Comparison of Short and Long Multi Wall Carbon Nanotube and Polymethyl Methacrylate Composites

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Introduction

Polymers are extremely dynamic and widely used materials, with the ability to create new and exciting structures. One such example is the capability for the amorphous polymer to form a segregated, organized network when the polymer matrix is mixed with a smaller filler material. This project focuses on the formation of such a segregated network in Polymethyl Methacrylate (PMMA) and carbon nanotube composites and looks to compare the effects of long versus short nanotubes on the percolation threshold across a range of filler concentrations.

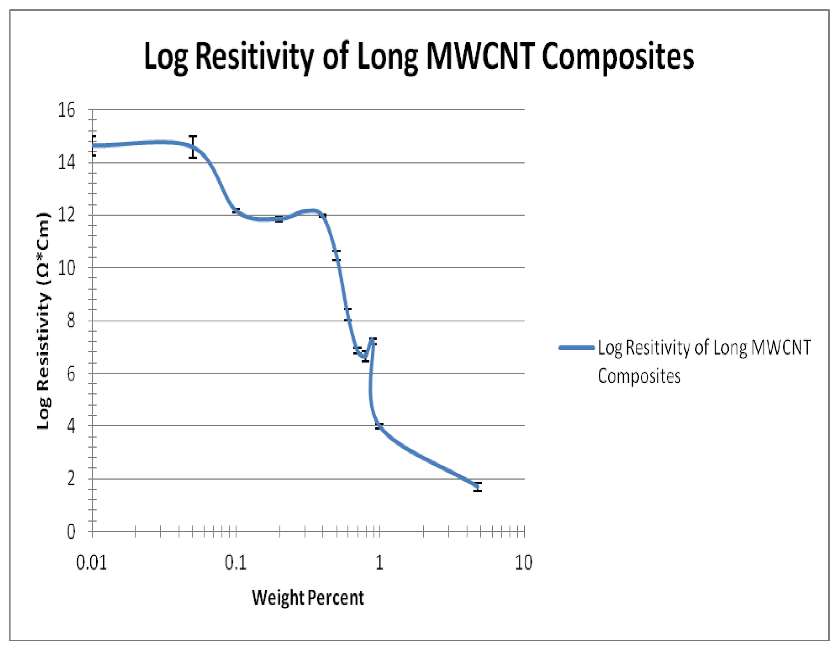
Objectives

This work aims to delve deeper into the use of MWCNT as fillers in conductive polymer composites. The goal of this research is to further understand how the length of the MWCNT affects the creation of the segregated network and the concentration at which the percolation threshold occurs. The possible effects of different pressing temperatures to make the samples will also be briefly investigated.

Method

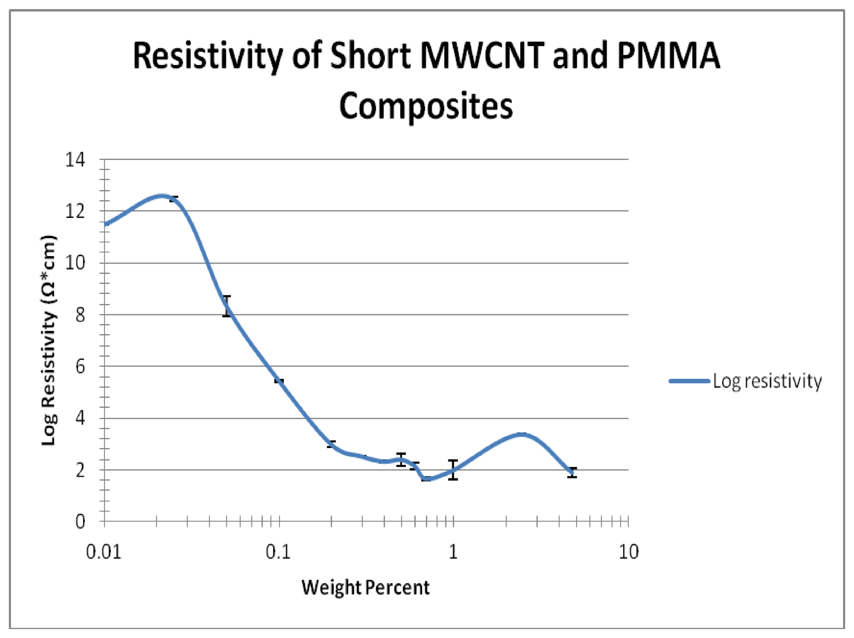
Samples with varying weight percentages were created using compression molding. These samples were tested for their electrical impedance using impedance spectroscopy and that data was used to calculate electrical resistances.

Experimental Results



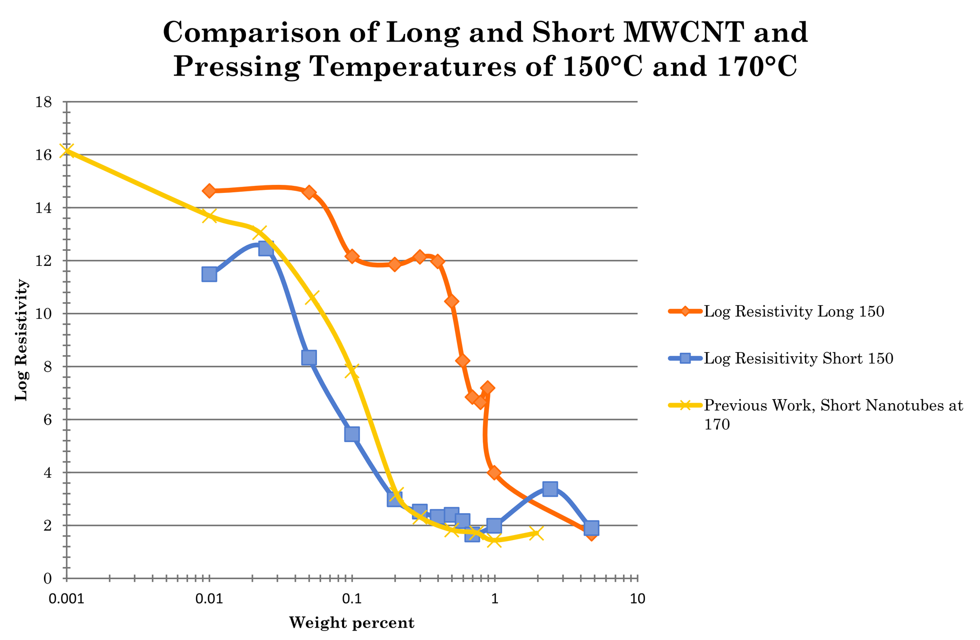
The plot shows a drastic drop in the electrical resistance at about 0.5 weight percent. The nature of this curve suggests that instead of creating an organized network, the long MWCNTs create a random microstructure.

The data from 0.9 and 1.0 weight percent samples show interesting and unexpected results

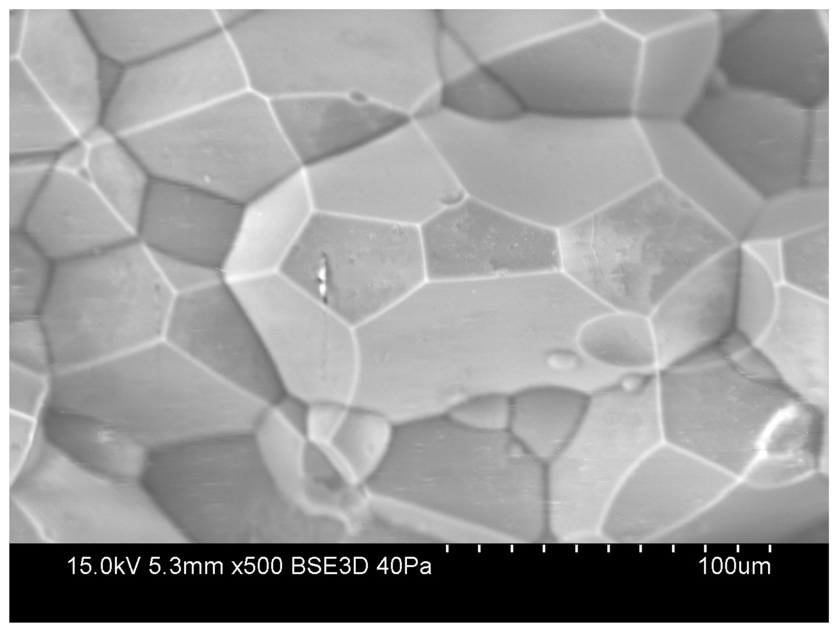


The plot shows how the electrical resistance drastically drops when small amounts of short MWCNTs are added to the matrix. This curve shows a more gradual slope, indicating that a conductive network of MWCNTs grows as the weight percent increases.

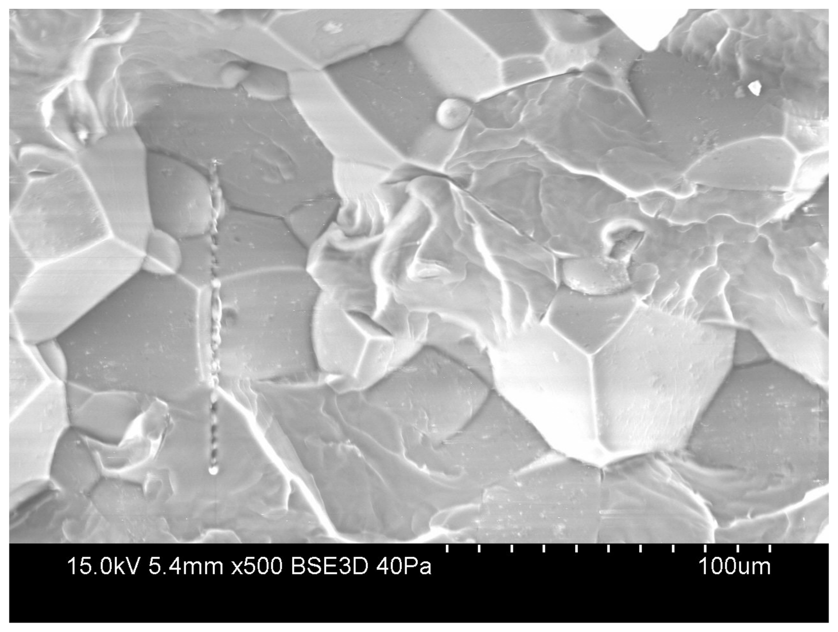
This figure compares the resistivity curves of the Long and Short MWCNT and PMMA Composites and the pressing temperatures of 150°C and 170°C. Data for short MWNT composites taken from Laura Prystaj's thesis.



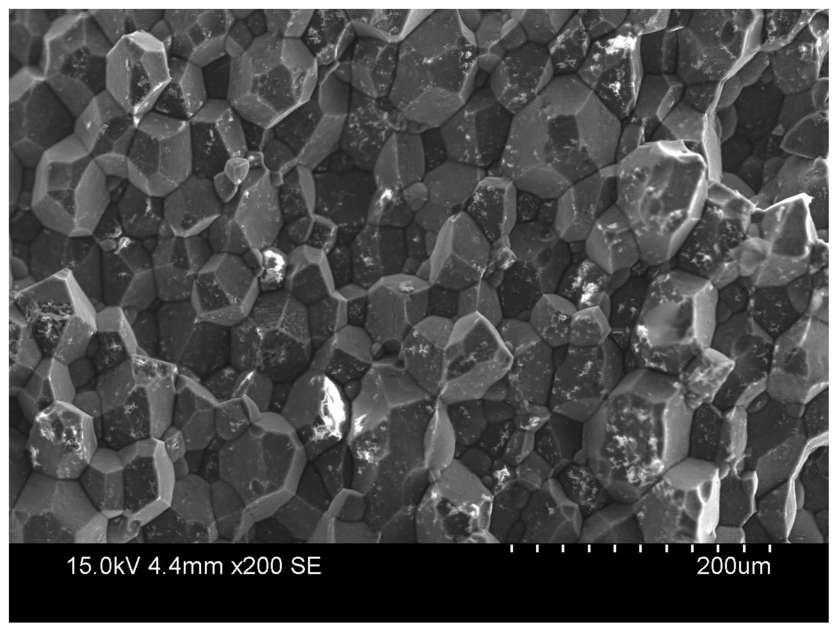
SEM Images of the Sample Fracture Surfaces



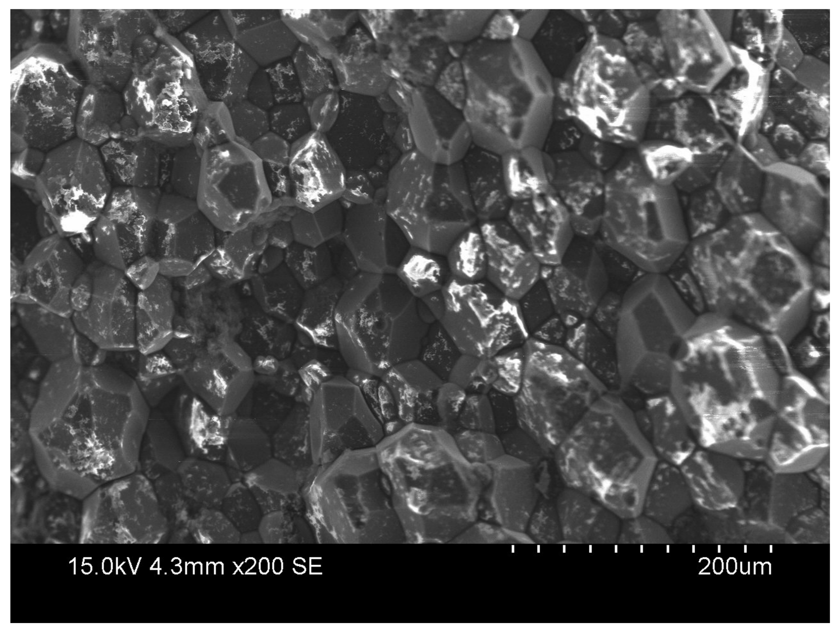
This SEM image of the fracture surface of a 0.1 weight percent Short MWCNT composite shows the fully percolated, segregated microstructure.



This SEM image of the fracture surface of a 01 weight percent Long MWCNT composites shows intergranular and transgranular fracture, indicating the microstructure is not fully formed and the sample is not percolated.



This SEM fracture surface image of a 1.0 weight percent Short MWCNT composite shows a relatively even coating of MWCNT, where small agglomerations are seen as white spots.



This SEM fracture surface image of a 1.0 weight percent Long MWCNT composite shows the agglomeration of MWCNT that prevents the formation of the segregated network.

Conclusions

This research looked into the creation of conductive polymer composites by utilizing the capability of amorphous polymers to form a segregated network when mixed with a smaller filler material. Focusing on PMMA and MWCNT composites, the experiments compare the effects of MWCNT length on the percolation threshold and overall conductivity of the composites over a range of filler weight percents. The results showed that the short nanotube composites had a percolation threshold at significantly lower concentrations, around 0.05 weight percent, and therefore reached significantly lower resistivities much earlier than that of the long nanotubes. Looking at the dimensions of the raw materials, the short nanotubes have a much smaller aspect ratio,2.6:50 vs. 30:50, and are consistently smaller in length than the diameter of the un-melted PMMA pellets, so it can be assumed that they easily coat the un-melted PMMA pellets and therefore create the intended segregated network when pressed. The lengths of the long nanotubes are significantly closer in length to the diameter of the polymer and do not form the segregated network, forming a random microstructure and significantly increasing the resistivity of the composite.

Acknowledgements

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