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Recognizing Innovation

COVID-19 can be transmitted when an infected person talks, coughs, sneezes or sings, expelling virus-containing respiratory droplets that can reach the mouth, nose or eyes of previously uninfected people. These aqueous droplets tend to fall rapidly out of the air and evaporate on the floor or the ground, but some smaller droplets can evaporate before reaching the ground, leaving virus nuclei floating through the air. Such infinitesimal aerosolized particles, or aerosols, can travel on air currents for hours and infect people, particularly when they spend prolonged periods of time in indoor settings that lack adequate ventilation. It is because transmission is possible via free-drifting aerosols that the coronavirus is referred to as an *airborne disease*.

During the pandemic, [Yangying Zhu](#), an assistant professor of mechanical engineering at UC Santa Barbara, and her research lab have analyzed the [evaporation and propagation of respiratory droplets and aerosols](#) under different temperatures and humidity conditions. They found that, under some conditions, respiratory droplets traveled farther than the six feet the Centers for Disease Control (CDC) recommends for safe social distancing, and that the effect increased in cooler and more-humid environments. Zhu says it is important to expand her research into evaporation dynamics and respiratory droplets.

“We are so fortunate that vaccines were recently made available; however, our effort to understand the transmission of respiratory diseases should continue,” said Zhu, who co-wrote a paper on the project that was published in the journal *Nano Letters*.

In recognition of her innovative and highly promising research in this area, Zhu has received a prestigious Early CAREER Award from the National Science Foundation. She will receive \$500,000 over five years for her project titled “Understanding Thermal Transport Across Phase-Change Interfaces via in Situ Micro-Raman Thermography.” The award is part of the NSF Faculty Early Career Development program that encourages junior faculty to pursue cutting-edge research and advance excellence in education.

“I am grateful as a junior faculty member to receive support from the NSF to pursue my proposed research,” said Zhu, who joined UCSB’s mechanical engineering department in 2019, after completing her Ph.D. in mechanical engineering at the Massachusetts Institute of Technology and a postdoctoral position at Stanford University. “I am motivated by the thermal-science community to pursue this particular research direction.”

“I offer sincere congratulations to Professor Zhu for receiving this highly esteemed award,” said Rod Alferness, dean of UCSB’s College of Engineering. “It reflects her tremendous potential to create new knowledge related to heat transfer and to design new phase-change technologies. It also recognizes her motivation to apply her findings to prevent future pandemics and to expand our understanding of respiratory-disease transmission.”

Zhu plans to continue her respiratory-related work by focusing on phase change, or the process by which matter transitions from a solid, liquid or gas into a different state. A phase change takes place because of heat transfer, or the exchange of thermal energy between physical systems. Liquids evaporate when sufficient heat energy is provided to break intermolecular bonds between molecules, allowing them to change into a gas. When a vapor comes in contact with the surface of matter with a lower temperature, it condenses into a liquid by releasing heat.

The evaporation of a respiratory droplet into an aerosol is an example of the phase change from liquid to vapor, as are boiling and condensation, which engineers have used to generate power, control building temperature, desalinate water and cool electronics. Technologies having superior heat-transfer performance have made the above-mentioned applications possible. Zhu says that understanding a phase change and heat transfer at the microscale will unlock secrets that can lead to next-generation technologies and increased energy efficiency at the very large scale while providing further insight into the spread of respiratory droplets at the scale of

viral transfer. She has proposed a project to develop a temperature-measurement technique that can directly probe the three-phase region, something that has been very difficult to realize before. The three-phase region refers to the location where liquid, vapor and solid meet during the phase change, such as the base of a bubble on a solid surface during boiling.

“During a phase-change process, heat is mainly transported from one phase to another within the three-phase region, which usually has a length scale of several hundred nanometers or a few micrometers,” said Zhu. “While we can measure the macroscopic heat-transfer performance, it has been very challenging to understand what happens at the phase-change boundary at the microscale, which is necessary if we are to design next-generation engineered devices for improved thermal transport control.”

In her NSF-funded project, Zhu seeks to develop an innovative platform to measure, with unprecedented accuracy and spatial resolution, the temperature near the solid-liquid-vapor contact line for both evaporation and condensation processes. Conventional methods use resistance temperature detectors and infrared cameras but they are limited, either by their spatial resolution or their remoteness from the region of interest. Zhu plans to use micro-Raman spectroscopy to measure temperatures and use a laser to probe the three-phase contact region non-invasively during phase change in an environmental chamber. Micro-Raman spectroscopy involves using scattered light to measure the vibrational energy modes of a microscopic sample, providing both chemical and structural information. Zhu, who says that the technique has never before been used to study phase-change heat transfer, believes that the ability to take high-spatial-resolution measurements *in situ*, where the process is actually occurring, will provide an exciting opportunity to gain new insights.

Zhu also plans to investigate the transfer of heat during phase change in nanostructures of semiconducting materials. Taking the temperature of the nanostructures will enable her to determine what materials and conditions result in the smallest temperature rise during phase changes. That insight should, in turn, allow her to design devices having a high critical heat flux (CHF) and a high heat transfer coefficient (HFC). The CHF refers to the maximum temperature reached during a phase change, while the HFC indicates the ease with which heat is exchanged between two materials.

“This experiment will produce data to better understand phase-change processes and identify factors that limit efficient heat transfer,” said Zhu. “The fundamental insights gained through this work will potentially lead to highly effective and improved phase-change devices that can enable energy savings and reduce freshwater withdrawals for power plant, as well as provide energy-efficient thermally driven desalination, effective heat dissipation for high-power-density electronic devices, and more-energy-efficient thermal control of buildings.”

As for her work’s relevance to COVID-19, Zhu will apply her findings to the transmission of respiratory diseases from the perspective of heat and mass transfer. This could lead to improved strategies for ensuring airflow and ventilation to prevent virus accumulation indoors, or to guidelines for facial masks that provide optimal filtering. Her findings also will be incorporated into her undergraduate and graduate courses through lab experiments, lectures and projects to further demonstrate heat transfer and phase changes.

“The COVID-19 pandemic has prompted me to reflect on how I, as a thermofluid engineer, can contribute to solving real-world problems and demonstrate to the younger generation how science and engineering can help combat and control the disease,” she said. “This NSF-funded project will allow me to accomplish both.”

About UC Santa Barbara

The University of California, Santa Barbara is a leading research institution that also provides a comprehensive liberal arts learning experience. Our academic community of faculty, students, and staff is characterized by a culture of interdisciplinary collaboration that is responsive to the needs of our multicultural and global society. All of this takes place within a living and learning environment like no other, as we draw inspiration from the beauty and resources of our extraordinary location at the edge of the Pacific Ocean.