INVESTIGATION OF LOW DIMENSIONAL MATERIALS ON SAPPHIRE SUBSTRATE FOR SENSOR APPLICATION

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In this paper we mainly analyzed the carbon nanotubes (CNTs) grown on c-plane sapphire substrate for performance of next generation sensors. The synthesis of CNTs on sapphire substrate was performed by A-CVD system with horizontal quartz reactor covered by movable electric furnace. The CNTs were grown at higher temperature (850-1000ºC) using the two different methods: 1) The CNTs were synthesized by decomposition of ferrocene (Fe(C5H5)2) mixed cyclohexane (C6H12) (5mg/ml) solution on pure sapphire. 2) The growth of CNT on thin Fe catalyzer (10-20 nm thickness) covered sapphire substrate using the pure cyclohexane as carbon source. Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM) and Raman spectroscopy methods have been used to observe morphology and structure of CNTs.

1. INTRODUCTION

Low dimensional materials composed of carbon and carbon nanomaterials are a remarkable class of materials with unique properties. Materials with a large surface area to volume ratio can be a good candidate in optoelectronics applications. The past decade has seen a rapid emergence in the use of nanomaterials for sensing applications including the development of high-sensitivity and high-specificity biosensors. Since their discovery CNTs have become important scientific objects of extensive research due to their remarkable physical properties and technological applications. CNTs share the mechanical strength of graphene, but the electronic structure has many features not seen in graphene, such as the van Hove singularities arising from the one dimensional confinement, that lead to many interesting optical and electronic effects [1–3].

On the other hand CNTs are promising nanomaterials due to their high aspect ratio, superlative mechanical, thermal and electronic properties such as high thermal conductivity, high elasticity and high optical transmittance. The chemical vapor deposition (CVD) growth produces high-quality, perfectly aligned CNTs on substrates [4–6]. In this paper we mainly analyze the synthesis of CNTs on sapphire substrate for performance of next generation (bio)sensors at the next research stage. As a continuation of this work, the grown of GaN layers on the CNT/sapphire and the role of CNTs to improve the quality of GaN will be study.

2. EXPERIMENTS

The synthesis of CNTs on the c-plane sapphire substrate was performed by aerosol-chemical vapor deposition (A-CVD technique from SCIDRE). The A-CVD system consists of horizontal quartz reactor covered by movable electric furnace. This technology is based on the injection of the solution in the reactor as an aerosol and its decomposition under high temperature (850-1500ºC). As a solution for the aerosol the carbohydrate liquids were used. The high frequency (790 kHz) has been used by ultrasonic device (transducer) to obtain an aerosol from solution. Ar/H_2 mixture was flowed to the system during the synthesis process as a transport gas and the total gas flow was 300 sccm. The CNTs were grown on c-plane sapphire substrate using Fe catalyzer and organic cyclohexane solvent with two different methods:

1) The CNTs were synthesized by decomposition of ferrocene (Fe(C5H5)2) mixed cyclohexane (C6H12) solution (5mg/ml ratio) on pure sapphire. In this case optimal ferrocene and cyclohexane ratio was 5mg/ml. the growth temperature and time were 950ºC and 10 minutes respectively (sample A).

2) The growth of CNTs on thin Fe catalyzer (10-20 nm thickness) covered sapphire substrate using the pure cyclohexane as carbon source. Fe catalyst was deposited on c-plane sapphire substrate in 10^{-6} Tor vacuum by e-beam evaporator (SNTEX) device. The thicknesses of catalyst approximately were between 10 and 20 nm. One piece of Fe covered sapphire substrate was annealed in air atmosphere at 500^0C for 30 minutes, and then CNTs were synthesized on this substrate (sample B). The CNT also was grown on the second piece of thin Fe layer covered (not annealed) sapphire substrate (sample C). The growth temperature and time for these two samples were same with sample A.

3. RESULTS AND DISCUSSIONS

Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM) and Raman spectroscopy methods have been used to observe morphology and structure of CNTs.

The Raman spectroscopy (532 nm) was used for detection of carbon nanotubes on sapphire and study of nanotube structure (Fig. 1). The samples were investigated at room temperature and pressure at 4mW and 8mW laser excitation powers.

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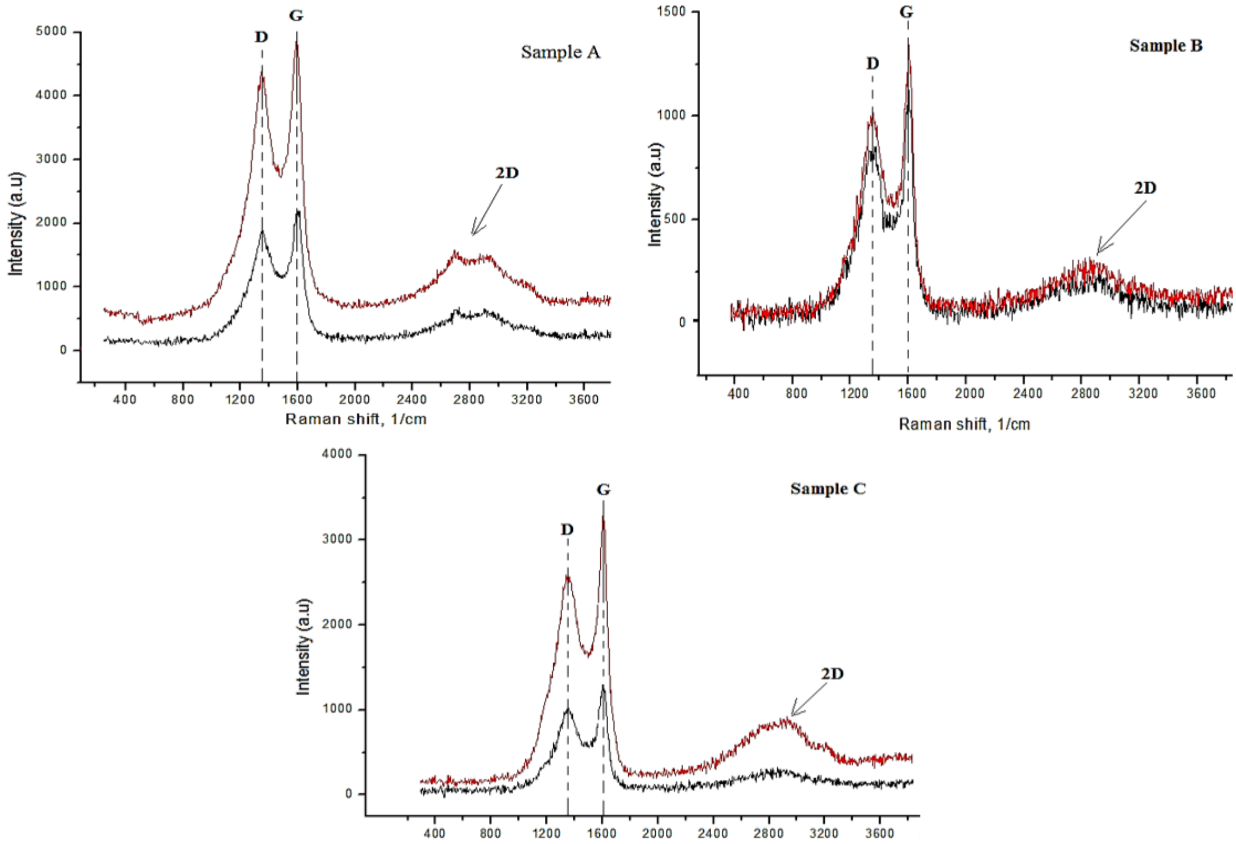

Fig. 1. Raman spectrum from a MWCNTs samples grown on sapphire substrate (black- at 4mW red- at 8 mW laser excitation powers).

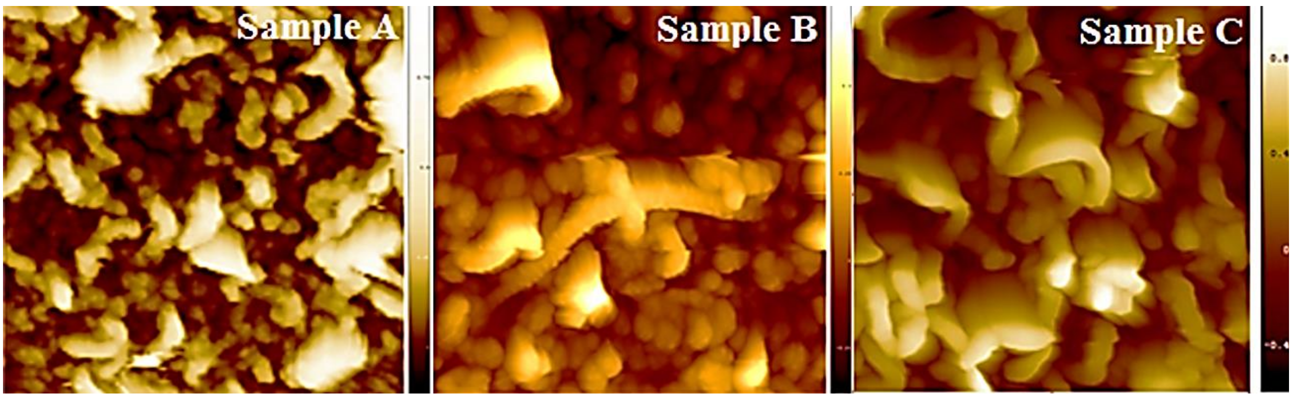

Fig. 2a-c show the atomic force microscopy topography forward 2D images of CNTs.

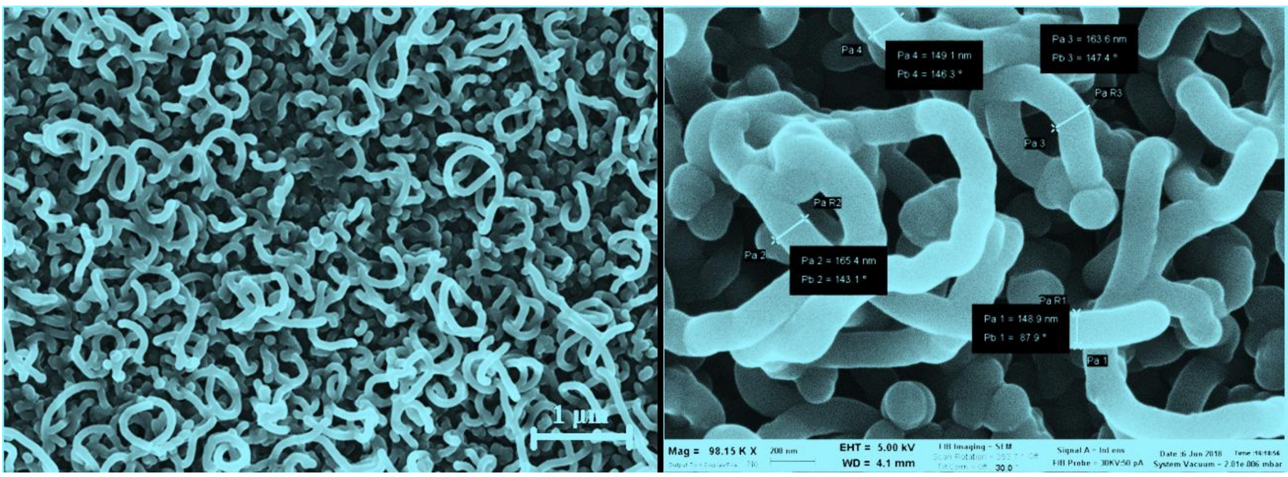

Fig. 3 SEM picture of the CNTs deposited on Fe covered c-plane sapphire substrate (left). On the right the magnification is enlarged. (SEM investigations were done at Institute of Materials for Electronics and Magnetism, in Italy)

Due to the specific Raman resonance effects it was possible to detect Raman scattering spectra of a small bundle of MWCNTs. A strong feature at around 1323 cm^{-1}, 1337 cm^{-1}, 1327 cm^{-1} respectively sample A, B and C, the so-called D line, assigned to disordered graphitic material. A group of peaks in the approximate range 1600–1610 cm^{-1} labelled the G band. In graphite, the G band exhibits a single peak related to the tangential mode vibrations of the C atoms. A line at around 2800 cm^{-1}, the second order harmonic of the D mode, labelled 2D. According to the Raman intensity and lines ratio samples C indicates high structure quality and less amorphous carbon to compare sample A and B.

AFM (Bruker) experiments were performed in ambient condition. Topography forward 2D images indicate the horizontal and mixed CNTs on sapphire substrate (Fig. 2). Comparison of AFM results from three examples it can be also seen that CNTs are more visible in sample C. Therefore the SEM investigation was done for only on sample C. SEM (ZEISS FE) investigations were confirmed that the empty (without Fe inside tube) CNTs were grown on sapphire substrate and the diameters some of them were between 145nm-165 nm (Fig. 3).

4. CONCLUSIONS

The CNTs have been grown on sapphire substrate at 950°C by two catalytic (Fe) methods. The optimal growth method was confirmed by Raman spectroscopy and AFM. SEM investigations were indicated that the most of CNTs were empty (Fe free) and the diameter and length of CNTs were 170 nm and 1 μm respectively.

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