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APPLICATIONS OF NANOTUBES PRODUCED WITH PLASMA METHOD

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A b s t r a c t. Paper shows methods of producing carbon nanotubes and fields of their applications.

K e y w o r d s: applications of carbon nanotubes, plasma method.

INTRODUCTION

Carbon nanotubes (Fig. 1) were first discovered in 1991 by a Japanese scientist Sumio Iijima. They are single- or multi-wall filiform structures, consisting of cylindrical (layers of graphite), where the carbon atoms are in sp^2 configuration. Another description, which can be met in literature, is that they are one-dimensional quantum conductors (1D wires) [1]. The length of carbon nanotubes may exceed tens of micrometers, when their diameter is less than a few nanometers.

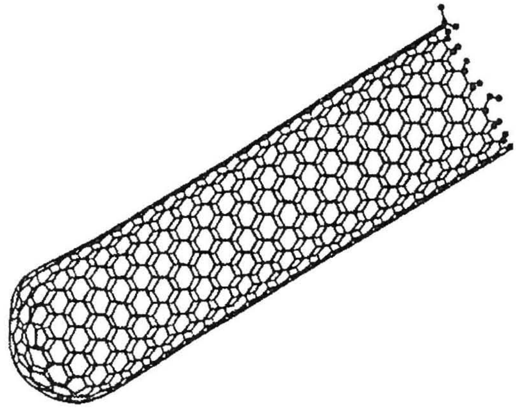

Fig. 1. A model of carbon nanotube open at one end, acc. to [1]

Single Wall Nanotubes (SWNT) can be obtained during a catalytic thermal decomposition hydrocarbons process (a method similar to CVD) and during laser sputtering of graphite. Nevertheless the most common method of gaining SWNT remains the electric arc discharge process, which is not expensive, rather efficient and the obtained nanotubes are not much structurally defected [2].

OBTAINING

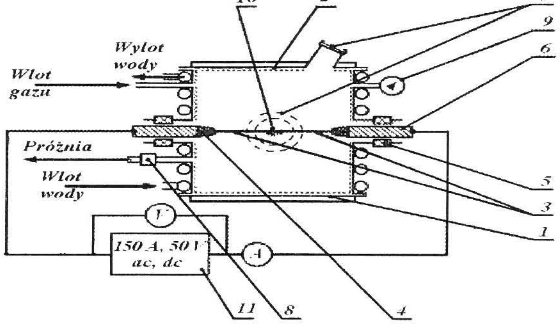

Fig. 2. Scheme of plasma generator for nanotubes deposition:: *1* - chamber walls, *2* -water-cooling, *3* - graphite electrodes, *4* - copper electrode handle, *5* - glass-metal isolator, *6* - bar, *7* - observation window, *8* - filter, *9* - manometer, *10* - carbon plasma, *11* - current source; acc. to [2]

During the process of electric arc discharge, the essential condition of keeping arc discharge stability (Fig. 2) is constant distance between graphite electrodes (ca. 0,5mm) – it influences the process efficiency. Optoelectronic equipment controls the electrode shift. It ensures productivity of about 60% of weight. Parameters of discharge: current 50-100 A, voltage 20-35 V. An important factor influencing the discharge process course is presence of buffer gas in the chamber (helium, ~$6{,}65 \cdot 10^4$ Pa). After lighting the arc, the graphite evaporates with speed of about 1 mm min^{-1}. The temperature of cathode area, where most of the nanotubes gather, has been valued at 2500-3000 °C.

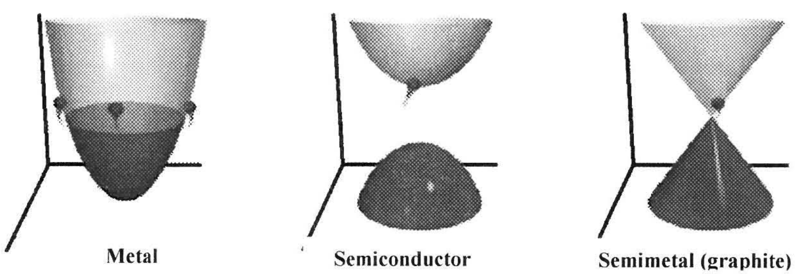

Fig. 3. Model of metal, semiconductor and graphite (semimetal); acc to [2]

PROPERTIES

Carbon nanotubes have very complex and interesting electron properties. The reasons are not only their sizes of nanometers (on quantum physics level) but also the fact they can be similar to graphite. Graphite is a semi-metal, a materiel where conductance and valence bands connect only in one point (Fig. 3) known as Fermi point. Twisting a single graphite sheet into a tube of nanometers diameter results in eliminating some electron states. Depending on type of the twist, SWNT is a metal or a semiconductor.

APPLIANCES

FET transistors

A few research teems in the world have already obtained working FET transistors (Figs 4 and 5) with semiconducting nanotube as channel [2]. Currently, performance of the transistors is comparable to similar silicon transistors. However, they need much less energy to work properly. Theoreticians also expect that in the future transistors made of nanotubes will be able to work at frequencies reaching 1 THz. It is also important that carbon nanotubes have much higher acceptable current-carrying capacity (ca. 1 GA/cm^2; according to [2]). Since SWNT can have properties of metals and semiconductors, a transistor made of just nanotubes is possible.

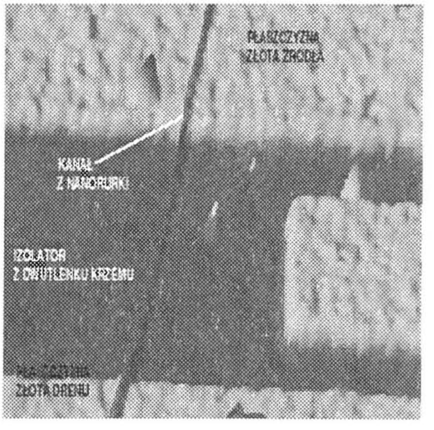

Fig. 4. FET transistor, where the role of channel is played by carbon nanotube; acc. to [2].

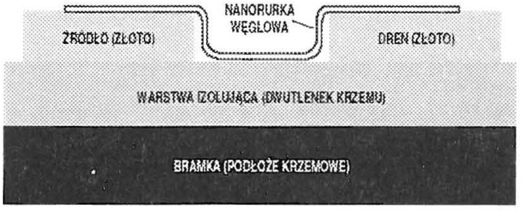

Fig. 5. FET transistor with silicon substrate as gate; acc. to [3].

Field emission

An interesting and already used property of carbon nanotubes is electron emission acquiring in external electric field (field emission phenomenon). The property of nanotubes, discovered in 1995, helped in production of displays (Fig. 6) where they are cold cathodes. Thanks to small diameter of nanotubes, electric field at its both ends reaches high values, which makes them one of the best electron sources. It is presumed that in the future this kind of displays may be an important competition for contemporarily popular LCDs.

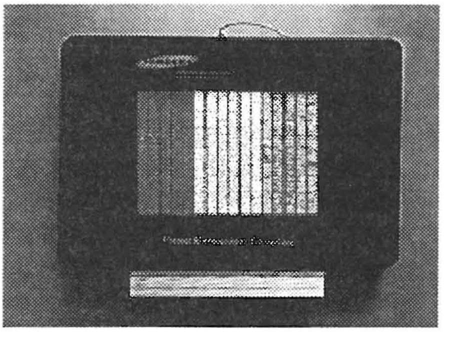

Fig. 6. Nanotube display.

Gas sensor

A new domain where Multi Walls Nanotubes (MWNTs) can be potentially applied, are gas sensors [4]. Operation of such sensor (Fig. 7.) is based on changing permittivity of sensitive layer ε_r into gas in presence of gas, which results in change of resonant frequency of active circuit. Gas sensitive layer consists of 60% SiO_2 and 40% MWNTs (according to weight).

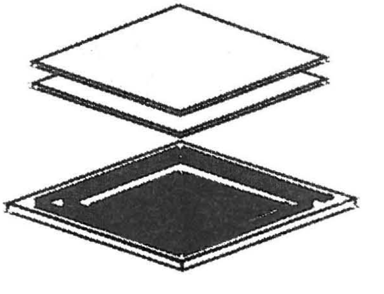

Fig. 7. A scheme of gas sensor made of carbon nanopipes; acc. to [4].

The described sensors are used in many commercial, industrial and medical appliances, e.g., oxygen sensors are used in combustion engines, ammonia sensors - for detecting its concentration hazardous for health, CO_2 sensors are used to determine precision of wrapping.

Heteronanostuctures

Electron properties of SWNT are much dependent on its shape, which is a consequence of very small size of nanotube. At the level of nanometers, as stated above, role of quantum phenomenon becomes more important. A defect in form of a pentagon-heptagon pair in SWNT results in a change of its twist degree, which has influence on bandgap width or even nanotube's polarity. Hence, there are high possibilities of producing equipment based on heterojunction or metal–semiconductor junction. STM microscope test proved that, within the length of few nanotubes, there are some m-s junctions in SWNT (Fig. 8). The junctions form naturally in carbon nanotube synthesis process. The advantages are obvious. First working electron devices operating in nanotubes field have already been produced [1].

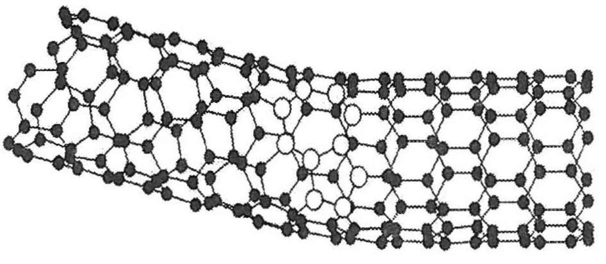

Fig.8. A model of heterojunction produced of SWNT by placing a defect (pentagon-heptagon pair) pentagon – heptagon; acc. to [1].

Other appliances

Despite their undeniable advantages and quantum properties of nanotube structures, nanoelectronics is not the only branch of science and technology where they can be used. High durability on mechanical stain - like bending, stretching or twisting - is also worth attention. It is suspected that nanotubes can in the future be structural elements of super-durable materials. By now, adding MWNT to already used stain durable materials does not worsen their properties [1,2]. Another property of SWNT, which engineers are interested in, is their ability to store hydrogen and helium ions. It potentially gives an opportunity to construct better fuel cells or accumulators. [1,2].

An example of device where nanotubes are used is an atomic force microscope, where SWNT plays the role of measuring needle. It results in over 10 times improvement of the microscope resolution [1,2]. With such a microscope DNA spiral can be observed and chemical markers, identifying one of few possible genes appearing in helix, can be recognized. By now they are used for short DNA fragments observations [2].

Scientists of Stanford University have used nanotubes to produce micro pencils enabling one to draw 10nm lines on silicon substrate with the speed of 0,5 mm/s. A nanotube put against the substrate removes the top level of hydrogen layer. Exposed silicon atoms are rapidly oxidized and thin carbon dioxide lines appear [5].

It is also worth mentioning that carbon nanotubes have good temperature resistance and are good heat conductors [2]. Nevertheless, these properties have not found concrete appliances yet, researches head in this direction.

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ZASTOSOWANIE NANORUREK WĘGLOWYCH WYTWORZONYCH METODĄ PLAZMOWĄ

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S t r e s z c z e n i e. Praca przedstawia metodę otrzymywania nanorurek węglowych i podstawowe obszary ich zastosowań.

S ł o w a k l u c z o w e : zastosowanie nanorurek, metoda plazmowa, otrzymywanie nanorurek węglowych.