High mobility p-channel HFETs using strained Sb-based materials


Antimonide-based p-channel HFETs with a 0.25 μm gate length have been fabricated with an InAlSb/AlGaSb barrier and a strained In₀.₄₁Ga₀.₅₉Sb quantum well channel. The modulation-doped material exhibits a Hall mobility of 1020 cm²/Vs and a sheet density of 1.6 x 10¹² cm⁻². The devices have a maximum DC transconductance of 133 mS/mm and an fT and fmax of 15 and 27 GHz, respectively. These values are the highest reported to date for this material system.

Recently, there has been considerable interest in the potential of III-V FET materials for advanced logic applications which could significantly enhance digital circuit functionality and extend Moore’s Law [1]. Sb-based HFETs are attractive candidates for these high-performance logic circuits owing to their high-speed and low-power potential. Sb-based complementary circuits needed for this technology will require p-channel HFETs with high hole mobility. For this purpose, the In₀.₄₁Ga₀.₅₉Sb alloy system is attractive since the binary endpoints have the highest bulk hole mobilities of any III-V compound and a significant valence band barrier to enable quantum confinement [2, 3]. This potential can be enhanced by using strain to produce advantageous band splitting as has been exploited to great effect in Si and SiGe pMOSFETs. As work in this direction, we report on the fabrication and characteristics of Sb-based HFETs with an InAlSb/AlGaSb barrier, a strained, high-mobility, p-type In₀.₄₁Ga₀.₅₉Sb quantum well channel, and no highly-reactive AlSb material within the structure.

The Sb-based HFET material was grown by molecular beam epitaxy on a semi-insulating (100) GaAs substrate. A 1.5 μm undoped Al₀.₇Ga₀.₃Sb buffer layer was used to accommodate the 8% lattice mismatch. A cross-section of the device, showing the material layer design, is given in Fig. 1. Details of the growth procedures will be described elsewhere [4]. Because the In₀.₄₁Ga₀.₅₉Sb channel layer is grown epitaxially on the relaxed AlGaSb buffer, it will be in a state of biaxial compressive strain. For this particular composition, the strain grown epitaxially on the relaxed AlGaSb buffer, it will be in a state of biaxial compressive strain. A TiW/Pt/Au Schottky-gate was then formed using PMMA e-beam lithography and lift-off techniques. The selective etch properties of the InAlSb barrier enabled the use of a gate recessetch through the InAs cap layer prior to gate metal definition. After a Ct/Au overlay metal pattern was formed, device isolation was achieved by wet chemical etching. With this etch, a gate air bridge was formed which extends from the channel to the gate bonding pad.

The drain characteristics obtained for a HFET with a 0.25 μm gate length are shown in Fig. 3. The low-field source-drain resistance at VGS = −0.4 V is 7.6 Ωmm. The contact resistance was estimated to be 2 Ωmm using TLM measurements. The dependence of the transconductance on the gate voltage is shown in Fig. 4. At VDS = −2.5 V, a maximum transconductance of 133 mS/mm is observed at VGS = −0.05 V which is the highest reported for this material system. The gate-source diode I-V characteristic exhibits good rectification and a gate current of 2.5 A/cm² at a gate-source bias of 1 V. The use of an MIS approach to reduce the gate current is currently under investigation. A threshold voltage of 0.14 V was measured at VDS = −2 V. The subthreshold slopes at VDS = −0.05 V and −2 V were 114 and 170 mV/dec, respectively. These values are elevated owing to a source-drain leakage current that is also currently under investigation.

Fig. 1 Starting MBE material structure

![Image](image1)

Fig. 2 p-Channel HFET energy-band diagram

![Image](image2)

![Image](image3)
Fig. 4 HFET transconductance against gate voltage at $V_{DS} = -2.5$ V

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References


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