CARBON NANOTUBES APPLICATED IN PRESSURE MEASUREMENT

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ABSTRACT

Novel pressure sensors have been achieved utilizing carbon nanotubes (CNTs) arrays as the electron source in emission sensor or as the surface increase element in capacitance sensor. Both sensors consisted of the elastic electrode-sensing film fabricated by wet anisotropic etching process and solid electrode. The emission sensor has elastic anode electrode with membrane and multi-wall carbon nanotubes (MWCNTs) arrays cathode in the vacuum chamber. The capacitance sensor has the same topology extensive by CNT on both electrodes without vacuum chamber. The MWCNTs were grown by plasma enhanced chemical vapour deposition (PECVD).

1. INTODUCTION

The pressure sensors are very important microelectronic devices. We are able to recognize several types of them mostly divided due to their function principles. The CNT are promising materials with wide range usage. We start working on two different types of pressure sensors; field emission pressure sensor and capacitance pressure sensor. The field emission vacuum sensor has excellent temperature stability, low-power dissipation, resistance to radiation and quick response. Up to now, devices using electron emitters are typically composed of array silicon tips fabricated by etching process.

The capacitance sensors are world-wide usage. The major problem is small electrode surface which has influence on the capacitance value. The CNTs utilization gives us the possibility how to increase the electrode surface.

2. ANALYSE

The CNTs were synthesized in an atmospheric pressure microwave torch. This technique has many advantages, absence of the vacuum system being the main. Microwave power from a generator (2.45 GHz) is supplied via a rectangular waveguide, matching unit and coaxial line to an iron nozzle electrode. The inner conductor of the coaxial line is a hollow double-walled tube accommodating a dual gas flow. Argon flows through the center of the line and nozzle. Reactive gases (H_2 and CH_4) are added sideways to the torch.

The CNTs were grown on silicon substrates coated with a thin iron catalytic layer (10 nm thick) which was vacuum evaporated.

The substrates with the catalytic layer were directly used for the deposition of nanotubes. The treatment of the catalytic layer producing catalytic particles necessary for the growth of CNTs was an integral part of the deposition. Typical deposition conditions were: flow rates of argon, methane and hydrogen - QAr = 1000 sccm, QCH_4 = 50 sccm and QH_2 = 200–300 sccm, respectively, microwave (mw) power of 400 W, substrate temperature 900 – 1100 K, deposition time 1 minute. The micrographs of as deposited nanotubes obtained with scanning electron microscope (SEM) are shown in Figure 1.

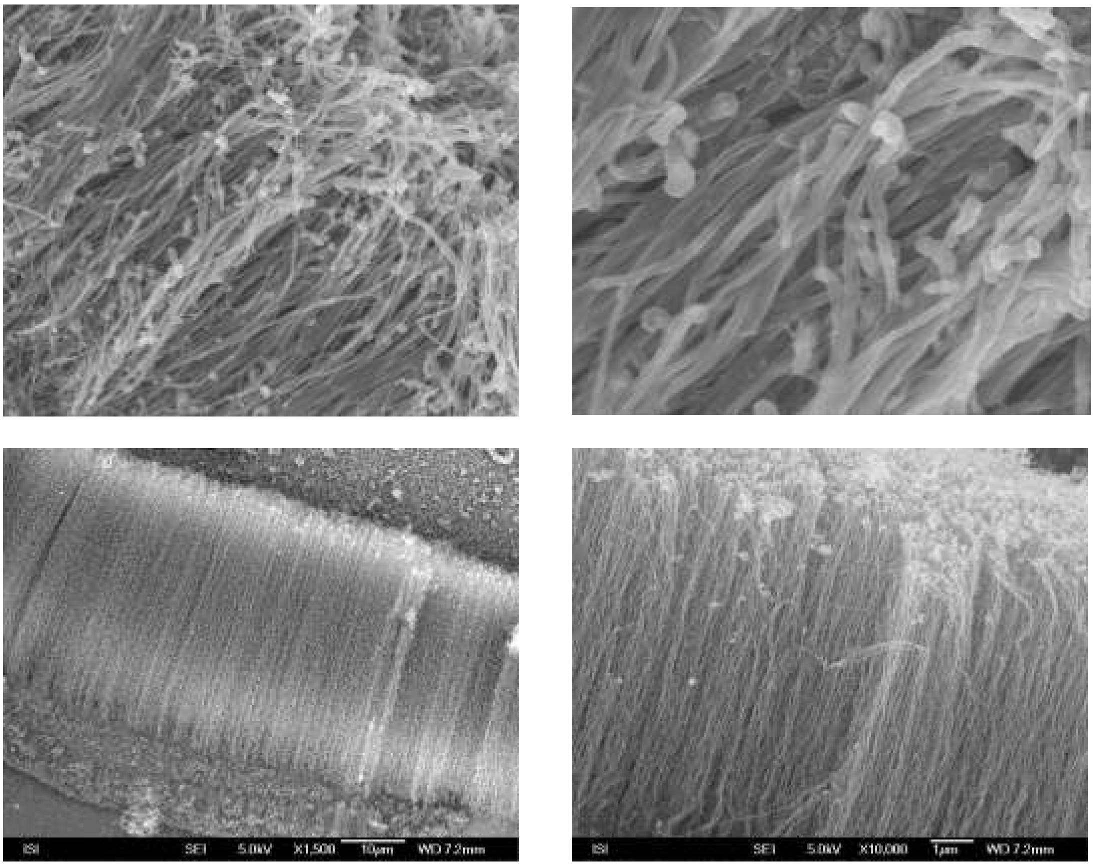

Figure 1: The SEM micrographs of as deposited CNTs.

2.1. SUBSTRATE

The material for sensing film was single crystalline n-Si wafer, <1 0 0> oriented and with 0,005 Ωcm resistivity and 525 µm thickness. The purpose for choosing so thick wafer is to cover the cathode emitter to get the vacuum chamber. The Si wafer was powered on both sides by silicon dioxide mask. Then the anisotropic silicon etching was performed without difficulty. A relatively deep etching (325 µm) on one side with a square section diaphragm (5 x 5 mm) assures the appropriate anode–cathode (emission sensor) or top-bottom electrode (capacitance sensor) spacing. Special care should be taken to establish the optimum SiO_2 layer thickness for the sensing film etching.

2.2. FIELD EMISSION PRESSURE SENSOR

The structure of the device is shown in Figure 2, which was composed of four major parts: anode, cathode, insulator, and vacuum chamber. When the external pressure bended the anode sensing film, the anode-emitter distance changes accordingly. Such device was based on the fact that the field emission current was correlated with the electrical field strength, i.e. the anode-emitter distance when the applied voltage was fixed.

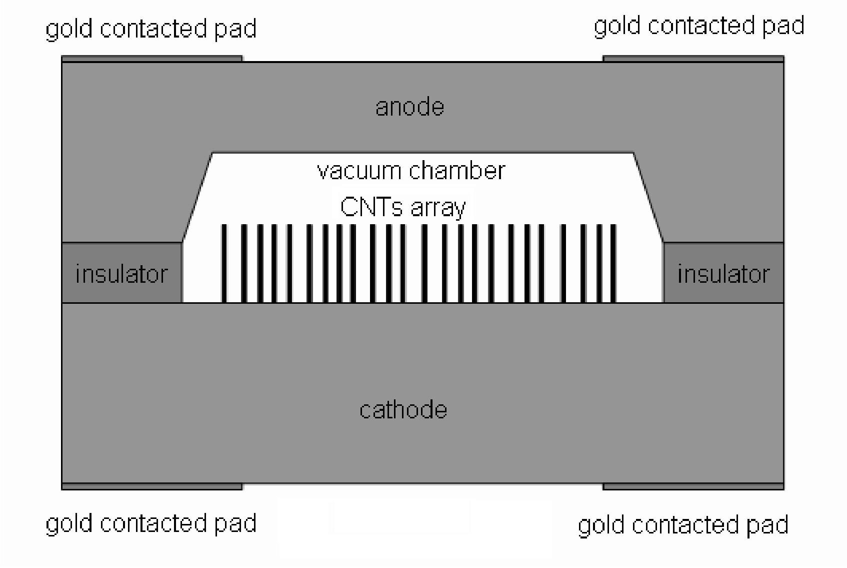

Figure 2: Topology of the field emission pressure sensor.

2.3. CAPACITANCE PRESSURE SENSOR

The capacitance pressure sensor has the similar topology as the field emission pressure sensor. The difference is only at anode surface and in vacuum chamber absence. The vacuum is compensated by the air which served as gaseous dielectric. Both of electrodes are enrichment with carbon nanotubes arrays which increase their surface several times. The Figure 3 and 4 are shown the structure and orientation of the both electrodes.

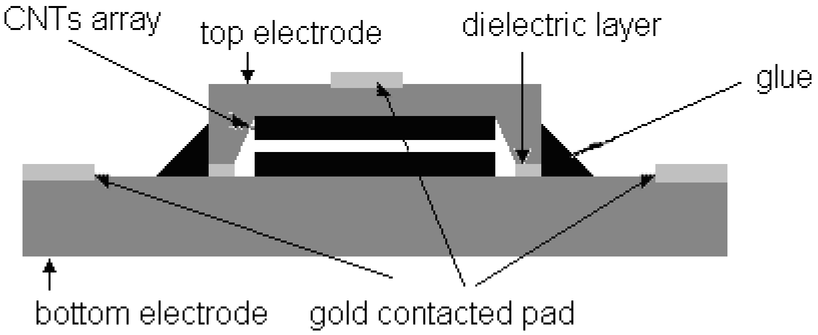

Figure 3: The structure of capacitance pressure sensor.

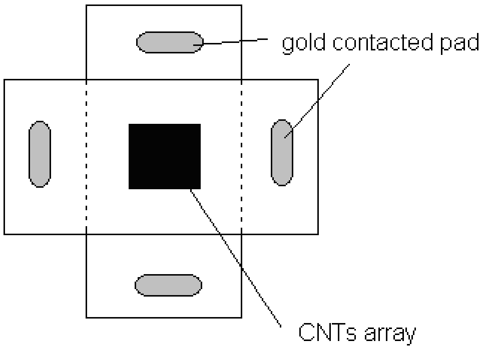

Figure 4: The top and the bottom wafer orientation.

3. CONCLUSSIONS

Novel pressure sensors have been developed utilizing multi-wall carbon nanotubes (CNTs) arrays as the electron source in emission sensor or as the surface increase element in capacitance sensor. The single crystalline n-Si wafer was chosen as a substrate. This wafer was modified by several technology processes such as wet etching to create a desire topology.

ACKNOWLEDGEMENT

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REFERENCES

[1] R. Ficek, R. Vrba, B.H. Kim, S. Goodnick, S. Milicic, Z. Kučerová, L. Zajíčková, M. Eliáš: Carbon nanotubes synthesized by plasma enhanced CVD: Preparation for measurements of their electrical properties for application in pressure sensor, IEEE SYMPOSIUM ON COMMUNICATIONS AND INFORMATION TECHNOLOGIES 2006, Bangkok, October 2006

[2] B. Mahar, C. Laslau: Development of Carbon Nanotube-Based Sensors, IEEE Sensors Journal, vol. 7, no. 2, pp. 266-282, February 2007