High electron mobility transistors (HEMTs) made from III-V materials (e.g., AlN, GaN and InN) are capable of operating in extreme high temperature (up to 1000°C), making them promising candidates for the realization of sensing and electronic devices that can survive and operate within harsh environments. Such technology can be used as instrumentation to collect critical data within in extreme environments such as the subsurface (oil and gas well bores), deep space and combustion engines. HEMTs leverage a two-dimensional-electron gas (2DEG), which is created by the spontaneous and piezoelectric polarization in these hetero-structured materials. The amount of charge in the 2DEG is changed by the application of an external strain, which leads to a shift in the current-voltage (I-V) characteristic of the HEMT, thus allowing the applied strain level to be detected. This fundamental concept can be translated to applications in pressure, force, acceleration and torque sensing applications. In addition, the ion sensitivity of the HEMT surface can be used to create chemical and biological sensors.

This project focuses on the design, fabrication, testing and evaluation of HEMT-based sensors and electronics for oil and gas exploration applications. In this project, thermo-electro-mechanical simulation models of HEMTs are used to numerically predict their strain response and are leveraged for sensor design. The effect of the III-V material stack, layer thicknesses and strain configuration are being studied for optimizing strain sensitivity. In addition, we are fabricating released micro-cantilevers and thermal actuators with in-built HEMTs to experimentally obtain strain sensitivity from room temperature to 600°C. The experimental results will be used to validate and improve the simulation model. This fundamental work will lay the foundation for designing a variety of strain-sensitive, HEMT-based MEMS sensors in harsh environments using III-V materials. Ultimately, HEMT-based sensors can be integrated with interface electronics and energy harvesters to create autonomous sensing systems for prohibitive environments (high temperature, radiation-rich, chemically corrosive).