Carbon nanotube photocathodes for optically driven multiple X-ray sources

P. Legagneux[1], P. Ponard[2], L. Gangloff[1], S. Xavier[1], C. Bourat[2], J. Martinez[2], C.S. Cojocaru[1], A. Gohier[1], JP Mazellier[1], JP Schnell[1], D. Pribat[1], K.B.K. Teo[3].

[1]Nanocarb, Thales-Ecole Polytechnique, Palaiseau, France
[2]Thales Electron Devices, Thonon, France
[3]Aixtron, Cambridge, UK
Pierre.legagneux@thalesgroup.com

We have demonstrated the first optically driven X-ray source based on carbon nanotube (CNT) photocathodes. It is a compact dual X-ray source and the two sources are accurately and independently controlled with two laser diodes illuminating the photocathodes. Thanks to the emission stability, high quality images have been obtained. This dual source provides two images from two different viewing angles. This concept can be easily extended to multiple X-ray sources. Associated with linear or 2D X-ray detectors, low cost, compact/mobile, efficient and stationary (gantry free) tomosynthesis scanners could be realized. Such systems which provide 3D imaging can be used for security applications, non-destructive inspection in the industry and for medical applications. The innovation is the use of CNT photocathodes [1]. X-ray sources based on these photocathodes exhibit the following features: galvanic insulation for current control, fast switching and accurate control of X ray emission.

The CNT photocathode is an array of vertically aligned multiwalled CNTs (electron emitters) associated with individual p-i-n photodiodes. These photodiodes act as optically-driven current sources. The emitted current varies linearly with the optical power delivered by the laser diode located under the photocathode.

Figure 1 shows a schematic description and SEM pictures of the fabricated photocathodes which are based on silicon photodiodes. CNTs are grown on n+ doped areas defined by ion implantation in a 5 µm thick intrinsic layer. The p+ doped silicon wafer is thinned to obtain a 7 µm thick membrane and to enable backside illumination of the photocathode. In order to demonstrate the proof of concept of this new system, we have fabricated a dual X-ray source based on two CNT photocathodes (see figures 2-4). The distance between the two sources is 10 cm. Due to the galvanic insulation (optical control), we can use a simple diode configuration with a high voltage applied to the photocathode and with a grounded anode. Compared to the power supply used in a conventional X-ray tube, no high voltage filament transformer is required. Thus our high voltage power supply is compact (see Figure 4). Being grounded, the anode is a tungsten film directly deposited on the X-ray window. The anode cooling is then simply performed by air convection. To obtain X-ray images, we have used a 2D X-ray detector and positioned different objects between the source and the detector. With this dual source, 2 views in parallel are obtained (see Figure 5). Figure 6 shows an image of an animal obtained with one single CNT photocathode.

This work was funded by the ANR project SPIDERS. Through the ANR project NANOSCANNER, we are currently studying the fabrication of CNT photocathodes based on low temperature grown GaAs photoswitches that should exhibit very large ON/OFF ratio (a few hundreds).

References

[1] L. Hudanski, E. Minoux, L. Gangloff, K.B.K. Teo, J.-P. Schnell, S. Xavier, W.I. Milne, D. Pribat, J. Robertson, P. Legagneux, "Carbon nanotube based photocathode", Nanotechnology 19 105201 (2008).

Figures

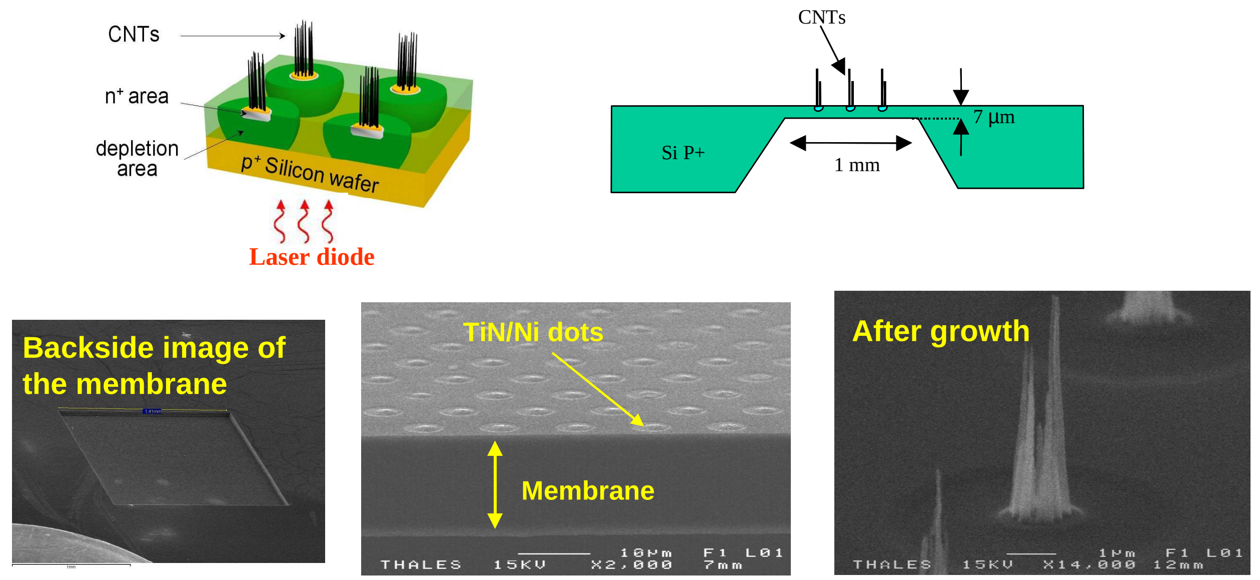

Figure 1: Schematic description and SEM pictures of the CNT photocathode. The photocathode uses multiwalled CNTs as electron emitters and silicon p-i-n photodiodes to control the emission. CNTs are grown on n+ doped areas defined by ion implantation in a 5 µm thick intrinsic layer. The p+ doped silicon wafer is thinned to obtain a 7 µm thick membrane. This enables backside illumination of the photocathode.

Figure 2: Picture showing the two "satellites" holding the CNT photocathodes. The backside of the upper left photocathode is illuminated.

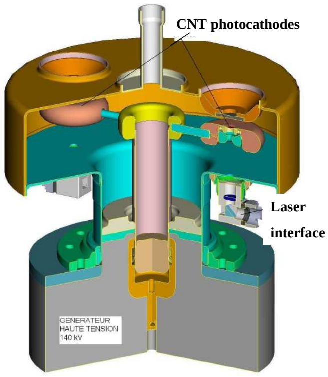

Figure 3: Schematic description of the optically driven dual X-ray source

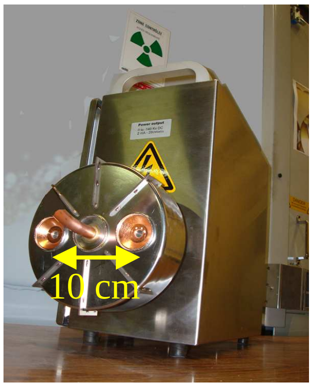

Figure 4: Picture of the dual X-ray source associated with the power supply.

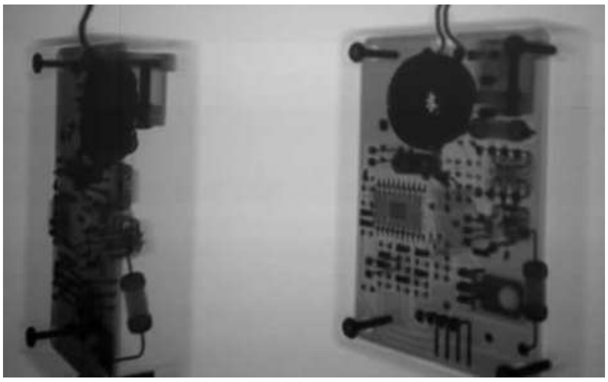

Figure 5: Images of a printed circuit board obtained on the 2D X-ray detector with the dual source (2 views in parallel)

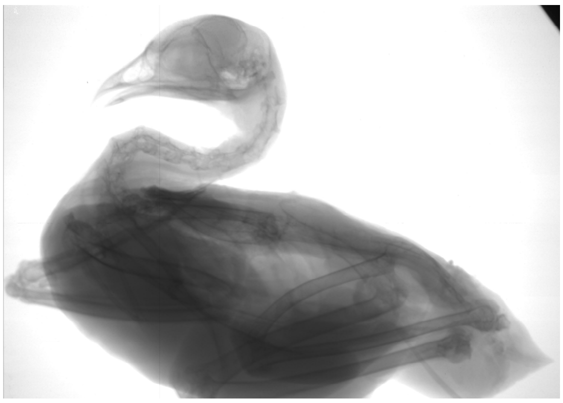

Figure 6: Image of a bird realised with a single CNT source.