High Efficiency Capture of Multiple Bacterial Species by Microfluidic Dielectrophoresis Filter

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ABSTRACT

Fluid-Screen, Inc. presents a bacterial concentration and filtration method based on dielectrophoresis (DEP). DEP has been known to induce particle motion since the 1960's [1]. However, yields and reproducibility have consistently been low in practice, reducing the potential of DEP for practical applications [2,3]. Here we present a novel, patent-pending electrode design to induce high electric field gradients for universal bacterial capture. This design allows for rapid and efficient capture of diverse bacteria from aqueous solutions of varied composition. By using a spiral electrode and tuning the electric field to species-specific frequencies, we show caputre of over 99% of bacteria within seconds of gradient application. Our method of DEP induces responses in both the representative Gram-negative *Escherichi coli* and the Gram-positive *Enterococcus faecalis* bacteria. The filter unit can be used with any number of standard bacterial detection methods for rapid pathogen analysis.

Keywords: dielectrophoresis, microfluidics, bacteria, microelectronics, radio frequency

1 BACKGROUND

Dielectrophoresis (DEP) takes advtange of a particle's response to a non-uniform electric field [1]. DEP acts on non-charged particles by inducing a polarization gradient that generates manipulable motion. Depending on the frequency of the applied field, the particles' Clausius-Mossotti factor, and the conductivity of the medium, DEP can attract particles to or repel them from a surface.

Fluid-Screen has improved on previous electrode designs for DEP by creating a unique electrode that enables a steep concentration gradient. This design results in improved efficiency of bacterial capture, from about 70% [2,3] in the previous state of the art to over 99% currently.

2 RAPID BACTERIAL CAPTURE

Equilibrium repositioning of suspended bacteria can be seen within miliseconds of applying the external electric field to the DEP filter. As shown in Figure 1, captured bacteria collect onto the electrode and show nearly complete capture within seconds of applying of the electric field gradient.

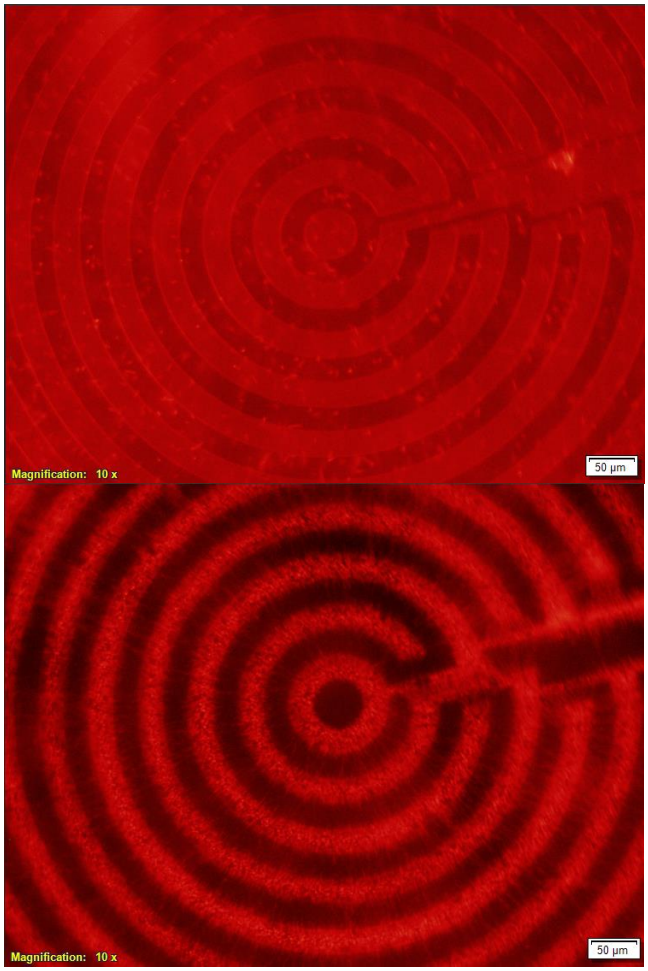

Figure 1: mCherry-tagged *E. coli* bacteria captured on the Fluid-Screen DEP epectrode. Photos show 10x magnification and were taken before (top) and 30 seconds after (bottom) application of the electric field.

3 CAPTURE OF MULTIPLE SPECIES

In addition to laboratory-standard *E. coli* bacteria, the Fluid-Screen DEP filter captures *Enterococcus faecalis* and *Bacillis subtilis* bacteria. Figure 2 below below shows an active DEP filter unit with Gram-positive *E. faecalis* bacteria expressing GFP.

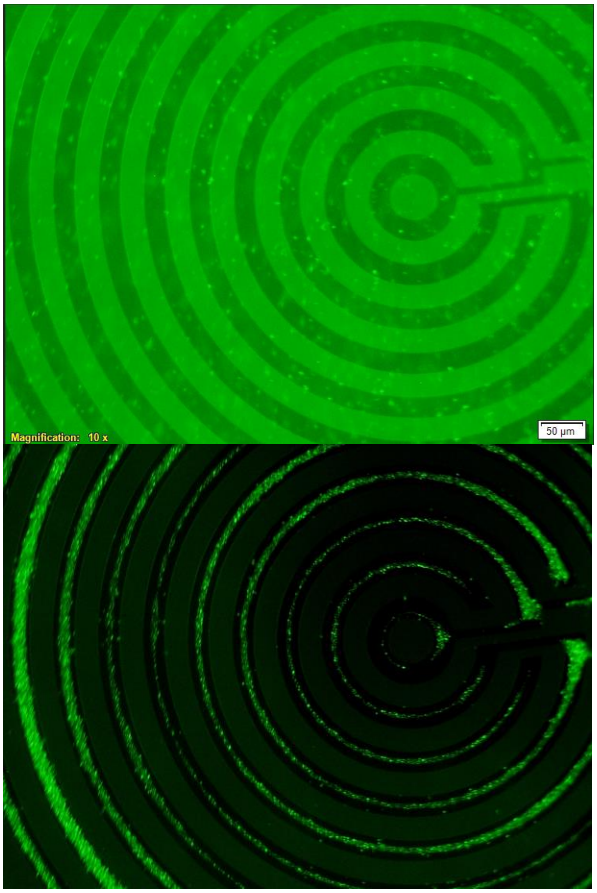

Figure 2: GFP-tagged *E. faecalis* bacteria captured on the Fluid-Screen DEP epectrode. Photos show 10x magnification and were taken before (top) and 30 seconds after (bottom) application of the electric field.

4 UNIVERSAL CAPTURE

The applied frequency of the DEP electrode can be tuned for capture of more than one species at once. Figure 3 shows simultaneous capture of *E. coli* (red) and *E. faecalis* (green). Universal capture of diverse bacteria allows for efficient detection of bacterial contamination in a variety of contexts, regardless of the identity of the contaminant.

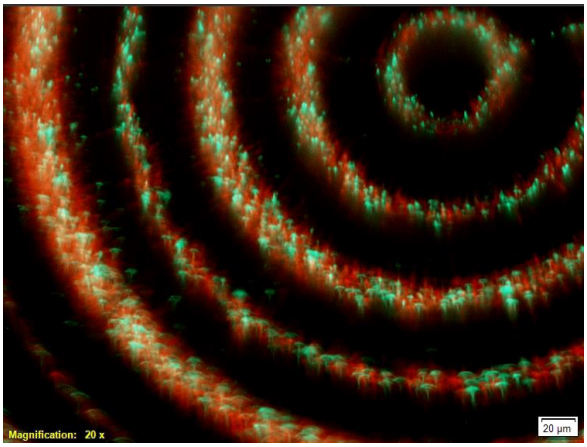

Figure 3: GFP-tagged *E. faecalis* (green) and mCherry-tagged *E. coli* (red) bacteria captured simultaneously on the Fluid-Screen DEP filter. Photo was taken at 20x magnification, 30 seconds after application of the electric field.

5 POTENTIAL APPLICATIONS

DEP can be used to either attract or repel bacteria from the electrode based on the particles' Clausius-Mossotti factor at different applied frequencies, allowing for universal capture and controlled release of bacteria. Fluid-Screen capitalizes on the improved dielectrophoretic filter design as a module to directly detect bacteria from water samples for applications as diverse as environmental regulatory reporting and point-of-care medical diganostics for acute infectious agents [4].

By processing fluid samples with the Fluid-Screen DEP filter, users can concentrate low levels of bacteria in aqueous samples for transfer to any number of bacterial detection or identification apparatuses. In this way, bacterial detection with Fluid-Screen bypasses time-consuming culture-based amplification methods. Finally, because DEP applies to other particles in addition to bacteria, the feature design can be optimized to manipulate other contaminants such as viruses for universal medical diagnostics.

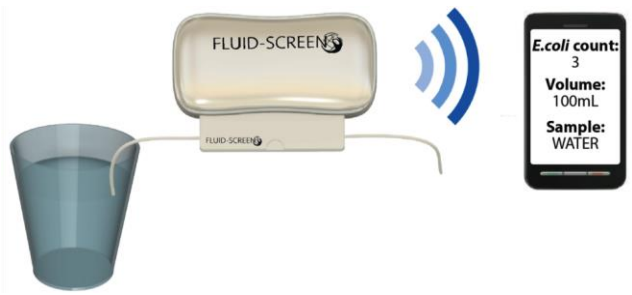

Figure 4: Design of optimized Fluid-Screen bacterial detector unit. A sterile disposable chip inserts into a handheld Bluetooth-enabled portable reader. Microfluidic pumps process the fluid sample. After 30 minutes, results are transmitted to a smartphone or other device.

6 CONCLUSIONS

Fluid-Screen, Inc. owns patented technology for bacterial capture and concentration that enables rapid, portable, and accurate universal pathogen detection in a variety of fluids. Pilot studies are underway for feasibility testing in multiple industries, and interested parties are encouraged to reach out to learn about opportunities for creating customized bacterial detectors to fit their specific pathogen testing needs. The first commercially available manufactured prototype bacterial capture devices will be available for purchase in late 2016.

REFERENCES

[1] H.A. Pohl, "Theoretical Aspects of Dielectrophoretic Deposition and Separation of Partiles." Journal of the Electrochemical Society 115(6), 155c-161c, 1968.

[2] J.W. Choi, S. Rosset, M. Niklaus, J.R. Adelman, H. Shea, and D. Psaltis. "3-Dimensional Electode Patterning Within a Microfluidic Channel Using Metal Ion Implantation." Journal of the Royal Society of Chemistry, 10, 738-788, 2010.

[3] R.S. Kuczenski, H.C. Chang, and A. Revzin. "Dielectrophoretic microfluidic device for the continuous sorting of Escherichi coli from Blood Cells." Biomicrofluidics 5, 032005:1-12, 2011.

[4] Weber, M; Lo, S.L.; Montanaro, O.; Hazael, F.; Yerino, C.D.; Reed, M.A. (2015) *Electronic Device for Pathogetn Detection*. US Patent 9120105.