HIGH FIELD DRIFT VELOCITY OF 2DEG IN Si / SiGe HETEROSTRUCTURES AS DETERMINED BY MAGNETORESISTANCE TECHNIQUES

S. MADHAVI AND V. VENKATARAMAN
Department of Physics, Indian Institute of Science, Bangalore - 560 012, India.
Fax : 080-3341683, email : maddy@physics.iisc.ernet.in
C.W.LIU AND J.C. STURM
Department of Electrical Engineering, Princeton University, Princeton, NJ, 08544, USA
email : sturm@tiger.princeton.edu

Recently Si / SiGe n- MODFETs with transconductances exceeding 300 mS/mm at 300K and 600 mS/mm at 77K have been demonstrated [1,2] by many groups. Accurate modelling of these short channel devices (L <1μm) requires knowledge of hot electron drift velocities as a function of the electric field . Many theoretical calculations have been done to determine these dependences [3,4]. Experimental data for 300K and 77K have been reported by Ismail et al [5]. We present here the first experimental determination of the high field drift velocity of 2DEG in Si/SiGe n-type modulation doped structures at 10K and 77K for fields varying from 0.1 V/cm to 3000 V/cm by magnetoresistance measurements.

The samples are n-type modulation doped single quantum wells grown by RTCVD [6] . They consist of a modulation doped 75 A° strained Si quantum well on a relaxed graded SiGe buffer layer. The carrier density and mobility at 77K are typically 2.5×10^{12} cm $^{-2}$ and 9000 cm^2/ Vs. The samples were processed into ungated FET geometries with channel lengths L = 20 μm to 86 μm and widths W = 300 μm and 510 μm respectively [Fig.1]. Ohmic contacts were formed by Au-Sb lift off and annealing. The contact metallisation and annealing temperatures were optimised to reduce the contact resistance. From a plot of the total resistance versus the channel resistance [Fig.2.] the extrapolated contact resistance was found to be ~ 50% of the channel resistance at low fields and ~ 30% at high fields for the 20μm device. This was taken into account to calculate the electric field in the channel.

Geometric magnetoresistance technique was used to extract the mobility of the 2DEG at 10K and 77K . Voltage pulses up to 10 V of width 100μs and repetition rate 0.1 Hz were applied to obtain high fields without lattice heating. The change in the current through the sample for fixed bias voltage was measured as a function of magnetic field up to 0.5 Tesla . The measured current was fitted to the relation $J(B) / J_0 = 1 / (1+\mu^2B^2)$ [7] where μ is mobility [Figs.3, 4.]. The fitting is not sensitive to parallel conduction in the low mobility cap and substrate layers. The 2DEG mobility was found to decrease rapidly beyond fields of ~ 100 V/cm . At 77K the reduction in mobility is ~ 50% for applied field of 3000 V/cm. For the sake of device simulations an empirical expression $\mu / \mu_0 = 1 / (1 + E / E_c)$ was found to fit the data well [Fig.5.]. The parameter E_c , which depends on the carrier-phonon interaction, is fitted to be 1100 V/cm at 10K and 5900 V/cm at 77K.

The mobility data was used to calculate the drift velocity as a function of electric field. The drift velocity at 2000 V/cm is 2.1×10^7 cm/s (10K) and 1.7×10^7 cm/s (77K), which is a lower bound for the saturation velocity [Fig. 6.]. These results are consistent with Monte-Carlo simulations of ref. [3] and experimental results of ref. [5].

Drift velocities were also measured at 200K up to fields of 200V/cm . Currently work is in progress to extend the measurements to higher temperatures / higher fields. In conclusion, we present here experimental hot carrier transport data at 10K and 77K in Si / SiGe n-modulation doped structures.

REFERENCES

1. K. Ismail, S. Rishton, J.O. Chu, K. Chan, and B.S. Meyerson, *IEEE Elec. Dev. Lett.* , Vol. **EDL-14,** p. 348, (1993).
2. U. Konig, A.J. Boers, F. Schaffler, and E. Kasper, *Electron. Lett.*, Vol. **28**, p. 160, (1992).
3. "Electron mobilities and high field drift velocities in strained Silicon on Silicon Germanium substrates " Th. Vogelsang and K.R.Hofmann , Device Research conference , (1992).
4. H. Miyata, T. Yamada, D.K. Ferry, *App. Phy. Lett.*, Vol. **62**, p. 2661, (1993).
5. K. Ismail, S. F. Nelson, J. O. Chu and B. S. Meyerson, *App. Phy. Lett.,* Vol. **63**, No. 7, p. 660, (1993).
6. V.Venkataraman, C.W.Liu and J.C.Sturm, J. Vac. Sci. Tech.B., Vol. **11**, p. 1176, (1993).
7. W. T. Masselink, W.Kopp, T.Henderson , H.Morkoc, , *IEEE-EDL,* Vol. **EDL-6,** No.10, p.539, (1985).

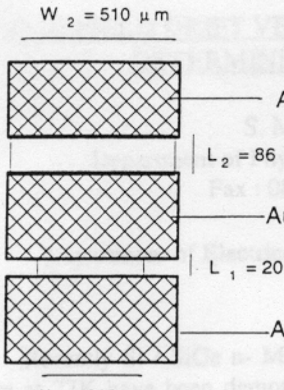

Fig.1. - Sample FET geometry

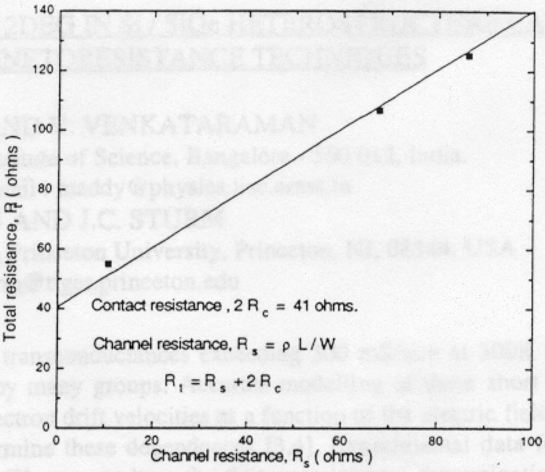

Fig.2. - Total resistance Vs. the channel resistance.

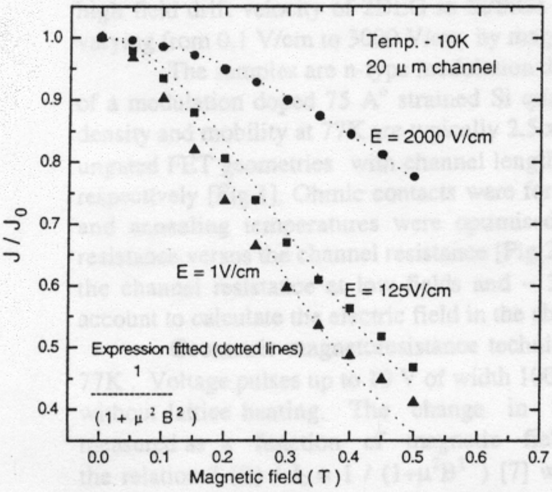

Fig.3. - Current density Vs. magnetic field for three electric fields.

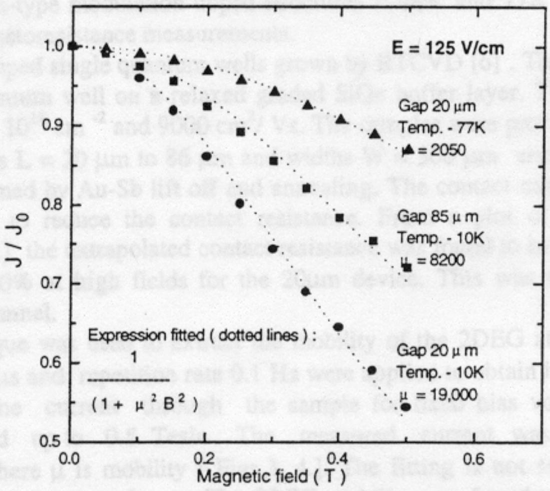

Fig.4.-Current density Vs. magnetic field for different conditions.

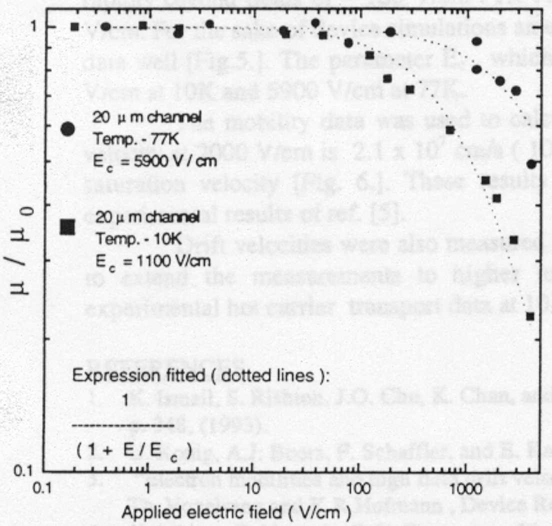

Fig.5. - Mobility Vs. electric field at two different temperatures.

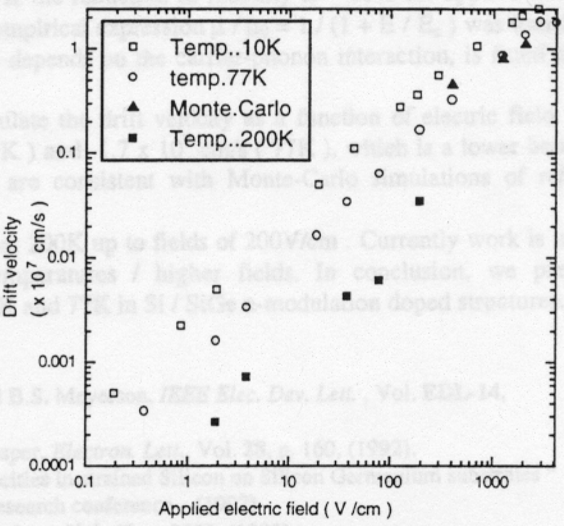

Fig.6 - Drift velocity Vs. electric field for the 20μm channel.