2023/09/20 @ Osaka International Convention Center

International Symposium
of the Graduate School of Engineering,
Osaka Metropolitan University

World-Leading Engineering Research

Conceptual proposal for a compact droplet remover using photocatalyst

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（In Japanese）

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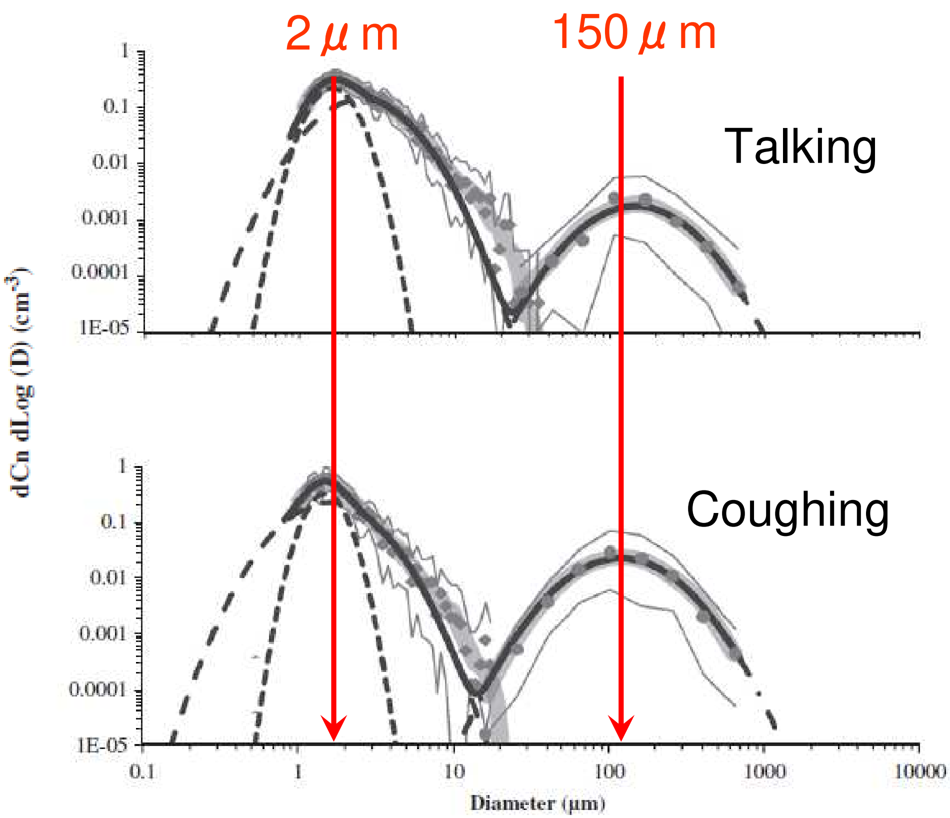
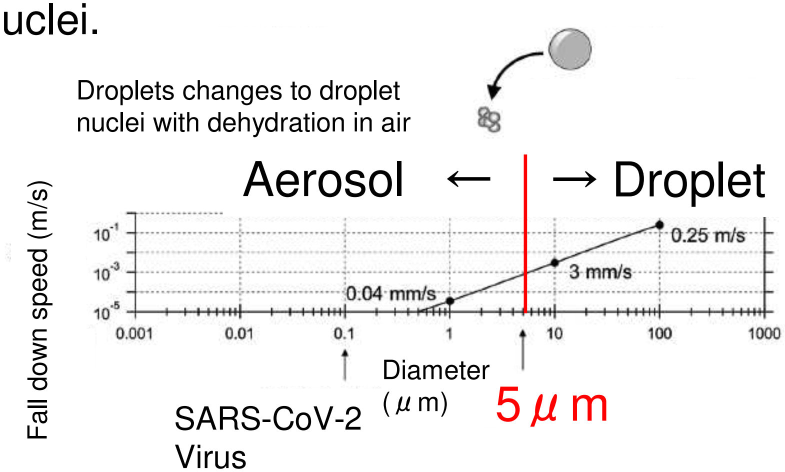
Size distribution of particles released from the oral cavity



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

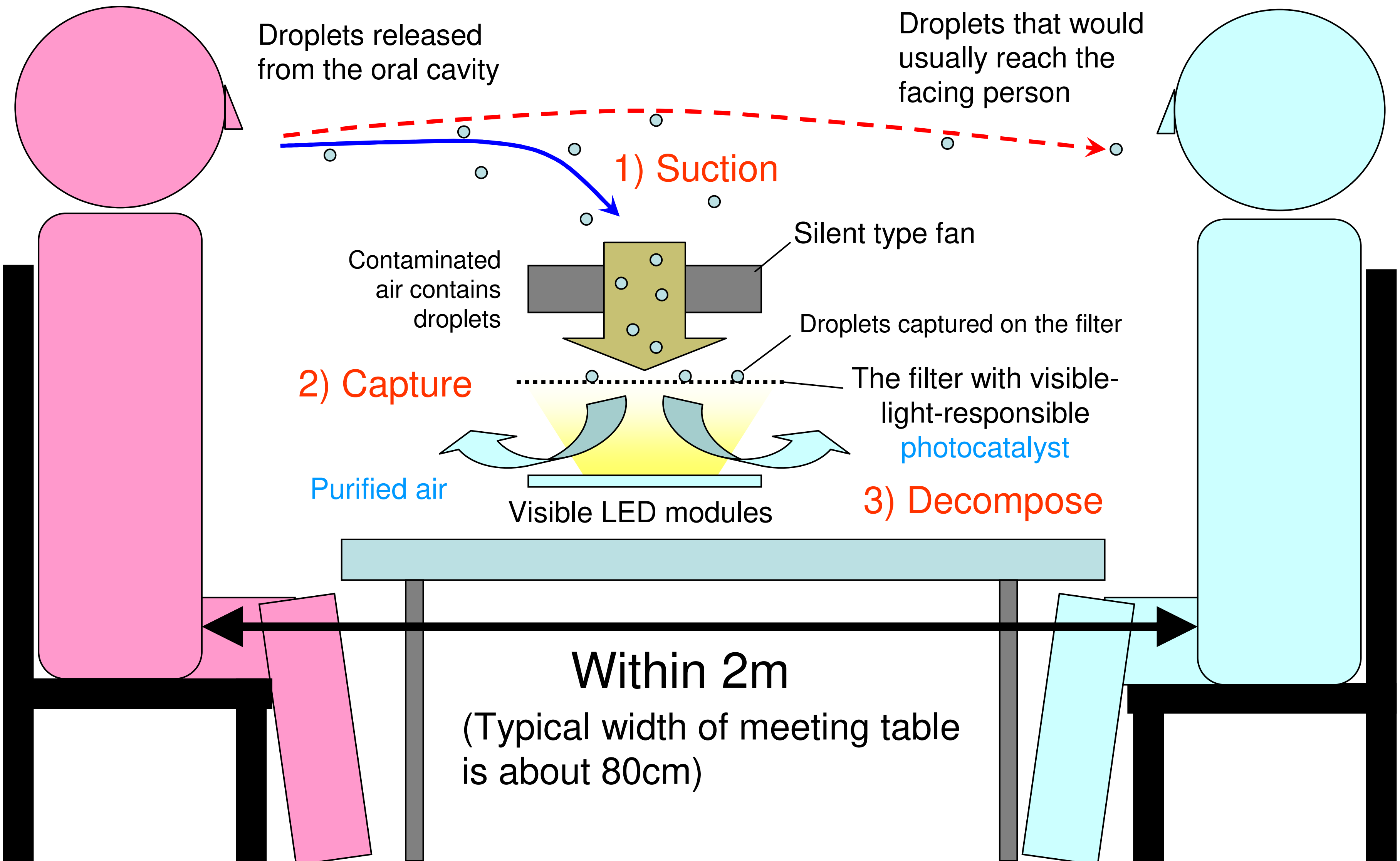
In medical studies, particles released from oral cavity are distinguished between **aerosols** and **droplets** at a diameter of 5 μ m.

The actual size distribution of particles released from the oral cavity is two-peaked, with 150 μ m **droplets** falling in about two seconds and reaching only about two meters, while 2 μ m **aerosols** drift in the air for a long time. In some cases, the droplets is dehydrated to form aerosol-sized droplet nuclei.



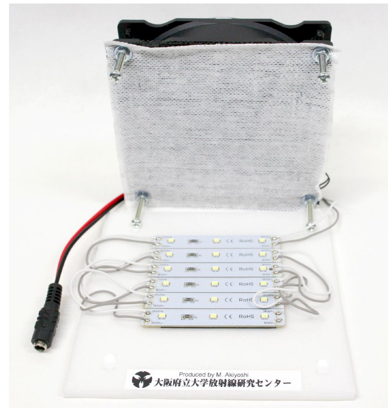
Nobuyuki Takegawa, Aerosol, Droplet Transmission, and Airborne Transmission, Earozoru Kenkyu, 36 (2021) 65-74.

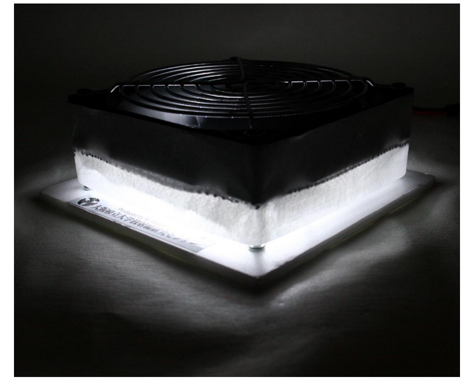
A specialized device that removes droplets flying between person-and-person



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

NOT commercial product



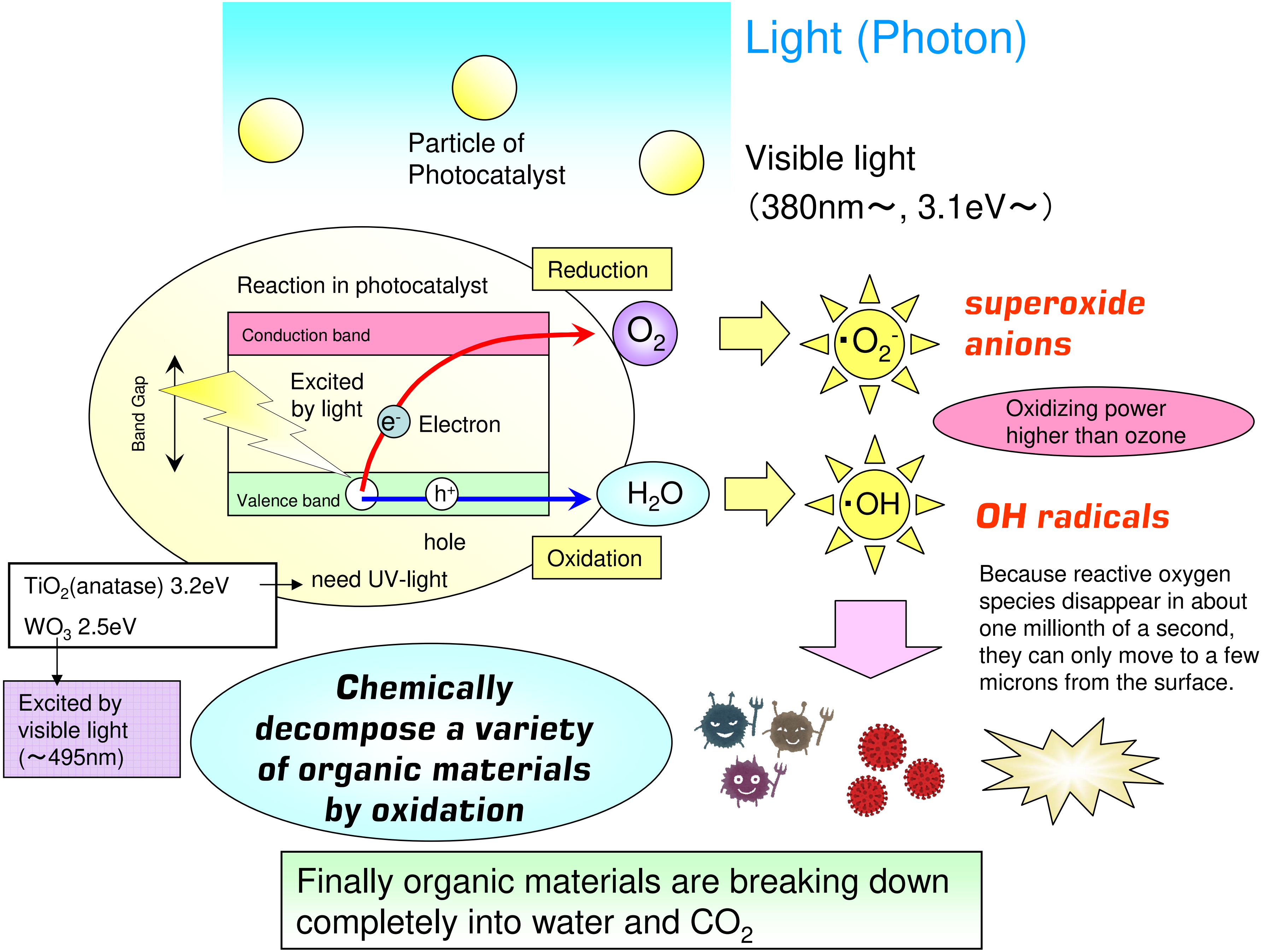


Shading leaked light with Japanese paper

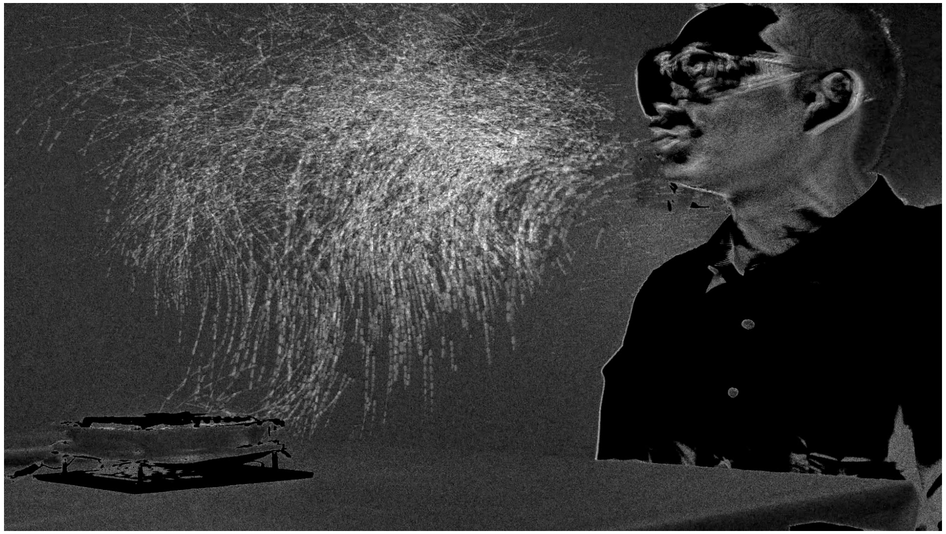
The size is 12 cm square and 5 cm high. Fan noise is only 19 dB. Power consumption is less than 5 W, and can be powered by a mobile battery

Luminary light between person-and-person

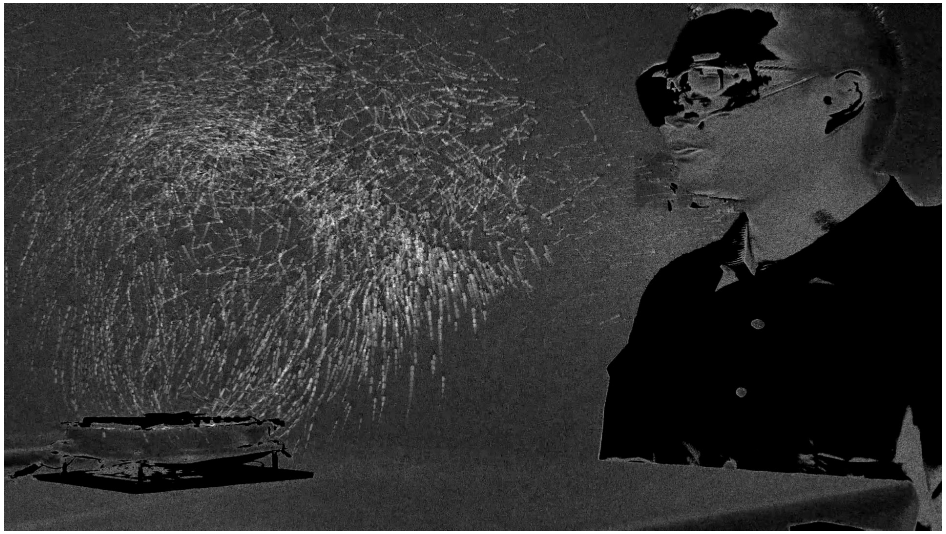
Using visible light-responsive photocatalyst, it does not need to be completely shielded from leaking light and can be made with a simple structure. It is made by combining commercial PC parts, therefore it cost only 1200 yen per unit. The photocatalyst filter can be manufactured with a simple non-woven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

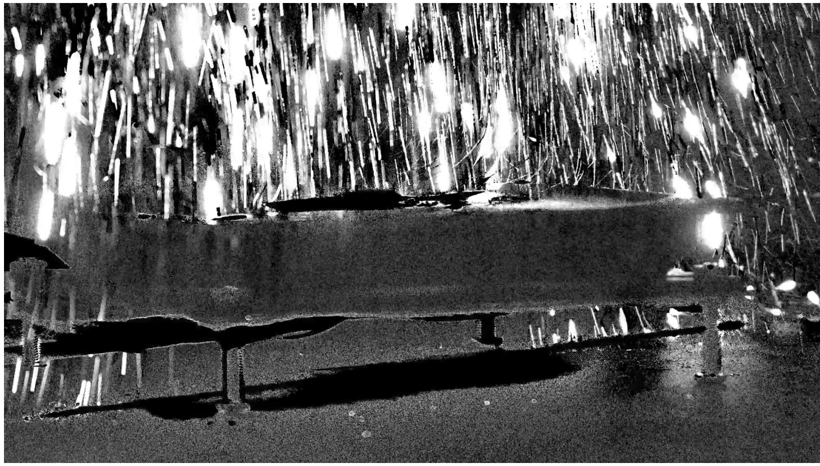

Light (Photon)
Particle of Photocatalyst
Visible light
(380nm～, 3.1eV～)
Reaction in photocatalyst
Reduction
Conduction band
Band Gap
Excited by light
e^-
Electron
Valence band
h^+
hole
O_2
H_2O
Oxidation
need UV-light
$\cdot O_2^-$
superoxide anions
Oxidizing power higher than ozone
$\cdot OH$
OH radicals
Because reactive oxygen species disappear in about one millionth of a second, they can only move to a few microns from the surface.
TiO_2(anatase) 3.2eV
WO_3 2.5eV
Excited by visible light (～495nm)
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

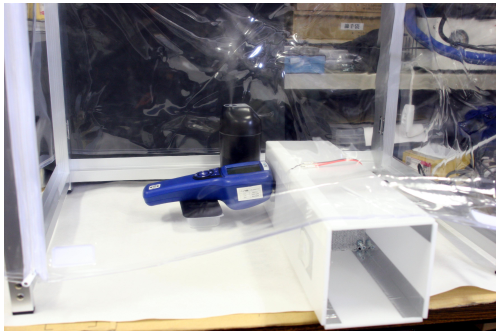


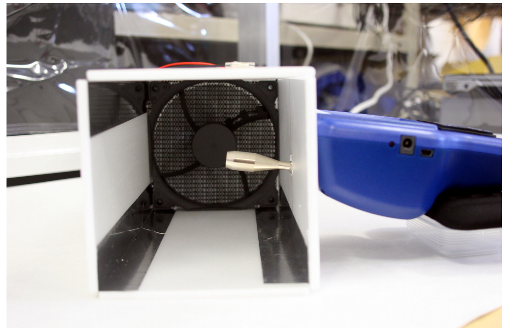
Special video recording was conducted to visualize droplets in the air. Within a range of about 50cm, we can see that droplets emitted by speech from the oral cavity with a "booming" sound are inhaled and stopped by the filter in the same way as a mask.





Transmittance rate of droplets to a filter

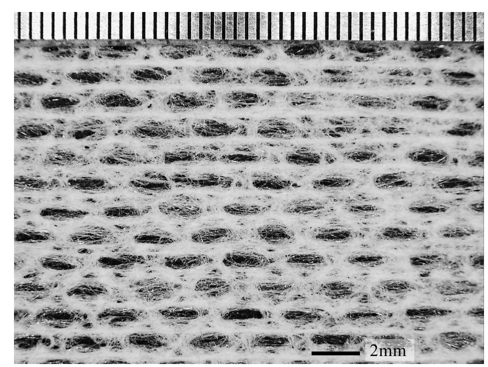




A duct was set up in a clean booth using HEPA filter unit, and the rate at which ultrasonic sprayer mist, simulating droplets from the oral cavity, was captured by a non-woven fabric filter was evaluated. As a result, it was confirmed that droplets of 5 μm or larger could be almost completely captured.

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}

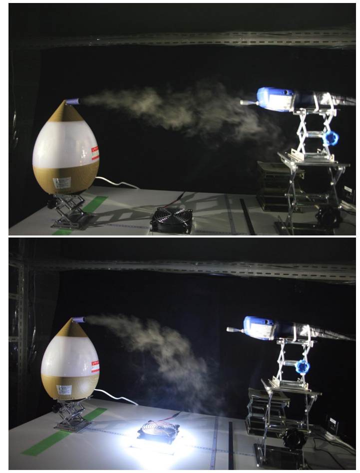
Catching and slowly decomposing

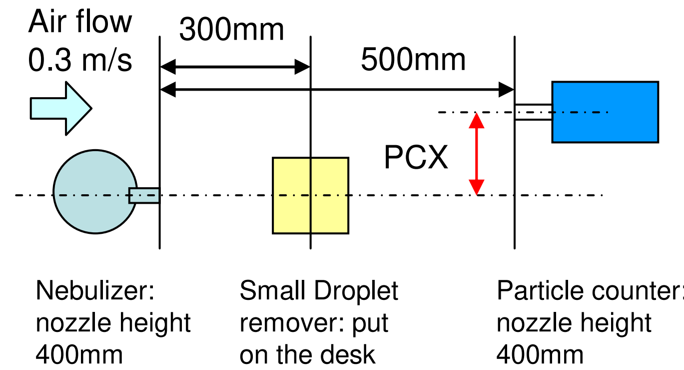


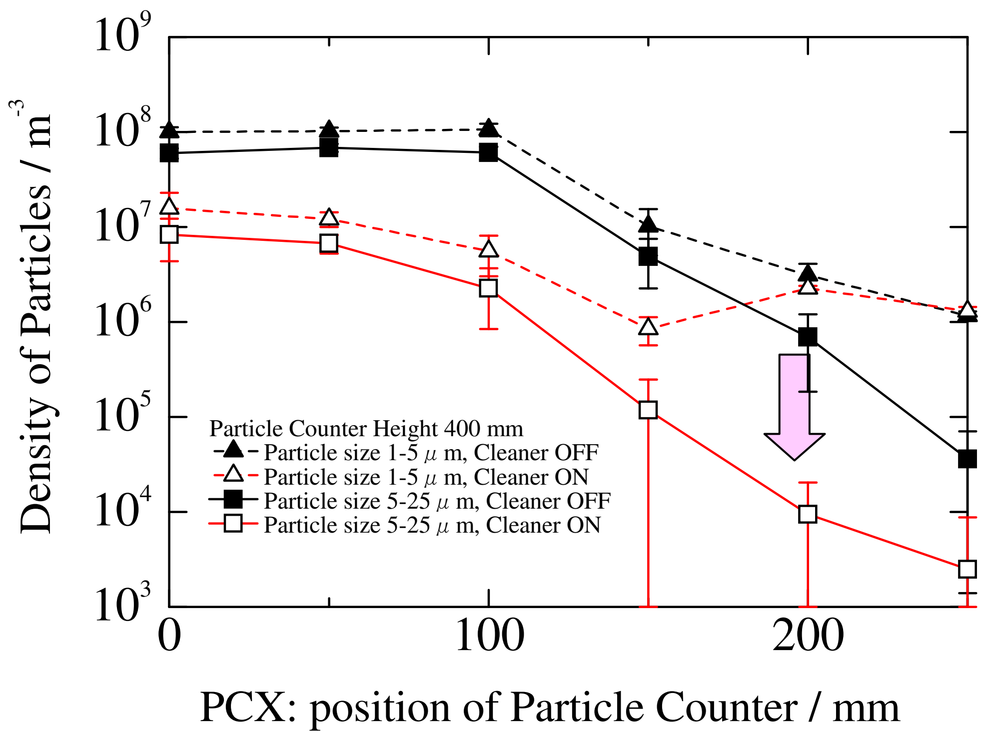
The non-woven fabric filter used in this study

Collection rate of droplets flying in space

Large clean booth: 1.5 × 1.5 × 2.4m



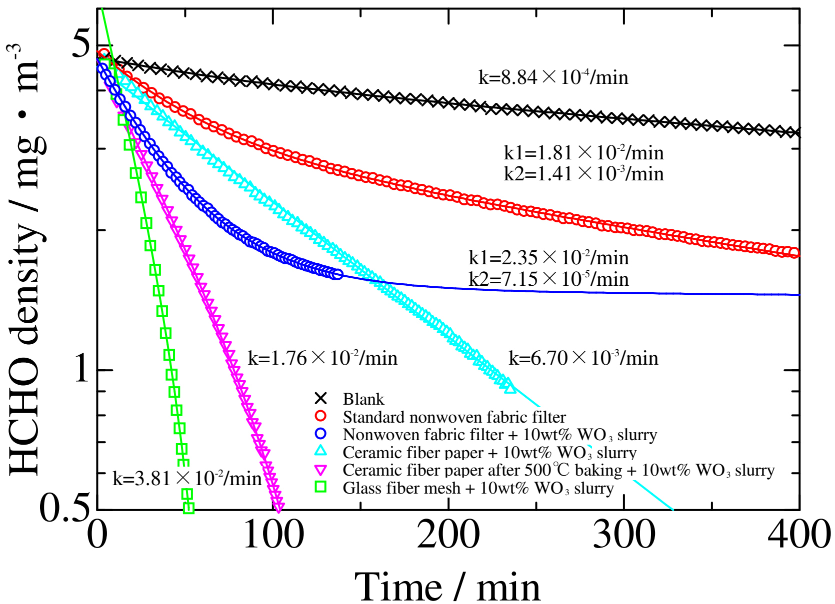


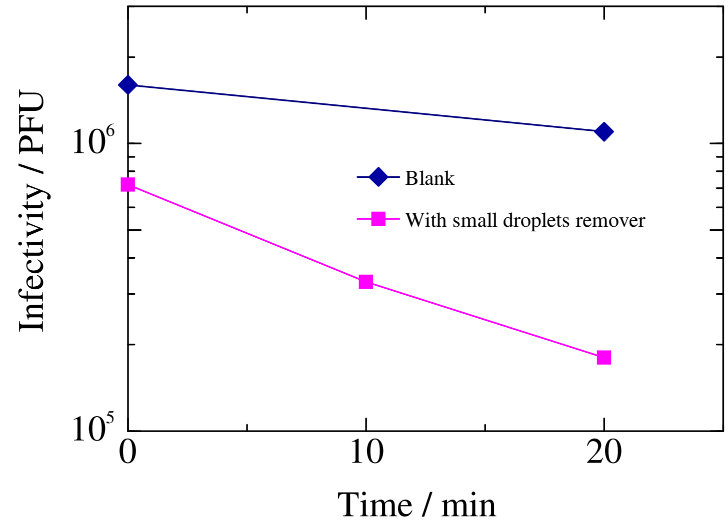


Performance of the small droplet remover in open space was estimated using large clean booth. Particle counters were placed off-center axis of nebulizer and the remover. The nozzle of the nebulizer was set horizontally and the mist flied almost straight with a following wind of 0.3 m/s from air purifier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

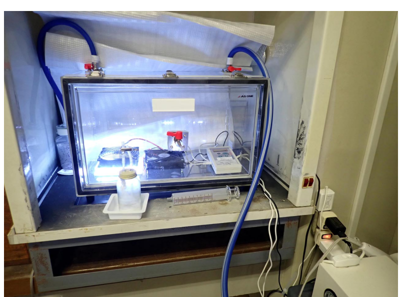
Large droplets with diameters of 5.0 to 25 μ m were reduced to about 1/10 in all position. **Aerosols** of 1.0 to 5.0 μ m, which are close to the peak diameter of the aerosol emitted from the actual oral cavity, were also reduced to about 1/10 from center to 15cm, but at 20 and 25cm almost no reduction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

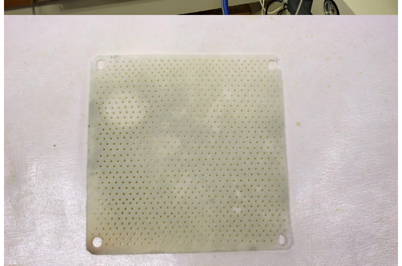
Decompose performance for organic gas and virus in aerosol





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.





Using a 38L size acrylic desiccator, changes in the concentration of formaldehyde (HCHO), a kind of organic gas, were measured using a formaldehyde meter htV-m. The non-woven fabric filter that was initially used was organic, so there was a limit to the improvement in performance even if the amount of photocatalyst loaded was increased. A filter made of inorganic material was used, and by applying appropriate pretreatment, a significant improvement in performance was achieved.

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