ENVIRONMENTAL ASSESSMENT OF CARBON NANOTUBES SYNTHESIS *via* CHEMICAL VAPOR DEPOSITION

A. F. Trompeta[1], N. Vlachou[1], D. K. Perivoliotis[1], M. A. Koklioti[1], V. Markakis[1], G. Tsiliki[2], H. Sarimveis[2], C.A. Charitidis[1,*]

[1]Research Unit of Advanced, Composite, Nano-Materials & Nanotechnology, School of Chemical Engineering, National Technical University of Athens, 9 Heroon Polytechniou St., Zografos, 15780, Athens, Greece

[2] Unit of Process Control and Informatics, School of Chemical Engineering, National Technical University of Athens, 9 Heroon Polytechniou St., Zografos, 15780, Athens, Greece

*charitidis@chemeng.ntua.gr

Keywords: Life Cycle Assessment, Chemical Vapor Deposition, Carbon Nanotubes, Supported Catalyst Approach, Environmental Impacts

ABSTRACT

The identification of the environmental impacts of a process in the early stages of process design via life cycle assessment (LCA) methodology is becoming more and more essential for an eco-friendlier material synthesis/manufacture. These impacts are also inherent in the background processes involved in a process or a material production, e.g. the formation of the resources used together with emissions and waste streams. As a result, LCA seems to be a prerequisite tool for the environmental assessment of chemical processes, in order to define them as 'green'.

The LCA methodology is a well-documented procedure that is based on the international standards ISO 14040: Principles and Framework, and ISO 14044: Requirements and Guidelines. For the conduction of an LCA study, the stages of goal and scope definition, inventory analysis, impact assessment and the interpretation of results are obligatory.

In this study, LCA has been conducted on the growth of multi-walled carbon nanotubes (MWNTs) via thermal chemical vapor deposition (T-CVD). The supported catalyst approach has been chosen for the growth MWCNTs and as catalyst Fe/Al_2O_3 has been used. The LCA functional unit, to which all environmental impacts relate, has been considered to be for a typical laboratory 'batch' of the MWNTs grown, approximately 5g of product. Inventory data in this study has been collected through onsite measurements, direct energy readings, materials usage and Ecoinvent software database. These data include the materials used (precursors, catalysts). The stages of packaging and transportation to the laboratory are not taken into account. The gaseous emissions formed during the reaction are considered as specific laboratory waste. The development of mathematical models that relate the process parameters with environmental impact identifies the activities that largely affect the life cycle impact of producing CNTs and guides the optimal design of additional experiments towards process optimization.

It is obvious, that the CVD process is an energy intensive activity; the environmental burdens inherent in current energy use dominate the overall life cycle impact of producing CNTs products. The electrical energy consumed in heating the furnace seems to be the activity with the single largest impact and is dominant in the overall footprint of grown MWCNTs. The LCA output presents the environmental impact of each of the discrete reaction steps and highlights areas where implementable changes and refinement could mitigate potential impacts. It follows, that the use of LCA can thus be appreciated as an instructive tool in achieving the objectives of green chemistry, and a stepping-stone on the path of sustainable industrialization of CNTs growth.

Acknowledgements

This research is funded by the Hellenic and European Regional Development Funds (ERDF) under the Action Synergasia (Cooperation) 2011: Partnerships of Production and Research Institutions in Focused Research and Technology Sectors, of the Project 'Novel Self-Healing Eco-friendly Coatings with Antifouling and Anticorrosion Properties for Maritime Applications (MARIPAINTS)'. AFT acknowledges 'IKY Fellowships of Excellence for Postgraduate Studies in Greece – Siemens Program'.