Technologies for reducing hazardous chemical emissions

Tens of thousands of different types of chemicals are being produced and sold on a commercial basis and they are valuable in our daily lives. Among these chemicals, some have the potential (i.e., present the risk) of adversely affecting human health or natural ecosystems. However, as reducing all the risks to a level of zero would cost immense amount, it is required to assess the relative risks in accordance with the benefits to be gained in exchange for those risks, select those risks which are particularly high and monitor such chemicals to take appropriate measures (i.e., measures to reduce risk levels) to realize a sustainable recycling society in harmony with the environment (See Figure 1).

Below we introduce some of the researches now being performed at AIST on technologies for reducing hazardous chemical emissions.

Reducing emissions of volatile organic compounds

(1) Using electromagnetic heating in adsorption recovery

Although over half of all emissions of benzene and other volatile organic compounds (VOCs) released into the atmosphere come from small- and mid-sized sources, existing emissions control technologies are hardly used in practice because of the expensiveness and large-scale systems. Although technologies which use adsorption have gained attention as a means of controlling emissions on the grounds that VOC is reusable, these technologies are impractical for use at small- and mid-sized emissions sources without improvement of the heating desorption process after adsorption. For this reason, AIST is currently conducting research on ways of using electromagnetic fields to perform heating desorption with the aim of developing simpler, less expensive, and more compact systems. This may be rather unexciting research, however if it succeeds, it would be the most effective technology available. We believe that this method would make it possible to handle emissions from almost all sources where the emissions consist of high concentrations of a single material. Field tests are already being conducted of electric heating systems with the aim of developing a practical working system. The basic research work on radiofrequency heating has already been completed and we have now entered the stage of working on the research and development of an actual device. Since the radiofrequency heating is a very unique technique in terms of partial heating and temperature control, its application can be put to use not only in heating desorption but also in a wide variety of others as well, and the new range of applications of the technologies might be too numerous to even guess at.

(2) Nonthermal plasma decomposition

Nonthermal plasma, which is also known as non-equilibrium plasma, an unique reaction media where only the motions of electrons are accelerated. In nonthermal plasma, strong covalent bonds of hazardous air pollutants can be broken within a short reaction time using the energy of the high-speed electrons even when gas temperature is not higher than average room temperature. It is also possible to generate high concentrations of free radicals with high decomposition reactivities toward hazardous air pollutants. Recently, nonthermal plasma has attracted much attention as a key technology in various applications such as air cleaners, systems for decomposition of VOCs emitted from stationary sources, and disinfection and sterilization devices. Investigations have been initiated on the development of actual working systems using this technology. Since such systems require no high-temperature furnaces and can be operated simply by turning a power switch on and off, nonthermal plasma technology is viewed as a compact and low-cost technology ideal for reducing environmental risks. To make this technology a more feasible one, it is important that we find ways to promote oxidation and decomposition of hazardous air pollutants and further improve energy efficiencies, and we are accordingly making much effort in the research and development on the hybridization of nonthermal plasma, oxidation catalysts, and photocatalysis. (See Figure 2).

(3) Environmental purification through photocatalysts

As environmental purification technologies using photocatalysts (mostly titanium dioxide, or TiO_2), which can use sunlight or indoor lighting as energy sources, have been highly regarded as a means of removal of nitrogen oxides (in concentrations on the order of parts per billion) along roadsides, we have now expanded our research objectives to include aldehydes, BTX (benzene, toluene and xylene), polycyclic aromatic hydrocarbons, organics in particulate matter, and other air pollutants. It has been found out that, in the decomposition of aldehydes or BTX, it is possible to improve the rate of decomposition and increase the effective life of the catalysts by illuminating at temperatures of over 100 °C and by having the reactions take place upon a photocatalyst under a minute platinum load. We are also working on the development of new photocatalysts. While normal titanium dioxide photocatalysts can only use light in the ultraviolet range with wavelengths of 400 nm or shorter (see Figure 3), our research group has developed a nitrogen-doped titanium dioxide catalyst using a nitrogenous titanium complex which can use light with wavelengths up to 650 nm. This catalyst has been shown to be much more efficient than other nitrogen-doped photocatalysts in the oxidation of NO, and we are now conducting further research to improve this photocatalyst for practical applications.

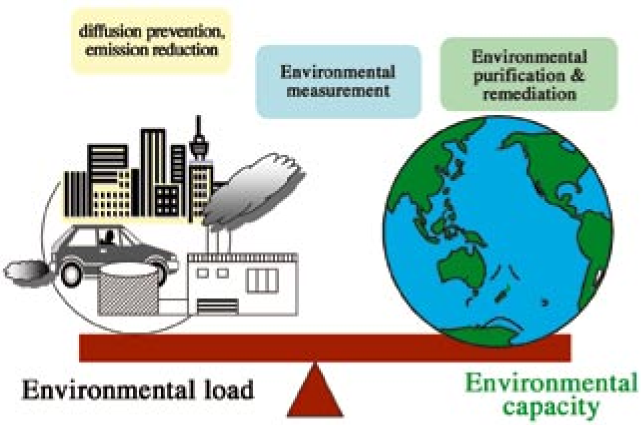

Fig. 1 Sustainable recycling society in harmony with the environment

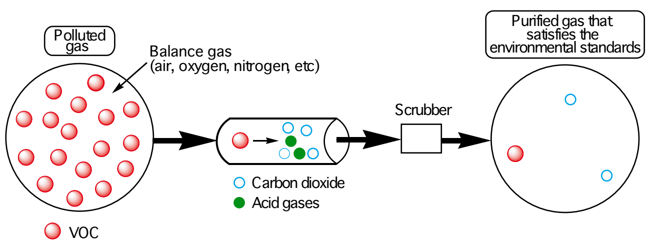

Fig. 2 VOCs treatment by low-temperature plasma

Development of technologies for controlling exhaust emissions from diesel vehicles

The particulate matter (PM) released by diesel vehicles is considered to be a highly hazardous substance in view of the degree of risk to human health, therefore, steps are now being taken to enact much stricter sets of regulations concerning PM emissions. The use of diesel particulate filters (DPFs) is thought to be promising as a method of reducing such emissions. In order to maintain the effectiveness of a DPF, the collected PM must be burned and removed, and to do so, a DPF would normally have to be heated to a temperature of 600 °C or higher. At AIST, we have developed a catalyst consisting of platinum, titania and silica (Pt/TiO_2-SiO_2) which can be used to promote the combustion (i.e., complete oxidation) of PM, thus making it possible to burn PM at temperatures around 320 °C. As such temperatures are still higher than those normally found in diesel vehicle exhaust emissions, we are also working on the development of new types of DPFs which, when used in combination with this catalyst, would be able to burn PM without using extra amounts of energy (See Figure 4).

Reduction of dioxins through waste incineration

Up until now, dioxins have been generated as a result of mainly the waste incineration and released into the environment. Today, measures have been taken in accordance with tightened regulation, and the volume of such emissions has become extremely smaller, especially the emissions from large-scale waste incineration plants. This does not mean, though, that no dioxins whatsoever are being generated, and there is a tendency to use excessive amounts of energy and money to reduce the volume of emissions. The reason for this is because how dioxins are generated during incineration is not completely understood and because many of the techniques which have been used to reduce emissions are based on empirical rules alone. Through research performed at AIST, we have learned that degradations in combustion conditions in incineration furnaces increase the volumes of soot and other pollutants which are thought to form the base material for reactions, thus resulting in an increase in dioxins generated. While temperature, chlorine contents, and many other factors are considered to be involved in the generation of dioxins, virtually all of these affect the process of combustion and the amounts of dioxins generated. If we learn to understand the mechanisms by which dioxins are generated and put the understanding to use in development, then the better technologies for reducing dioxin emissions should be available (See Figure 5).

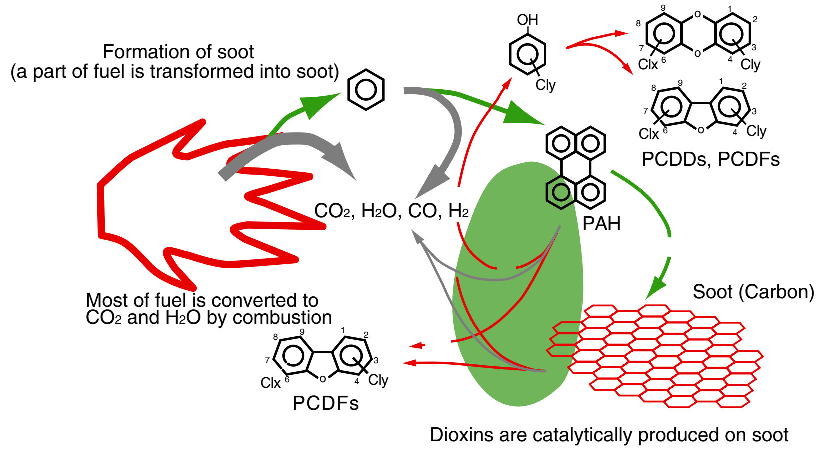

Fig. 5 Estimated formation scheme of dioxins in combustion processes

Hazardous chemicals

Among those chemicals artificially produced to address given needs, there are some whose effects on human health or natural ecosystems become apparent only as a result of the ways in which they are used or as a result of long-term exposure. The sources from which these chemicals are generated are varied in nature, and in order to reduce exposure on the part of human beings and natural ecosystems we must take steps to reduce the volumes of such chemicals released into the environment. Standards exist for reducing emissions of such chemicals including benzene, trichloroethylene, dioxins, and suspended particulate matter (SPM).

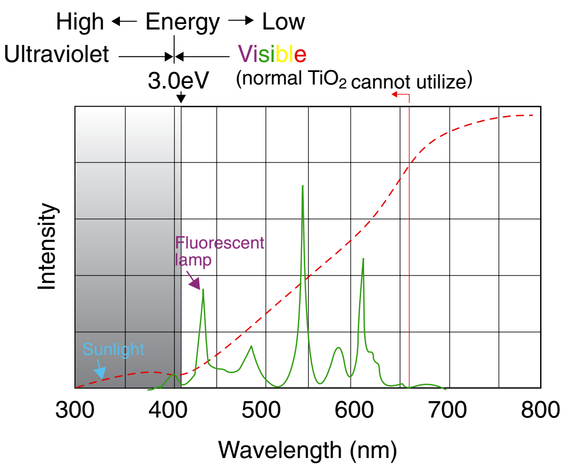

Fig. 3 Wavelength range utilized by photocatalysis

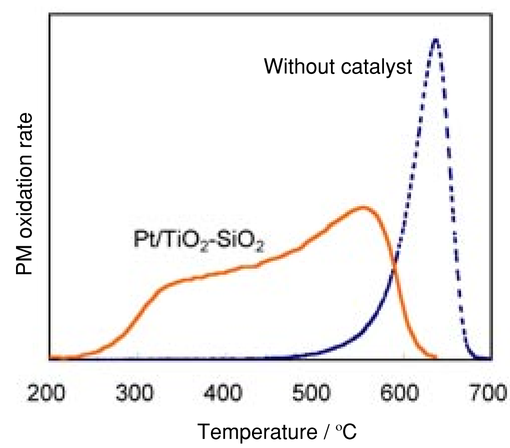

Fig. 4 Performance of the catalyst developed for PM combustion
(results based on temperature-programmed reaction)