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A Review of "Carbon Materials and Nanotechnology"

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Book Review

Carbon Materials and Nanotechnology, 2010, by Anke Krueger, Wiley-VCH, Berlin, 490 pp., $115.00 (paperback), ISBN-13: 978-3-527-31803-2

Since the discovery of the fullerenes in 1985, followed by the first generation of carbon nanotubes in 1991, and finally, after the first isolation of graphene in 2004, research in the direction of synthetic carbon allotropes and carbon nanomaterials has seen a tremendous development. Carbon-based materials exhibit a number of outstanding and sometimes unprecedented properties. Already, diamond and graphite, which represent the classical forms of carbon, are characterized by materials properties which range from superior electrical and thermal conductivity to mechanical strength and hardness. As a consequence, carbon allotropes find a number of exciting applications in a variety of fields, such as batteries, drilling tools, lubricants, and components for organic photovoltaic devices. Of particular interest is also the possibility of chemically functionalizing synthetic carbon allotropes, for example, by the direct binding of organic molecules to the carbon scaffold or by converting already existing functionalities at defect sites. Chemical derivatization offers numerous possibilities and allows for the combination of the interesting physical and chemical properties of nanocarbons with those of other compound classes.

These new developments served as the starting point for the monograph by Anke Krueger entitled "Carbon Materials and Nanotechnology." Anke Krueger is a well-known expert in the field of production and chemical conversion of nanocarbons, in particular of nanodiamonds. The monograph is based on a series of lectures that Anke Krueger delivered at the University of Kiel, Germany. The monograph is composed out of six thematical chapters, followed by an epilog and a listing of a further readings and figure references.

Chapter 1 starts with a historical description of diamond and graphite and also provides an insight into the natural sources of these forms of carbon, such as mines spread over the entire globe. Moreover, the structure and bonding properties of diamond and graphite and a couple of other nanoforms are outlined in a clear way in this first chapter. Emphasis is also given to the outstanding physical and chemical properties of diamond and graphite.

Chapter 2 is devoted to the fullerenes, which represent the first type of new synthetic carbon allotropes. After describing the building principles of fullerenes as well as their electronic properties, orbital structures and their physical and chemical properties, Anke Krueger presents the various protocols for fullerene generation and production. This includes the classical arc-burning procedure developed by Krätschmer and Huffman, as well as a couple of rational synthesis approaches. After having described the most common purification procedures of fullerenes, their physical properties are discussed in detail. The next part of the second chapter is devoted to the chemical functionalization of fullerenes. Special focus is laid on exohedral functionalization methods. Next to the addition chemistry

itself, concepts for regioselective multiple additions to the fullerene core and examples of supramolecular fullerene chemistry are outlined. Finally, the author also describes a couple of possible applications of fullerenes and their derivatives, such as solar cells, composite materials with interesting electronic properties as well as endo-fullerenes as contrasting agents.

Chapter 3 highlights the various developments associated with carbon nanotubes. First of all, the structures and morphologies of the different types of carbon nanotubes, such as single-walled carbon nanotubes, double-walled carbon nanotubes, and multi-walled carbon nanotubes, are outlined. This description is accompanied by a number of protocols for carbon nanotube formation, ranging from arc discharge methods to chemical vapor deposition procedures. The important issue of carbon nanotube purification and separation, which still represents a challenge within carbon nanotube research, is pointed out in detail, before various suggestions for growth mechanisms are discussed. Physical and mechanical properties of carbon nanotubes, but especially their remarkable electronic properties such as their structure-dependent metallic or semiconducting behavior, accompanied by high stability, are described on the basis of fundamental solid-state physics principles. The research on carbon nanotubes requires a couple of sophisticated spectroscopic and microscopic methods, which are reviewed in detail. The last part of this chapter is devoted again to the chemical functionalization. Especially, exohedral covalent and non-covalent functionalization concepts are described. Endohedral functionalization of carbon nanotubes leads to the formation of pea pods or other types of interesting supramolecular structures. Finally, the author highlights various aspects of supramolecular chemistry of carbon nanotubes. The last part of Chapter 3 is devoted to applications and perspectives for carbon nanotubes. Interesting applications are field emission displays with high luminosity and low-energy consumption, field effect transistors, and sensors for small molecules.

In Chapter 4, Anke Krueger describes carbon onions and related materials, which represent spherical nanoforms of carbons. Especially, the structure of carbon onions is pointed out in detail, because in general, a number of defects are required to build up their shapes. These defects, on the other hand, are important for a couple of properties and also for the chemical reactivity of carbon onions.

In Chapter 5, the state-of-the-art of nanodiamonds is reviewed. After having described the natural occurrence, the artificial production, and the structure of nanodiamonds, various aspects of spectroscopic characterization, with an emphasis on the role of defects, are pointed out. Like in the case of the nanocarbons described in the previous chapters, surface functionalization has been developed as an important field of research. Anke Krueger introduces various methods for nanodiamond functionalization as well as composite formation. In general, the chemical functionalities at defect sites play the dominant role for chemical derivatizations. This is also true for the diamond films presented in Chapter 6. Such films find applications, for example, as mechanically resistant coatings of components and implants. One can expect that further applications in electronic devices are possible.

Every thematic chapter ends with the presentation of a summary and one or several highlighted boxes containing the most important take-home messages. This contributes nicely to the overall clear and didactically elegant presentation of the subject of carbon materials in the monograph. Unfortunately, a chapter devoted to graphene, being probably one of the most important carbon-based materials, is missing in this first edition. However, this might be caught up in a possible second addition of the monograph. Altogether, the

author presents a very comprehensive and well-written monograph, which is recommended not only for the specialist in the field but for anyone interested in materials science.

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