Three-Dimensional Electroplated Nickel Interdigitated Electrode Microbiosensor for Rapid, Reagent-Free Electrical Detection of Cancer-Associated Environments

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Early disease diagnostics rely primarily on biochemical reactions requiring centralized laboratories or significant processing time. However, malignant transformation alters the electrical properties of biological environments due to metabolic reprogramming. Cancer cells exhibit the Warburg effect, characterized by elevated aerobic glycolysis and excessive lactate production, leading to altered ionic composition, pH imbalance, and modified ion transport. This study aims to determine whether metabolic changes associated with malignant transformation can be rapidly detected through changes in electrical resistance in biological environments. A cleanroom-fabricated microfluidic platform integrated with interdigitated electrodes was developed and transformed from a planar two-dimensional configuration into a three dimensional architecture through controlled nickel electroplating. The three-dimensional structure increased effective surface area by approximately 45%, enhancing electrode–electrolyte interaction and electrical sensitivity. Electrical resistance measurements were obtained from four sample groups: deionized water, phosphate-buffered saline, normal cell culture media, and cancer cell culture media. Measured resistances were approximately 19.19 ± 0.15 MO, 400.6 ± 1.1 kO, 311.3 ± 1.5 kO, and 332.5 ± 1.9 kO, respectively. Cancer-conditioned media consistently exhibited higher resistance than normal media. The sensor showed high repeatability with a linear response ($R^2 > 0.98$), with measurements acquired in less than 10 seconds without chemical reagents. These results demonstrate repeatable electrical differentiation between metabolically distinct biological environments and highlight the potential for rapid, reagent-free diagnostic applications.

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