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Development of a small droplet remover for infectious disease control

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

（In Japanese）

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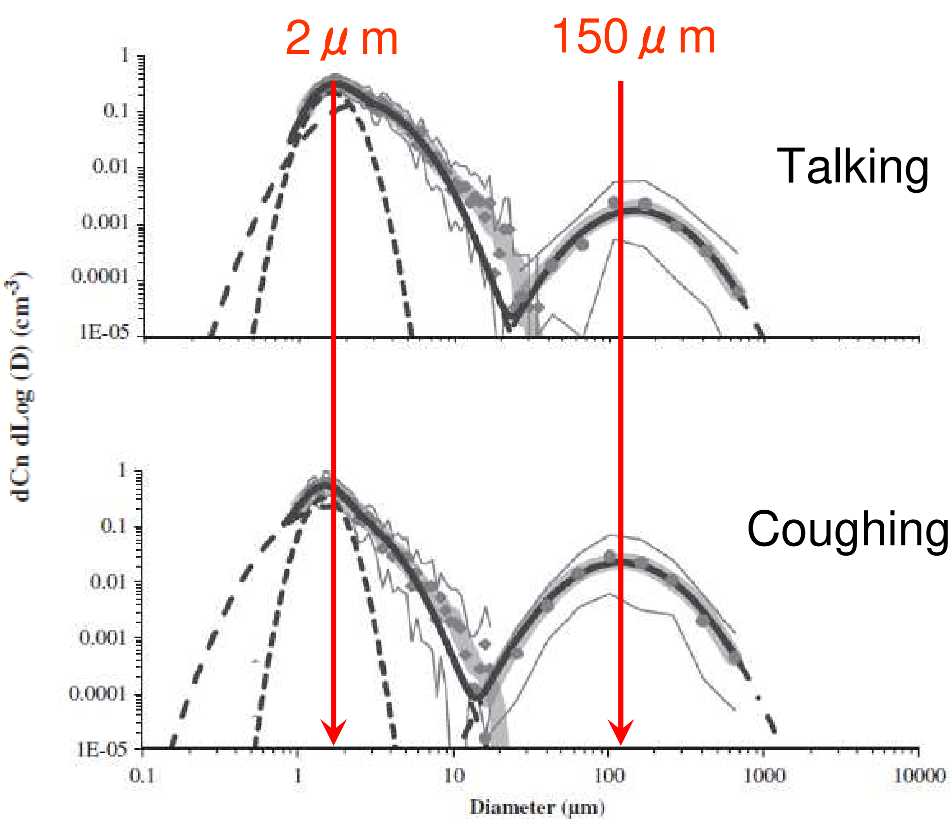
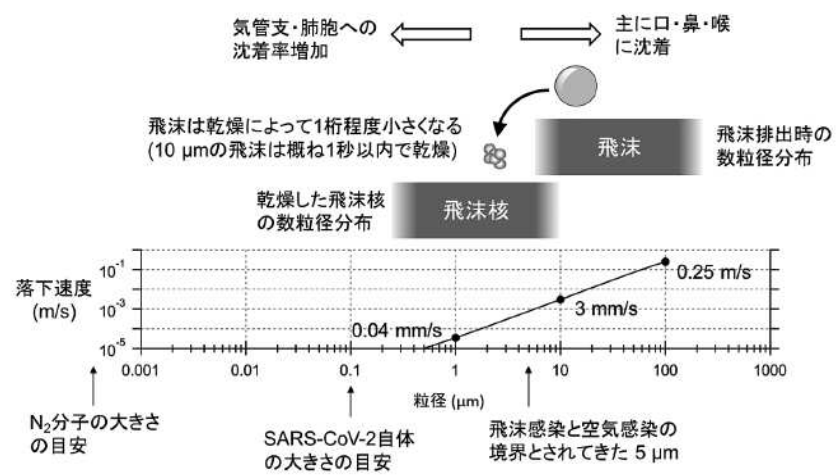
Particle size distribution of droplets released from the oral cavity



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

The actual distribution of particles sizes released from the oral cavity is two-peaked, with 150 μm "**droplets**" falling in about two seconds and reaching only about two meters, while 2 μm "**aerosols**" drift in the air for a long time.

In some cases, the droplets evaporate to form aerosol-sized droplet nuclei.

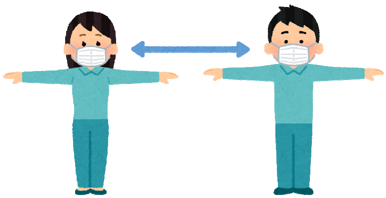


Nobuyuki Takegawa, Aerosol, Droplet Transmission, and Airborne Transmission, Earozoru Kenkyu, 36 (2021) 65-74.

Investigation of Engineering Countermeasures against COVID-19 (1)

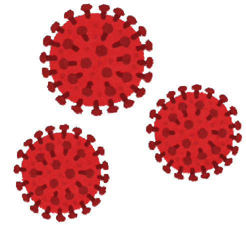
~~Crowded places~~

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

Wet particles larger than 5 μm emitted from the oral cavity are called **droplets** and actually have a distribution peak at about 150 μm. These large **droplets** can be scattered over a distance of up to 2 meters in a few seconds.

To prevent the release of **droplets**, wear mask is 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. Furthermore, it is difficult to wear a mask during meals and drinking.

Wear Mask

Requirement for Droplets Remover

Investigation of Engineering Countermeasures against COVID-19 (2)

Enough Ventilation

Carbon dioxide concentration is one indicator of ventilation status.

~~Closed Space~~

Aerosol

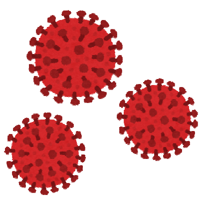
Air Purifier

△Active disinfection with Chlorine dioxide or 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.)

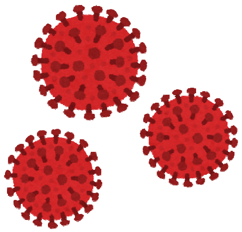
Particles smaller than 5 μm are called **aerosols**, and the solids that remain after the droplets have dried are also called droplet nuclei. They stay in the air for several minutes and can spread over a wide area. It can be dispersed even by talking.

Fly around in the air for long periods of time.



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

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.

Falled droplets cause contact infection

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. Dispersed droplets fall in several second, but the virus contained in the droplets remains on the rurface.

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.

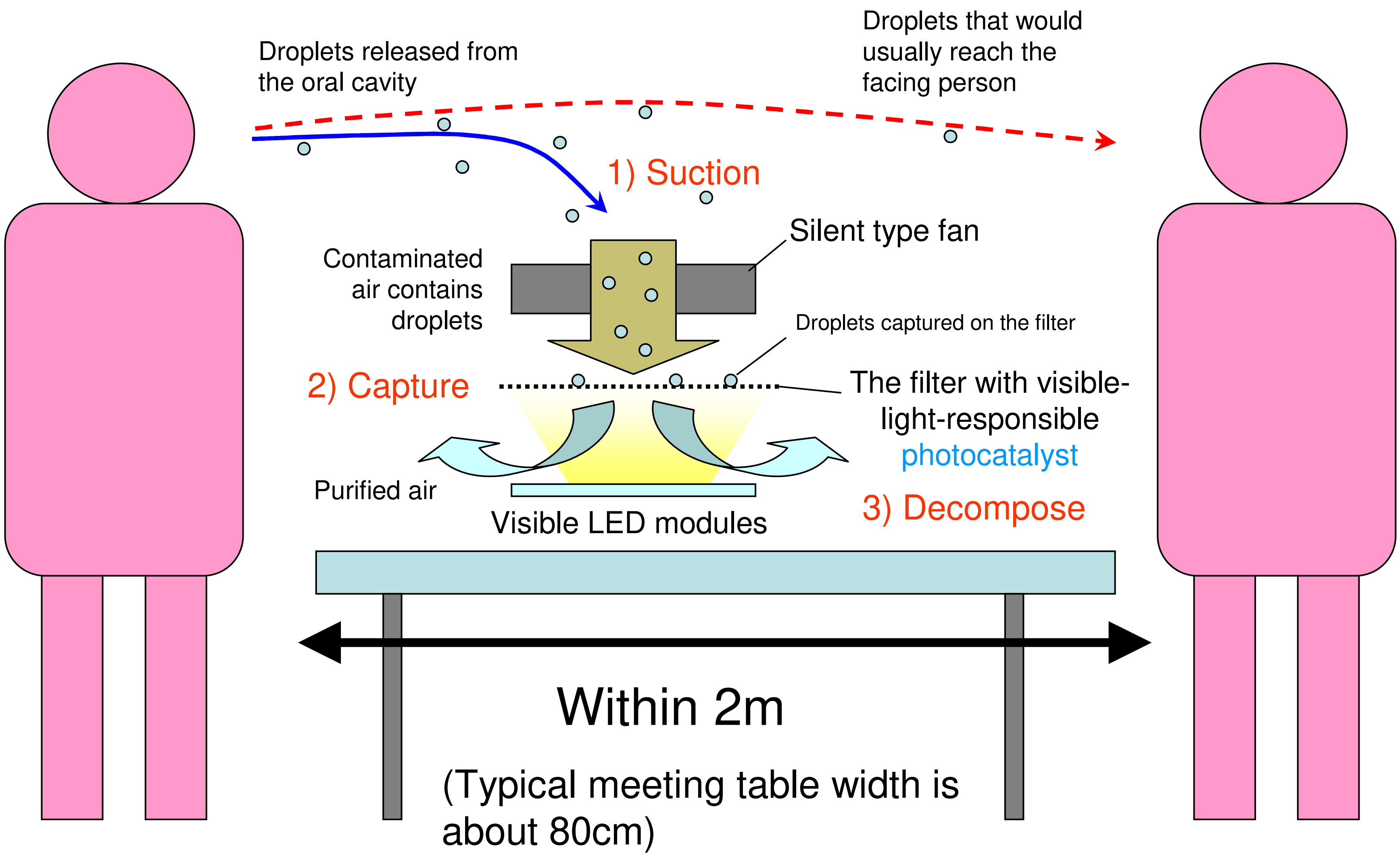
UV-C irradiation to object surfaces

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

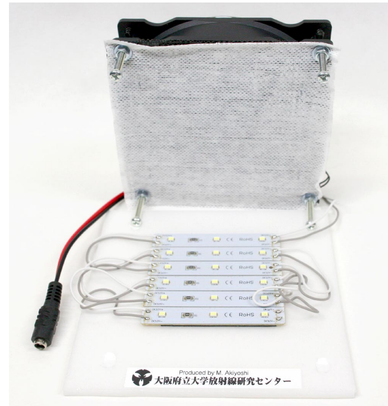
The application of photocatalyst to the surface of an object always produces a gradual deactivation effect. Some metal-containing photocatalysts, such as copper, are effective for a certain period of time even after dark. The simplest way is to apply copper foil tape.

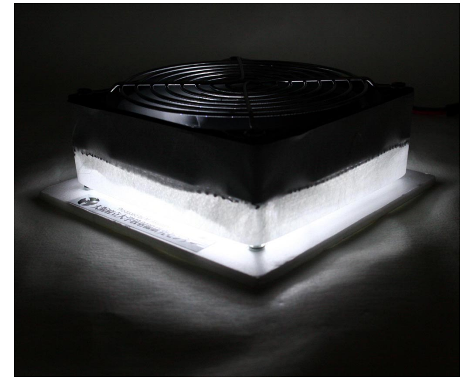
A specialized device that removes droplets flying between person-and-person



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

NOT commercial product



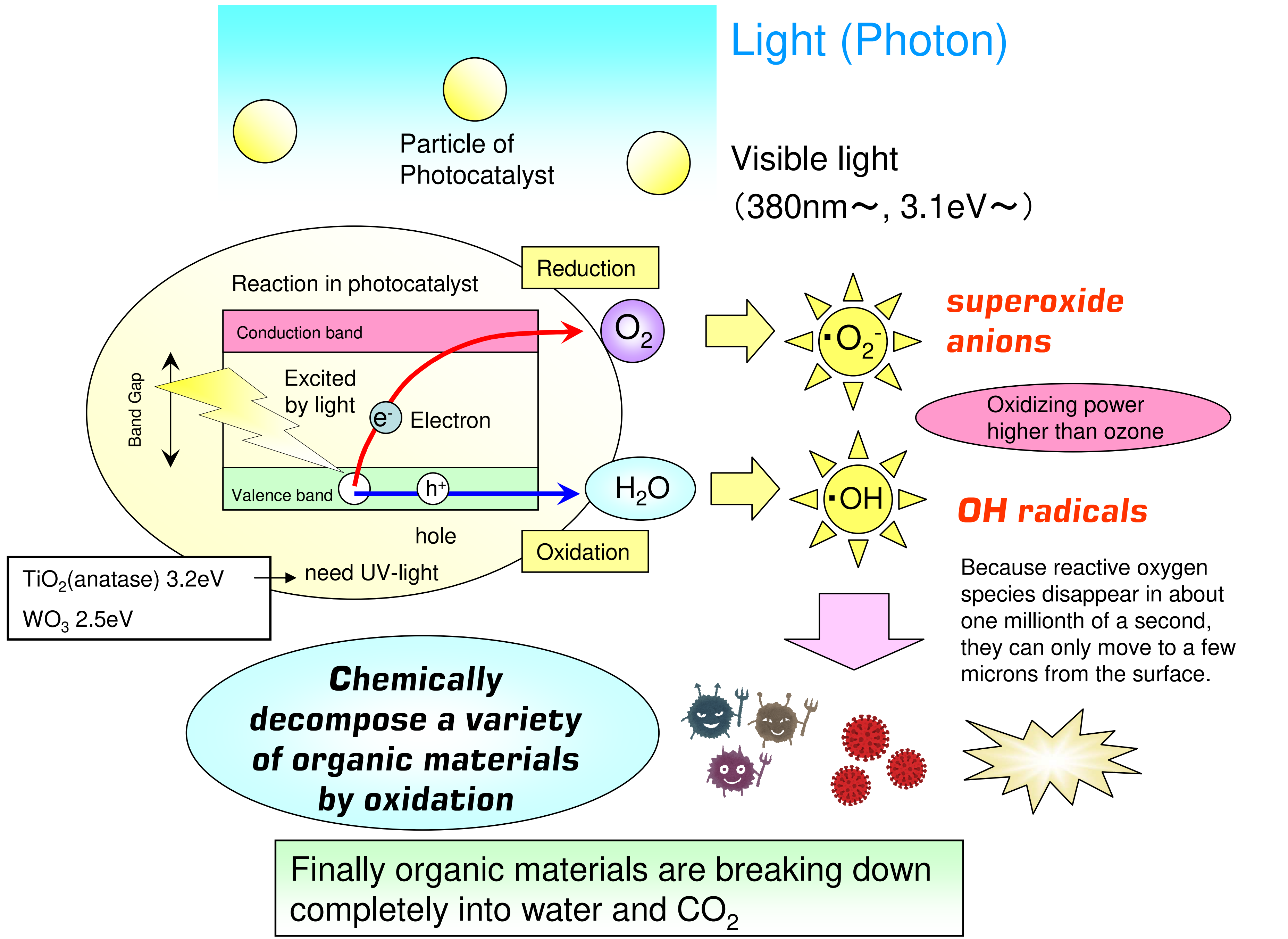


Shading leaked light with Japanese paper

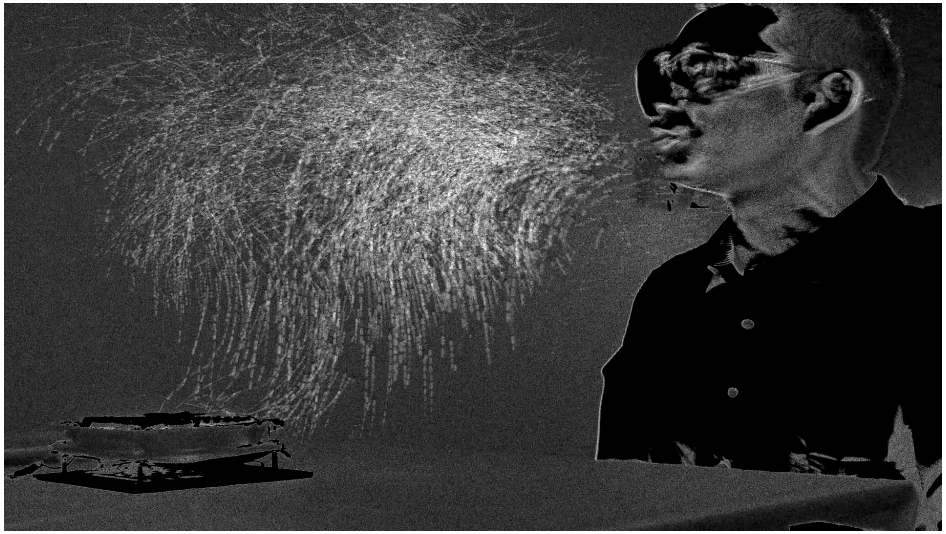
Luminary light between person-and-person

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

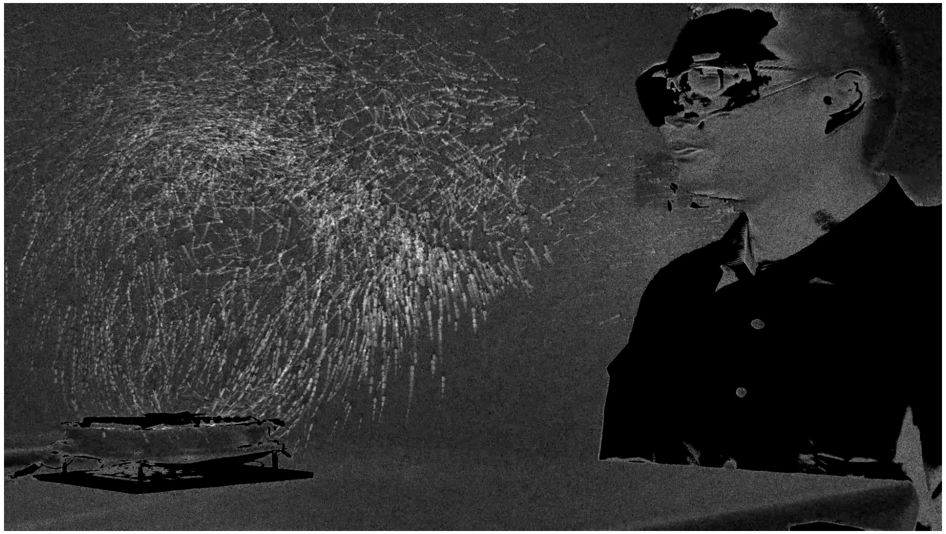
Using visible light-responsive photocatalyst, it does not need to be completely shielded from leaking light and can be made with a simple structure. It is made by combining commercial PC parts, therefore it cost only 1200 yen per unit. The photocatalyst filter can be manufactured with a simple non-woven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

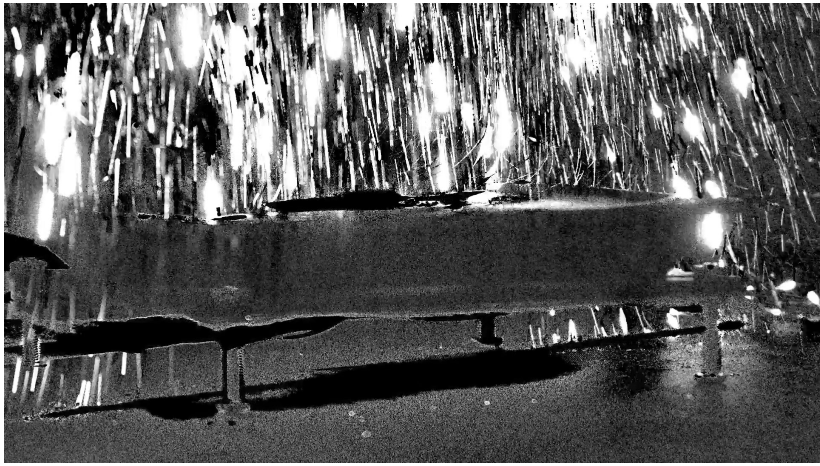

Light (Photon)
Particle of Photocatalyst
Visible light
(380nm～, 3.1eV～)
Reaction in photocatalyst
Reduction
Conduction band
O_2
Band Gap
Excited by light
e^-
Electron
Valence band
h^+
H_2O
hole
Oxidation
TiO_2(anatase) 3.2eV
need UV-light
WO_3 2.5eV
$\cdot O_2^-$
superoxide anions
Oxidizing power higher than ozone
·OH
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

Visualization of droplet suction by special imaging system



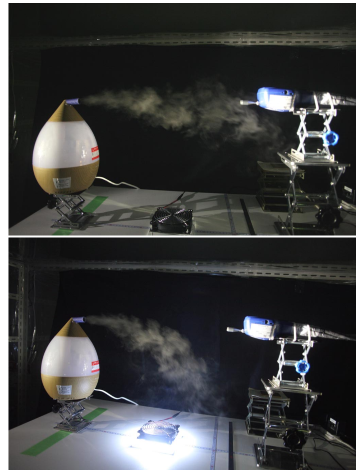
Special video recording was conducted to visualize droplets in the air. Within a range of about 50cm, we can see that droplets emitted by speech from the oral cavity with a "booming" sound are inhaled and stopped by the filter in the same way as a mask.

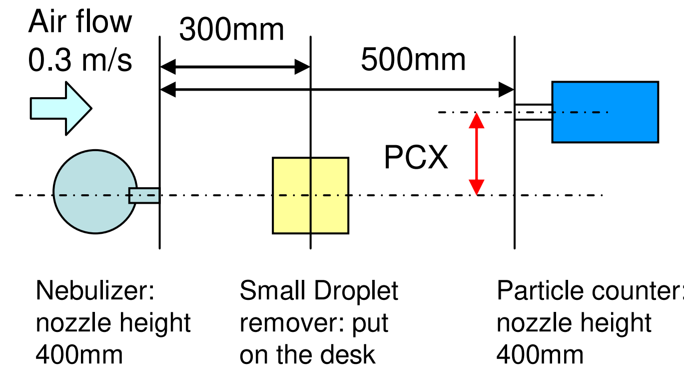


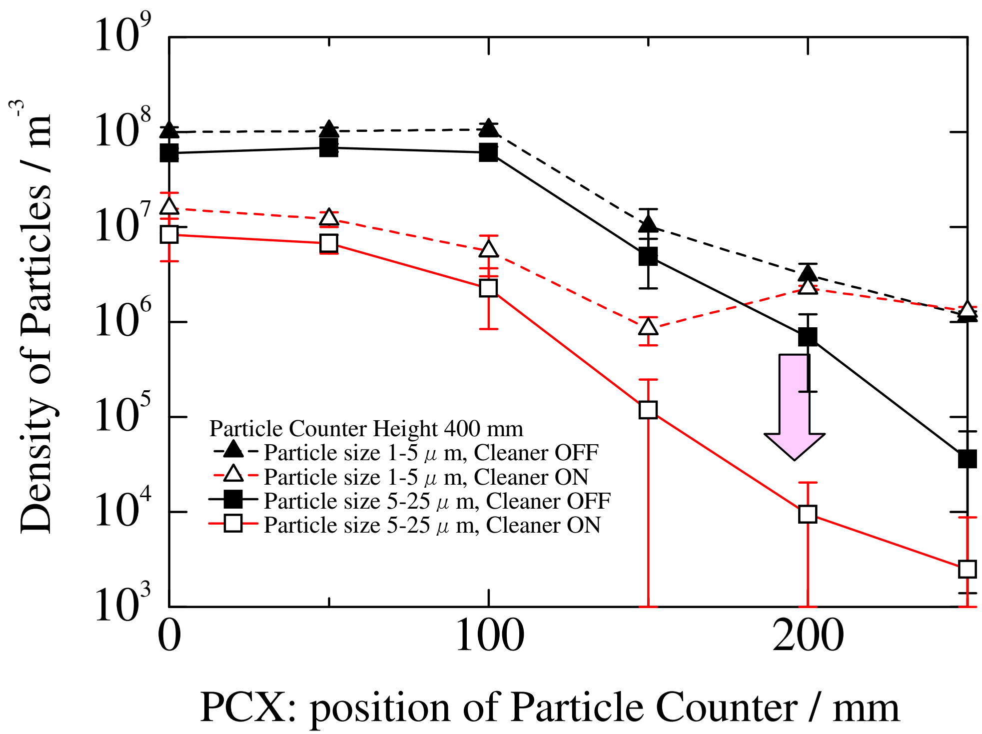


Collection rate of droplets flying in space

Large clean booth: 1.5 × 1.5 × 2.4m



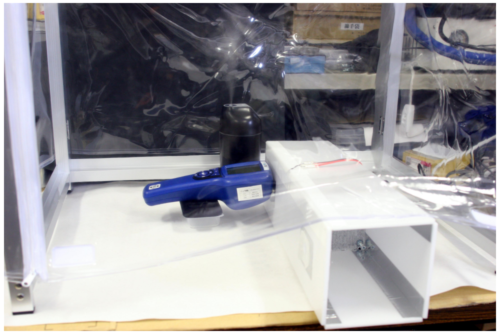


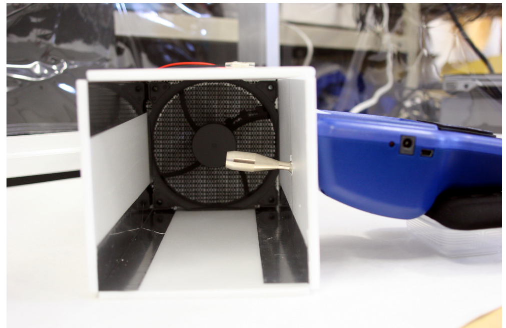


Performance of the small droplet remover in open space was estimated using large clean booth. Particle counters were placed off-center axis of nebulizer and the remover. The nozzle of the nebulizer was set horizontally and the mist flied almost straight with a following wind of 0.3 m/s from air purifier units.

Large droplets with diameters of 5.0 to 25 μm were reduced to about 1/10 in all position. **Aerosols** of 1.0 to 5.0 μm, which are close to the peak diameter of the aerosol emitted from the actual oral cavity, were also reduced to about 1/10 from center to 15cm, but at 20 and 25cm almost no reduction was observed.

Transmittance rate of droplets to a filter

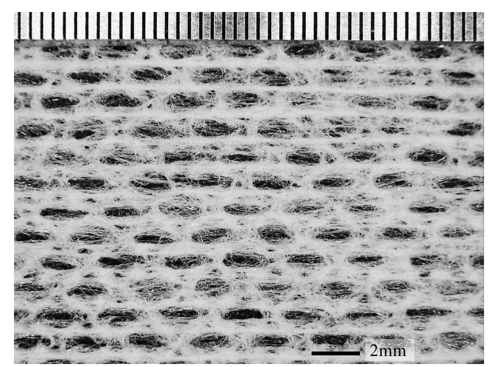




Condition	Particle Size	Concentration of particles		Transmittance
		before the filter	after the filter	
	μm	m^{-3}	m^{-3}	
with a little air dust	0.3～1	7.4×10^{6}	2.7×10^{6}	0.37
	1～5	5.1×10^{4}	1.7×10^{4}	0.34
	5～25	9.0×10^{2}	1.8×10^{2}	0.20
in the clean booth	0.3～1	1.2×10^{4}	6.7×10^{3}	0.54
	1～5	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.

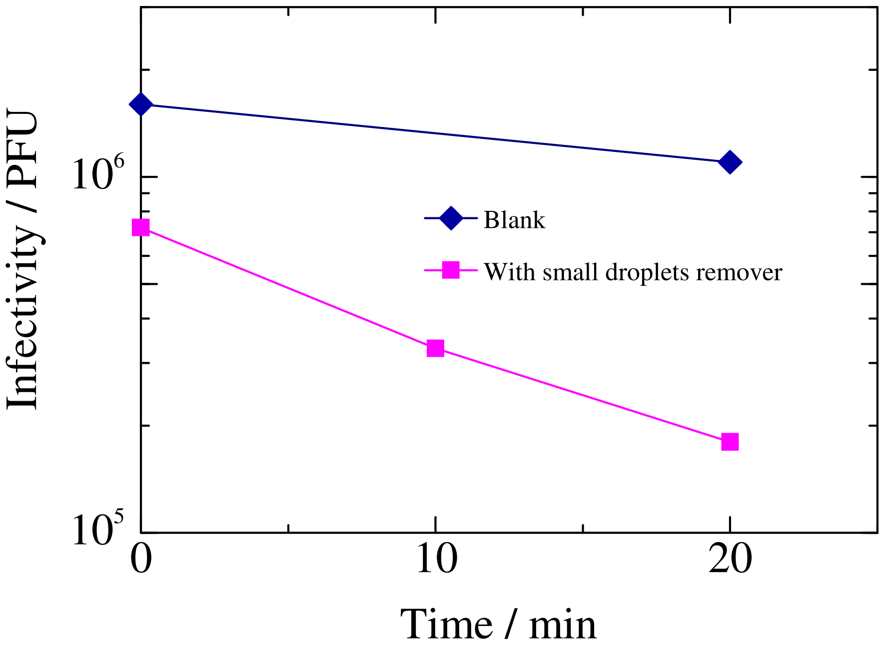
Catching and slowly decomposing



The non-woven fabric filter used in this study

Removal performance for virus in aerosol

A solution containing bacteriophage Qβ was sprayed with a nebulizer in a 370 L glove box to make an aerosols. At the measurement time, 10 L air was sampled through a gelatin filter and the infectivity was evaluated by the plaque method.
As a result, the infectivity decreased in the blank from 1.6×10^6 PFU to 1.1×10^6 PFU in 20 minutes, a decrease of about 30%.
On the other hand, the use of the small droplets remover with an inorganic high-performance filter resulted in a decrease from 7.2×10^5 PFU to 3.3×10^5 PFU after 10 minutes and 1.8×10^5 PFU after 20 minutes, approximately half in every 10 minutes.



Although aerosols suspended in the air for long time cannot be caught by the filter, it was suggested that viruses contained in aerosols can be removed by the small droplet remover using a photocatalyst.