**Experimental Investigation of pHEMT at 4.2K : Fabrication and Characterization**

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In this paper, we will present our recent experimental investigation of the pseudomorphic HEMT at 4.2K. Our previous works on the pHEMT at 4.2K have shown that with a large gate surface of 4µm by 4000µm, the equivalent input 1/f voltage noise can be less than 1nV/√Hz when the frequency is higher than 5.5 kHz. However, the large gate surface is translated into a high input capacitance, which induces a low intrinsic cutoff frequency $f_c$ and thus limits device's applicability in various circuits. To decrease this capacitance, HEMTs with a smaller gate surface of 1µm by 4000µm have then been realized on (Al,In)GaAs/GaAs heterostructures with a InGaAs well of 17nm and a AlGaAs spacer layer of 4nm.

All DC and noise parameters have been characterized at 4.2K. As usual, neither collapse nor kink effect has been detected in the current-voltage characteristics. Drain-current $I_{ds}$ variation from micro to several tens of milli-Amperes can be obtained with a gate-bias variation of about a quarter volt(see Fig.1), and the gate leakage current $I_{gs}$ is limited less than 0.5pA under all bias conditions. The low gate leakage current in this device can then ensure a high input impedance and the shot noise can be less than 0.3fA/√Hz. Under a fixed drain bias $V_{ds}$ of 0.3V, high transconductances $g_m$ ranging from 480mS to 7mS with corresponding $I_{ds}$ of 39mA to 0.1mA have been achieved (see Fig.2). It is interesting to note that by biasing the gate voltage $V_{gs}$ from 0 to -0.4V, the channel resistance (with $V_{ds}$=4mV) of this device can increase more than $10^9$ times from 0.8Ω to 6GΩ. Depending on $V_{gs}$, the measured input capacitance varies between 13 and 5pF. Taking into account of the above high $g_m$ values, $f_c$ can reach 6GHz.

For the noise measurement, a 4.2K preamplifier is made with the HEMT to be tested. The voltage gain of the device can thus be measured *in-situ* for each noise spectrum acquisition. Then, the value of the voltage gain is used to deduce the equivalent input voltage noise $e_n$. As an example, with $V_{ds}$=0.3V and $I_{ds}$=0.5mA, the corresponding measured voltage gain is 11.5. The spectrum of $e_n$ (see Fig.3) shows that $e_n$ down to 1.3nV/√Hz can be reached at 100kHz. As the 1/f noise frequency corner in this HEMT can be much higher than 100kHz, its input noise $e_n$ should then be lower than 1nV/√Hz when the working frequency is higher than 200kHz.

Finally, the investigation of the gate bias shift with the thermal cycle and the $I_{ds}$-$V_{ds}$ characteristics will be provided; and a systematic study of the 1/f noise as the function of $V_{ds}$ and $I_{ds}$ will be reported in detail. So far, this HEMT should be a suitable device for the switch application owing to its extremely large variation of channel resistance. This device should also be used in the low-power preamplifier with a voltage noise level lower than 1nV/√Hz for operating frequencies higher than 200kHz, and a shot noise level less than 0.3fA/√Hz.

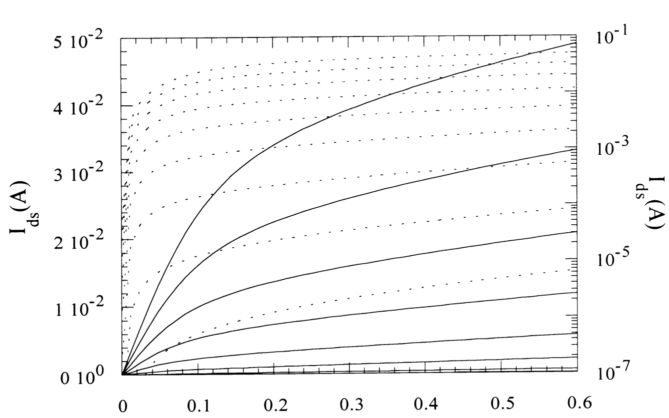


Fig.1 $I_{ds}$-$V_{ds}$ curves at 4.2K as a function of the gate bias, from top to bottom: $V_{gs}$=0V and the steps of –0.03V. $I_{ds}$ are plotted by full lines in decimal scale, and by dashed lines in logarithmic scale for the illustration of $I_{ds}$ under sub-milli Amperes regimes.

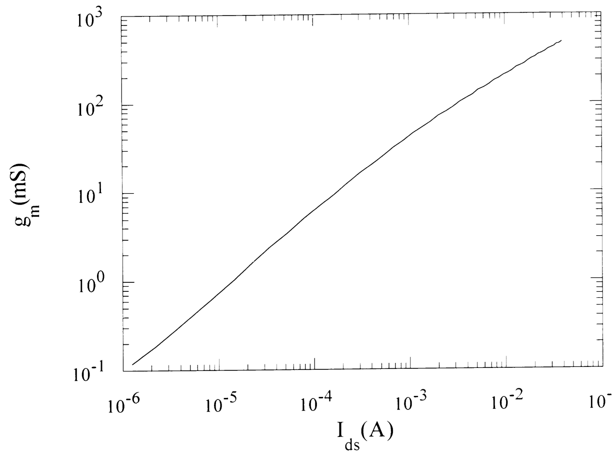


Fig.2 Transconductance $g_m$ as a function of $I_{ds}$ with a fixed drain bias $V_{ds}$ of 0.3V.

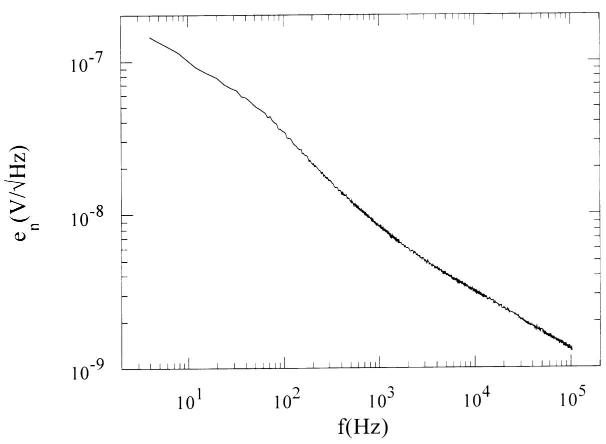


Fig.3 Equivalent input voltage noise $e_n$ spectrum at 4.2K, with $V_{ds}$=0.3V and $I_{ds}$=0.5mA.