AlGaN/GaN BioFET Sensors for Detection of Microcystin-LR and Other Toxins

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Cyanobacteria (more commonly known as blue-green algae) have become a significant problem in environmental health and water safety. Algal blooms in particular, have caused a great deal of concern due to the increased production of a variety of toxins such as microcystins, cylindrospermopsins, and saxitoxins. Amongst these, microcystin-LR (MC-LR) has been identified as the most toxin and the most concerning. Conventionally, methods like ELISA, PCR, and LC-MS are used to evaluate toxin levels in lake water samples, but these can be costly, time consuming, and have a limited dynamic range.

To combat this problem and further bolster the information provided by the above methods, we present the use of a bio-FET based in an AlGaN/GaN heterojunction semiconductor platform. Each chip has the ability to detect the presence of Microcystin-LR and other variants depending on how the device is functionalized. In this work, we focus primarily on MC-LR detection due to the severity of its impact. Each chip is approximately 2 cm x 2 cm and operates by exploiting the intrinsic charge attached to each Microcystin. This charge, utilizing the field affect, deflects or attracts charge flowing through the sensor and results in a change in electrical current (often denoted as ΔI_{ds}). This ΔI_{ds} varies depending on the concentration of microcystin in the water sample and allows for the quantification of the toxin. In laboratory conditions, ΔI_{ds} has been shown to give a 60-90% increase in current levels.

Surface functionalization is performed using a two-step chemistry. In solution, EDC-NHS chemistry is combined with anti-MC-LR (in this case, clone MC10E7) to form a semi-stable compound with the antibody linked. This is then combined with the surface of the device itself (sensing area) previously modified with silane chemistry (APTES) to allow for a fully functionalized surface. Folowing surface functionalization is to complete a base level signal measurement prior to the addition of analyte (MC-LR). MC-LR toxin is suspended in DI water for quantitative analysis of toxin concentrations throughout a dynamic range of pM to µM. For reference, the EPA health advisory standards, which sets an upper limit at 0.3 - 1.6 µg/L for children and adults respectively[1].

[1] U.S. Environmental Protection Agency Office of Water, Drinking Water Health Advisory for the Cyanobacterial Microcystin Toxins 820R15100, June 2015.

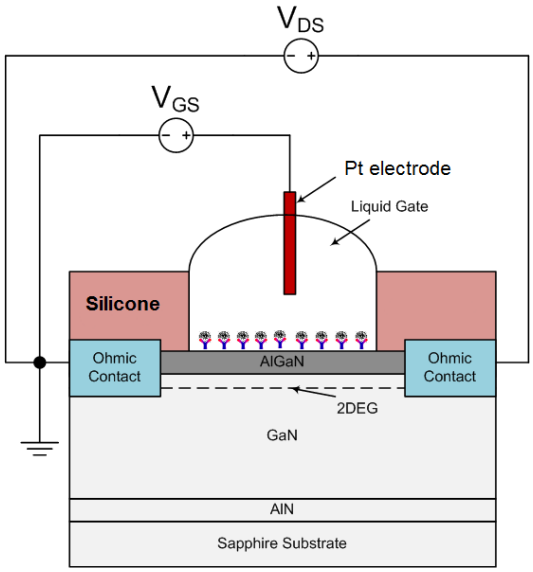

Figure 1: AlGaN/GaN Biosensor illustration and layout showing 2DEG sensing channel.

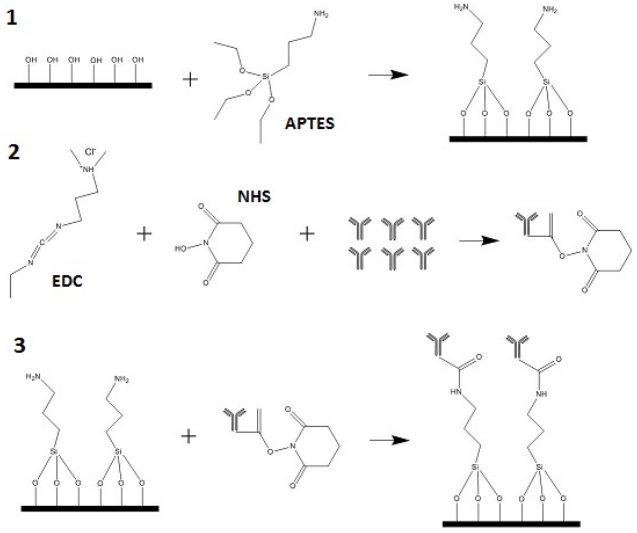

Figure 2: Surface modification protocol showing two step procedure (lines 1 and 2) and their combination to create the fully functionalized surface (line 3)

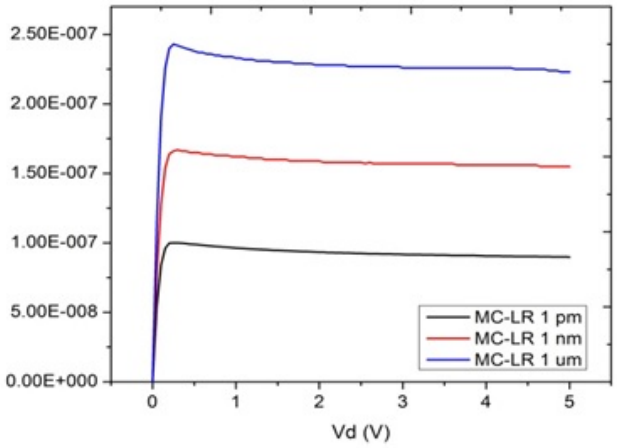

Figure 3: Sensing results for different concentrations of MC-LR in DI water solution showing partial dynamic range for the AlGaN/GaN biosensor for toxin detection.

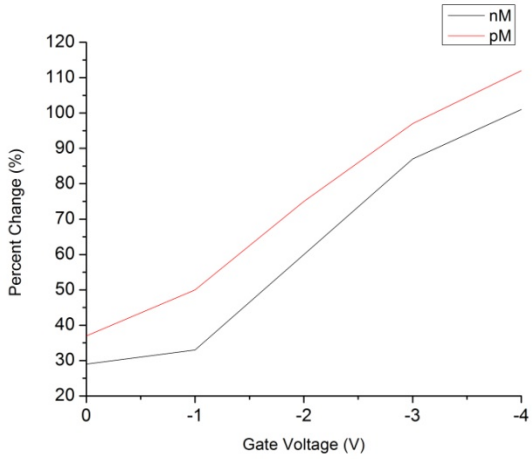

Figure 4: Percentage changes in sensing current (source-drain current) at different gate voltages for two conditions (pM and nM MC-LR concentration levels) illustrating higher sensitivity as VG approaches to the sub-threshold regime.