QUANTUM TECHNOLOGIES, METAMATERIALS, AND THE FUTURE OF CB SENSING

Quantum Multiplexed Molecular Nanoscale Sensors

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Quantum-enabled detection of biological threats is an emerging area, promising detectors smaller than a stick of gum, weighing ounces, and consuming mW of power. Battelle is pursuing Silicon Carbide (SiC) quantum integrated photonics sensors as they are mass producible, reusable, and inherently ruggedized for field use. Unlike other sensor modalities, our technology holds the promise of extreme sensitivity, enabling rapid and label free detection of even minute quantities of biothreat agents. We have shown materials compatibility from photonics substrates through biological-based threat agent capture tags. SiC's ability to function as both a photonic and electronic substrate eliminates fiber attach and the need for lasers and optical detectors as results are read electronically. Designs are inherently ruggedized; they are completely solid state and attached to a simple PCB board. SiC provides unique advantages for biodetection. Although intrinsic (or label-free) detection technology has been shown in the literature, signals are extremely low and designs are complex. Our designs are capable of label-free threat agent detection because of the high chip quantum efficiency (QE), fast response times, and frequency selectivity of our sensors. We are exploring known improvements to our already >80% QE sensors to enhance signal recognition sensitivity in the presence of even minute quantities of threat agents. While fluorescence detection produces a higher signal, it requires more complex manufacturing than our label-free design chips. We have models of both our labeled and label free sensor designs and are actively producing prototypes, undergoing laboratory testing, and estimating performance. We have multiple capture technologies compatible with the SiC stack, including DNA, aptamer, and enzyme-based approaches. SiC is doped to create 80-100% QE photodetectors at UV wavelengths, making it viable for label-free detection. In addition, we have an abundance of photoluminescent color centers to choose from that are compatible with excitation/emission wavelengths common to biodetection. Adjustments to material stacks on the SiC allow us to tune photodetection into the visible and near IR wavelengths. Silicon can be epitaxially grown on SiC, and provides a 532nm (green) photoabsorber. This forms the basis of our tagged detection stack. The patternability of SiC allows for sputtering of thinfilm metals (e.g., nickel, gold, tungsten), creating transparent binding surfaces amenable to biological materials and capture tag attachment. Conjugation of tags to chips is through proven methods (e.g., histidine binding to nickel). Testing is actively evaluating both label free and de-quenching approaches to measuring binding, working toward a pure label-free multiplexed approach. Our SiC optoelectronic design embeds source, detector, binding sites, and control circuitry onto one chip for both label-free and fluorescence detection without the need for complex equipment. Detection of threat agents is indicated via electrical changes using a fieldable PCB system with visual or other sensory readout. This provides a simple field-portable system able to be rapidly deployed to even semi-permissive environments. Reducing the complexity and size of detection technology, while increasing sensitivity, enables operators to simplify workflows and decrease time from sampling to result.