Nanofiber face masks improve filtration efficiency, need replacing more often

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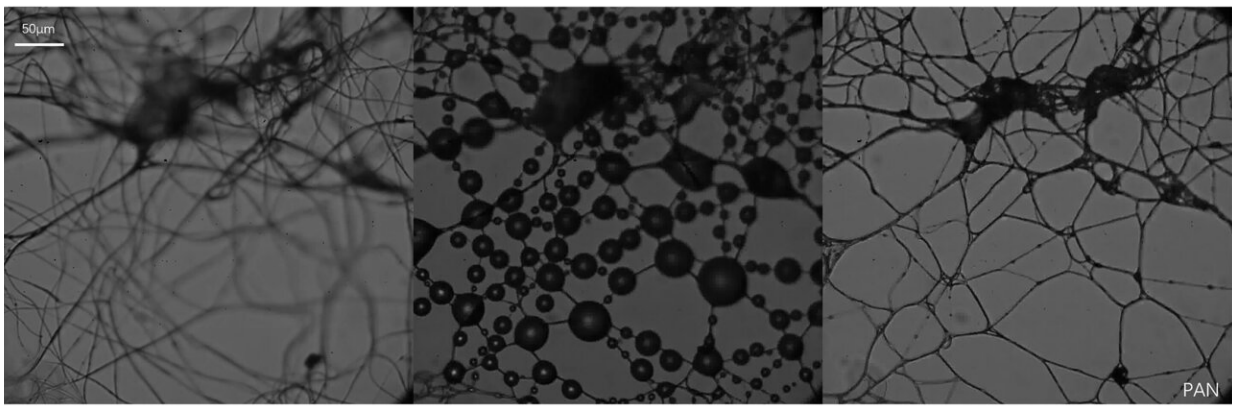

Polyacrylonitrile nanofiber mesh before (left), during (middle), and after (right) capturing water aerosols. The mesh becomes coarser as some nanofibers stick together after the captured water droplets are fully evaporated. Credit: Southern University of Science and Technology, Shenzhen, China

Since its outbreak, the COVID-19 virus has infected more than 207.7 million people worldwide and has claimed more than 4.3 million lives, according to the World Health Organization coronavirus dashboard as of

Aug. 17.

However, many medical professionals attribute the consequential role of face masks in slowing the spread of the virus and protecting human health.

Innovations to improve mask efficacy, with increasing focus on nanofiber manufacturing, have resulted in higher filtration efficiency, greater comfort, and easier breathing capacity. However, the effects of microwater droplets on the integrity of nanofibers are relatively unclear.

In *Physics of Fluids*, researchers from Southern University of Science and Technology in Shenzhen, China, examine these ambiguities through a visualization of nanofibers interacting with water aerosol exposure.

"When COVID-19 first hit, face masks were in extremely short supply everywhere, and people came up with all kinds of ways to 'rejuvenize' used face masks. It was like a chef's contest, with boiling, steaming, grilling, and even smoking involved," said co-author Boyang Yu. "Our intuition told us this can't be right. We have to look into it and see what exactly happened with the nanofibers."

Yu and his colleagues used high-speed microscopic videos to systematically visualize the evolution of nanofibers made of polymers with different contact angles, diameters, and mesh sizes under water aerosol exposure.

"Filming nanofibers is like taking portraits of babies," said Yu. "They don't like to stay in place for the camera. This is because nanofibers are very soft and flimsy, especially with the aerosol flow blowing through. But with enough care, patience, and luck, we eventually got nice shots for our analysis."

The images produced reveal nanofibers coalesce irreversibly during the "droplet capture stage" as well as the subsequent liquid evaporation stage, significantly reducing the effective fiber length for capturing aerosols. They show hydrophobic and orthogonally woven fibers can reduce capillary forces and decrease the fiber coalescing rate.

"We confirmed three things," said co-author Weiwei Deng. "One, nanofibers are superb at capturing droplets in aerosol. Two, the nanofibers are bonded together after the aerosol is captured. And three, this bonding is tight and irreversible, even after the captured droplets evaporate.

"Wetted fibers tend to bond to each other in the same way that wet hairs tend to bundle together. It is because of the capillary force, which becomes dominant as the size scale shrinks, and it is extremely strong for nanofibers."

The study's findings are expected to help improve design, fabrication, and use of face masks made with nanofibers. They provide direct visual evidence for the need to replace face masks frequently, especially in cold environments.

"The winter is coming," said Deng. "When it's cold outside, your breath contains more droplets that may make the nanofiber mesh collapse more quickly."

More information: "Visualization of the interaction of water aerosol and nanofiber mesh" *Physics of Fluids*, aip.scitation.org/doi/full/10.1063/5.0061847

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