THERMAL CVD SYNTHESIS OF CARBON NANOTUBES IN SWIFT HEAVY ION TRACKS OF SILICON DIOXIDE

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During the last years, a growing interest in the creation of micro- and nanoelectronic devices by use of the swift heavy ion track technology in a combination with carbon nanotubes (CNTs) is observed in several research centers worldwide. The CNTs were grown in etched ion tracks in SiO_2 layers on Si. For this purpose, Ni-catalyst nanoclusters were electrochemically deposited within the ion tracks. The geometry of the obtained nanostructures has been analyzed. Structure features of CNTs obtained by thermal chemical vapor deposition have been investigated.

1.Introduction

At present a strong tendency is observed to use the swift heavy ion (SHI) track technology for creation of various devices for micro- and nanoelectronics. To create an ion track, being a narrow zone with altered physical and chemical properties, one needs to apply a beam of SHIs, with energy in the MeV to GeV range [1-4] to a suitable material. Further, by means of the chemical etching of latent tracks, pores of various forms and dimensions (typically 10-1000 nm)

depending on irradiation parameters, etching conditions and substrate type, are formed.

As was shown by Berdinsky *et al*. [4], due to CNTs deep rooting within the ion tracks, the CNTs should be more stable than others against a mechanical influence. Moreover, any chemical vapour deposition (CVD) process allows to get bended CNTs, which are interlaced that leads to an increase of mechanical stability of the CNTs array. This could prevent decomposition of CNTs during the field emission process. Therefore, the conventional thermal chemical vapor deposition (TCVD) process can give the array of CNTs and randomize location of their tips with different height.

1. Experimental techniques

N-doped Czochralski-grown 76 mm silicon wafers of typical thickness 500-550 μm and (100) orientation were thermally oxidized, and Si dioxide layer thickness was 0.7 ± 0.1 μm. Thereafter, the wafers were homogeneously irradiated by $^{197}Au^{26+}$ ions with energy of 350 MeV at the BIBER (Berlin Ion Beam Exposure and Research Facility) chamber of the ISL heavy ion accelerator of the Hahn-Meitner-Institute, Berlin, Germany, at a flux of typically 0.1 nA up to fluences of 5×10^8 cm^{-2}. The resulting latent SHI tracks produced in the oxide layer were etched by 1.35 wt.% HF solution at 20±1ºC for 40 min, until the track opening was detected. The geometry of etched tracks (nanopores) is a truncated cone with the base diameter of 150-200 nm at the Si/SiO_2 interface and 250-300 nm on the top. The final depth of pores (200 nm) was less than the initial thickness of SiO_2 layer due to etching process of SiO_2 film.

It is known that nickel can serve as a catalyst for the subsequent CNTs growth. Ni nanoclusters were deposited electrochemically on the exposed silicon at the bottom of etched tracks. For this purpose the nanoporous samples have been inserted into an electrochemical cell with the nanoporous oxide facing solution of 0.5 mol/l H_3BO_3 + 0.5 mol/l $NiSO_4$, and the backside being contacted as the cathode with application of -1.2 V DC [5].

A growth of CNTs by TCVD was carried out under the following technological conditions: CH_3CN was used as the carbon source with consumption of ~ 1 cm^3/h. Temperature of the synthesis was 800ºC and the synthesis time was 15 min. The synthesis took place in nitrogen environment. A flow rate of nitrogen was 150 ml/min. The area of silicon substrate was 6 × 12 mm^2.

2. Results

According to the goal of the present research to create etched ion tracks with subsequent electrochemical deposition of Ni-catalyst and growth of CNTs, our concept is presented in Fig. 1.

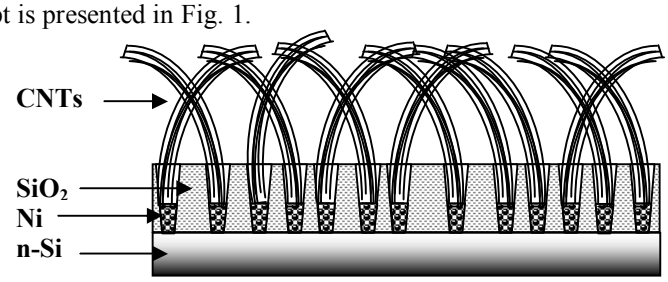
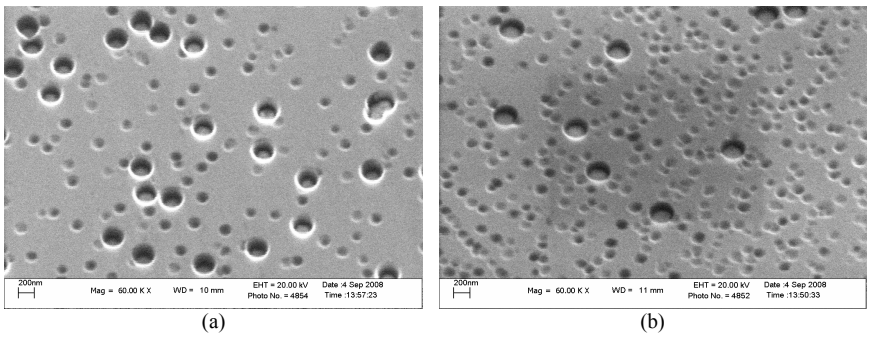


Figure 1. Fabrication of an array of carbon nanotubes in the n-Si/SiO_2/Ni nanoporous structure.

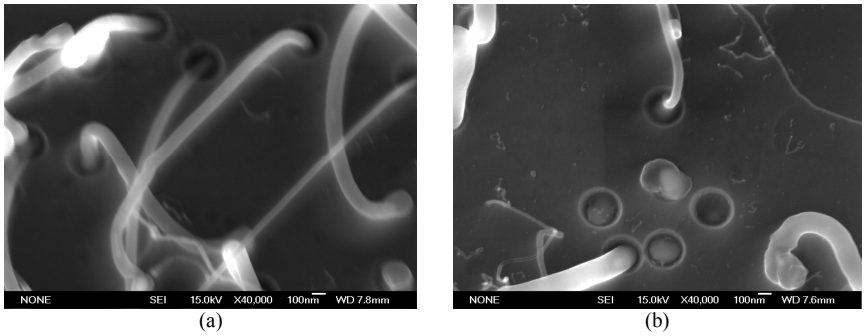
Ni nanocluster catalyst serves as a "bridge" between the conventional Si technology and CNTs synthesis. Previous investigations [6] have shown that for an effective synthesis of CNTs it is important that ion tracks should not be filled by Ni on their entire depth. At the complete Ni filling of ion tracks the CNTs would be mostly grown along the surface of the dielectric layer. For the CNTs growth partially perpendicular to the dielectric layer surface it is necessary that the growth direction is determined by the ion track channel axis. In accordance with that task, the electrochemical deposition technology has been adapted to the partial deposition of Ni nanoclusters into the ion tracks. In this way, the samples with nanopore filling on 1/3 of its depth (Sample1) and 1/2 of its depth (Sample 2) at the deposition time of 30 s and 60 s, correspondingly, were obtained. This has been confirmed by the scanning electron microscopy (SEM) imaging and X-ray spectral microanalysis on a LEO-1455VP set up (Fig. 2).



(a) (b)

Figure 2. SEM images of Ni nanoclusters in nanopores of SiO_2 layers for the sample 1 (a) and the sample 2 (b). The electron beam scanning was made by an angle of 30º to the specimen's surface.

CNTs in n-Si/SiO_2/Ni nanoporous structure were synthesized in accordance with the above techniques and their arrays have been fabricated. This was confirmed by SEM investigations (Fig. 3). Raman spectroscopy characterization of the obtained structures have confirmed the formation of multiwall CNTs.



(a) (b)

Figure 3. SEM images of CNT arrays in n-Si/SiO_2/Ni nanoporous structures for the sample 1 (a) and the sample 2 (b). The electron beam scanning was made perpendicular to the specimen's surface.

3. Conclusion

The obtained nanostructure containing CNTs can be proposed for creation of field emission cathode prototypes, in particular, for novel display systems.

Acknowledgments

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