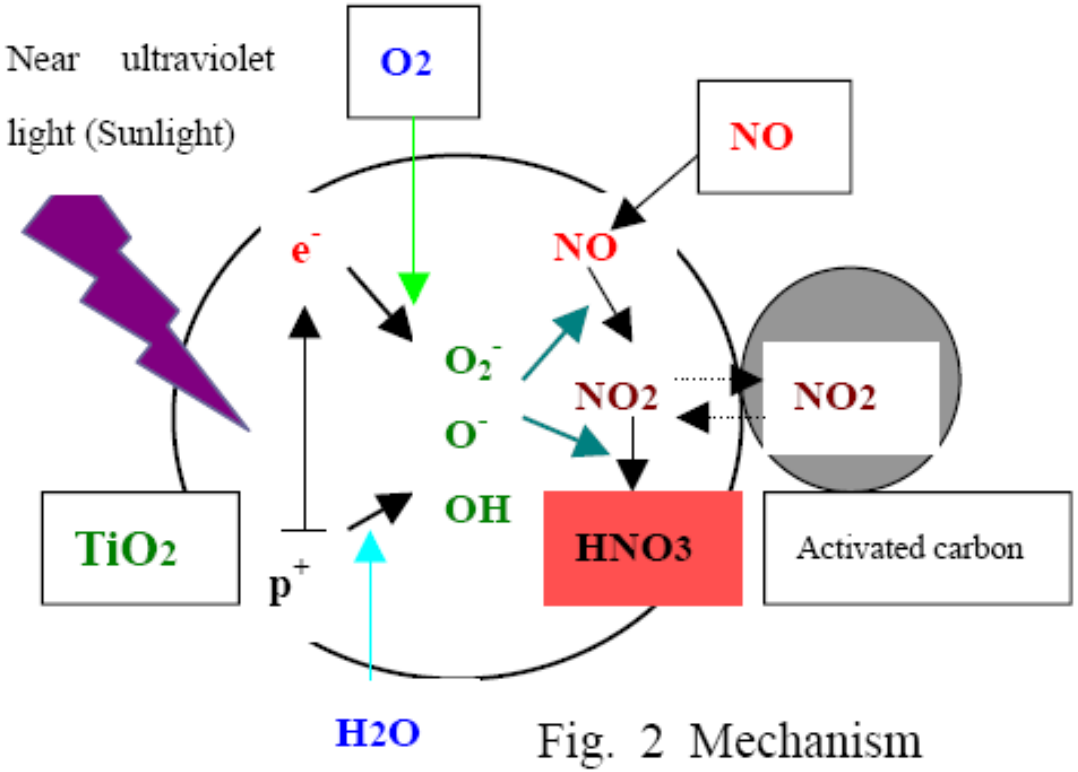

Fig. 2 Mechanism of photocatalysts

Passive vs. active PCO

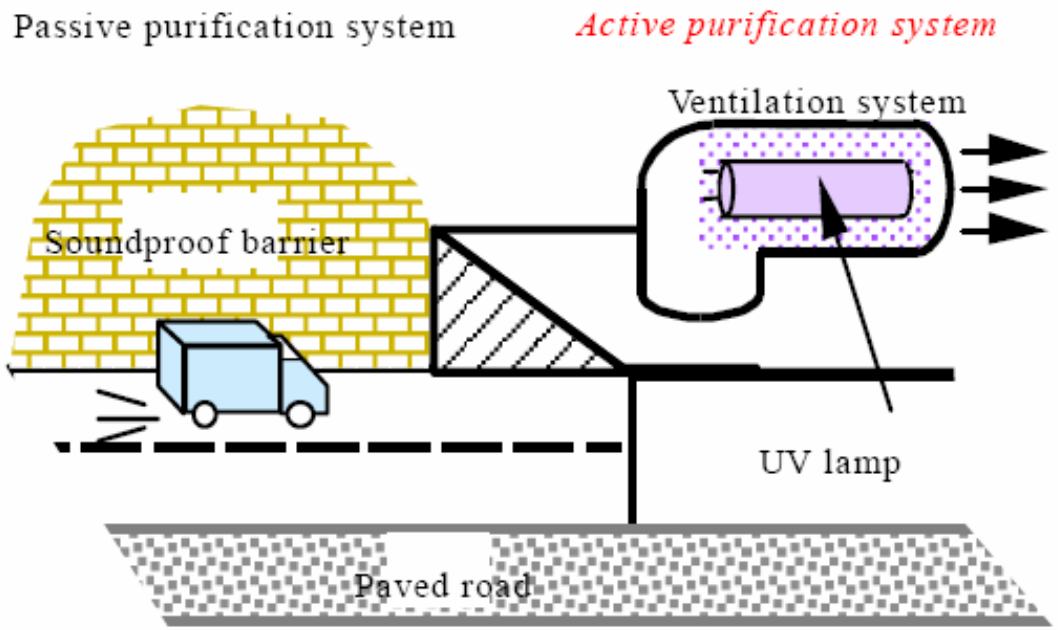

Fig. 4 Environmental purification by photocatalyst

(Use of sunlight: Passive purification, Use of artificial light: Active purification)

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Reaction products (mineralization)

- Hydrocarbons → CO_2, H_2O
- Nitrogen → HNO_3
- Sulfur → H_2SO_4
- Chlorine → HCl

- Incomplete oxidation → CO, NO_2, HCHO (formaldehyde), …

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Other characteristics of TiO_2 photocatalytic surfaces

- Self-cleaning
- Anti-bacterial
- Superhydrophilic
  - Anti-fog mirror

Self-cleaning tent

Self-cleaning tent material

These small test-size tents were located on the grounds of a factory in Saitama prefecture, north of Tokyo, where they were exposed to significant air pollution. After a three-month exposure, the conventional tent material, seen on the left, had become severely stained. On the right, the photocatalytic tent material has remained clean, having been washed off periodically by rainwater.

ordinary white tent

(Courtesy of
Taiyo Kogyo Corporation)

photocatalytic white tent

This tent, located in Tsukuba Science Center, is a full-size storage tent made from the photocatalytic tarpaulin material. Also having been washed by rainwater, it remains clean.

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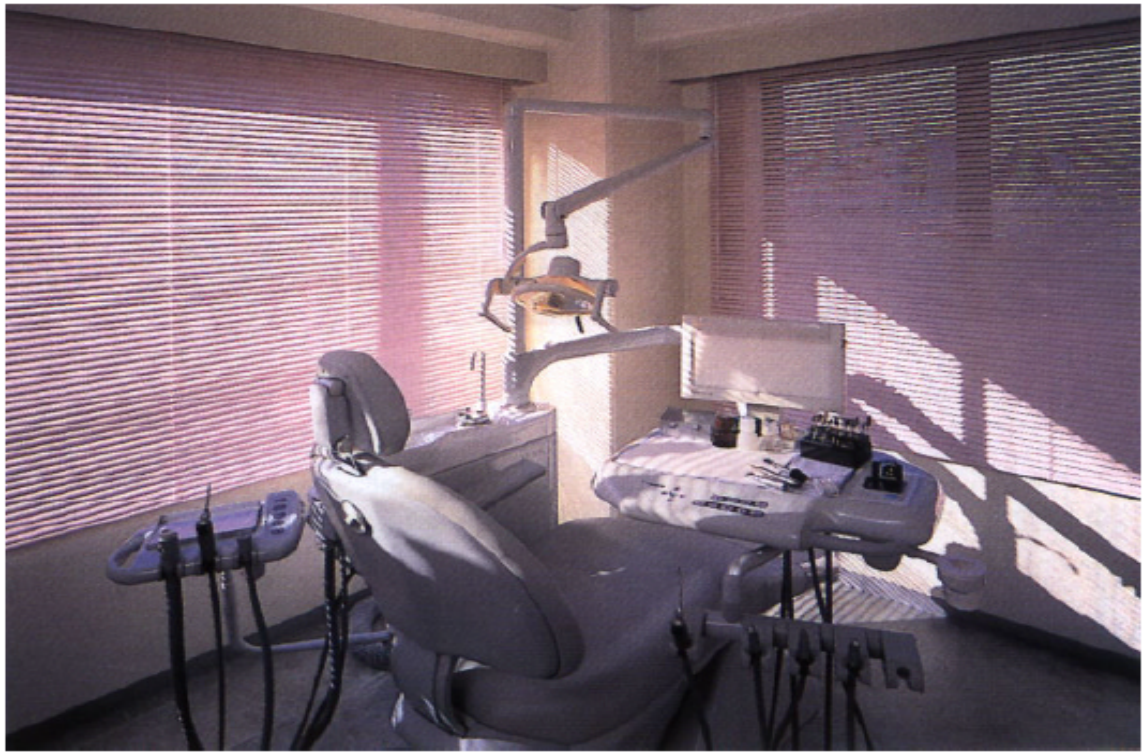
Self-cleaning window blind

Self-cleaning window blind

This titanium dioxide-treated window blind, shown here in use in a dental office, has three functions: 1) it keeps itself clean, 2) it helps keep the air in the office clean, and 3) it helps to kill bacteria in the office.



(Courtesy of Nichibei Trading Co., Ltd.)

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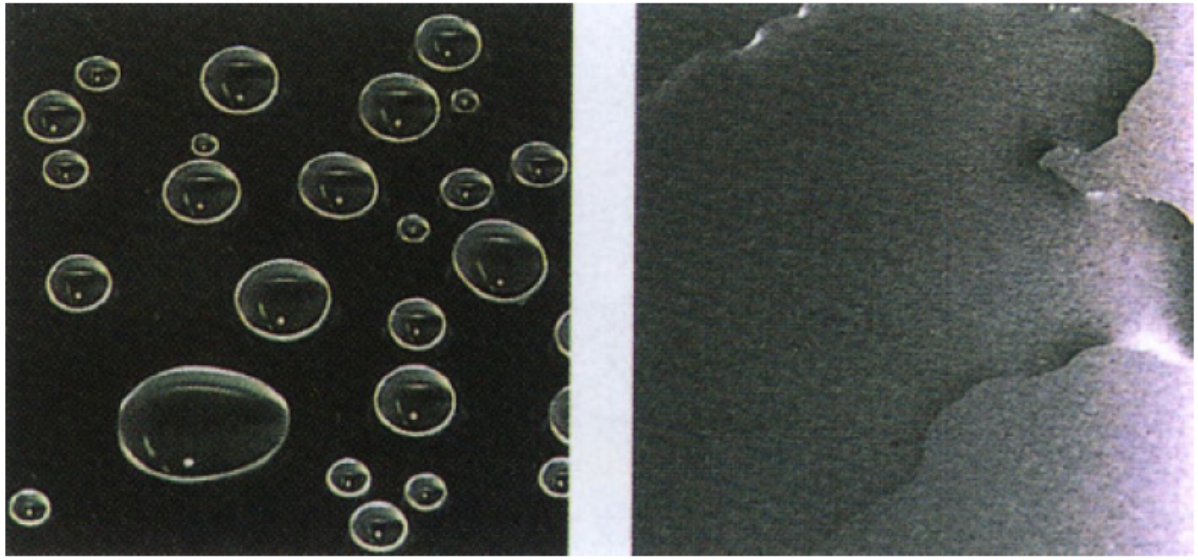
Superhydrophilic surface after exposure to UV light

Anti-fogging glass

Generally, if moist air comes in contact with glass, small water droplets form, and the glass becomes fogged. However, on titanium dioxide-coated glass, the water forms a continous flat sheet, so that there is no fogging. This is an example of what we call "superhydrophilicity"



Small water droplets are responsible for fogging.

Here the water forms a thin sheet, with no fogging effect.

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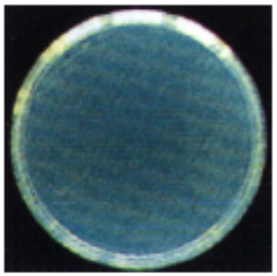
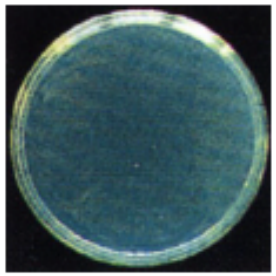
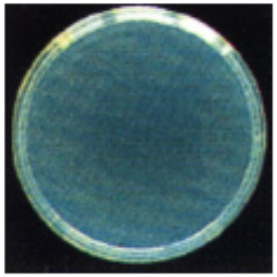
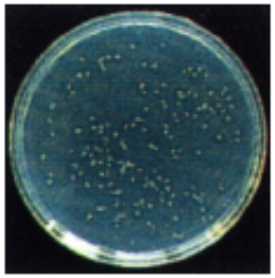
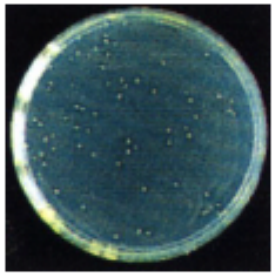
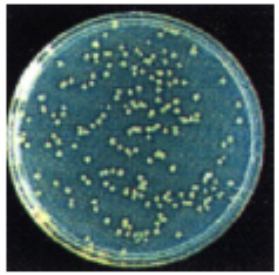
Anti-bacterial effect

		E. coli	Methicillin-resistant *Staph. aureus* (MRSA)	*Pseudomonas aeruginosa*
Photocatalytic anti-bacterial tiles	1000 lux illumination (1 hour)			
Ordinary Tile	1000 lux illumination			

A program for California (i)
(presumes ongoing basic research)

1. Applied research
   - System design including catalyst support
   - Experimental catalyst characterization
   - Effects of incomplete oxidation
   - Catalyst lifetime and regeneration
   - Additional technical issues that arise
2. Mathematical modeling, to reduce number of expensive large-scale experiments
   - Theoretical analysis of experimental data as functions of temperature, UV flux, reactant concentrations, etc.
   - Local modeling
   - Regional modeling

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A program for California (ii)

3. Demonstrations
   - Small scale (a wall, a roof, a road)
   - Large scale (a city block)

4. Market development and implementation
   - Industrial collaborations with the state
   - Policy issues
   - Regional standards and codes
   - Analysis of regional credits

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