Self heating and nonlinear current-voltage characteristics in bilayer graphene

J. K. Viljas[a], A. Fay[a], M. Wiesner[b], and P. J. Hakonen[a]

[a]Low Temperature Laboratory, Aalto University, P.O.Box 15100, FI-00076 AALTO, Finland
[b]Faculty of Physics, Adam Mickiewicz University, 61-614 Poznan, Poland

Our low-temperature experiments[1] have shown that the current–voltage (I–V) characteristics of diffusive two-lead bilayer graphene (BLG) samples on SiO_2 substrates tend to be superlinear at bias voltages V below 0.1 V. The superlinearity is weakly dependent on (n-type) doping by a back gate and is also similar for our short (350 nm) and long (950 nm) samples. These findings are in contrast to monolayer graphene (MLG), where the I–V characteristics are typically linear, apart from very low-mobility samples close to the Dirac point, where superlinearity has previously been attributed to Zener-Klein tunneling.[2]
We have also analyzed the I–V characteristics of MLG and BLG with numerical simulations based on solving semiclassical quasiequilibrium transport equations together with the Poisson equation, assuming carrier scattering to be due to charged impurities. It is concluded that the superlinearity seen in our BLG experiments can be explained by Joule heating. As the electron system heats from 4 K in equilibrium to 200–300 K at $V = 0.1$ V the conductivity increases as a result of the thermal creation of electron-hole pairs. This effect is stronger in BLG than in MLG because of the larger electronic density of states close to the Dirac point in the former. The simulations and the experimental data are in good agreement.

[1]J. K. Viljas, A. Fay, M. Wiesner, and P. J. Hakonen, arXiv:1102.0658; Phys. Rev. B (2011).
[2]N. Vandecasteele, A. Barreiro, M. Lazzeri, A. Bachtold, and F. Mauri, Phys. Rev. B **82**, 045416 (2010).