Chapter 13
Carbon:
A Gem, a Molecule, and a Heart of Nanotechnology

ABSTRACT

"Carbon: A Gem, a Molecule, and a Heart of Nanotechnology" is about related habitats and technologies seen from the scientific, artistic, and educational points of view. It explores carbon as mineral: coal, carbon as a molecule, carbon as soft matter, and biologically inspired models for computing. Art inspired by carbon and enhanced by digital technologies are a means to understand and interpret nature- and science-related concepts.

INTRODUCTION: BACKGROUND DATA

Themes discussed in this chapter comprise: Carbon as mineral, meaning coal: in fossil fuels, as a source of energy, in surface mining with its environmental cost. Next, carbon as a molecule is examined: in the carbon cycle, carbon monoxide CO, carbon allotropes and isotopes. Finally, carbon as soft matter: present in computers, nanocomputers, quantum computing, and biologically inspired models for computing.

Organic chemistry is about carbon compounds and thus it is also about us. Carbon was known in ancient civilizations, e.g., Egyptian and Roman, in the forms of soot and charcoal. Diamonds were known in China about 2500 BC. Scientists described almost ten million organic compounds formed by carbon. Carbon is the fourth most abundant element in the universe after hydrogen, helium, and oxygen. There is a lot of carbon in the Sun, stars, and comets. On the Earth it is the main constituent of many minerals and biological molecules. Inorganic carbon is contained in carbonate rocks: limestones, dolomites, marbles, and in carbon dioxide (CO_2); it occurs in organic deposits such as coal, peat, oil, and methane hydrate. Carbon is present in all life forms and is crucial for life on Earth because it forms many bonds to form complex organic molecules (carbon makes up to four bonds per atom). Strong Carbon-carbon bonds to other carbon atoms combine into long, strong, stable, rich in energy chains and rings, such as in a DNA that is made of two intertwined molecules built around a carbon chain. The carbon exchange results from the chemical, physical, geological,

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and biological processes. Carbon exists in the atmosphere as carbon dioxide (810 gigatonnes of carbon: one gigatonne = 10^9 metric tons), in water bodies (36,000 gigatonnes of carbon), and in the biosphere (1,900 gigatonnes of carbon). The amount of carbon in simple organic compounds (carbon plus hydrogen) of hydrocarbons, such as coal, petroleum, and natural gas, is around 900 gigatonnes. Carbon combines with hydrogen and oxygen into sugars, lignans, chitins, alcohols, fats, aromatic esters, carotenoids, and terpens. Carbon dioxide is the most important human-contributed greenhouse gas (which absorbs and emits infrared radiation) resulting in the greenhouse effect. A chemical element carbon C has atomic number 6. Carbon nucleus contains 6 protons and 8 neutrons (carbon isotopes have 2–16 neutrons). As a nonmetallic element, carbon in its solid form is dull and brittle, forms acidic molecules with oxygen, and has a tendency to attract electrons, making four electrons available to form very strong covalent chemical bonds (with pairs of electrons shared between atoms). It does not react with oxidizers at room temperature; when heated, it forms carbon oxides, which are used in the iron and steel industry. Carbon atoms can form covalent bonds to many other types of atoms and form many materials such as wood or body cells.

Organic carbon is a crucial component and a source of energy stored in carbon bonds and used by all living beings. Organisms (called autotrophs) extract carbon from the air in the form of CO_2 converting it into organic carbon and building nutrients. Using the sunlight's energy plants and plankton absorb and combine CO_2 and water to form sugar (CH_2O) and oxygen: $CO_2 + H_2O +$ energy $= CH_2O + O_2$. Glucose, fructose, and other sugars, through processes such as respiration, create fuel for further metabolic processes. Plants can break down the sugar to get the energy. Other organisms (called heterotrophs) must obtain organic carbon by consuming other organisms. Animals (including people) can get energy from breaking down the plant or plankton sugar; they have to eat it first. Oxygen combines with sugar to release water, carbon dioxide, and energy: CH_2O

Figure 1. Jennifer Funnell, Carbon. (© 2011, J. Funnell. Used with permission)