New ultrafast water disinfection method is more environmentally friendly

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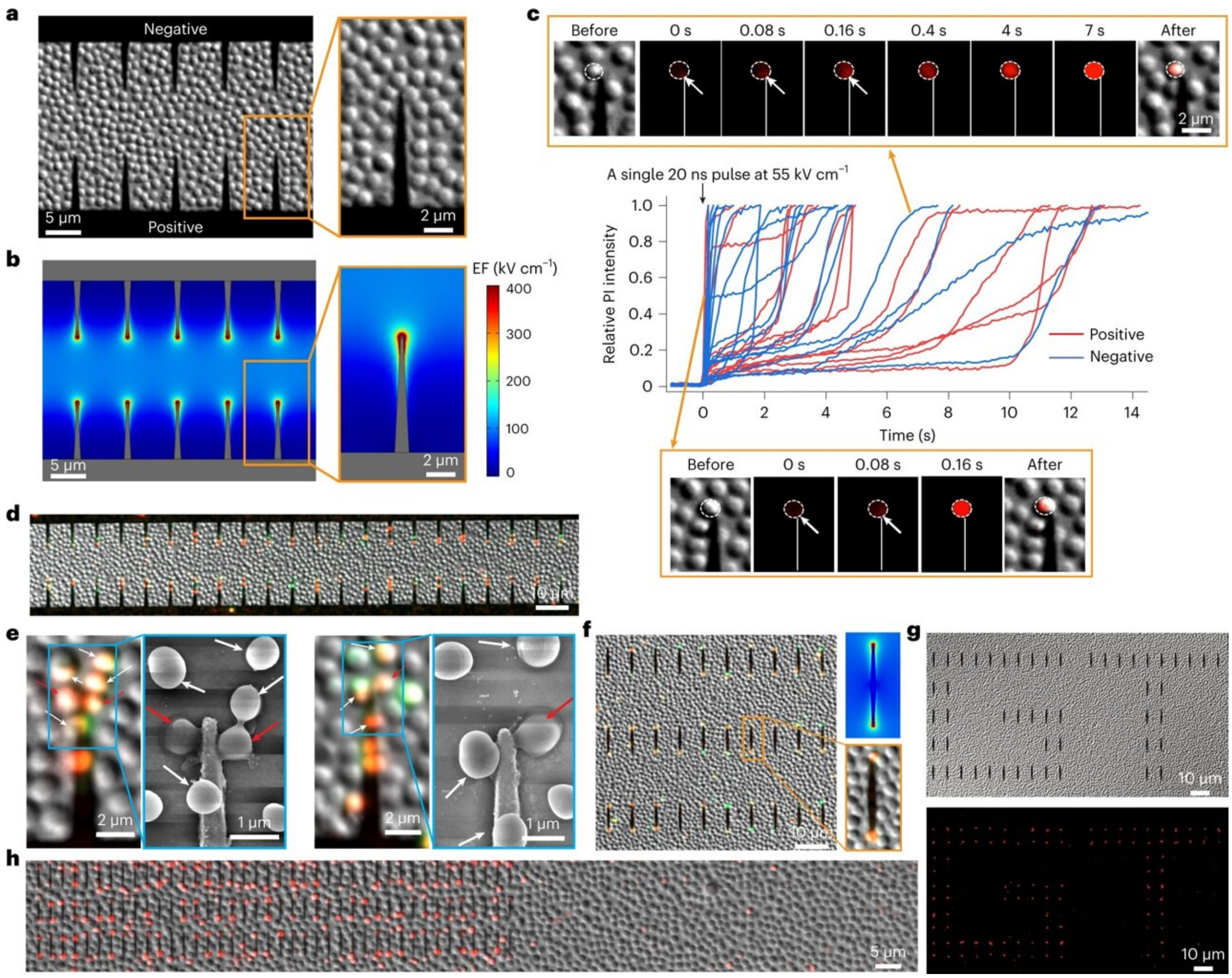

Bacteria inactivation by nanosecond pulses at the nanowedge tips. **a**, The model bacteria *S. epidermidis* are immobilized on the chip. **b**, The simulated nano-enhanced electric field under 55 kV cm^{-1} applied electric field. **c**, The relative PI intensity of individual cells after a single pulse is applied. Each line represents a single cell located at the nanowedge tip on either the positive or the negative electrode. The microscopy images show the PI dye diffusion pattern. **d**, Bacteria inactivation after LEEFT (20 ns pulse, 40 kV cm^{-1}, ten pulses). The red and orange cells are inactivated cells stained with PI. **e**, Side-by-side comparison of optical microscopy and SEM images after LEEFT (20 ns pulse, 55 kV cm^{-1}, ten pulses). The red arrows indicate the flattened cells, while the white arrows indicate the inactivated cells that still maintain a good shape. **f**, Bacteria inactivation achieved by non-connected nanowedges, and the simulation of the nano-enhanced electric field. **g**, Bacteria inactivation at the nanowedge tips that are arranged in a 'GT' pattern. Top: DIC channel microscopy image before LEEFT. Bottom: fluorescence channel microscopy image after LEEFT. **h**, Bacteria inactivation achieved by densely packed nanotips. The inactivated cells in **g** and **h** are only indicated by PI stain and show red fluorescence. Credit: *Nature Water* (2023). DOI: 10.1038/s44221-022-00003-2

Having safe drinking water is vital for public health, but traditional methods of disinfection cause their own environmental problems. Chlorine is cheap and easy to use in centralized water systems, but at the expense of harmful chemical byproducts.

Georgia Institute of Technology researchers have found a way to use small shocks of electricity to disinfect water, reducing energy consumption, cost, and environmental impact. The technology could be integrated into the electric grid or even powered by batteries.

"This is a pretty new disinfection technology, and we want to demonstrate in the small scale first, and then improve its real-world applications for point-of-use or off-grid water purification," said Xing Xie, the Carlton S. Wilder Assistant Professor in the School of Civil and Environmental Engineering.

Xie and his postdoctoral researcher Ting Wang published the paper, "Nanosecond Bacteria Inactivation Realized by Locally Enhanced

Electric Field Treatment," in *Nature Water* in January.

Localizing Electricity

Although conventional electric field treatment (CEFT) is applied for food pasteurization, it hasn't been widely used for drinking water disinfection because of the relatively high cost. When water and bacteria are exposed to electricity, the bacteria cell membrane acts like a capacitor in a circuit. Typically, in CEFT, water's low conductivity means nanosecond pulses won't charge the membrane fast enough to kill bacteria.

The researchers created a locally enhanced electric field (LEEFT) that brought the electricity directly to the bacteria. The electrodes have gold nanotips that build up concentrated charges instantly when connected to electricity, enabling the charges to travel to the membrane and kill the bacteria much faster.

"This ultra-fast bacteria inactivation just using the nanosecond pulses is a surprise because, theoretically, nanosecond pulses are just too short to kill the bacteria in conventional electric field treatment because the membrane takes time to charge," Wang said. "But with LEEFT's nanowedges and nanostructures, the bacteria cells can be charged directly by the nanometal, quickly disinfecting water."

Electric Innovation

To test the technology, they fabricated gold nanowedges on the electrode edge of a chip. Then they added model bacteria Staphylococcus to the chip, a commonly used bacteria in labs and often found in water systems. Next, they applied electric pulses and watched how the bacteria reacted in real time under a microscope.

When electricity was applied at 40 kilovolts per centimeter for 200 nanoseconds, 95% of nanowedges successfully killed the bacteria. Compared to conventional EFT, LEEFT lowers applied eclectic field strength by eight times—and shortens the treatment time by 1 million times.

"We found that even nanosecond pulses could kill the bacteria in the LEEFT and not other circumstances," Wang said. This near-instantaneous decontamination reduces how much electricity is needed to disinfect water, making this an affordable sanitation option and pointing to a future in which producing clean water may take less of a toll on the environment.

More information: Ting Wang et al, Nanosecond bacteria inactivation realized by locally enhanced electric field treatment, *Nature Water* (2023). DOI: 10.1038/s44221-022-00003-2

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