High electric field transport in graphene: impact of screened coulomb interactions

José M. Iglesias*, Mª Jesús Martín, Raúl Rengel

Universidad de Salamanca, Applied Physics dept., Plaza de la Merced, S/N, 37008 - Salamanca, Spain
*e-mail: josem88@usal.es

Abstract

Since the breakthrough of the prime isolation of a single-atom-thick carbon crystal [1], graphene has attracted a huge amount of attention due to its outstanding electronic properties. At room temperature it exhibits extremely high mobilities [2] and carrier population can be tuned by electrostatic gating, which makes it a promising material for future developments of a wide range of highly efficient electronic devices [3]. In our work we will study the role that electron-electron interaction plays on the electronic transport subjected to high longitudinal electric fields by means of the Monte Carlo method. Our simulator takes into account the graphene's linear dispersion relation and includes the transverse-acoustic (TA), longitudinal-acoustic (LA), transverse-optic (TO), and longitudinal-optic (LO) phonon branches [4], as well as surface polar phonons (SPPs) associated with the underlying substrate [5], a screened Coulomb potential model for electron-electron interactions [6] and impurity scattering. A proper treatment of the dual-carrier scattering probabilities implies its calculation depending on the electron wavevector orientation, resulting in a highly anisotropic probability, as it can be seen in Fig. 1, when the distribution of the carriers is noticeably displaced in the field direction (fig. 2). Further analysis steaming from carrier distribution in energy and in the *K* space is presented, taking into account the microscopic aspects of these collisions and their function as relaxation mechanisms. The influence on the carrier mobility is also analyzed, thus elucidating the importance of carrier-carrier interactions in graphene and their interplay with impurity and phonon scattering.

References

[1] K. S. Novoselov, A. K. Geim; S. V. Morozov, D. Jiang, Y. Zhang, S. V. Dubonos, I. V. Grigorieva and A. A. Firsov, *Science*, **306** (2004) 666
[2] K. M. Borysenko, J. T. Mullen, E. A. Barry, S. Paul, Y. G. Semenov, J. M. Zavada, M. B. Nardelli, and K. W. Kim, *Phys. Rev. B*, **81** 121412 (2010)
[3] Y. M. Lin, C. Dimitrakopoulos, K. A. Jenkins, D. B. Farmer, H. Y. Chiu, A. Grill, and Ph. Avouris, *Science* **327**, (2010) 662
[4] R. Rengel and M. J. Martín, *J. Appl. Phys.*, **114** 143702 (2013)
[5] R. Rengel and M. J. Martín, *Appl. Phys. Lett.*, **104**, 233107 (2014)
[6] X. Li, E. A. Barry, J.M. Zavada, M. Buongiorno Nardelli and K. W. Kim, *Appl. Phys. Lett.*, **97** 082101 (2010)

Figures

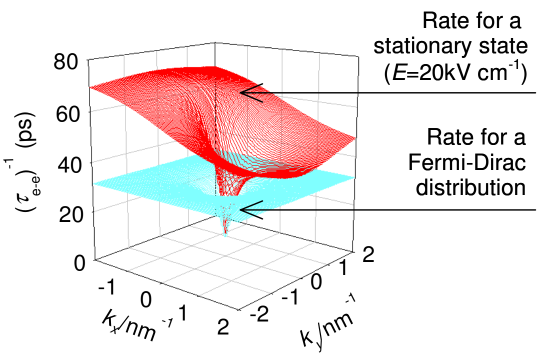

Fig. 1: Comparison of the anisotropic dual carrier scattering probabilities for a distribution in an equilibrium Fermi-Dirac distribution, and for a steady-state distribution for a 20 kV/cm applied field.

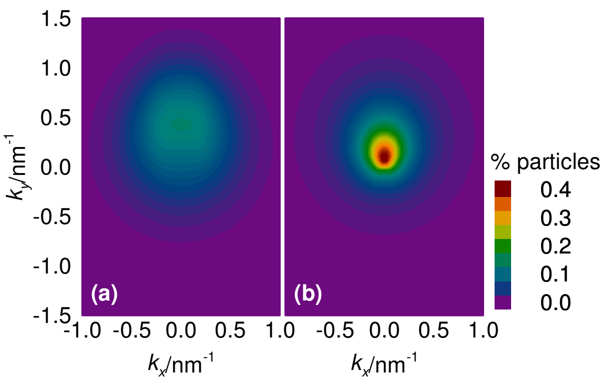

Fig. 2: Distribution functions for a reached stationary state when a 20 kV/cm electric field is applied on the *y* direction and dual carrier intraband interactions are (a) turned off, (b) turned on.