# Catalytic CVD production of carbon nanofilaments using ethanol and methods of fabrication CNT-based devices.

*Moscow State Institute of Electronic Technology (Technical University), Zelenograd, Moscow, 124498, Russia*

**Simunin M.M.**

To produce carbon nanofilaments we used catalytic deposition from ethanol vapor. A catalyst was placed in the reactor, which pumped out and heated up to necessary temperature. After departure of a working point the ethanol are feeding in the reactor. In the issue we get a sample depending on used catalyst, and carry out on atomic-force microscopy.
The nanotube growing occurred according to next model. Particles of catalyst adsorb and solute a carbon into itself, and as the result it floating in own adsorbate. A carbon, by cooling, "getting out" from catalyst grain in adsorbate, but because number of "sorbtion places" is finite, that carbon desorbs out from grain. Model supposes that grain motions on surface like a drop of water on a warming pan.
First catalyst we used was a stainless steel previously oxidizes in manganese solution. In the issue after reaction we have frame structure consisted of onion-like carbon filaments. Next catalyst which we used was nickel particles with diameter, approximately about fifty nanometers. Look, after reaction we have a carbon composite of nanofilaments. Last catalyst which we used was a sol-gel chloride hexaammonium-nickel($[Ni(NH_3)_6]Cl_2$) in ethanol, marking on corundum substrate. In the result we have a carbon film consisted of plait-like carbon nanofilaments. These filaments as we see are rope twined of carbon nanotubes.
At pressure lower one kilopascal and five-fifteen minutes reaction time, we get a dependence of thickness carbon nanofilaments of temperature and catalyst type.

| Used Catalyst | T=550°C | T=600°C | T=650°C | T=700°C | T=750°C |
|---|---|---|---|---|---|
| Stainless steel | | 250 – 300 nm | 150 – 250 nm | 100 – 200 nm | 50 – 100 nm |
| Nickel particles | | | | ~50 nm | ~50 nm |
| Sol-gel | 20 – 30 nm | 20 – 30 nm | 20 – 30 nm | 20 – 30 nm | |

In first case, as is easy to see, has decreasing filaments diameter by increasing temperature. This may be determined a temperature dependence quantity of adsorbate on a catalyst particle. In other cases this dependence is not observed, that may be determined by small size of catalyst particle.
When we have technology of nanotubes growth we may manufacture devices next methods. The first – marking (of 2-propanol solution) nanotube on beforehand prepared structure. The next – can make lithography over nanotube film. And at last may grow nanofilaments on functional structures.

For transistor manufacturing the test structures were produced on $SiO_2$ substrates prepatterned with graphitized carbon electrodes with thickness 10 nm. The silicon substrate highly doped with boron was used as a back-gate. Carbon nanotubes dispersed in isopropyl alcohol were deposited on electrodes. As usual, carbon nanotubes assembled in bundles 1 – 15 nm in diameter with length up to 3 μm on the surface i.e. there are can be up to 100 single-wall CNT (SWCNT) in one bundle. The bundles of single-wall CNT form conducting channel between carbon electrodes. The current voltage characteristics (CVC) of such structures are nonlinear on principle that can be specified by the presence of tunnel contact between nanotube and electrode. In the work the tunnel contact decreased by annealing in 300ºC furnace. Fig. 1b shows the CVC of the structure with the bundles of nanotubes with dominant semiconducting conductivity for three values of gate potential ($V_{gate}$). When gate potential is increased to positive values, a bundle conductance decreases, that indicates the hole conductivity mechanism dominance. This behaviour corresponds to *p*-type semiconducting channel, that have been observed in scanning tunnelling microscopy of semiconducting SWCNT. The basic logic element - inverter has been created on the basis of SWCNT-bundle field effect transistor (FET). The off-chip resistor with nominal 1 megaohms was used as the loading resistor. The transistor drain was connected to supply $E_{sp}$ while free resistor contact was grounded.

Above described structure may serve as sensor vapor of ethanol. Conductivity of this structure increased three times by increased ethanol vapor concentration in atmosphere is twenty-five milligrams on liter. An ethanol come in camera via heat-variable resistor, and diffuse fall to sensor. As well as investigated a sensitive by appearance chlorum in atmosphere. In this case by increase chlorum concentration on zero-point-five ppm, conductivity increase in twelve times. A chlorum electrochemical producing from saturated solution sodium chloride in water. Gas is diffused in camera. The conductance of multi-walled carbon nanotubes, single-walled carbon nanotubes bundels networks and semiconductor single-walled carbon nanotubes was measured as a function of voltage and temperature between room temperature and 200ºC. The data show a logarithmic decrease in resistance as the temperature is rise.

In common the change in resistance equals to 25% for nanotube structures with metallic type of conductance.

For semiconducting nanotubes it can be more sensitive to temperature variation under the condition of positive gate potential. The measured resistance contains contributions from the nanotube-contact interface and from the nanotube itself.