Biomedical applications of double-walled carbon nanotubes and questions related to their potential impact on human health and the environment

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Carbon nanotubes (CNT), with an annual world production reaching several hundreds of tons, represent a special category of nanomaterials with exceptional characteristics. In particular, they are currently investigated for many biomedical applications, ranging from medical imaging (MRI, Raman) to targeted drug delivery and cancer treatment. Tissue engineering is a field in which CNT could bring many improvements as compared to existing biomaterials, and especially for regeneration of neuronal tissues as they provide a unique combination of useful electrical and mechanical properties at the nanometer scale. Double-walled CNT [1], at the frontier between SWNT and MWNT, are very promising for applications in the biomedical field.

Recent results will be presented, showing that through surface engineering, we can direct and guide the growth and differentiation of neural cells. Topographical grooves obtained by a moulding process against a silicon master turned efficient for both neural lines cells and adult neural stem cells. Double-walled CNT [1] patterns obtained by soft lithography were also found very efficient and have the advantage of possible electrical stimulation due to their metallic electrical behaviour. In both cases, low cost fabrication processes (moulding or soft- lithography) are developed, enabling further large scale applications for biological or medical purposes. Potential application of DWNT for medical imaging (MRI) and gene delivery will also be presented.

Although the toxicity and the environmental impact of CNT have now both been investigated by many different groups (although the latter never focused much attention until very recently), there is yet a controversy about the results and still no answer to the simple question: "are CNT toxic?" The fact is that the large range of kinds of CNT and methods to produce and then (in most cases) process them make any comparison almost impossible. The results presented here were obtained with the same batch of CCVD-produced DWNT [1] investigated for biomedical applications, and concern both the investigation of their potential impact on human health (*in vitro* / *in vivo* models) [2, 3] and the environment (*in vivo* models) [4]. They lead to the conclusion that all the experimental parameters (dealing both with CNT and biological models used) play a very important role and can easily explain the large differences between the results obtained by the different researchers.

[1] E. Flahaut et al., *Chem. Comm.* (2003) 1442.
[2] E. Flahaut, M.C. Durrieu, *, Ch. Baquey, Carbon, 44, (6), (2006), 1093-1099
[3] J. C. Debouzy, D. Crouzier, E. Flahaut, *Env. Toxicol. Pharmacology*, 30, (2), (2010), 147-152
[4] E. Flahaut, *Nanomedicine*, 5, (6), (2010), 949-590