

Applications and Benefits of Multi-Walled Carbon Nanotubes (MWCNT)

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1 Introduction

Carbon nanotubes (CNTs) describe a family of nanomaterials made up entirely of carbon. In this family, multi-walled carbon nanotubes (MWCNTs) are of special interest for the industry and will be the subject of this paper. Structurally MWCNTs consist of multiple layers of graphite superimposed and rolled in on themselves to form a tubular shape.

2 Improved Properties

Such cylindrical graphitic polymeric structures have novel or improved properties that make them potentially useful in a wide variety of applications in electronics, optics and other fields of materials science. Carbon nanotubes are endowed with exceptionally high material properties, very close to their theoretical limits, such as electrical and thermal conductivity, strength, stiffness, and toughness.

Moreover, MWCNTs are polymers of pure carbon and can be reacted and manipulated using the rich chemistry of carbon. This provides opportunity to modify the structure and to optimise solubility and dispersion, allowing innovative applications in materials, electronics, chemical processing and energy management, to name just a few.

In summary, three properties of MWCNTs are specifically interesting for the industry: the electrical conductivity (as conductive as copper), their mechanical strength (Up to 15 to 20 times stronger than steel and 5 times lighter) and their thermal conductivity (same as that of diamond and more than five times that of copper). A combination of these impressive properties enables a whole new variety of useful and beneficial applications.

3 Potential Applications

Because of their special physico-chemical properties, MWCNTs are expected to play a major role in numerous applications (see Figure 1).

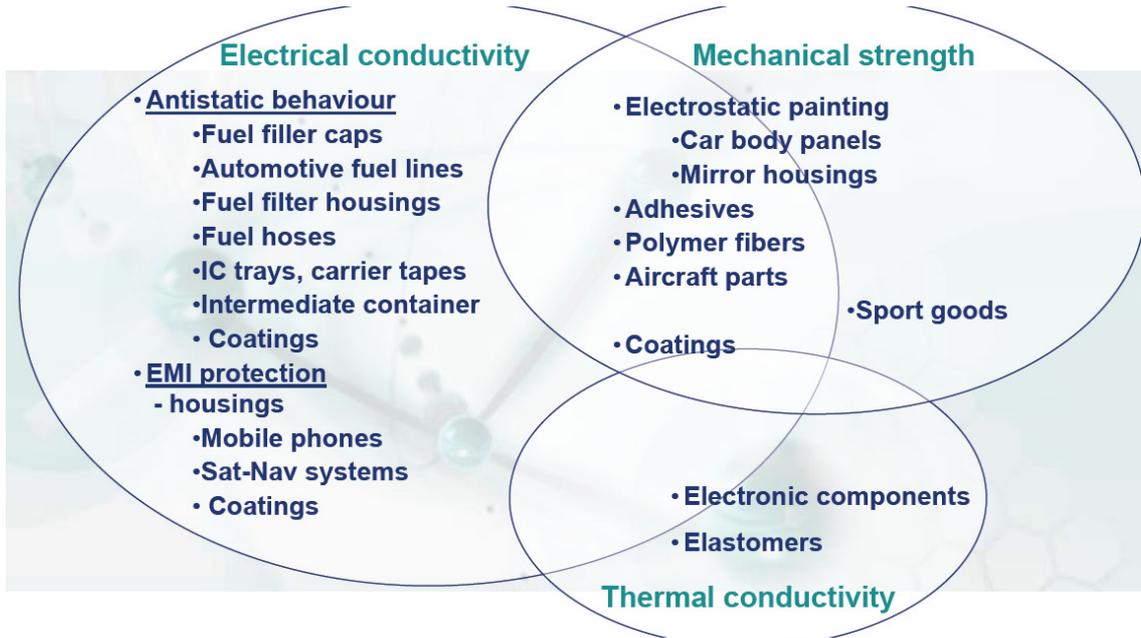


Figure 1: Key properties of MWCNTs give rise to a number of potential application fields.

Development time is an essential criterion that determines when an application will reach the market. When plotted against time, several broad categories of applications can be recognized: those in place currently or available in the short term, those to be expected mid-term, and those still in the realm of early R&D, classified as long-term (see Figure 2).

Current / Short-term	Mid-term	Long-term
Conductive polymers & composites (automobiles and electronics)	Coatings (conductive thin films)	Microwaves antennas
Sensors and Instruments (microscope probe tips, gas leak detectors)	Catalysts (petrochemical)	Seld-assembling yarns
Electromagnetic Shielding	Textiles & fibers	Aerospace
Sporting goods (tennis rackets)	Lithium ion batteries	Medical implants
	Membrane and filters	Drug delivery
	Lamps	
	Semiconducting materials	
	Advanced ceramics	
	Fuel Cells	
	Caulks and sealants	

Figure 2: Key potential applications of MWCNTs on the short, mid and long-term.

3.1 Current / short-term applications

Current or short-term applications are often based on the use of MWCNTs as a superior replacement of electrically conductive carbon blacks. Much of the history of plastics over the last half century has been a replacement for metal. For structural applications, plastics have made tremendous headway. However where electrical conductivity is required, metals are still preferred to plastics. This deficiency can be overcome by upgrading plastics with conductive fillers such as carbon black and graphite fibres. However the loading required to provide the necessary conductivity is typically high, and the structural properties of the resulting plastic parts are highly degraded. Due to their high conductivity, high aspect ratio, and natural tendency to form ropes, MWCNTs are ideal in providing inherently long conductive pathways even at ultra-low loadings. The lower loading of additive can offer several advantages such as better processability or higher retention of the mechanical properties of the original polymer. This is why the use of carbon nanotubes for antistatic and conductive applications in polymers is already a commercial reality, growing in sectors such as electronics and the automotive industry. For these applications, carbon nanotubes can compete with additives such as highly conductive carbon black on a price performance basis.

Applications that exploit this behaviour of CNTs include EMI/RFI (electromagnetic and radio frequency interference) shielding composites, electrostatic dissipation (ESD), antistatic materials and (even transparent!) coatings. Concrete examples in the automotive industry are fuel systems components and fuel lines (connectors, pump parts, o-rings, ...), exterior body parts for electrostatic painting as well as, in the electronic industry, conveyor belts, manufacturing tools and equipments, wafer carriers, clean room equipments, etc...

Structural composites made of carbon fiber (or glass fiber) and a thermoset (e.g. epoxide) have been improved quite substantially by the introduction of carbon nanotubes. The benefit is not achieved by replacing the reinforcing carbon fiber but by enhancing the properties of the matrix material (epoxide). Almost every sports item on the market can be improved by using CNT. These high-end models are usually used by professional athletes as they are often lighter weighted and more durable. For examples, the tennis champion Roger Federer is playing with CNT reinforced rackets while the famous national Finnish ice hockey team is equipped with CNT reinforced sticks.

These new structural composite materials based on CNT reinforced thermoplastics or thermosets combine low density and strong mechanical properties and will open the way to new developments in particular by replacing metals in various mechanical applications where a weight reduction could save energy, like in automotive industry. Moreover thanks to the good thermal conductivity of CNT, it is possible to develop composite materials able to quickly dissipate the heat and consequently to act as protective equipment in various fields.

3.2 Medium to long-term applications

Several running applications will be expanded to other industries. For example, the improvement of mechanical properties in epoxy-glassfiber or epoxy-carbon fiber composites already known from the sport industry can also be used in the construction of light weighted composites for wind power generators and in the aircraft industry. Due to the nature of these industries, more technical testing and longer certification time will be required. Other medium term applications may include electrical conductive inks for printable circuits, low cost RFID tags or antennas in cars. In the longer term, Carbon Nanotubes may also play a role in the modification of existing textile materials using electrostatic self-assembly and atomic layer deposition techniques to create novel and customizable surfaces on conventional textile materials with emphasis on natural fibres. This opens the way to the development of smart and intelligent textiles that combine new innovative functions.

4 Conclusion

Carbon nanotubes are endowed with exceptionally high material properties, very close to their theoretical limits. A combination of these impressive properties enables a whole new variety of useful and beneficial applications.

Depending of the amount of R&D efforts necessary to bring a particular product to the market, it can be differentiated between short, mid and long-term applications. Current or short-term applications are often based on the use of MWCNTs as a superior replacement of electrically conductive carbon blacks. This is especially advantageous in the automotive and electronic industries. New structural composite materials based on CNT reinforced thermoplastics combine low density and strong mechanical properties. Currently almost every sports item on the market can be improved by using CNT. This will open the way to new developments in particular by replacing metals in various

mechanical applications where a weight reduction could save energy, like in automotive industry.

On the medium to long-term a wide range of industrial sectors may benefit from the use of CNT. Due to the nature of some of these industries, more technical testing and longer certification time will be required before a market entry is possible. Improved mechanical properties of epoxy–carbon fiber composites can be used for wind power generators and in the aircraft industry. From improved textiles to electrical conductive ink for printable circuits, the range of impacted industries is staggering.