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EFFECTIVE MASS MEASUREMENT IN TWO-DIMENSIONAL HOLE GAS IN STRAINED $Si_{1-x-y}Ge_xC_y$/ (100) Si MODULATION DOPED HETEROSTRUCTURES C.L. Chang, S. Shukla, V. Venkataraman*, J.C. Sturm, and M. Shayegan Dept. of Electrical Engineering, Princeton University, Princeton, NJ 08544. * Dept. of Physics, Indian Inst. of Science, Bangalore 560012, India Tel: (609) 258-6624, Fax: (609) 258-6279, clchang@ee.princeton.edu

Strained $Si_{1-x-y}Ge_xC_y$ alloys on Si (100) substrates have attracted strong interest recently because the addition of substitutional C reduces the strain, leading to increased critical thickness. To date, however, there have been few reports on transport properties. In this paper, we present the results of two-dimensional hole gas (2DHG) in p-type $Si_{1-x-y}Ge_xC_y$/ (100) Si modulation-doped structures and the effective mass of holes in the $Si_{1-x-y}Ge_xC_y$ channel. Samples were grown by rapid thermal chemical vapor deposition at temperatures ranging from 575°C to 700°C for different layers. The sample structure consists of undoped Si buffer layer on a n-type Si substrate, undoped $Si_{1-x-y}Ge_xC_y$, 50-100Å undoped Si spacer, 50Å p-type Si doping supply layer ($2x10^{18}/cm^3$), 600Å undoped Si, and 100Å p-type Si shielding layer ($1x10^{18}/cm^3$). The Ge concentration is 13% and 24% and the low C content (up to 0.6%) yields $Si_{1-x-y}Ge_xC_y$ layers which are always commensurably strained, without any C precipitates, etc visible in TEM.

Hall measurements were performed on the samples with lithographically defined Hall bar geometries, For contacts, ~1500Å Al was thermally evaporated and annealed at 300 °C which yielded ohmic contacts good to the base temperature (0.35K). Initial results show that the hole mobility decreases as C is added.(Figure 1) It is not known if this decrease is due to increased alloy scattering or due to C-related point defects. Further evidence for the existence of 2DHG was obtained by the magnetoresistance [Shubnikov-de Haas (SdH)] measurements. Figure 2 shows the SdH oscillations of 2DHG in the $Si_{0.757}Ge_{0.24}C_{0.003}$ at 1.38K. Only odd filling factor are resolved which could be due to rather large g-factor causing the Zeeman splitting to match the Landau level splitting[1].

The hole effective mass in the $Si_{1-x-y}Ge_xC_y$ channel is determined by measuring the temperature dependence of the SdH oscillations amplitudes [2,3,4]. The amplitude decreases with increasing temperature due to broadening of carrier energies around Fermi energy, and is dependent on m* (hole effective mass) through the Landau level sapcing. The temperature dependence of the oscillation amplitude (A) can be expressed by

$$A \sim \frac{\xi}{\sinh(\xi)} \quad \text{where } \xi = \frac{2\pi^2 \kappa T}{\hbar\omega_c}, \; \omega_c = \frac{eB}{m^*}.$$

Analyzing the temperature-dependent amplitude data at various magnetic fields, we obtain the hole effective mass (m*) =0.30 ± 0.01 m_o in the $Si_{0.757}Ge_{0.24}C_{0.003}$ channel (see figure 3). Figure 4 shows the comparison of hole effective mass in the $Si_{1-x}Ge_x$ and $Si_{1-x-y}Ge_xC_y$ channels. There is no significant change in the m* as 0.3% C is added in the SiGe channel. The effective mass obtained in our samples is close to that reported by People et al. (who also obtained m* = 0.30 m_o) for an MBE-grown modulation-doped heterostructure without C by the above-mentioned method [4].

In summary, we have demonstrated the first effective mass measurement of 2DHG in $Si_{1-x-y}Ge_xC_y$ modulation-doped structures. The hole mobility decreases as more C is incorporated. We also find a hole effective mass m* = 0.30 ± 0.01 m_o in the $Si_{1-x-y}Ge_xC_y$ channel containing 0.3% C which is similar to that obtained in the controlled $Si_{1-x}Ge_x$ channel without C. We will present results with higher C level at the conference

[1] F.F. Fang et al, *Surf. Sci.* **263**, p. 175, 1992
[2] T.E. Whall et al, *APL*, **64**, p.357, 1994
[3] P.J. Wang et al, *APL*, **54**, p.2701, 1989
[4] R. People et al, *APL*, **45**, p. 1231, 1984

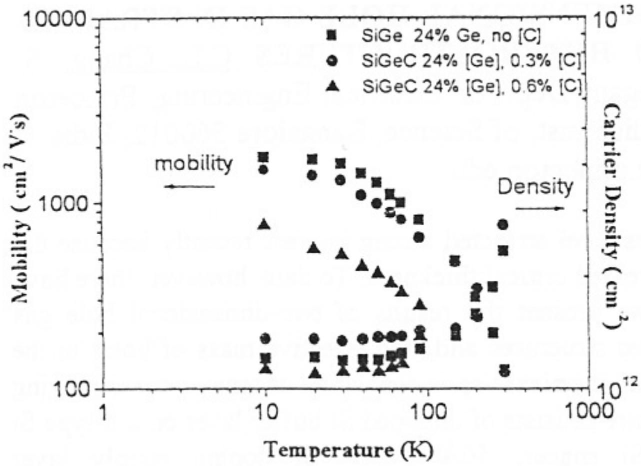

Fig 1: Carrier density and mobility as a function of temperature for the Si/SiGeC modulation-doped heterostructure.

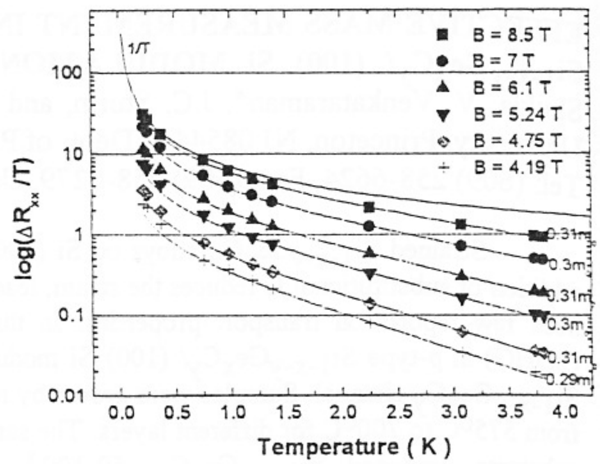

Figure 3: Hole effective mass in the $Si_{0.757}Ge_{0.24}C_{0.003}$ channel measured at various magnetic fields.

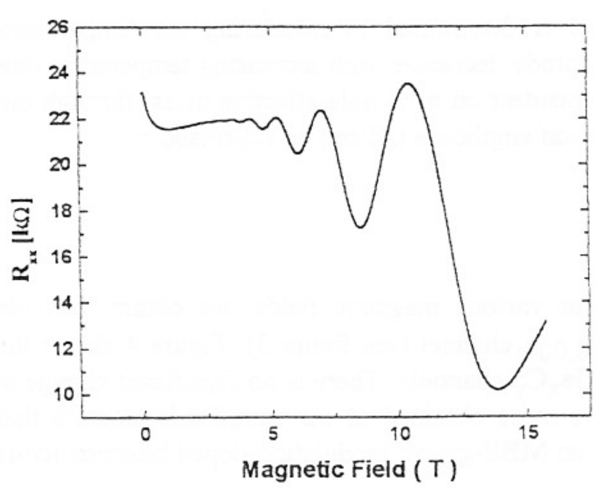

Figure 2: SdH oscillations of 2DHG in the $Si_{0.757}Ge_{0.24}C_{0.003}$ channel at 1.38K.

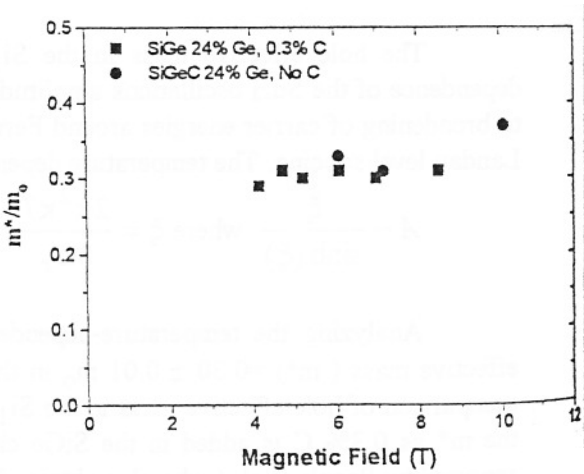

Fig 4: Hole effective mass in $Si_{1-x}Ge_x$ and $Si_{1-x-y}Ge_xC_y$ channel measured by various magnetic fields.