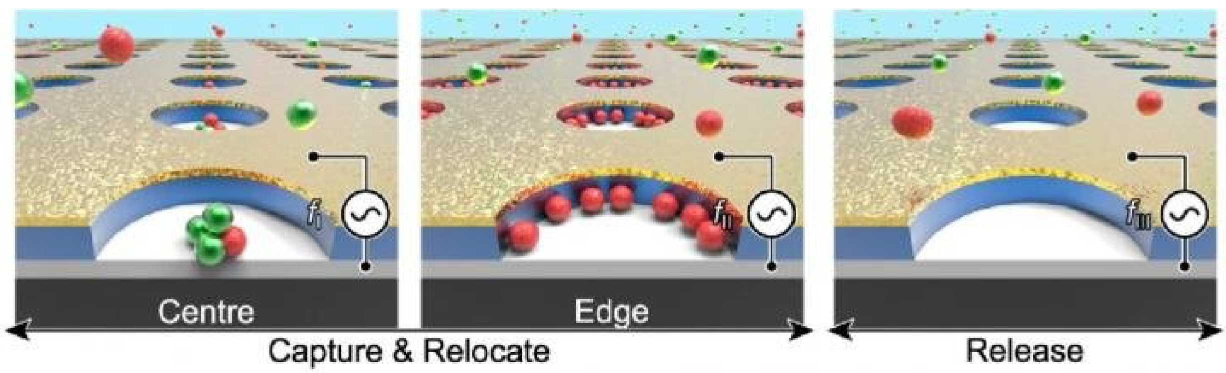
Researchers develop dielectrophoretic tweezers for toxic nanoparticles

July 15 2020



Model diagram of the nanogap electrodes allowing the dielectrophoretic tweezer technology. Credit: Korea Institue of Science and Technology(KIST)

A Korean research team has developed a technology that enables the effective control of fine particulate matter and nanoplastics, which are major causes of human toxicity and ecosystem disturbances. This technology, which allows for real-time sorting, purification, and concentration of nanoparticles invisible to the human eye has great potential application, not only for the removal of toxic particles from the natural environment, but also for removing viruses and detecting dementia-related proteins and cancer diagnostic markers. Due to its vast range of applicability, this technology is attracting much attention in scientific and academic circles.

The research team, led by Dr. Yong-sang Ryu of the Sensor System Research Center in the National Agenda Research Division at the Korea Institute of Science and Technology (KIST), working with a team led by Dr. Sin-Doo Lee of the Department of Electrical and Computer Engineering at Seoul National University, announced the development of a nanogap electrode able to capture ultra-fine floating particles as small as 20 nanometers (nm, 1/1000 the thickness of a human hair). The research team used the newly developed electrode in successful selective concentration and positioning experiments for extracellular vesicles (exosomes), which have potential in the drug development field and as new diagnostic markers for cancer and dementia-related proteins.

Researchers around the world are pursuing techniques to manipulate nano-size particles without damaging them. The optical tweezers technology, which received the Nobel Prize in Physics in 2018, is representative of such technologies. However, it has proven difficult to go beyond individual particle-level manipulation/measurement and to realize commercialization on a massive scale. Researchers have repeatedly run into technical limitations in scaling mechanisms for collecting, sorting, purifying and concentrating particles that are 100 nm or less in size; however, such mechanisms are needed to work in large-scale atmospheric and water environments.

The joint KIST-SNU research team, through centimeter-scale device production for particle concentration and purification experiments, was able to overcome these limitations and successfully scaled up the nanogap electrodes by sandwiching nanoscaled insulator film between two electrodes in a vertical alignment, allowing the dielectrophoretic tweezer technology to be applied to large areas. Dielectrophoresis is a technology wherein wavelengths vibrating several hundred to several thousand times per second are applied to two electrodes to form a non-uniform electrical field distribution around the electrodes. The electrodes are then used to attract or repel particles in the vicinity of the nanogaps.

The joint research team conducted experiments to find technologies that could use universally available semiconductor processes rather than existing expensive equipment. During the experiment process, the team found that the dielectrophoretic force produced by electrodes in an asymmetric electrode-arranged vertical array was over 10 times greater than that of a conventional horizontally aligned nanogap array. This discovery simultaneously solved the problems of scaling up and reduced the costs associated with the nanogap technology. Using the conventional horizontal electrode array production method, it is quite expensive to produce enough nanogap electrodes to cover the area of a fingernail. The new dielectrophoresis technology produces enough nanogap electrodes to cover the area of an LP disc at a fraction of the cost.

The vertical nanogap technology developed by the KIST research team makes it possible to scale up nanogap electrode technology, produce nanogap electrodes in numerous shapes and sizes, and radically reduces unit production costs. As such, the technology has a broad range of potential applications. According to the research team, when used in air or water filters, the nanogap electrodes can function under low voltage (such as that of an ordinary AA cell) to detect and remove, in real time, various microscopic floating particles such as fine dust, nanoplastics, viruses, germs, and bacteria.

Dr. Eui-Sang Yu, the principle author of the study, said, "The achievement has future application for the sorting and purifying of nano-sized particles, regardless of type of particle or the environment."

Dr. Yong-Sang Ryu of the KIST, the corresponding author of the study, added, "We hope that the study can make broad contributions to solving various social problems and enhance the general quality of human life."

More information: Eui-Sang Yu et al, Precise capture and dynamic relocation of nanoparticulate biomolecules through dielectrophoretic enhancement by vertical nanogap architectures, *Nature Communications* (2020). DOI: 10.1038/s41467-020-16630-w

Provided by National Research Council of Science & Technology

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