

Discriminating between viable and non-viable bacteria with a field-effect transistor based on Nano-Channels

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Summary:

The Meta-Nano-Channel (MNC) bioFET performs specific, label-free, and real-time quantitative sensing of *E. coli* bacteria. The sensing is performed for 0.5 μL unprocessed samples of Lysogeny Broth spiked with *E. coli*. Furthermore, the device capacity to distinguish viable from non-viable bacteria is demonstrated

Keywords: *E. coli*, bioFET, specific sensing, bacteria viability

Background, Motivation and Objective

Bacterial infections remain a leading cause of global morbidity and mortality [1]. Among these, foodborne diseases—arising from contamination across production, distribution, and consumption supply chains—present a major public health burden, causing pathologies ranging from acute gastroenteritis to chronic malignancies. Low-cost, point-of-need biosensors enable rapid on-site bacterial detection; however, most platforms fail to distinguish viable from non-viable cells—a critical limitation in assessing active contamination risks. To address this, we present a Meta-Nano-Channel field-effect transistor (MNC FET) that mitigates molecular localized gating limitations through multiple parallel nano-channels, each coupling surface binding events to channel conductance with distinct efficiencies.

Description of the New Method or System

This study utilizes the MNC bioFET, a platform specifically engineered to overcome traditional interface challenges such as molecular gating and solution gating. The MNC bioFET's unique multi-gate architecture allows for the excitation of various conducting channels that differ in size, shape, and spatial orientation. This diversity ensures that each channel is uniquely coupled to the potential variations at the sensing area, which are often non-uniform due to the irregular distribution of molecular interactions. Furthermore, the device enables the switching of these channels between off and on states while preserving the electrochemical equilibrium of the

solution and surface-bound biomolecules—a critical factor for accurate real-time measurements. Functionalized with anti-*E. coli* antibodies, the platform operates directly in unpurified 0.5 μL droplets of Lysogeny Broth (LB, 197 mM ionic strength, 200 mg/L background protein) without sample pre-treatment or wash steps.

Results

The device achieves a limit of detection (LoD) of a single bacterium in LB with excellent sensitivity and linearity [2]. This study presents the first direct bioFET detection of bacteria in complex matrix, achieved without any preprocessing or washing steps. Assay specificity was validated using bacterial controls subjected to antibiotic treatment, metabolic inhibition, and thermal inactivation. Furthermore, the platform's capacity to assess bacterial viability was validated by comparing the MNC FET response of live *E. coli* against populations subjected to thermal denaturation, antibiotic exposure, or metabolic inhibition. The sensor reliably differentiates viable from non-viable cells with a single-cell resolution, offering a robust foundation for real-time viability diagnostics. Leveraging standard CMOS fabrication, the MNC FET platform enables scalable, cost-effective biochip production with high multiplexing density and excellent sensing performance. Manufacturing costs remain low due to relaxed, micron-scale design rules that allow accessible photolithography. Furthermore, the platform's ability to resolve real-time temporal variations in electrical signals introduces a dy-

namic analytical dimension beyond conventional amplitude-based readouts

million-deaths-annually--young-children-at-high-est-risk (2026).

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