Micro-scale High Electron Mobility AlGaN/GaN Pressure Sensor for Venus Exploration

The goal of this research is to investigate the high-temperature response of the 2-dimensional electron gas (2DEG) that occurs at the interface of gallium nitride (GaN) heterostructures upon mechanical deformation. These studies will enable a new platform for sensing mechanical strain (e.g. pressure) within extreme harsh environments. Sensing within hostile environments can further the understanding of space environments and advance space technology. NASA is particularly interested in this technology for proposed missions to Venus, where the atmosphere is 480°C, 90 bar and largely CO₂, to understand the planet’s geophysics and meteorology. The proposed work will contribute to investigations of planetary atmospheric profiles and geophysical studies of seismic activity. Since silicon fails electrically at temperatures above 150°C, currently available sensors require extensive cooling systems and radiation shielding to prevent degradation of the electrical properties during operation. Additionally, GaN is piezoelectric and when interfaced with AlGaN and other III-nitride alloys the mismatch in crystal lattice constants creates a spontaneous polarization that attracts a layer of mobile electrons. This is known as the 2DEG effect, which can be exploited in the design of power electronics, high frequency electronics and sensors. An AlGaN/GaN high electron mobility micro-pressure sensor has been designed, fabricated and tested leveraging the 2DEG. The design of the sensor isolates the strain sensitive 2DEG to a ring around the edge of a 3 μm GaN membrane over a reference pressure cavity. This device was fabricated with typical micro-manufacturing techniques and the experimental results will be presented in this talk. A scanning electron microscope image (SEM) of the top surface of the device is shown in Figure 1a. We detect the strain through a transistor-based measurement of the 2DEG. Current-voltage measurements at different gate voltages while varying pressure between 0 and 1 bar. The drain current increases directly with pressure. Additionally, Figure 1b shows the percentage change in current increase with larger reverse gate bias (VG) and forward drain bias (VD). The increase in percent change of current due to the reverse bias was expected because the overall sheet carrier concentration is reduced, however the piezoelectric sensitivity is largely unchanged. Furthermore, the sensitivity also improves with higher drain voltages, which will be discussed at this talk.

Figure 1: (a) SEM image of ring shaped GaN pressure sensor. (b) Examination of pressure response of AlGaN/GaN high electron mobility pressure sensor from 0 to 1 bar, plotting percent change in drain current as a function of gate voltage between 0 and 1 bar.