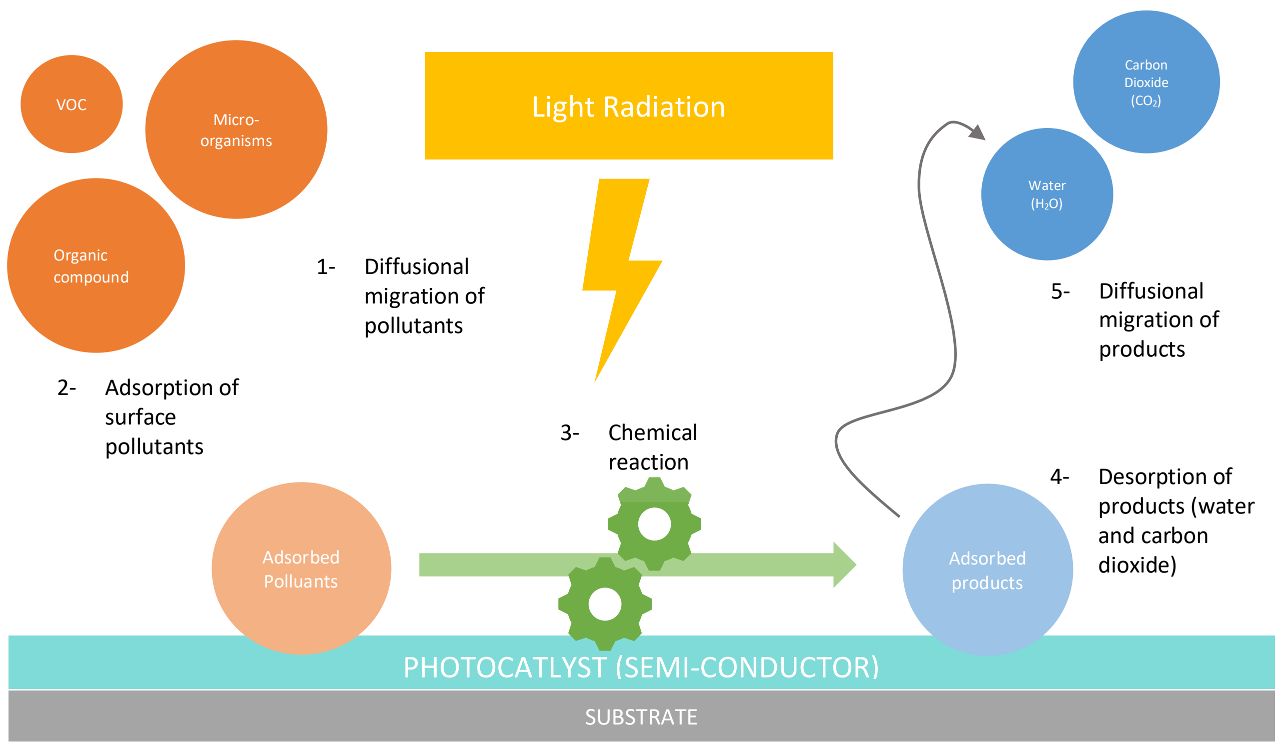
PHOTOCATALYSIS

Principle of Photocatalysis

The absorption of light radiation (mainly UV) causes on the photocatalyst made of a semiconductor (TiO2, ZnO , Fe2O3, ZnS , CdS ...) an excitation of the peripheral electrons which pass from the valence band (BV) to the conductance band (BC) by creating electron-hole pairs, capable, by reaction with oxygen in the air and/or atmospheric humidity, of forming radicals and initiating oxidation-reduction reactions. Historically, the most industrially used photocatalyst is TiO2, but in recent years other substances have emerged, such as ZnO .

The photocatalytic process can be divided into five independent steps:

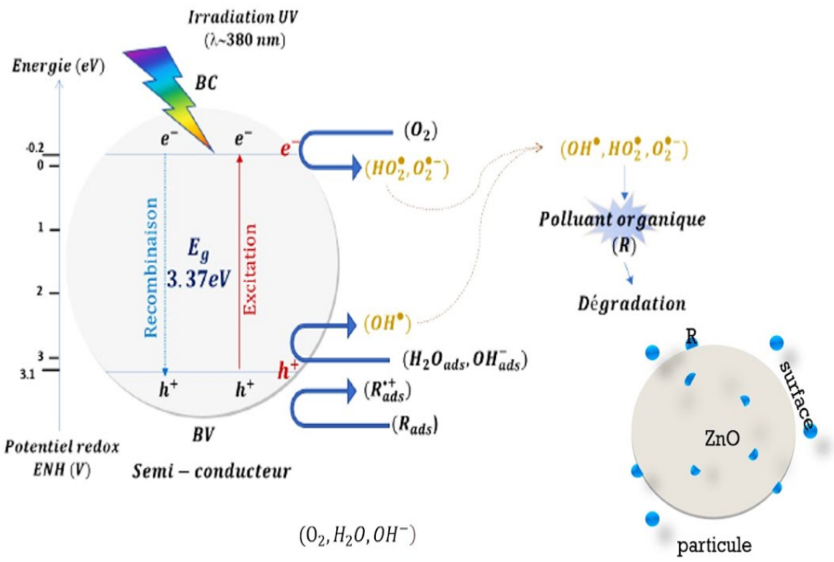
1. Diffusional migration of pollutants from a fluid phase (for example air or water) towards the surface of the photocatalyst, including in the porosity of the photocatalyst
2. Adsorption of pollutants on the surface of the catalyst
3. Chemical reaction in adsorbed phase
4. Desorption of products
5. Diffusional migration of the products from the surface of the catalyst towards the fluid phase.



Let's dive into the chemical processes!

When a semiconductor catalyst is illuminated by photons of energy equal to or greater than the energy of its forbidden band, or "band gap", (Eg < h **v**), there is thus absorption of these photons and creation of electron (e-) - hole (h+) pairs with the transfer of an electron (e-) from the valence band to the conduction band and the creation of an electronic vacancy (h+) at the level of the valence band .

Simultaneously, in the presence of a fluid phase (gas or liquid), spontaneous adsorption occurs and depending on the redox potential of each adsorbate, an electron transfer can take place towards the molecules of electro-acceptor character (A), while the positive photo-holes are transferred to the molecules of electron-donor character (D).



Reaction with the electro-acceptor A

$$O_{2(ads)} + e^-_{(CB)} \rightarrow O_2^{\bullet -}{}_{(ads)}$$

$$O_2^{\bullet -}{}_{(ads)} + H^+_{(ads)} \rightarrow HO_2^\bullet{}_{(ads)}$$

$$HO_2^\bullet{}_{(ads)} + e^-_{(CB)} + H^+_{(ads)} \rightarrow H_2O_{2(ads)}$$

$$H_2O_{2(ads)} + h\nu \rightarrow 2OH^\bullet{}_{(ads)}$$

$$H_2O_{2(ads)} + O_2^{\bullet -} \rightarrow OH^\bullet{}_{(ads)} + OH^-_{(ads)} + O_{2(ads)}$$

Reaction with the electro-acceptor B

$$H_2O_{(ads)} + h^+_{(VB)} \rightarrow OH^\bullet{}_{(ads)} + H^+_{(ads)}$$

$$RCOO^-_{(ads)} + h^+_{(VB)} \rightarrow RCOO^\bullet{}_{(ads)} \rightarrow R^\bullet{}_{(ads)} + CO_2$$

In summary, for the photocatalytic reaction to take place, the following conditions must be met:

1- The photocatalyst must be accessible to light radiation
2- Pollutants, whether solid, liquid, or gaseous, must be in contact with the photocatalyst to be degraded.
3- The light radiation must be such as to be able to activate the photocatalyst.

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Practical applications of photocatalysis

photocatalytic principle can be distinguished , active photocatalysis and passive photocatalysis .

- Active photocatalysis

It is mainly used for the depollution of air or water. The fluid to be depolluted is sucked by using a fan or a pump through a photocatalytic cell. This cell consists of a support treated with a photocatalytic solution . The assembly is irradiated by using an artificial light source consisting of a UV tube. The pollutants then will meet the photocatalyzed surface and will be broken down in the photocatalytic cell.

The efficiency of this type of reactor will depend on the flow rate of the fluid, the power of the light source, the irradiated surface and the concentration of pollutant.

This concerns the depollution of air inside the home with small individual systems up to industrial installations allowing the depollution of the air with flow rates of more than 50,000 m^3/h.

Water depollution systems will operate on the same principle in artificial or natural sources.

- Passive photocatalysis

In the case of passive photocatalysis, no reactor is used, the existing supports will serve as surfaces rendered photocatalytic.

This type of system will essentially lead to make surfaces self-cleaning and to depollute the air of VOCs outdoors.

Then, the photocatalytic materials can be:

- Deposited in situ during manufacturing processes
- Incorporated into materials
- Sprayed as a post-coating on the surface of the elements to be treated.

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Let's take a closer look at spray applications…

In the case of spraying, the photocatalytic product is formulated in the form of a stain which holds its self-cleaning properties according to two distinct principles:

- Decomposition of surface pollutants by oxidizing the organic matter (figure 1)
- Creation of a super hydrophilic surface favoring the runoff of rainwater and thus the washing of the surface (figures 2 and 3)

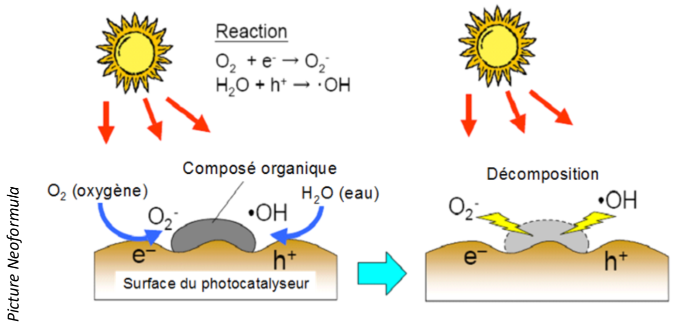

Figure 1 Material Degradation by photocatalysis

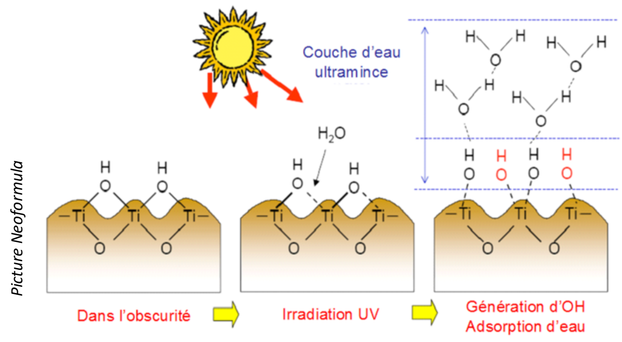

Figure 2 Superhydrophilic film formation with TiO2 as photocatalyst

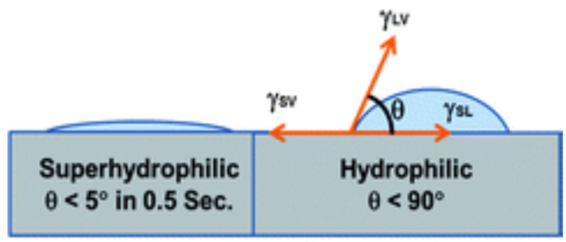

Figure 3 Characterization of a superhydrophilic surface by water droplet deposition

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