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The 8th Asian Particle Technology Symposium (APT2021)
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Evaluation of the droplet removal performance by a small on-desk air cleaner with photocatalyst

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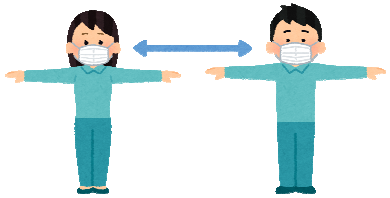
Web sute: http://anticovid19.starfree.jp/

（In Japanese）

Investigation of Engineering Countermeasures against COVID-19 (1)

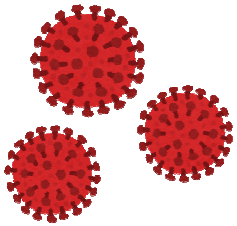
~~Crowded places~~

Social distance



Since the droplets only travel about 2 meters, you can protect yourself from flying droplets by keeping a distance from others.

Droplets



Large droplets with large amounts of virus

Stay Home

Droplets larger than 5 μm emitted from the oral cavity are called droplets and have a distribution peak at about 120-150 μm. These droplets can be scattered over a distance of up to 2 meters in a few seconds. They can be dispersed not only by coughing or sneezing, but also by normal talking.

Droplets Remover

The combination of filter and photocatalyst catches droplets and oxidizes and decomposes viruses.
The system is useless unless it is installed between people who are facing each other and within the distance of the flying droplets, so a large number of units are required.

To prevent the release of droplets, masks are effective. Non-woven or cloth masks can stop about 80% of the droplets, but the remaining 20% are dispersed through gaps. Therefore, there is a risk of infection when meeting within the range of droplets. In addition, it is difficult to wear a mask during meals.

Investigation of Engineering Countermeasures against COVID-19 (2)

Enough Ventilation

Carbon dioxide concentration is one indicator of ventilation status.

~~Closed Space~~

Aerosol

Air Purifier

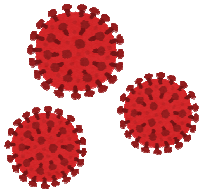
△Active disinfection with Chlorine dioxide and Ozone is not recommended

Various types air purifier are available, including those using photocatalyst, UV-C, and high-performance filters, which collect aerosols and inactivate viruses contained in aerosols.
Inactivation is also possible with fan heaters and stoves, which are subject to high temperatures. (Air conditioners cannot be used for this purpose.)

Particles smaller than 5 microns are called aerosols, and the solids that remain after the droplets have dried are also called droplet nuclei. They stay in the air for several minutes and can spread over a wide area. It can be dispersed even by talking.

Even if you wear a mask, nearly half of the aerosol is dispersed between fibers and through gaps. Since they stay for a long time, their concentration gradually increases if ventilation is poor.

Fly around for long periods of time and travel far on the wind.

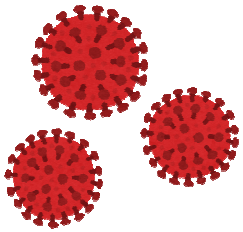


Upper-Room Ultraviolet Germicidal Irradiation

UV-C is harmful to the human body (strong inflammation of the cornea of the eye and skin). However, it is possible to inactivate viruses in the air by irradiating UV-C in a space above where it will not hit people. This UVGI is recommended by CDC.

Investigation of Engineering Countermeasures against COVID-19 (3)

~~Close-contact settings~~



Wash Hands

Disinfection

Coronaviruses are the type that have an envelope, a lipid membrane, on their surface, so it is important to dissolve the lipid. Just physically washing it away is effective.

You never know where a booby trap might be lurking

Contact infection from object surfaces

Depending on the environment, a virus attached to the surface of an object may retain its infectivity for several days. The virus is not transmitted by mere contact with the hands, but through ACE2 receptors in the mucous membranes of the oral/nasal cavity and eyes.

UV-C irradiation to PPE

Since the risk of removing personal protective equipment (PPE) is high in medical fields dealing with infectious diseases, UV-C irradiation to PPE at the boundary to the Cold area will reduce the risk of infection.

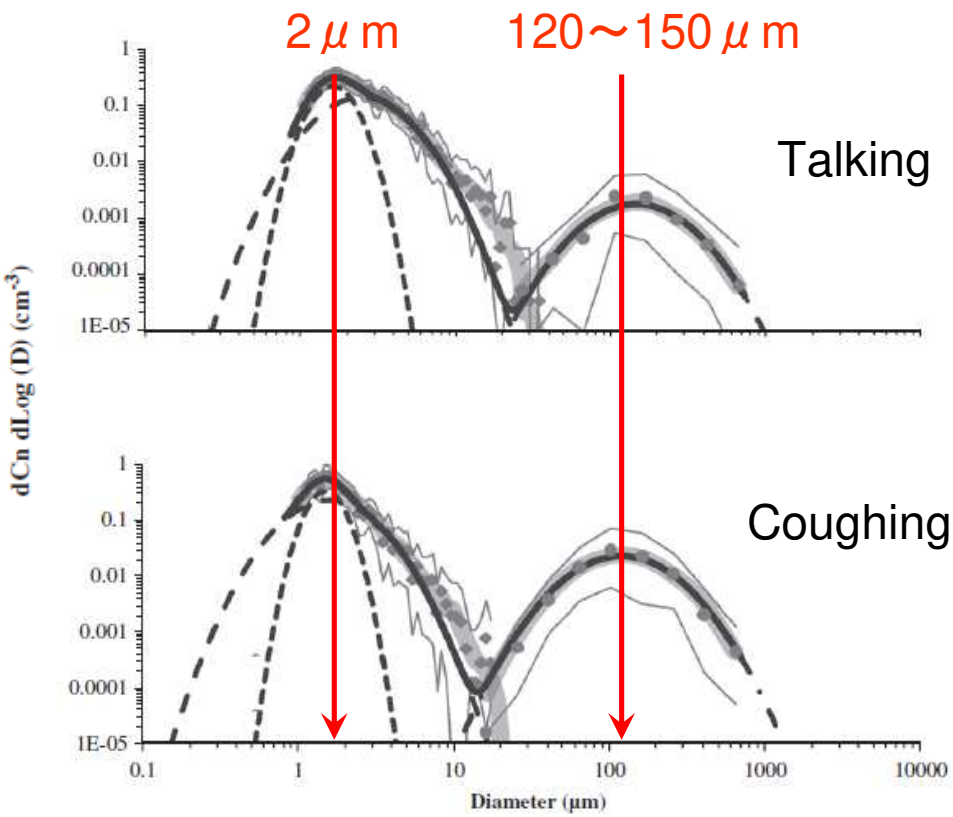
UV-C irradiation to object surfaces

Various papers have confirmed that it is possible to inactivate SARS-CoV-2 in a short time.
It cannot be used in the presence of people because it is harmful to the human body. There are some products using 222 nm UV that have very little effect on the human body, but they have not yet been certified as completely safe. It is necessary to understand various problems before using these products.

Application of photocatalysts and metal particles such as copper and silver to the surface of shared items

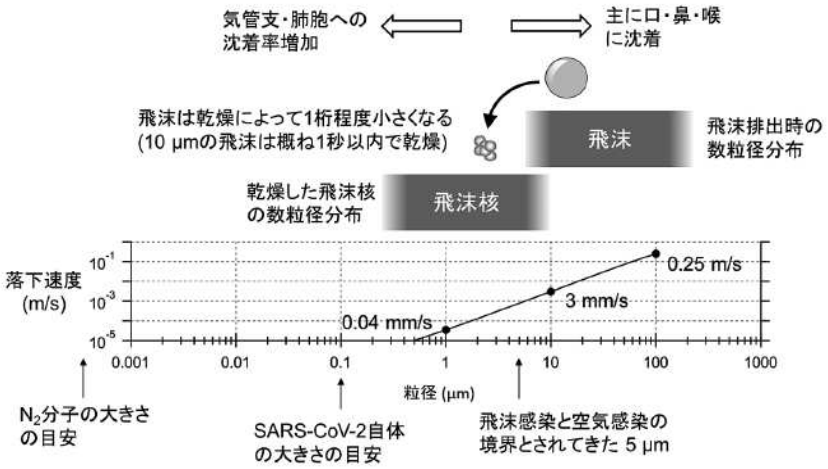
The application of photocatalyst to the surface of an object always produces a gradual deactivation effect. Some metal-containing photocatalysts, such as copper, are effective for a certain period of time even after dark. The simplest way is to apply copper foil tape.

Particle size distribution of droplets released from the oral cavity



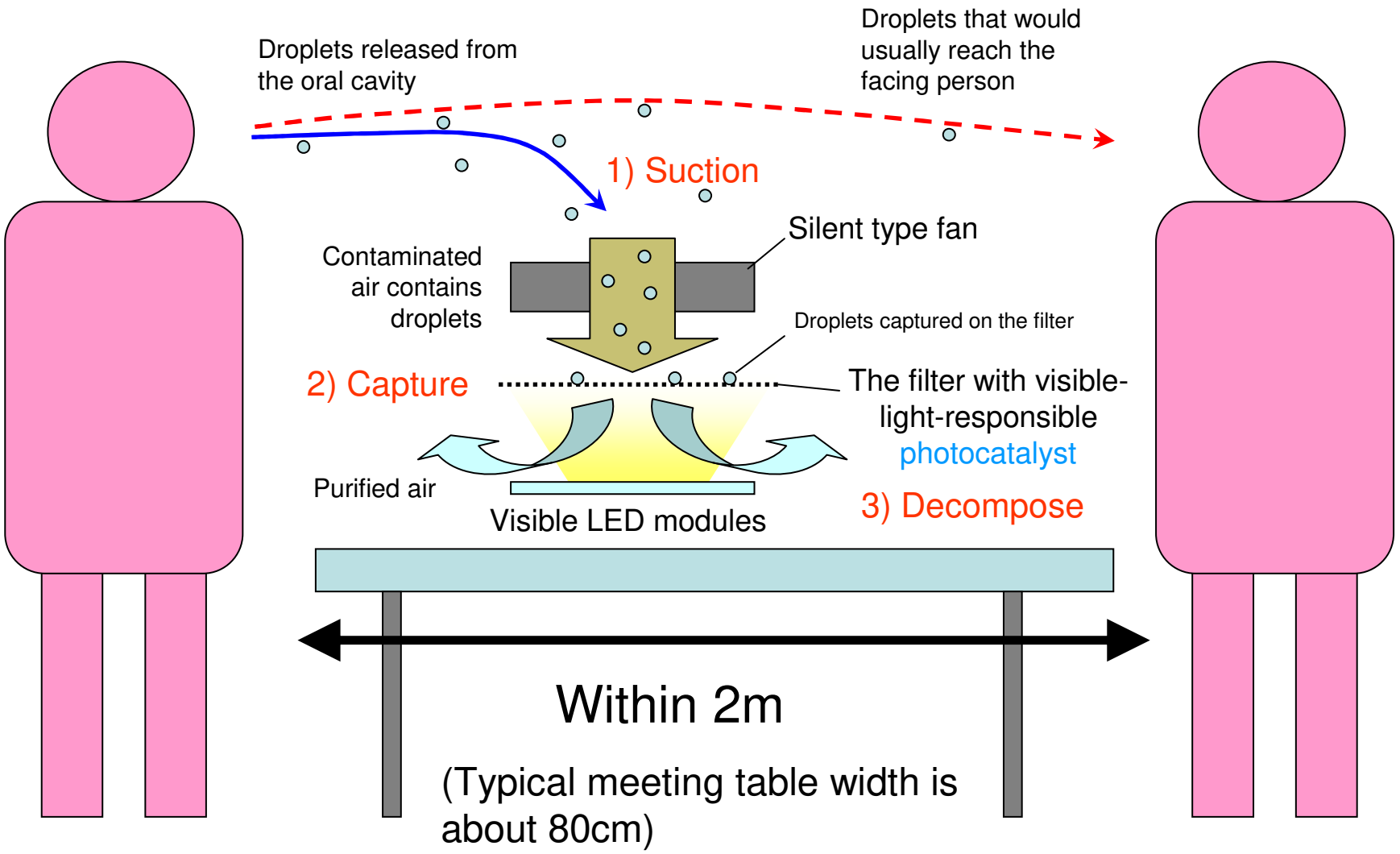
G.R. Jhonson et al., Modality of human expired aerosol size distributions, J. Aerosol Science, 42(2011)839-851.

The distribution of particles sizes released from the oral cavity is two-peaked, with 150 μ m "droplets" falling in about two seconds and reaching only about one to two meters, while 2 μ m "aerosols" drift in the air for a long time (without airflow, they do not move much). In some cases, the droplets evaporate to form aerosol-sized droplet nuclei.



Nobuyuki Takegawa, Aerosol, Droplet Transmission, and Airborne Transmission, Earozoru Kenkyu, 36 (2021) 65-74.

A specialized device that removes droplets flying between person-and-person



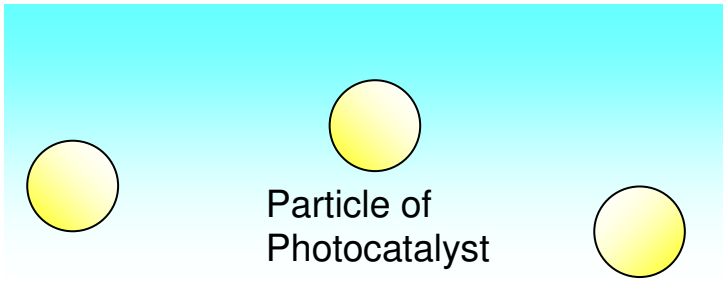
What is Photocatalyst?

Since the discovery of the Honda-Fujishima effect in 1967, which decomposes water into oxygen and hydrogen, "**photocatalyst**" has attracted attention as a technology originating in Japan, and development has continued. Photocatalyst is a type of semiconductor that generates electrical energy when exposed to light, just like a solar cell. Rather than extracting that energy as an electric current, it creates active oxygen such as superoxide anions and OH radicals on the surface of the tiny particles, and through its extremely strong oxidizing power, it decomposes organic matter, finally breaking it down completely into water and CO_2. Viruses and bacteria are no exception, and there have been no reports of ineffectiveness.

Conventionally used TiO_2 (anatase type) has a band gap of 3.2 eV, so its response to visible light is small, requiring irradiation with ultraviolet rays. On the other hand, WO_3 with a band gap of 2.5 eV, which have been put to practical use in recent years, respond to light of wavelengths below 480 nm (visible light region of green to blue).

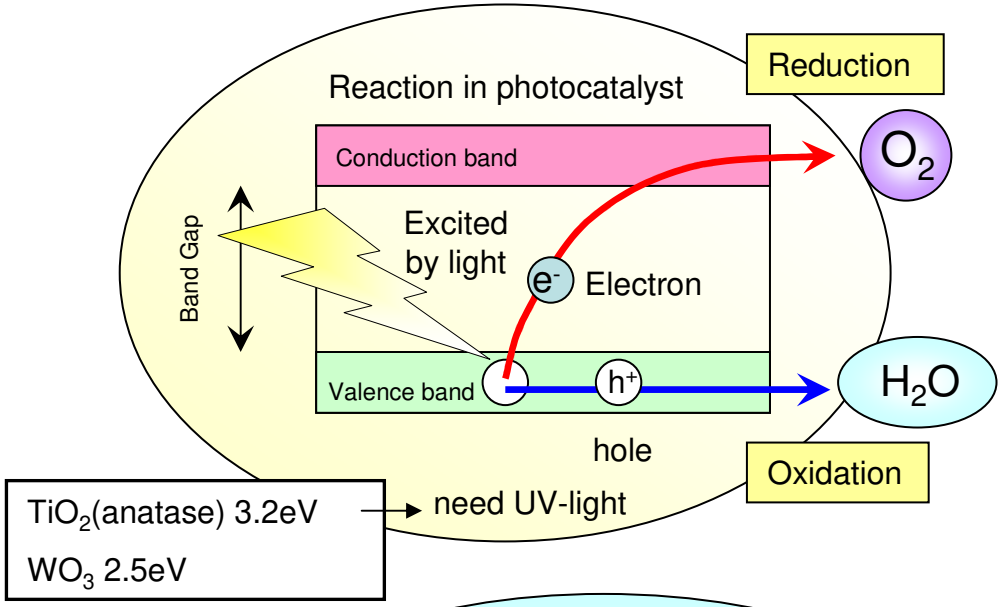
Both TiO_2 and WO_3 have already been reported to inactivate SARS-CoV-2 in academic papers.

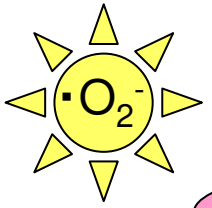
By combining this visible light responsive tungsten-based photocatalyst with visible light LEDs, we are able to manufacture a safe droplets remover with a simple structure.



Light (Photon)

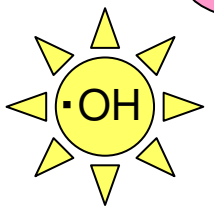
Visible light
（380nm～, 3.1eV～）





superoxide anions

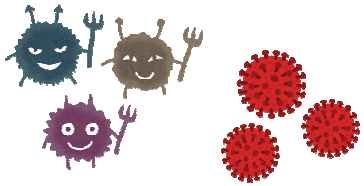
Oxidizing power
higher than ozone

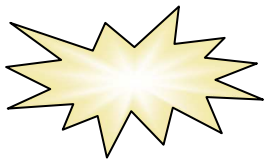


OH radicals

Because reactive oxygen species disappear in about one millionth of a second, they can only move to a few microns from the surface.

Chemically decompose a variety of organic materials by oxidation

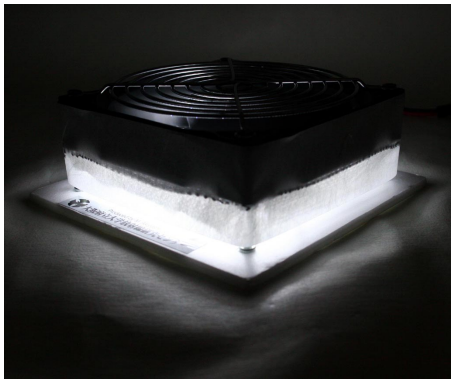




Finally organic materials are breaking down completely into water and CO_2

Ultra-low-cost droplet removal system "Hikari Cleaner" using visible light responsive photocatalyst

NOT commercial product



Shading leaked light with Japanese paper

The size is 12 cm square and 5 cm high. Fan noise is only 19 dB. Power consumption is less than 5 W, and can be powered by a mobile battery

Luminary light between person-and-person

Using visible light-responsive photocatalyst, it does not need to be completely shielded from leaking light and can be made with a simple structure. It is made by combining commercial PC parts, therefore it cost only 1200 yen per unit. The photocatalyst filter can be manufactured with a simple non-woven fabric filter and Toshiba's "Renecat" spray, which is commercially available. The suction performance can be improved by using a more powerful fan.

Inactivation of viruses by visible light responsive photocatalysts

from Toshiba RENECAT™ Website

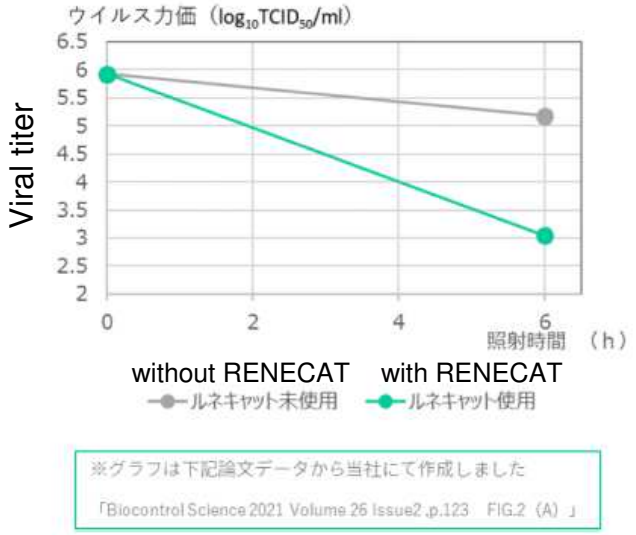
新型コロナウイルス
(SARS-CoV-2)

Masashi Uema et al., "Effect of Photocatalyst under Visible Light Irradiation in SARS-CoV-2 Stability on an Abiotic Surface", Biocontrol Science, 26 (2021) 119-125.

・ウイルス力価：実験的に測定されるウイルスの細胞感染能力
（数値が低いほど感染能力があるウイルスの存在が少ない）

試験条件

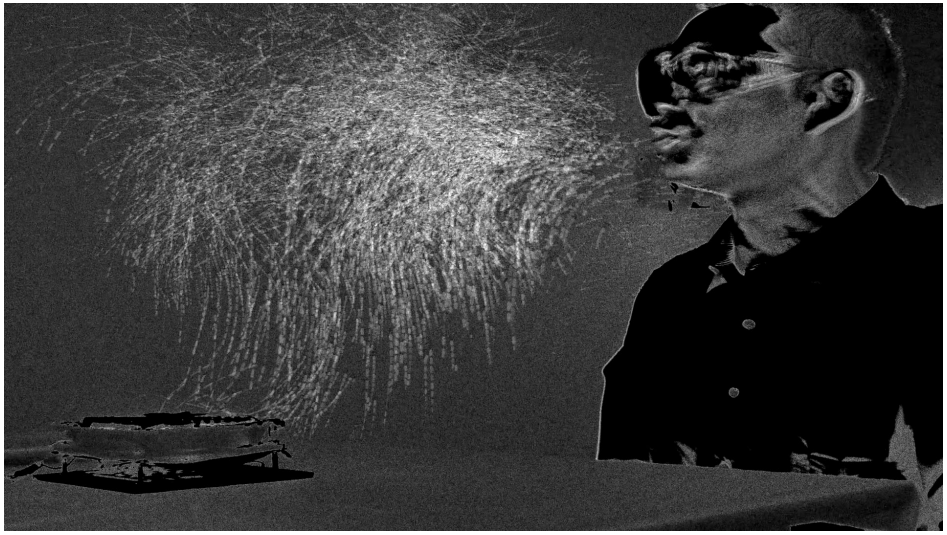
抗ウイルス性試験方法	フィルム密着法 ISO 18071:2016ファインセラミックス(先進セラミックス，先進技術セラミックス)－屋内照明環境下の半導体光触媒物質の抗ウイルス活性の求め方－ バクテリオファージQ-ベータを使用する試験方法を参考に実施
光源	白色蛍光灯 3000lx （380nm以下の紫外光はフィルターでカット）
作用時間	6h
試料塗布量	4g/m^2
サンプルサイズ	30mm×30mm

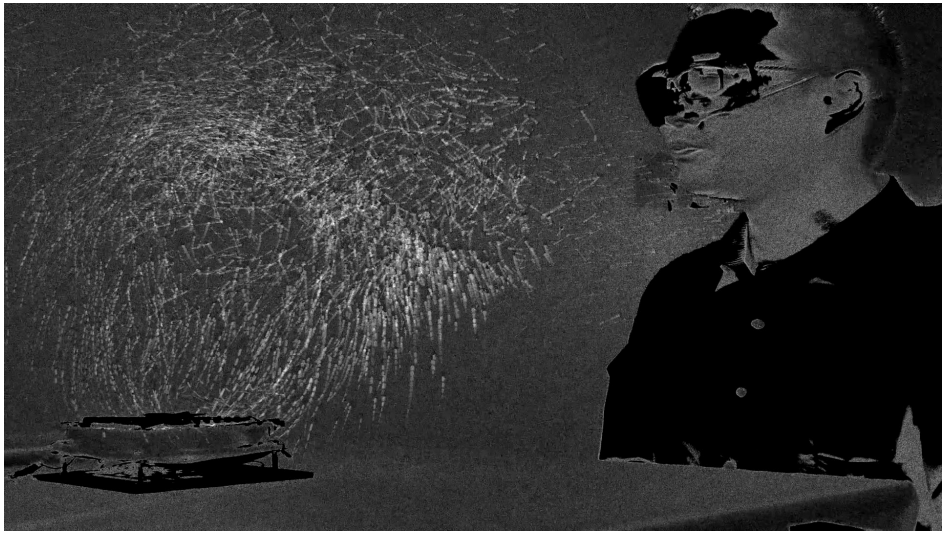


The amount of photocatalyst applied is about 0.7 g/m^2 in the standard specification of Hikari Cleaner, but it is about 14.3 g/m^2 in the high-performance filter that can be mass-produced.

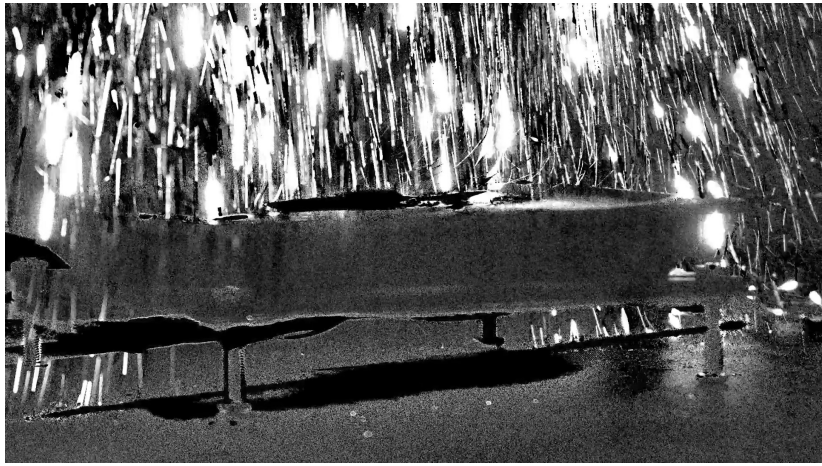
The illuminance on the filter surface of the Hikari cleaner is more than 68,500 lux. Therefore, the Hikari Cleaner is expected to inactivate at a faster rate than the above conditions.

Visualization of droplet suction by special imaging system

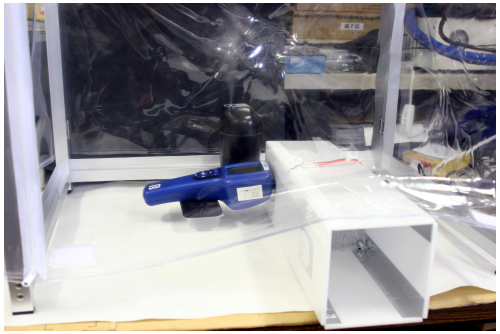


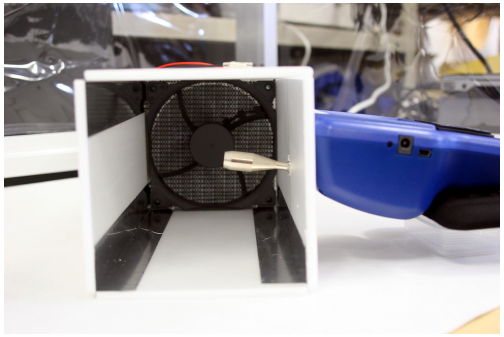


Special video recording was conducted to visualize droplets in the air. Within a range of about 50cm, we can see that droplets emitted by speech from the oral cavity with a "booming" sound are inhaled and stopped by the filter in the same way as a mask.



Transmittance rate of droplets to a filter

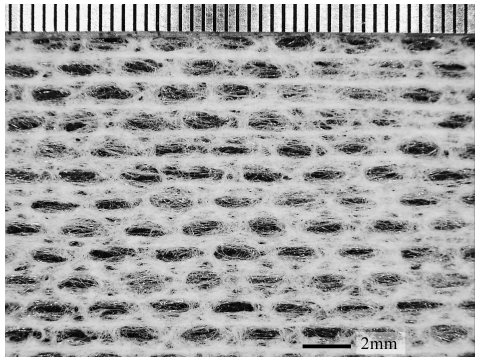




Condition	Particle Size	Concentration of particles		Transmittance
		before the filter	after the filter	
	μm	m^{-3}	m^{-3}	
with a little air dust	0.3～1	7.4×10^{6}	2.7×10^{6}	0.37
	1～5	5.1×10^{4}	1.7×10^{4}	0.34
	5～25	9.0×10^{2}	1.8×10^{2}	0.20
in the clean booth	0.3～1	1.2×10^{4}	6.7×10^{3}	0.54
	1～5	1.4×10^{2}	1.8×10^{1}	0.13
	5～25	2.0×10^{1}	0	0
with a nebulizer (1st, dual nozzle)	0.3～1	4.1×10^{8}	4.6×10^{8}	1.14
	1～5	1.2×10^{7}	3.6×10^{6}	0.30
	5～25	3.7×10^{6}	2.1×10^{2}	5.8×10^{-5}
with a nebulizer (2nd, single nozzle)	0.3～1	2.8×10^{8}	2.5×10^{8}	0.87
	1～5	2.6×10^{6}	1.0×10^{6}	0.40
	5～25	3.0×10^{5}	1.8×10^{1}	6.0×10^{-5}
with a nebulizer (3rd, single nozzle)	0.3～1	2.7×10^{8}	2.7×10^{8}	0.99
	1～5	2.0×10^{6}	1.5×10^{6}	0.76
	5～25	1.1×10^{5}	5.3×10^{1}	4.7×10^{-4}

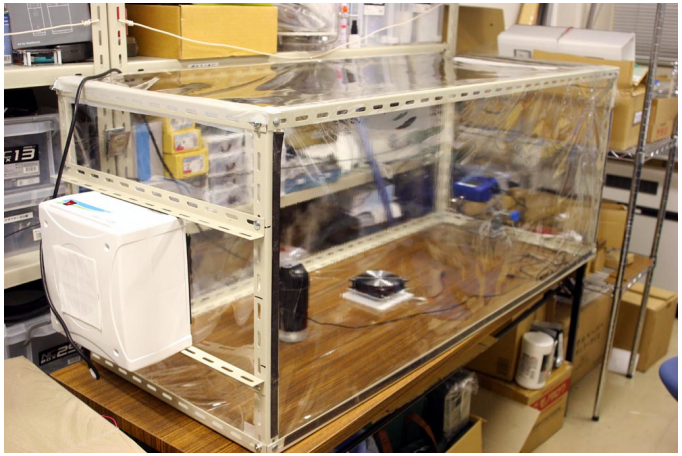
A duct was set up in a clean booth using HEPA filter unit, and the rate at which ultrasonic sprayer mist, simulating droplets from the oral cavity, was captured by a non-woven fabric filter was evaluated. As a result, it was confirmed that droplets of 5 μm or larger could be almost completely captured.

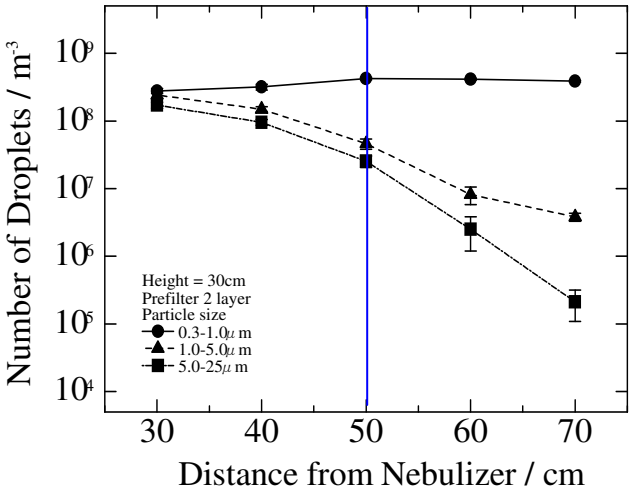
Catching and slowly decomposing



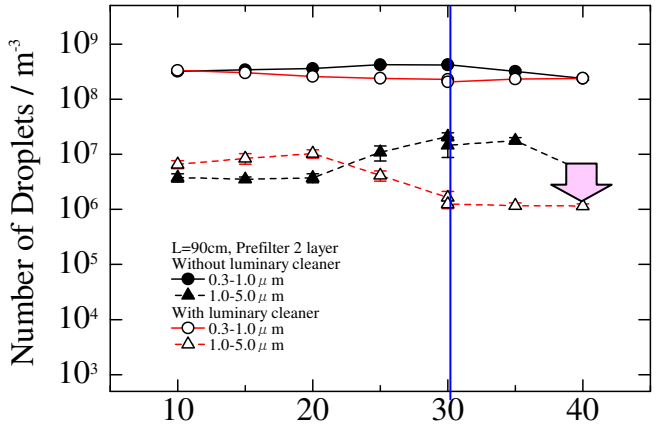
The non-woven fabric filter used in this study

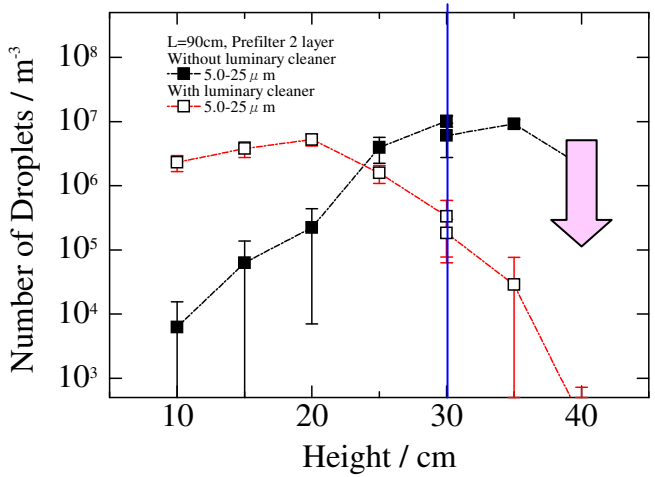
Collection rate of droplets flying in space





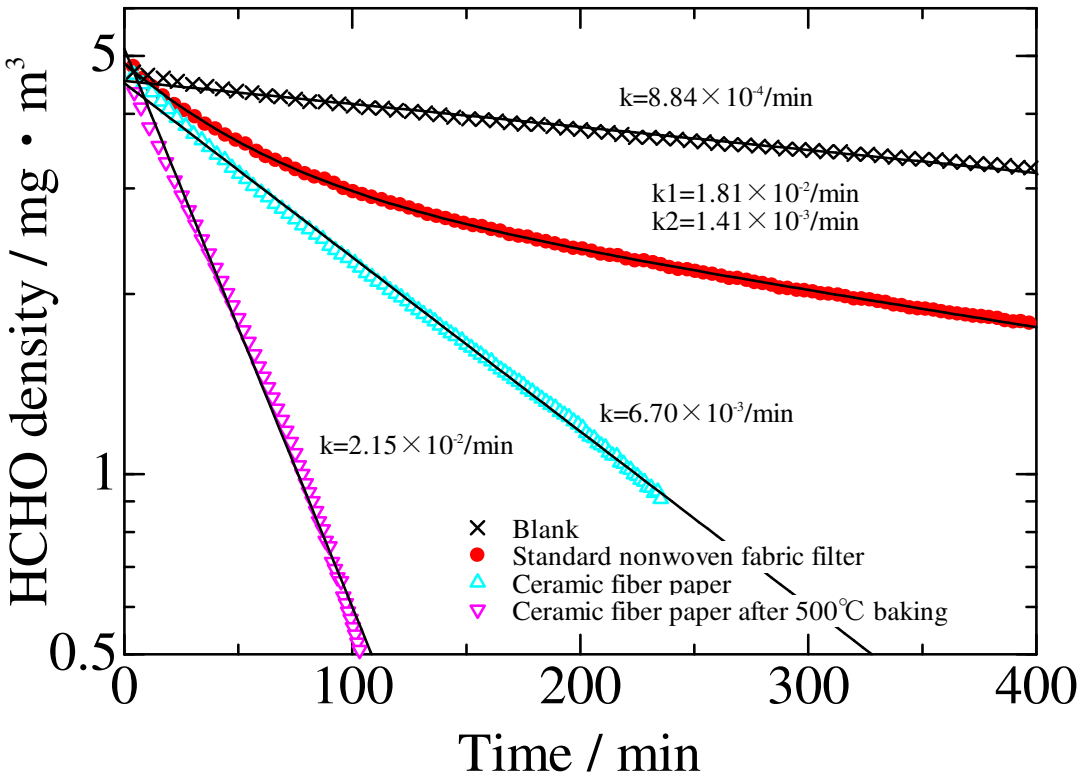
Dependence of droplet concentration on distance from the nebulizer.

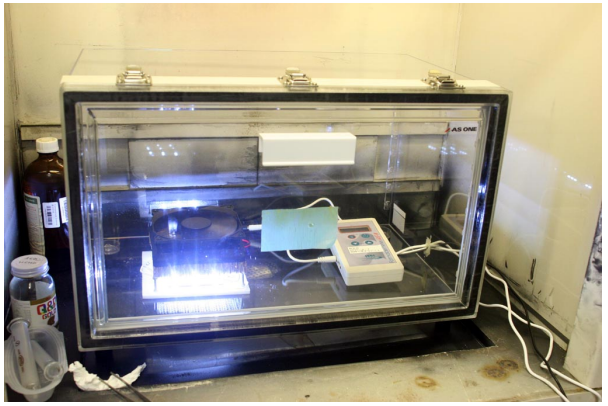


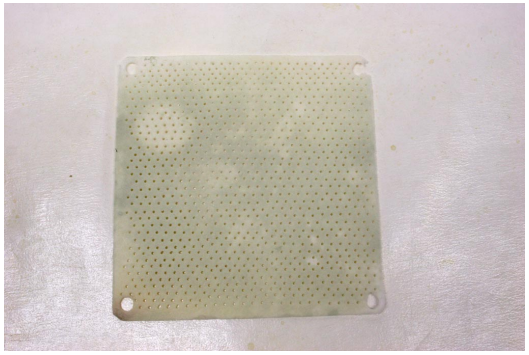


The droplet collection examinations were conducted in a clean bench with a wind speed of about 0.6 m/s.
The number of large particles decreased with distance. This may be due to both falling by gravity and shrinking by evaporation.
It was confirmed that the droplet removal system significantly reduced the number of droplets at the level of the face when a person seated at a table.

Formaldehyde decomposition experiment







Using a 38L size acrylic desiccator, changes in the concentration of formaldehyde (HCHO), a kind of organic gas, were measured using a Formaldiameter htV-m.
Reliable decomposition performance was confirmed even with a standard type droplet removal device with a simple structure and low cost, which is being considered for widespread use by self-made devices in educational and medical fields. In addition, the prototype system that using a filter with a high concentration of photocatalyst and inorganic materials showed a performance that far surpassed that of commercially available small air purifiers.