# Highly conductive nanotube-filled polymers with exceptional properties

Thomas Tiano, Richard Czerw, Robert Coffin, Robert Adams

NanoTechLabs Inc.
409 W. Maple St.
Yadkinville, NC 27055
TTiano@nanotechlabs.com

## ABSTRACT

NanoTechLabs (NTL) has developed methods for preparation of highly conductive high-performance polymers utilizing novel, scalable methods to incorporate high aspect ratio, low diameter, metallic multi-wall nanotubes into high performance engineering resins and plastics. By incorporation into commercial high performance plastics and resins, our conductive polymers can be utilized in demanding structural and aerospace applications with minimal impact on mechanical performance. Polymers can be procured from NTL as either a master-batch or at a specified concentration. We offer standard resins or can develop a formulation in a resin of your choice. Applications include EMI shielding, static dissipation, electrostatic paint substrates and conductive coupling.

***Keywords***: conductive nanocomposite, EMI shielding, carbon nanotube

## 1 INTRODUCTION

This paper gives a brief overview into the properties and applications of conductive nanocomposites developed by NanoTechLabs and marketed through NTL Plastics. These conductive nanocomposites consist of dispersions of multi-walled carbon nanotubes (MWNTs) in engineering resins, epoxies, thermosets, elastomers or commodity plastics. NanoTechLabs prides itself in its ability to prepare these plastics to the specifications of its customers in terms of electrical, physical and mechanical properties, tailoring the nanotube loading in order to achieve the desired balance of properties.

Material can be supplied in the format desired by the customer. For thermoplastic materials, the resin can be supplied as pellets or powder either directly at the desired loading or as a highly loaded master batch that can be let down to the desired loading by a compounder. Thermoplastic may also be supplied as extruded of injection molded parts, as desired by the customer. An example of a nanocomposite master batch is shown in Figure 1. Thermoset materials are typically supplied as two-part systems either in separate containers or in SEMCo dispensers.


Figure 1: Pelletized masterbatch consisting of 10% CNTs in polycarbonate.

## 2 NANOTECHLABS' CARBON NANOTUBES

NTL currently produces high conductivity MWNTs that are used in its conductive nanocomposites as well as in its conductive buckypaper. While a single wall carbon nanotube (SWNT) resembles a sheet of graphene in cylindrical form, MWNTs are a series of concentric carbon cylinders (or tubes) as seen in Figure 2.

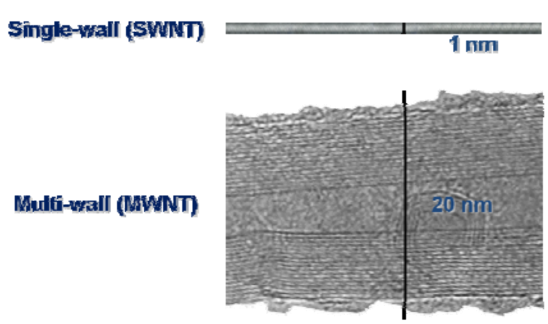


Figure 2: While a single wall carbon nanotube resembles a sheet of graphene in cylindrical form, a multi-walled carbon nanotube is a series of concentric carbon cylinders.

The use of MWNTs is advantageous in nanocomposites because, unlike SWNTs in which two-thirds are semi-conducting and only one-third conducting, each individual MWNT is conducting as it contains, in essence, a large number of concentric SWNTs.

NTL's MWNTs, featured in Figures 3a and 3b, are typically 5 to 30 nm in diameter with lengths from approximately 100 µm to over 5 mm. The material is extremely pure with little to no amorphous carbon and is grown by a modified float CVD method.

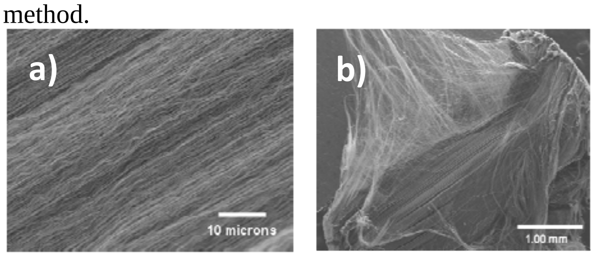


Figure 3: (a) SEM Micrograph of MWNTs Produced by NTL; (b) NTL's Ultra-long MWNT (~ 3mm)

## 3 PROPERTIES OF NTL PLASTICS

NTL has developed methods to incorporatate its high performance MWNTs into highly conductive polymer systems for such applications as EMI shielding and static dissipation. While the conductivity is not as high as that achievable using metallic fillers, the use of carbon nanotubes offers other advantages:

- The low loadings of nanotubes required for electrical percolation and the inherent synergy between nanotubes and polymers allows fabrication of conductive polymers that retains toughness and flexibility of the original polymer.
- As the specific gravity of nanotubes is similar to that of most polymers, the filled polymer systems retain the low density of the base resin, making these viable materials for aerospace and space applications.
- Since the nanotubes do not oxidize or corrode, the conductivity of the polymer does not decrease with environmental exposure.

The goal of NTL's work is to develop polymer systems with the specific properties requested by the customer. NTL works closely with its customers to define the design space available based on polymer requirements and potential properties imparted by NTL's MWNTs. Below we summarize specific examples of some of NTL's products and development efforts.

### 3.1 Thermoset Elastomers

A great deal of NTL's work has focused on conductive thermoset elastomers for aerospace applications. Typical conductive elastomers employ metal or metal coated particulates to impart conductivity to the elastomer. While this results in a highly conductive elastomer, the additional of metal particles significantly reduces the flexibility of the elastomer, as well as adding a significant amount of weight, which is a huge detriment in the aerospace community.

These advantages can be seen in our conductive aerospace gasket product. Figure 4 shows the conductivity vs. nanotube concentration for a filled liquid rubber for gasketing applications. As can be seen, resistance lower than 0.5 ohm-cm can be achieved at nanotube concentrations in the single digit percents. This level of conductivity can be attained while maintaining the properties, look and feel of a rubber gasket, as seen in Table 1.

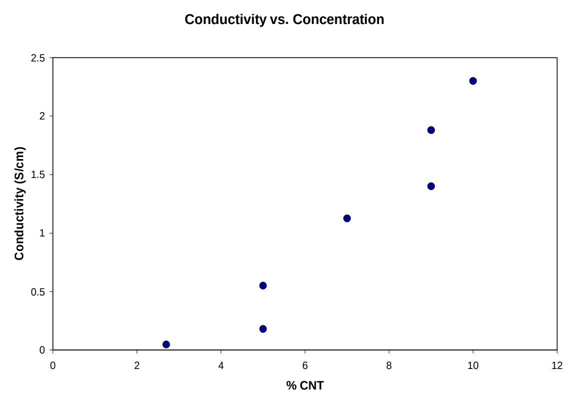


Figure 4: Conductivity of elastomeric gaskets exceeds 2 S/cm (<0.5 ohm-cm) at nanotube loadings in the single digit percentages.

| | |
|---|---|
| Tensile Strength, psi | **310** |
| Tensile Modulus, psi | **1390** |
| Elongation to Break | **>100%** |
| Hardness, Shore A | **50** |
| Specific Gravity | **1.33** |
| Color | **Black** |

Table 1: Properties of nanotube-filled conductive gaskets demonstrate retention of elastomeric properties at high conductivity.

A second elastomer product under development utilizes a thermoset polyurethane as the base resin. The conductivity requirements for this product are higher than those for the liquid rubber and therefore a higher nanotube loading is required.

A graph of the conductivity vs. loading for this polymer is shown in Figure 5.

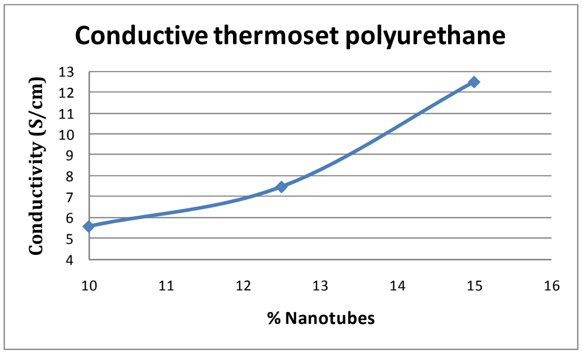


Figure 5: At higher nanotube loadings, the conductivity of filled elastomers can exceed 12 S/cm (<0.083 ohm-cm). Each point is an average of three test specimens.

## 3.2 Thermoplastic Polymers

NanoTechLabs has experience with several thermoplastic polymers, such as: thermoplastic polyurethane, polyvinyl chloride, polycarbonate, and polyester. MWNTs can be dispersed at relatively high loadings (typically 15%) into most thermoplastic resins and supplied as a master batch to the customer. The customer can then let down the master batch to the desired conductivity using a twin screw extruder. Alternatively, NTL can supply the resin at the desired concentration.

The conductivity of the resulting polymer is highly dependent on the polarity of the polymer. For polar polymers, such as thermoplastic urethanes, the conductivity can exceed 12 S/cm at a loading of 15%.

Nanotube-filled thermoplastic polymers can be subjected to the same types of polymer processing techniques available to neat and inorganic-filled polymers. NTL has subjected its polymers to: fiber extrusion (Figure 6), injection molding (Figure 7) and hot pressing.

Figure 6: Nanotube-filled PET can be melt-spun into conductive fibers and woven into fabrics.


Figure 7: Injection molded tensile bars consisting of 10% carbon nanotubes in polycarbonate.

## 3.3 Static Dissipative Epoxy

Based on the previous examples, we have shown that high conductivity can be achieved in both thermoset and thermoplastic polymers using carbon nanotube loadings of 5 to 15 weight percent. In addition to high loading and high conductivity, low loadings (<0.5%) of carbon nanotubes can be used to impart static dissipation to materials. The benefit of using carbon nanotubes for static dissipation is in the effect, or lack of effect, such a low filler addition has on mechanical properties.

The example we use is a static dissipative epoxy developed for space applications. Requirements for materials used in space are very stringent, and qualification is a tedious process. That being said, once a polymer is qualified, it is advantageous to remain with that polymer. Our customer came to us with a space-qualified epoxy system with the desire that we use nanotubes to impart static dissipation. It was required that all mechanical properties remain the same. NTL provided the customer with a formulation that met the customers electrical requirements at such a loading that the customer could not measure a change in mechanical at properties. This product is still ordered in small amounts by our customer.

# 4 CONCLUSION

While nanotube-filled polymers will not take the place of metal filled polymers for routine applications, NanoTechLabs has developed a viable solution for applications that require high conductivity combined with good mechanical properties and/or low weight requirements not achievable using metallic fillers. NanotechLabs polymers can also meet static dissipation requirements with no measurable change in polymer properties.


NSTI-Nanotech 2011, www.nsti.org, ISBN 978-1-4398-7142-3 Vol. 1, 2011