Chapter 1

Introduction

1.1 Preface

Carbon, the sixth element of the periodic table, is without doubt one of the most versatile elements known to man, as can be seen by the fact that it is the basis of life on this planet. Carbon forms the basic building block of virtually all organic chemistry and of the 20 million known molecules, about 79 % are classifies as organic.

Carbon in its ground state has an electronic structure of $1s^2 2s^2 2p^2$, but the 2s and 2p wave functions are normally hybridized to form 4 degenerate orbitals in a now sp^3 hybridized atom. This allows the carbon atom to form 4 identical covalent bonds to other atoms and gives the atom a tetrahedral geometry. The reasons why carbon is such a diverse element is that it can form bonds to a huge range of other compounds, such as N, S, O, Cl, Br and P which crucially are all thermodynamically stable. In addition to this, carbon can form single, double or triple bonds to other atoms and crucially, can also form these bonds to other carbon atoms. These carbon-carbon bonds have a very high intrinsic strength compared to similar bonds between other elements, for example, the bond strength of a C-C single bond has a value of 356 $kjmol^{-1}$ compared to a value of 226 $kjmol^{-1}$ for the equivalent Si-Si bond. As a result of this, it is possible to form carbon chains of phenomenal lengths, which is a property that allows materials such as carbon fibers to be produced. In addition to the wide range of organic molecules which contain carbon, there are several very important allotropes of carbon: fullerence, nanotubes, graphite, and diamond, as shown in fig. 1.1. Discovered a few years ago, carbon nanofoam, the fifth known allotrope of carbon, is discovered by the researchers of Australian National University [1].

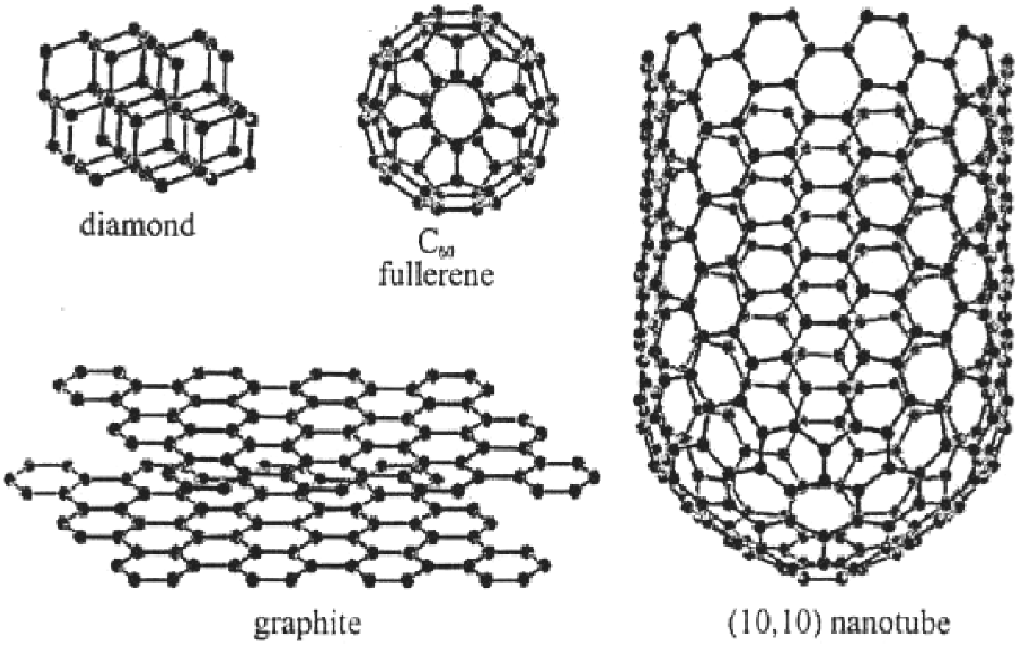

Fig. 1.1 Various forms of carbon: diamond, fullerene, graphite, and nanotube[1].

Carbon science has attracted great attention in recent years since the discovery of fullerence in 1985 by Kroto [2]. While it has long been known that carbon fibres can be produced with a carbon arc, and patents were issued for the process, it was not until 1991 that Sumio Iijima, a researcher with the NEC Laboratory in Tsukuba, Japan, observed that these fibres were hollow [3]. This feature of nanotubes is of great interest to physicists because it permits experiments in one-dimensional quantum physics. Techniques have been developed to produce nanotubes in sizeable quantities, but their cost still prohibits any large scale use of them.

Carbon nanotubes are wires of pure carbon with nanometer diameters and lengths of many microns. A single-walled carbon nanotube (SWNT) may be thought of as a single atomic layer thick sheet of graphite (called graphene) rolled into a seamless cylinder. Multi-walled carbon nanotubes (MWNT) consist of several concentric nanotube shells. The TEM image of a single-walled carbon nanotube (SWNT) and multi-walled carbon nanotubes are shown in fig. 1.2 [4].

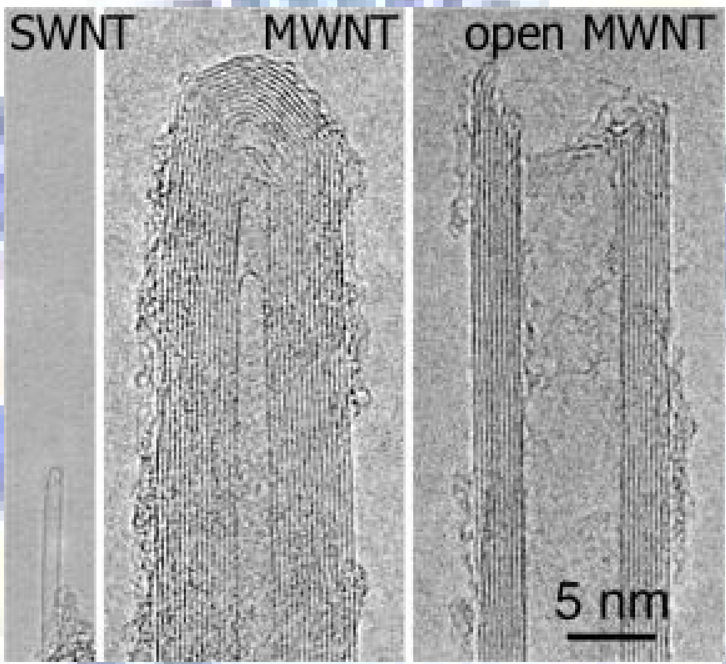

Fig. 1.2 TEM images of a single-walled carbon nanotube (SWNT) and multi-walled carbon nanotubes [4].

Understanding the electronic properties of the graphene sheet helps to understand the electronic properties of carbon nanotubes. Graphene is a zero-gap semiconductor; for most directions in the graphene sheet, there is a band gap, and electrons are not free to flow along those directions unless they are given extra energy. However, in certain special directions graphene is metallic, and electrons flow easily along those directions. This property is not obvious in bulk graphite, since there is always a conducting metallic path which can connect any two points, and hence graphite conducts electricity. However, when graphene is rolled up to make the nanotube, a special direction is selected, the direction along the axis of the nanotube. Sometimes this is a metallic direction, and sometimes it is semiconducting, so some nanotubes are metals, and others are semiconductors. Since both metals and semiconductors can be made from the same all-carbon system, nanotubes are ideal candidates for molecular electronics technologies.

In addition to their interesting electronic structure, nanotubes have a number of other useful properties. Nanotubes are incredibly stiff and tough mechanically- the world's strongest fibers [4,5]. Nanotubes conduct heat as well as diamond at room temperature. Nanotubes are very sharp, and thus can be used as probe tips for scanning probe microscopes, and field emission electron sources for lamps and displays.

1.2 Motivation

The unique electronic properties of carbon nanotubes had increasingly stimulated significant potential for future application in nanoscale electronic devices, such as field emission display (FED). The FED regarded as a serious contender to replace the cathode ray tube (CRT) is one of the most important and application of CNTs. Generally, glass substrates have been used for the application. Therefore, low temperature growth under 600 ℃ has been required to maintain thermal stability of glass materials. For large-area TV application, the important subject will also be to find the most cost-effective way to produce FED panels with large screen size.

Thick-film printing or spin–on glass (SOG) processes are mainly used for preparing a carbon nanotube field emission display, which has a strong cost advantage for large-size flat panel display. They can be applied to most substrates, including glass or a flexible one.

There are several methods to synthesize CNTs emitters. Among them, CVD is an effective method for direct growth of CNTs on certain substrates at relatively low temperature. Especially, it was reported that the patterned CNT emitters grown by microwave plasma enhanced chemical vapor deposition (MPCVD) possessed good field emission properties [6].

Combining the advantages of screening printing method and MPCVD method above-mentioned, in this study, we used solution deposition method and sol-gel method to prepare the thick films with catalysts on glass substrates. Then the CNTs grown on the thick films were synthesized by MPCVD at low temperature.