Student Paper

Smart Detection of MIG Using AlGaN/GaN High Electron Mobility Transistors

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In this research a minimally invasive technique is presented for label-free detection of a key protein in allograft rejection (CXCL9 / MIG) using packaged AlGaN/GaN High Electron Mobility Transistors (HEMT) devices. This is an alternative to currently existing invasive techniques, where biopsies of the transplanted organ are typically used to confirm rejection. The use of HEMT devices for various biosensor applications has been studied and proven to be strong candidates for such applications due to its chemical and thermal stability[1]. Exploiting characteristics of commercially available, packaged HEMT devices, and utilizing the presence of a 2DEG (two-dimensional electron gas) at the hetero-junction interface, a floating gate configuration can be used to chemically modify the gate surface of the device with proper thiol chemistry. While previous uses of AlGaN/GaN unpackaged devices for similar biosensors based on floating gate configuration have been shown to be successful, the use of biosensors of this type are difficult to realize without the use of sophisticated equipment (due to the small size of the physical device, and miniscule quantities of solutions needed).

Monokine induced by interferon gamma (CXCL9 / MIG) is a critical biological marker for determination of transplant rejection. CXCL9 is formally a cytokine belonging to the CXC family of chemokines. Secretions of MIG produced by macrophages result in chemotaxis of T lymphocytes via the CXCR3 chemokine receptor[2]. These secretions have been shown to be existent in allografts and result in destruction of the transplanted organ by the body's own immune system.[3] Early detection of this key biomarker is significant and can result in quicker/appropriate treatment.

To achieve detection, a simple circuit is constructed to observe real-time amperometric response. Floating gate configuration is utilized and self-assembled monolayers (SAM) are formed at the gate electrode to allow immobilization and reliable cross-linking (via dithiobis succinimidyl propionate [DSP]) between the surface of the gate electrode and the antibody (Anti-MIG) (Fig.1). The negatively charged antibody upon immobilization yields an increase in drain current as additional electrons are induced into the channel. Upon introduction of the target analyte (MIG), we observe a decrease in drain current as the positive charges of the MIG are paired with the electrons gained from the previous step (Fig. 2). Furthermore, usage of a depletion mode device ensures that any changes in drain current are strictly based on the effect of successful conjugation of the protein and the antibody.

Before any chemical modifications, DC I-V characteristics of the HEMT devices have been observed by means of a DC probe station in conjunction with IC-CAP software. Floating gate DC current of a clean device operating in the saturation region is observed at 66.89 mA. The construction of SAM layer yields a .08 mA rise in current which gives indication that electrons were successfully induced into the channel (Fig. 3). Introduction of 2 μL of MIG in a 0.1M phosphate buffer environment yields a rapid response with a decrease in steady state current after 30 seconds. While such a response is not as prominent as unpackaged HEMT devices, this demonstrates that such a biosensor in the packaged form can be

constructed, utilized while exhibiting strong potential to create more convenient biosensors that can be easily prepared. Further testing needs to be conducted to determine other key issues; susch as repeatability, effect on threshold voltage, effect of VDS magnitude, and effect on current with varying concentrations of target solutions.

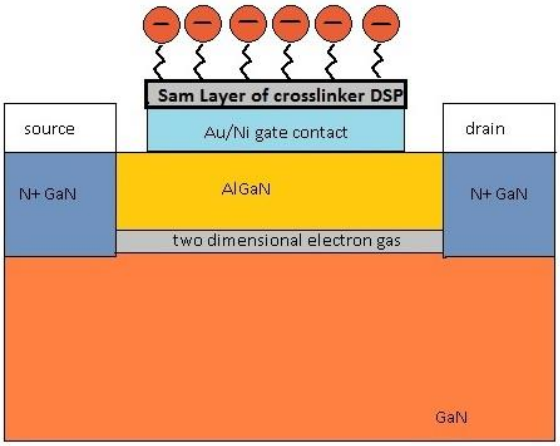

Fig. 1: Visualization of the device when it is ready to use. The addition of Anti-MIG antibody induces additional negative charges to the channel which results in an increase in drain current.

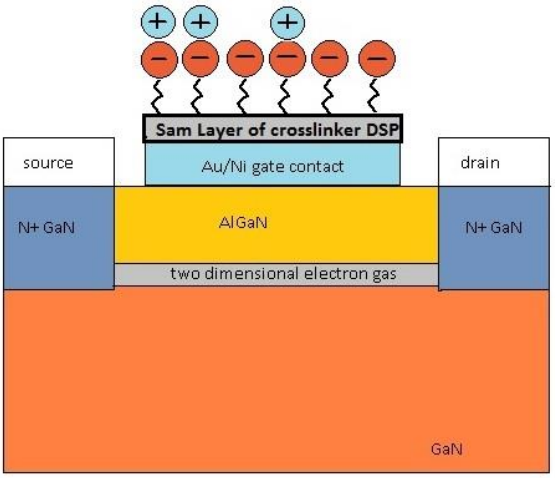

Fig. 2: Visualization of the device once conjugation between protein and antibody has taken place. The positive charges of the MIG introduced to the channel pair with electrons gained in the previous step.

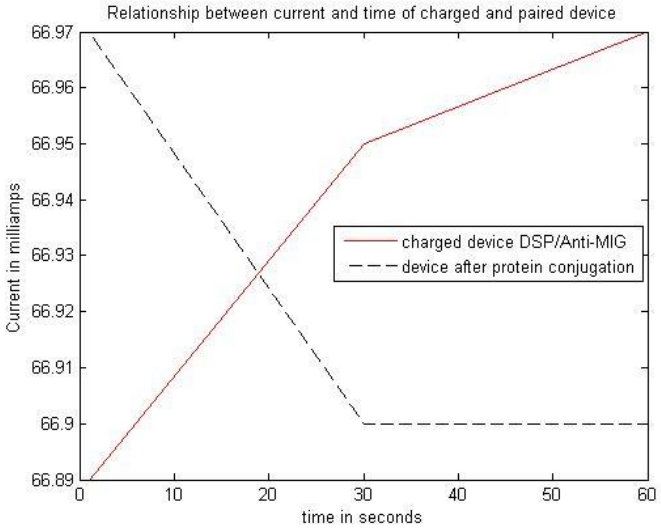

Fig. 3: Behavior of Drain Current ID before and after protein conjugation. The changes in current can be compared to clean device steady state current of 66.89mA.

References

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