Absolute negative resistance in ballistic field effect transistor

Michel I. Dyakonov and Michael S. Shur
Université Montpellier II, France and *Rensselaer Polytechnic Institute, U.S.A.*

At small feature sizes (25 to 45 nm or so for silicon transistors), the electron transport becomes ballistic (collisionless) or quasi-ballistic and the average electric field in the channel reaches well into the MV/cm range even at reduced power supply voltages. The lateral control of the electron concentration in the channel under the conditions of the ballistic transport becomes very important even for the mainstream silicon technology.

In this paper, we analyze ballistic transport in a ballistic variable threshold field effect transistor[1,2] (which is a transistor in which the threshold voltage in the device channel varies as a function of distance). Using hydrodynamic equations, we show that a change in the threshold voltage along the channel leads to a jump in the channel potential, which is independent of the current direction and depends on the magnitude of the device current (being proportional to device current squared at relatively small channel currents). Thus, for one current direction, the current flows opposite to the voltage drop, i.e. the resistance becomes locally negative. This predicted voltage jump and the electron flow "choking" analyzed earlier[3] are similar to the pressure jump and fluid flow choking in a frictionless pipe with a variable cross section. These unusual features of a ballistic variable threshold FET could be used for novel circuit applications and for the measurements of the threshold voltage distribution in the device channel.

1. M. S. Shur, "Split-gate field effect transistor", *Appl. Phys. Lett.* **54**, 162 (1989); M. S. Shur, "Split-gate field effect transistor", U.S. Patent 5,012,315, April 30 (1991) and U.S. Patent 5,079,620, January 7 (1992)
2. G. U. Jensen and M. S. Shur, "Variable threshold heterostructure FET studied by Monte Carlo simulation", in: K. Hess, J. P. Leburton, and U. Ravaioli, eds., *Computational Electronics. Semiconductor Transport and Device Simulation*, Kluwer Academic Publishers, Norwell, MA (1991), pp. 123-126.
3. M. Dyakonov and M. S. Shur, "Choking of electron flow – A mechanism of current saturation in field effect transistors", *Phys. Rev. B* **51**, 14341 (1995).