Specific HEMTs for deep cryogenic high-impedance and low-frequency readout electronics

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For decades, high-impedance and low-frequency readout electronics with the lowest noise level is based on silicon JFETs (Junction Field-Effect Transistors) with an equivalent input voltage noise of about 1 nV/sqrt(Hz) at 1 kHz. But their operating temperature is limited to be higher than 100 K due to their intrinsic structure. It is well known that HEMTs (High Electron Mobility Transistors) are intrinsically available for very low temperature operation, but conventional HEMTs suffer high gate leakage current and large excess channel low-frequency noise under cryogenic condition. In order to overcome these two major issues, conventional HEMTs have been extensively investigated at 4.2 K as a function of the cooling condition. The correlation between the band diagram at a given working point and gate leakage current or excess channel low-frequency noise has been found out and this has allowed us to devise a new transistor structure. Specific AlGaAs/GaAs HEMTs have then been fabricated. At 4.2 K, our HEMTs can attain a noise level lower than 1 nV/sqrt(Hz) at 1 kHz with an input gate-source capacitance of less than 30 pF and a power consumption of 0.05 mW and their gate leakage current can be limited below 0.1 pA. This result shows that our specific HEMTs may be a suitable transistor for future ultra-low noise deep cryogenic high-impedance and low-frequency readout electronics.