RF Noise Performance of Low Power InAs/AlSb HFETs

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The combination of electron mobility ~ 20,000 cm^2/Vs and sheet charge > 3.5×10^{12} cm^{-2} make the InAs/AlSb HFET an excellent candidate for ultra-low power MMIC technology targeted specifically for low-noise applications. In the present work, we report on the complete RF noise characteristics of a 0.25 μm gate-length InAs/AlSb HFET exhibiting a minimum noise figure F_{min} less than 1 dB from 2–25 GHz. The only previously published RF noise measurements in the InAs/AlSb material system reported F_{min} in excess of 1 dB at all frequencies above 2 GHz for a 0.1-μm gate-length HFET.[1]

The HFET was grown using MBE on a semi-insulating GaAs substrate, with a 1 μm AlSb metamorphic buffer, shown in Fig. 1. The devices were fabricated in a conventional mesa isolated HFET process, with 0.25-μm gates defined by electron-beam lithography. The DC HFET characteristics in Fig. 2 show very low gate leakage, g_m > 1.7 S/mm, and I_{dss} > 1 A/mm at V_{ds} = 0.4 V. Note that the gate leakage current increases by two orders of magnitude when V_{ds} increases from 0.1 V to 0.4 V, due to impact generated holes being collected by the negatively biased gate. Nevertheless, these results represent, to our knowledge, the lowest gate leakage in any HFET reported in the InAs/AlSb material system. Low leakage is an important requirement for low-noise applications and has likely limited the noise performance of the previous InAs/AlSb HFET from Boos,[1] where F_{min} was 1 dB at 2 GHz and increased to 2 dB at 18 GHz. According to Agilent, a 1dB reduction in the receiver F_{min} gives the same improvement as increasing the antenna diameter by 40% or doubling the transmitter power.[2]

Full noise parameter measurements were conducted on our HFET over a broad range of bias conditions from 2–25 GHz. The minimum noise figure and associated gain G_{assoc} (Fig. 3) are 1.0 dB and 11 dB, at 25 GHz, comparable to a state-of-the-art GaAs PHEMT with similar gate length.[3] The noise figure represents the best published value in InAs/AlSb material system. A key advantage of the InAs/AlSb HFET is that it offers comparable performance at a drain voltage bias of only 0.2 V vs. 2.0 V for the GaAs PHEMT; a 90% reduction in dissipated power. The noise-limiting factor at 2 GHz is shot noise from the gate leakage current. The contour plots of Fig. 4 show that at 2 GHz, despite the lower g_m, the lowest F_{min} = 0.35 dB is obtained at a drain bias of V_{ds} = 0.1 V, where I_g is –0.8 μA. At 25 GHz, however, the contours of Fig. 5 show the optimal bias is V_{ds} = 0.2 V, where the measured F_{min} was 1.0 dB with I_g of –3.4 μA. The correlation of noise figure to gate leakage at low frequency is consistent with theory due to the constant spectral density of the gate leakage-induced shot noise[3]. As frequency increases, thermal noise sources dominate, making F_{min} less correlated to gate leakage, and the HFET can be operated at higher drain bias, where the gain is higher. Similarly, at higher drain bias V_{ds} = 0.4 V, noise attributable to the impact-generation of carriers adds significantly to F_{min} at low frequencies. This impact-ionization noise decreases rapidly with increasing frequency.

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[1] Boos, *et al.*, in *Proc. IPRM 1997*, pp. 193-196.
[2] Fundamentals of RF and Microwave Noise Figure Measurements, Agilent App. Note 57-1
[3] Shin, *et al.*, *IEEE Trans. Electron Devices*, vol. 44, pp. 1883-1887, Nov. 1997.

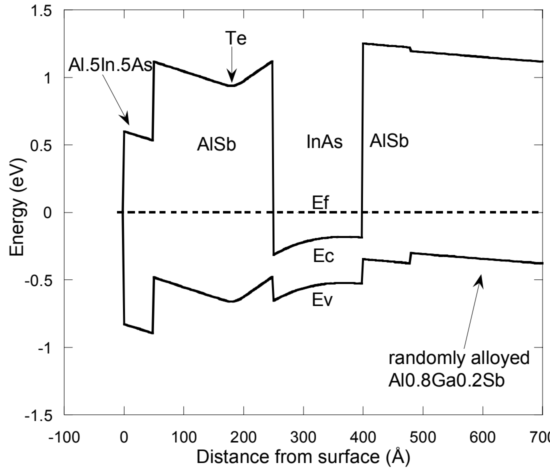

Fig. 1. The Energy band diagram of the InAs/AlSb HFET. Te δ-doping provides charge to the channel.

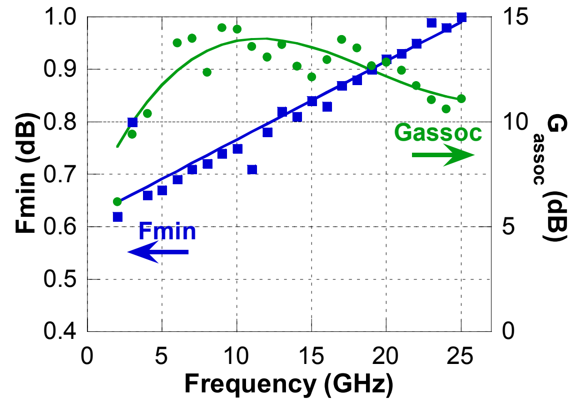

Fig. 3. The noise measurements indicate low minimum noise figure and good associated gain at a drain bias of only 0.2V. The 0.62 dB noise figure at 2 GHz is limited by shot noise from gate leakage, and thermal noise adds to F_{min} as frequency increases.

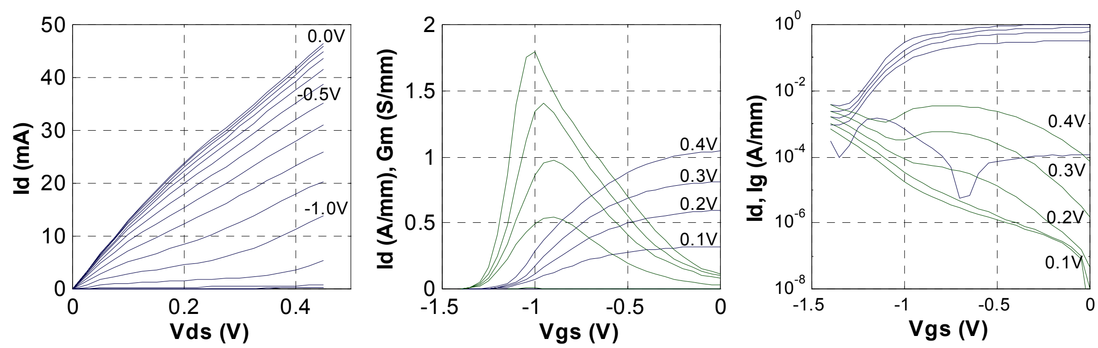

Fig. 2. The DC characteristics show high DC g_m and $I_{d,ss}$. The sub-threshold plot (right) indicates low gate leakage for this technology, with impact-generated holes causing a large increase in the gate leakage current with increasing drain voltage.

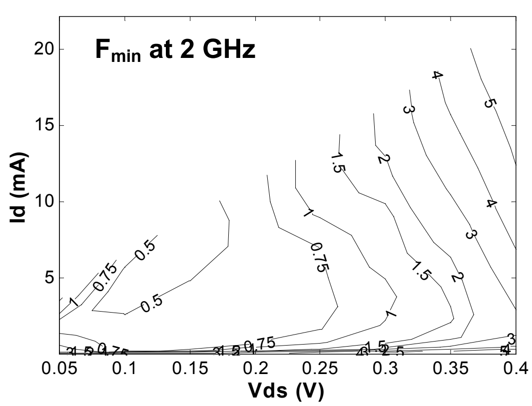

Fig. 4. The F_{min} contour plot at 2 GHz shows a minimum at V_{ds} = 0.1-0.15V. The low optimum bias voltage is due to the gate leakage induced shot noise. Impact generation adds to the noise figure at 0.4V drain bias at this frequency.

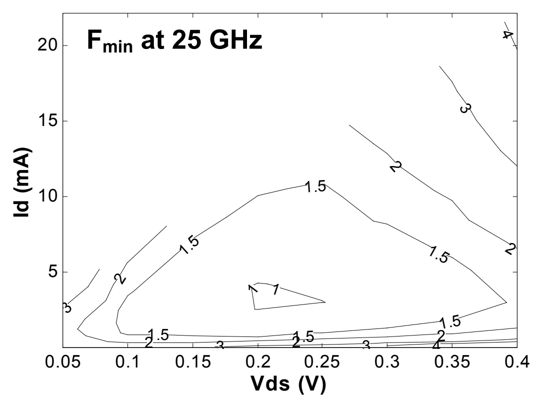

Fig. 5. The F_{min} contour plot at 25 GHz shows F_{min} minimized at V_{ds} =0.2V. As frequency increases, the contribution of thermal noise to the noise figure moves the optimum bias to larger drain bias, where the gain is higher.