Optimisation of CNT Based Nanostructures for Use as Electron Sources

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The aim of this paper is to describe the growth and optimization of carbon nanotube (CNT) based nanostructures to produce novel electron sources for use in a variety of applications including, Electron microscopy, e-beam lithography, travelling wave tubes (TWTs), backlighting and x-ray sources.

Because of their unique properties including their shape and current carrying capabilities Carbon Nanotubes are ideal as electron sources. The emitters studied in this project include spaghetti type layers of CNTs and regular array of vertically aligned CNTs. They will also include CNT/ZnO nanostructures as alternative sources. The objectives of this work are to develop a cathode that is able to deliver a stable current density of > 1A/cm^2 at DC and even higher in pulsed mode and to produce cheap, stable light emission sources for lighting applications such as backlighting which are able to run at comparatively high pressures to provide 1 mA/cm^2. In order to attain the large current densities with reasonable uniformities and long life time required for application to X-ray sources, it is necessary to prevent the best CNT emitters in the array from emitting too large a current by use of an integrated ballast resistor. In this paper we will also describe our recent work in this area.

Although we can get significant emission from the spaghetti type layers of CNTs, which are suitable for use in backlight structures in AMLCDs, as shown in Figure 1 (a), the CNTs we have investigated most frequently are in arrays which are vertically aligned, as previously described in reference [1]. Such a cathode design allows us to minimize the electric field shielding effects and lead to the higher current densities needed in TWTs and X-ray sources. A typical array is shown in Figure 1(b).

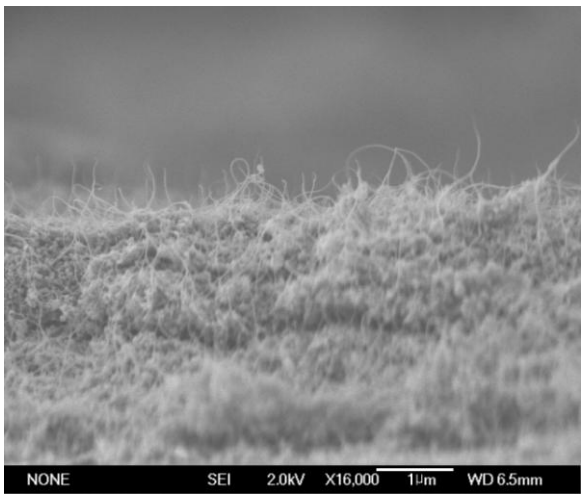

Fig. 1(a) Spaghetti type CNTs

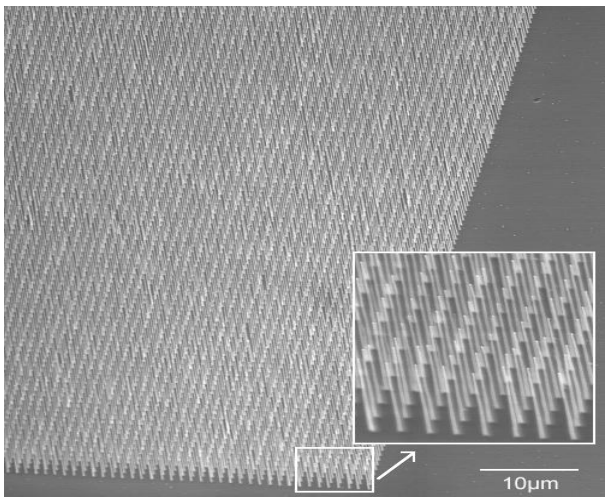

Fig. 1(b) Vertical array of MWCNTs

A smaller version of such an array consisting of a 22.5 μm x 22.5 μm array of CNTs spaced 2.5 μm apart providing 100 CNTs, produced a current density of 18A/cm^2 at 9V/μ. In order to attain such large current densities with reasonable uniformities and long lifetimes, however, it is necessary to prevent the best CNT emitters in the array from emitting a current larger than the current which induces their destruction (around 100 μA). To solve this problem, a ballast resistor must be integrated.

Our initial efforts to produce the ballast resistor structure was based on an SOI (undoped-Si/SiO_2/Si) substrate employing electron beam lithography and plasma enhanced chemical vapour deposition (PECVD). First, a catalyst dot array similar to that shown in figure 1(b) was produced using e-beam lithography and Ni metal sputtering. Finally, a top-contact layer of tungsten was used to bias the CNTs, with the gap between the tungsten and CNTs of undoped Si acting as the ballast resistor.

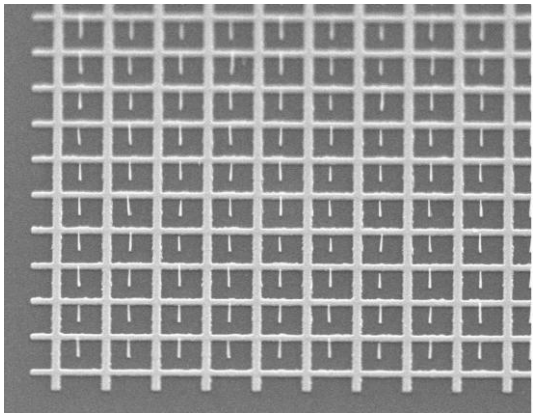

Fig. 2 An array of CNTs grown on undoped SOI.

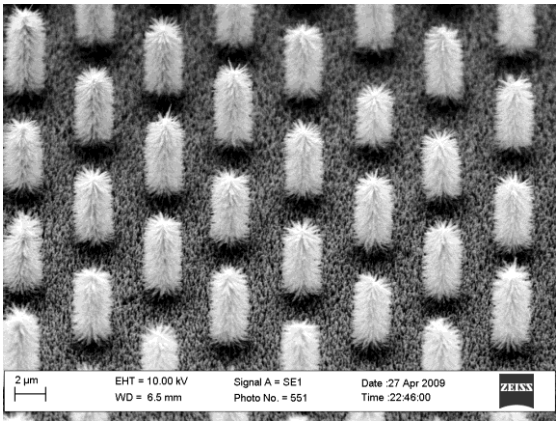

Fig 3 ZnO coated CNT array

However, the fabrication process for this structure is very complex. This may be acceptable for expensive x-ray sources and Travelling Wave Tubes, but is undesirable for lighting applications and thus a novel, but simpler structure, incorporating a combination of Carbon Nanotubes and ZnO nanowires, has been produced for this application.

Firstly a CNT array such as the one shown above in Figure 1(b) was produced and then ZnO nanowires were grown onto these using a simple hydrothermal method to produce the arrays shown in figure 4. A solution of zinc acetate dehydrate (98%, Aldrich) in 1-propanol (spectroscopic grade) was prepared. The solution was then spin coated onto the VACNF array at 2000 rpm for 30 s. The substrates were then annealed at 100°C fpr 2 minutes after each spin coating step to promote adhesion. A uniform seed layer was obtained after three layers of spin coating. The ZnO nanowires were then grown by dipping the substrates in an equimolar mixture of 25 nM zinc nitrate hexahydrate ($Zn(NO_3)_2 \cdot 6H_2O$, Sigma Aldrich) and hexamethylenetetramine (HTMA, Sigma Adrich) in deionized (DI) water heated in an oven at 80°C.

This presentation will therefore describe the growth and production of the CNT emitters, their optimisation and their use in electron microscope sources, parallel e-beam lithography, travelling wave tubes, portable X-ray sources and backlights.