

Preface

According to N.R. Pace, “All living things contain carbon in some form and it is the primary component of macromolecules including proteins, lipids, nucleic acids (RNA and DNA), and carbohydrates.” Indeed, it exists in all living animals. As a matter of fact, it is the backbone of all organic (chemistry) compounds.

Organic chemistry is the elementary description of life because the chemical reactions required for the faithful propagation of a living organism require a high degree of specificity in the interactions of the molecules. Only two of the natural atoms, carbon and silicon, are known to serve as the backbones of molecules large enough to carry biological information; however, opinion is divided on whether silicon-based life is a realistic prospect.

Carbon is a long-studied element, but there is always more to discover. Indeed, in 1985, Richard Smalley and Robert Curl of Rice University, and their colleagues discovered a new form of carbon, the fullerene, also known as “buckyballs.” Since then, “buckyballs” and “buckytubes” have been the subject of intense research both for their unique chemistry and technological applications in material science, electronics, and nanotechnology.

In 2010, Andre Geim and Konstantin Novoselov of the University Of Manchester, England, won the Nobel Prize in Physics for their groundbreaking experiments regarding the two-dimensional (2-D) material graphene—an allotrope of carbon. The global market for graphene reached 9 million dollars in 2014. In the year 2010, scientists reported the invention of flexible conductive textiles dipped in carbon nanotube (CNT) ink that could be used to store energy, perhaps paving the way of wearable batteries, solar cells, and other electronics.

The next important chemical which belongs to the carbon family is polymer. The term “polymer” was first introduced in 1833 by the Swedish chemist Jöns Jacob Berzelius. Many polymers such as silk, cotton, starch, sand, asbestos, as well as complex polymers including RNA (ribonucleic acid) and DNA (deoxyribonucleic acid), which hold genetic codes, exist in nature. John Steele Gordon wrote: “It has been a curious silent revolution. . . when we think of scientific triumphs of twentieth Century, we think of nuclear physics, medicine, space exploration, and the

computers. But all these developments would have been much impeded, in some cases impossible, without . . . plastics . . . most of them are made of polymers.” Indeed, Moore’s law, which dictates the size of a transistor, depends mostly on the magic polymer—the photoresist.

I was fascinated with and excited by all the discoveries, as the wonder nacre—carbon—can exist in many forms and do wonderful things. Indeed, one of its allotropes, the diamond, is exquisitely beautiful. All the characters of carbon that have been explored so far led me to write a small scientific history of carbon. This book *Carbon: The Black, the Gray, and the Transparent* is not a complete scientific history, but focuses on some of the wonderful discoveries about this old faithful element that was known to prehistoric humans in the form of charcoal.

This book is not intended strictly as a textbook, but should serve as a reference book, which will satisfy the expressed needs that brought it about. I strongly believe that it will be an interesting document to all polymathic scholars. I realize it is difficult to provide a complete picture and the history of carbon, but that is the mission of this book.

Chapter 1 attempts to illustrate a complete picture about the existence of carbon. Carbon’s discovery is said to be a lost one. According to the Swinburne Center for Astrophysics and Supercomputing, it forms in the belly of stars in a reaction called the triple-alpha process.

Chapter 2 is dedicated to activated carbon (AC) which is used in our everyday lives, starting with water filtration to medical science as an absorbent of poisonous materials. I also discuss the kinetic theory related to its absorption and desorption properties.

Chapter 3 is devoted to some of the important composites of carbon, like carbon fibers, and metal matrix composites that are being used in so many commercial products like airplanes, cars, building walls, footbridges, diffusion coatings, electroplating, and in heat sinks. It has been a material of great interest to the Air Force and NASA because of its high modulus or resistance to stretching. The inelasticity of carbon composites plays an important role in reinforcing rigid structures such as the nose cones in hypersonic aircraft.

Chapter 4 discusses the miracle material polymer. It has been said that all the twentieth centuries’ developments would have been much impeded, in some cases impossible, without plastics, and almost all of them are made of polymers. Polymers are also a part of the nano-world, and with the development of a miracle polymer known as photoresist, it is possible to fabricate a transistor having a structure of ~22 nanometer (which has raised a dilemma in tunneling physicists regarding George Gamow’s theory).

In Chap. 5, some of the important characters of black carbon are presented. According to physics, it is difficult to distinguish a material which is black and which is not. The black carbon coal discussed in Chap. 5 is not exactly black, but to ordinary people it is black. The highest rank coal, anthracite, followed by bituminous and lignite are discussed along with their use as a source of energy in our daily lives. Products from the coal, mainly coal tar and its derivatives, are also discussed.

Chapter 6 is all about graphite—the gray carbon. The highest grade of black coal is called carbon gray, which is also known as meta-anthracite. It has been used extensively by the manufacturers of lead pencils and of lead-bismuth alloy (due to its relatively low melting points and low neutron absorption). It has also been used as a coolant in some nuclear reactors. Lead has been proposed as a coolant in fast reactors, as part of the Generation IV reactor initiative. Its physical characteristics, along with its electrical properties, are discussed in this chapter. Graphite mining, beneficiation, and milling are also discussed.

Chapter 7 deals with the two-dimensional (2-D) carbonaceous material called graphene. It is an allotrope of carbon, and the groundbreaking experiments to produce the 2-D graphene are discussed in this chapter. According to Connor, the creation of graphene, a wonder material and the result of brilliant serendipity, stands alongside the accidental discovery of penicillin by Alexander Fleming. The electrical and the optical properties of this remarkable material are also discussed.

Chapter 8 is all about the carbon nanotube (CNT). Everything, when miniaturized to the sub-100-nanometer scale has new properties. CNTs are no exception to this. Indeed, CNTs are used in materials from the mundane to the lifesaving, from sunscreen to chemical catalysis to antibacterial agents. In this chapter, its fabrication along with its different characteristics is discussed.

Chapter 9 describes briefly the transparent carbon diamond, an allotrope of carbon. Its splendid colors, transparency, and physical properties have made diamond not only a precious gemstone, but have made it the material of choice for radiation detection in nuclear medicine. Different experimental methods for synthesizing synthetic diamond, nano-diamonds, and diamond-like carbon (DLC) are presented along with their properties and uses.

Chapter 10 addresses another important material—the buckminsterfullerene. It is said that fullerenes are beautiful both physically and intellectually. Their qualities, and even some of their properties, can be appreciated instantly and intuitively by non-scientists. This chapter discusses the synthesis, properties, separation, and purification of fullerenes and the effects of dopants on the original material.

Acknowledgment

The book *Carbon: The Black, the Gray and the Transparent* would not have been possible to write without direct and indirect help of so many scientists. It is not possible to mention all the names of the scientists, but I shall mention some of the leading scientists in this area who have helped me the most. First of all I want to mention Drs. Andre Geim and Konstantin Novoselov, Nobel Laureates in Physics (2010), at the University of Manchester, England. Professor Geim has kindly given me some of his valuable publications to include in my book. I gratefully

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