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book reviews

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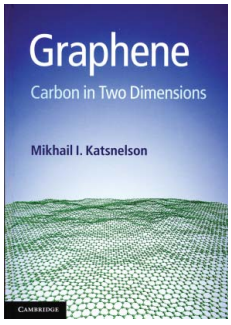

Graphene: Carbon in Two Dimensions. By Mikhail I. Katsnelson. Cambridge University Press, 2012. Price (hardcover) GBP 45.00. ISBN-13: 9780521195409.

This unconventional material has for several years been attracting the attention of structurally minded scientists wishing to understand its unusual properties. At a first glance, the present book looks like a textbook on theoretical solid state physics, focussing on carbon. As such, it is certainly an easy-to-grasp introduction for physicists with a standard undergraduate-level knowledge of quantum and statistical physics and solid state theory. The table of contents attests to that: 1, The electronic structure of ideal graphene; 2, Electron states in a magnetic field; 3, Quantum transport *via* evanescent waves; 4, The Klein paradox and chiral tunnelling; 5, Edges, nanoribbons and quantum dots; 6, Point defects; 7, Optics and response functions; 8, The Coulomb problem; 9, Crystal lattice dynamics, structure and thermodynamics; 10, Gauge fields and strain engineering; 11, Scattering mechanisms and transport properties; 12, Spin effects and magnetism. References. Index.

However, the text on theoretical physics is not our major goal here. When browsing through the text, I felt that the experimentally minded crystallographer may also benefit from reading the book, if he or she is interested in understanding the structure–property relationships of that less-common material. Note that the two-dimensional world differs in several aspects from what we are used to find around us in three-dimensional objects. The accompanying text to the formulae enables the physical basics behind them to be grasped more easily.

Let us start with the alarming statement that, in a rigorous sense, two-dimensional crystals cannot exist at finite temperatures. This was predicted by R. Peierls in 1934 and it is supported by more sophisticated recent calculations, but Katsnelson simultaneously presents experimental evidence against this statement as good news on the cover of the book as well as in the text. The apparent contradiction is resolved by recognizing that freely suspended graphene is in fact, at room temperature, not strictly a plane sheet but corrugated, with ripples in the out-of-plane direction, which seem to stabilize the system.

Ripple formation in graphene proves crucial for a number of other properties. A key chapter to the whole book and to this phenomenon is Chapter 9. Starting with the phenomenological elasticity theory of thin plates the author gives a deeper insight into the mechanics of membranes, eventually refined by atomistic Monte Carlo simulations. Calculated and measured elastic constants are also reviewed. Per atomic layer, Young's modulus is an order of magnitude higher than that of steel. While phonon spectra of graphene have not yet been obtained experimentally, the book describes nicely thermodynamic and thermal properties that are currently or will in the near future be accessible to experimentalists, providing simultaneously theoretical predictions as guidelines. Examples are the results that show thermal expansion coefficients changing sign as a function of temperature, while lattice parameters and nearest-neighbour distances follow different temperature dependences. Some basic ideas of experimental tools like Raman spectroscopy are also discussed in Chapter 9. Spectacular physical properties like the largest thermal conductivity among all materials known so far is another topic referred to by the author. Atomistic simulations predict the decomposition of the structure of graphene at temperatures as high as 4900 K, hence making graphene the most refractory material.

Other consequences of the unavoidable corrugations are considered in Chapter 10. These are various interdependences of ripples, pseudomagnetic fields, external strain and electronic states. Manipulation of the electronic structure of graphene *via* strain engineering is envisaged as a potential route towards novel applications. In Chapter 11 the author turns to the applicability of the conventional theory of electronic transport for the case of graphene. A fundamental equation for the relaxation rate is derived, which allows to one analyse various scattering mechanisms, in particular the conductivity of graphene on a substrate, the intrinsic transport properties of suspended flakes and transport in magnetic fields. Several rather unexpected features are revealed and the mobilities of charge carriers are calculated quantitatively for various cases.

A very hot topic is addressed in the final Chapter 12. This is the existence of magnetic ordering in graphene. There are serious doubts about this. Nevertheless, the author feels that the counterarguments are worthy of consideration. Particularly when including defects and edge states in the discussion, the physics of the problem can be understood more deeply. In the context of this discussion, the author draws attention to ferromagnetic states due to an external electric field, which appear possible under certain conditions.

M. Katsnelson has himself contributed many important theoretical publications to this subject area from the very

beginning of this booming field. The present book deals with the fundamentals which will not be modified as quickly as the possible applications. The text is reasonably independent of other textbooks, making the reading easier. Moreover, the reader will benefit from an extensive list of references and a comprehensive index. The whole book is well produced, with carefully chosen figures.

The author admits – in the preface – that he has skipped all practical aspects of graphene technology and applications as well as of graphene chemistry. For those purposes other books should be consulted.

At the bottom line, the book can be recommended to students interested in the physical fundamentals of the phenomenon of graphene. Unlike three-dimensional materials science, theory is ahead of experiment in many aspects of exploring physical and chemical properties. Hence researchers who want to get suggestions for further projects can also take advantage of having a copy of 'Graphene' at hand.

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