11. Ultralow Temperature Studies of Electronic Conduction in Submicron Silicon Inversion Layers

Academic and Research Staff

Prof. M.A. Kastner, Dr. J. Melngailis

Graduate Student

J.C. Licini

Joint Services Electronics Program (Contract DAAL03-86-K-0002)

Marc A. Kastner

Field effect transistors have been fabricated, with widths as narrow as ~50 nm, in the Submicron Structures Laboratory. The narrow gate of these MOSFET's is created by glancing-angle evaporation of tungsten into a 50-nm step etched in the 100-nm oxide on the Si(100) surface. The tungsten wires are more uniform than those fabricated previously of Al, presumably because of the smaller grain size.

During the past year we have focused attention on the regime of gate voltage V_G well above threshold, in which the fluctuations of conductance with V_G are much smaller. In experiments carried out in collaboration with D.J. Bishop of AT&T Bell Laboratories, we measured the magnetoresistance of our MOSFET's at ultralow temperatures. We discovered aperiodic magnetoresistance oscillations similar to those seen previously in ultranarrow metal wires and narrow strips of GaAs. The magnitude of the magnetoresistance fluctuations is about the same as that of the fluctuations of resistance with gate voltage. The latter have been ascribed by other groups to structure in the density of states resulting from one-dimensional subbands. If this assignment is correct, then the magnetoresistance structure would result from a shift of the energy of these subbands with magnetic field. To explore whether field-induced energy shifts of the density of states could be the origin of the structure in the magnetoresistance, we measured the magnetoresistance at closely spaced values of V_G. If the effect of the magnetic field were to shift the energies of states relative to the Fermi energy, then small changes in V_G should cause the structure in the magnetoresistance to shift in field. On the contrary, we found that the oscillations in magnetoresistance remain unchanged for small changes in V_G below a critical value and become uncorrelated for changes in V_G larger than this value.

This provides strong evidence that the oscillations do not result from energy shifts of electronic states but rather from field-induced changes in the phase of the wavefunctions. We believe that the fluctuations in resistance with V_G and magnetic field are an example of the quantum–interference effect predicted for all disordered conductors.[1]

Our experiments have provided another example of the importance of ultralow temperature measurements in understanding quantum mechanical transport phenomena in submicron structures. In order to carry out such experiments at M.I.T. we have ordered a dilution refrigerator and 10T superconducting magnet from Oxford Instruments. The funds to pay for this came, in part, from a grant from the AT&T foundation.

References

1. P.A. Lee and A.D. Stone, Phys. Rev. Lett. 55, 1622 (1985).