Electrical and Thermal Conductance Quantization in Nanostructures for Nanoelectronics

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In the paper technological problems connected to electron transport in nanostructures, especially nanowires, are considered. Both electrical G_E and thermal G_T conductance of a nanostructure describe the same process: electron transport in nanostructures. Quantization of electrical conductance in nanowires has been observed in units of $G_0 = 2e^2/h = (12.9\ \mathrm{k\Omega})^{-1}$ up to five quanta of conductance according to the theory proposed by Landauer. In the paper we present our measurements of electrical conductance quantization in semiconductor nanowires (Ge) as well as in metallic nanowires: Au, Cu, Ni and Co nanowires at room temperature.

Quantized thermal conductance in one-dimensional systems (e.g. nanowires) was predicted theoretically by Rego using the Landauer theory. The thermal conductance is considered in a similar way like the electrical conductance. In one-dimension systems conductive channels are formed. Each channel contributes to a total thermal conductance with the quantum of thermal conductance G_{T0}. Quantization of thermal conductance and its quantum (unit) G_{T0} was confirmed experimentally by Shwab. The quantum of thermal conductance G_{T0} [W/K] = $(\pi^2 k_B^2 /3h)T = 9.5\times10^{-13}T$ depends on the temperature. At T = 300 K value of $G_{T0} = 2.8\times10^{-10}$ [W/K]. In small structures a dissipated energy is quite large. For the first step of conductance quantization, $G_E = G_{E0} = 7.75\times10^{-5}$ [A/V], and at the supply voltage V_{sup} = 0.4 V the current in the circuit I = 29 μA (I = 54 μA for the second step of quantization). The power dissipation in terminals of nanowires is $P = I^2/G_{E0}$ = 11 μW for the first step and P = 19 μW for the second step. One ought to notice that the density of electric current in Si nanowires is extremely high. The diameter of the Si nanowire on the first step of quantization can be estimated to D = 0.22 nm, so for I = 29 μA the current density $J \approx 7.6\times10^{10}$ [A/cm^2].