# Insulator-based dielectrophoretic particle separator and concentrator - iDEP

## Selective Particle Concentrator and Sorter for Biomedical and Homeland Security Applications

### Context

Protecting our nation's supply of drinking water is a key priority in homeland defense. Verifying the safety of drinking water against both natural contaminants (i.e., Cryptosporidium parvum) and terrorism threats (i.e., Bacillus anthracis) is a complex and time-consuming task.

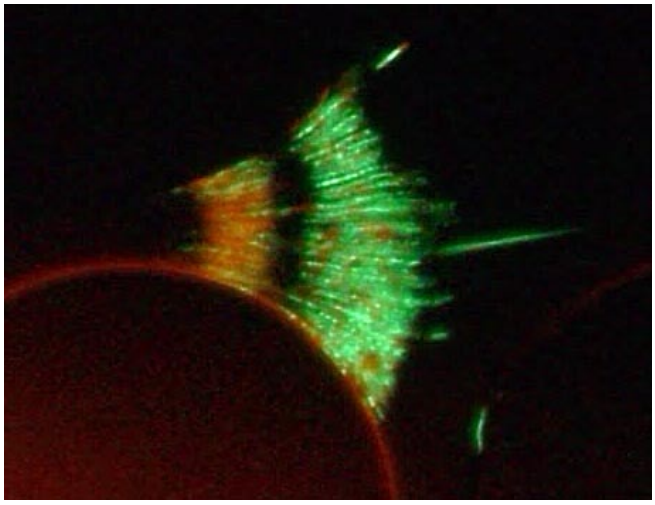

*Fig 1. Micrograph of iDEP concentration and separation of live and dead E. coli bacteria. Live cells are labeled fluorescent green; dead cells are labeled fluorescent orange. The circles are insulating obstacles on 200 µm centers. The 1 µm-cells are collected from the flow of ~1 mm/s from right to left under an applied field of 130 V/mm.*

### Solution

Bacteria can be dangerous in concentrations as low as 1 viable organism per liter of drinking water. Even with sensitive detectors, the entire liter must be sampled efficiently and effectively. By selectively concentrating the live pathogenic bacteria, insulator-based dielectrophoresis (iDEP) devices can deliver detectable amounts of material to analytical devices in greatly decreased sample volumes, eliminating the need for overnight culturing steps. This represents a significant improvement over previous methods.

Within microanalytical instrumentation, iDEP provides run-time-tunable selective concentration to solid density, resulting in the highest possible detector sensitivity. Devices can be fabricated and conventionally replicated in any impermeable insulating material like most plastics and glass and can be readily integrated with other devices to enhance "lab-on-a-chip" performance.

### Scientific Advantage

In a spatially non-uniform electric field, particles that have a different conductivity than their suspending fluid move under a dielectrophoretic force as first reported by Pohl in 1951. The difference in conductivity of live cells (good insulators) and dead cells (weak conductors) can separate live and dead cells dielectrophoretically. Previously this was demonstrated by flowing a suspension past arrays of electrodes that apply an AC waveform in a channel. These electrodes produce the non-uniform field needed for dielectrophoresis, but present several disadvantages including fabrication complexity, charging effects, fouling, electrochemistry, and gas bubbles at the electrode surface. iDEP avoids these problems by using patterned insulating obstacles to produce non-uniformities in the electric field applied through the liquid by remote electrodes. The remote

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electrodes minimize electrochemical and electrolytic effects, fouling and polarization effects, and importantly, do not require costly and fragile electrode patterning.

**Advantages and Capabilities:**

- Discrimination and separation of live and dead cells
- Differentiation of vegetative and sporulated cells
- Differentiation between cell types
- Capable of selectively concentrating particles (cells, spores, viruses, proteins, inert particles)
- High instrumental resolution capable of differentiating and separating particles based on submicron differences
- A wide range of insulator architectures available to tailor to the operational requirements of the system
- Scalability from micro- and nano-liter scale microdevices through liter-scale high-throughput macrodevices
- Capability for continuous and batch mode operation
- Operability over two orders of magnitude with respect to particle size
- Host substrate can be any insulating and impermeable material (glass, silica, plastic, ceramic)
- Ease of replication through injection molding and hot embossing

**Principal Applications**

- Water analysis for public utilities and public health
- Live vs. dead differential sorting in cell culturing
- Differentiation and detection of cancerous cells for diagnostic health care
- Protein isolation and concentration for proteomics and drug discovery
- Spore and vegetative cell differentiation, for homeland security and public health
- Sample concentration and focusing, analytical chemistry, mass spectrometry for proteomics and drug discovery
- Medical diagnostics for diseases that produce anomalous cell morphology (cancer, sickle cell anemia, leukemia) that can be detected through iDEP
- Verification of biological decontamination efficacy for viable cell populations as contrasted to inactivated cells and denatured proteins.
- Separation of nanoparticles and nanotubes for materials synthesis applications and industrial settings

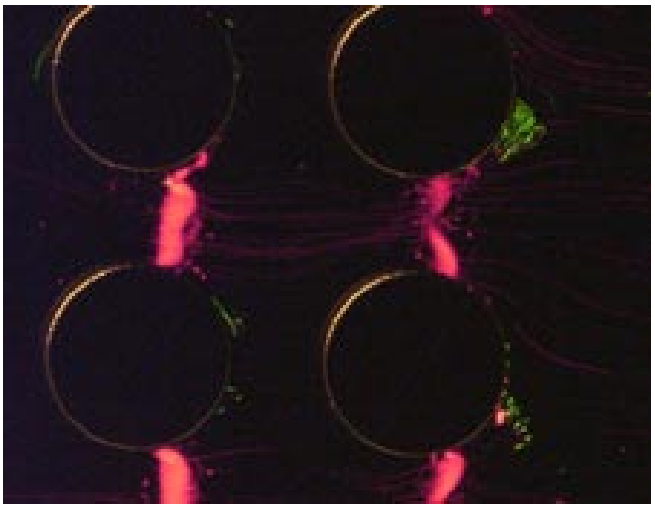

*Fig 2. Image of simultaneous concentration and separation of live E. coli (green) and1-µm polystyrene particles (pink). The circular insulating posts on 200-µm centers produce gradients in a 200 V/mm applied electric field. These gradients produce field-tuneable dielectrophoretic barriers that instantly collect and segregate particles.*

**Status**

Sandia scientists, B. Simmons, R. Davalos, A. Skulan, G. Fiechtner, G. McGraw, Y. Fintschenko and E. Cummings are actively pioneering iDEP devices, architectures, and theory for concentrating and separating of bacteria, spores, viruses, and other particles.

***Learn more at: http://www.ca.sandia.gov***

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