NEXT-GENERATION BIOAEROSOL DETECTION & IDENTIFICATION

Next Generation Biosensor

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Defense against biological weapons of mass destruction remains a vulnerability for US armed forces. Current methods to identify adversarial use of biological warfare agents on the battlefield involve manual collection, transport, and complex laboratory-based sample processing and analysis. These "detect to treat" methods take too long for timely battlefield decision making. GTRI, in collaboration with commercial (Cardea Bio) and government (CCDC ARL) biotechnology organizations, has combined old and emerging technologies to develop, optimize, and test a promising new autonomous, stand-off, and near real-time pathogen identification capability. The four technologies we brought together are 1) Wet-walled bioaerosol collector; 2) fluidics sample filtering and concentration; 3) graphene-based field effect transistor; and 4) artificial antibody-like bioreceptor constructs with high thermal stability for needed transport, storage, and use in the field.

The GT-developed wet-walled cyclone pulls in 1,800 liter per minute of air and has demonstrated over 70% collection efficiency for nebulized 4.8 µm diameter particles. This size is the median diameter of the hazardous human respiratory particle size range of 0.5 to 10 µm. Using a novel recirculation design, the device consumes less than 50- mL of collection buffer per collection run. Collection times as little as 2 minutes in an environment of 1x104 particles per liter of air can collect sufficient sample material for downstream processing and identification. The GT-developed fluidics filtering and concentration module has demonstrated 80% efficiency in retaining surrogate E. coli bacteria while excluding non-target sized particles greater than 10 µm. Concentration capability of 1.5X – 2X has been demonstrated with surrogate influenza virus while reducing sample volumes from 10 mL to 250 µL. The ARL-developed antibody-like Protein Catalyzed Capture (PCC) molecules demonstrate high thermal stability, target sensitivity and specificity, and rapid, low cost manufacturing. These bioreceptors are conjugated to the gate terminal of Cardea Bio's graphene-based field effect transistor (gFET) for a demonstrated target detection sensitivity of only 1,500 pfu of SARS-CoV-2 virus. Specificity has also been demonstrated by the competing presence of an overabundance of rhinovirus and influenza virus. The 4-channel gFET design is able to incorporate many more parallel gate terminals for high multiplexing detection capability along with channels to control for false negative and false positive results.

Time to identification by the gFET has been shown to be less than 15 minutes following 7 minutes of sample filtering/concentration and 2 minutes of bioaerosol collection time for a total sample-to-result time of less than 30 minutes. The process of integrating these technologies into a single device prototype has begun and a path forward to achieve the size, weight, and power (SWaP) necessary to fly this device as a package on a UAV have been identified. UAV-deployment would allow for airborne collection via directed flight into a suspected biological plume or hovering (rotor-wash) over a suspected biological material deposition. Alternative use as a stand-alone perimeter sensor are also feasible. The final device would would have replaceable cartridges for the filtering module, gFET sensor, and collection buffer replenishment for rapid turn-around between mission runs.

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