Flexural phonon spectrum of suspended graphene measured by electron diffraction

Demid Kirilenko

Ioffe Institute, Politekhnicheskaya 26, 194021, St-Petersburg, Russia

Demid.Kirilenko@mail.ioffe.ru

Flexural phonons in graphene represent phenomena of great fundamental interest as well as of practical importance. The out-of-plane undulations caused by flexural phonons reach relatively high amplitudes in low-dimensional crystal [1], thus, considerably affecting its electronic and mechanical properties [2]. At the same time, physics of the flexural phonons in graphene is rather non-trivial and involves essentially anharmonic dynamics [3].
Manifestation of the flexural phonons is the most pronounced, indeed, in suspended sheet and only in this case the corresponding undulations carry information on the very intrinsic properties of graphene. However, direct measuring of the ultrathin suspended crystal relief is practically impossible. For this reason, there is a lack of experimental data on the flexural phonons in graphene, whereas numerous theoretical considerations of the problem are presented in the literature.
Here we present a technique for measuring of the flexural phonon spectrum in suspended graphene. The technique is based on analysis of electron diffraction patterns [4,5]. The main advantage of electron diffraction is the possibility to get the information on rapidly varying atomic shifts because of the small interaction time of a fast electron with the crystal.
The remarkable finding is the q^{-4} dependence at the right hand part of the spectrum, which is in agreement with the theoretical predictions. This allows direct measuring of graphene bending rigidity. At the same time, the dependencies at smaller q are considerably weaker than the predicted. Thus, our experimental data raises questions on the role of different mechanisms involved in the flexural phonon dynamics. Additionally, the presented technique is applicable to studying of suspended 2D crystals of any other types and under varying conditions.

References

[1] J.C. Meyer, A.K. Geim, M.I. Katsnelson, K.S. Novoselov, T.J. Booth, S. Roth, Nature 446 (2007) 60-63
[2] S. Das Sarma, S. Adam, E. Rossi, Rev. of Mod. Phys. 83 (2011) 407-470
[3] A. Fasolino, J. H. Los, M. I. Katsnelson, Nature Materials 6 (2007) 858-861
[4] D. A. Kirilenko, A. T. Dideykin, G. Van Tendeloo, Phys. Rev. B 84 (2011) 235417
[5] D.A. Kirilenko, P.N. Brunkov, Ultramicroscopy 165 (2016) 1-7

Figures

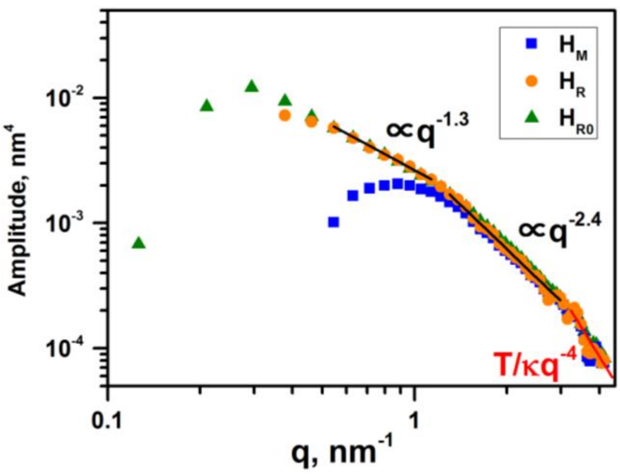

Figure 1: Measured flexural phonon spectrum (H_M) and its reconstructions (H_R and H_{R0}) reducing the effect of finite electron beam coherency.