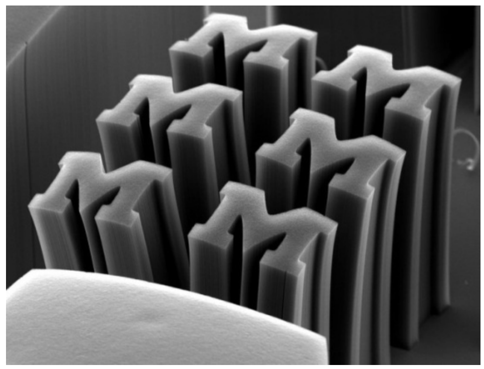
ME 450 PROJECT 2

ROBOTIC FURNACE SYSTEM FOR CARBON NANOTUBE (CNT) GROWTH



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ABSTRACT

Carbon Nanotubes hold much promise with regards to its potential application in various fields. However, due to the sensitive nature of its manufacturing process, efforts to produce a batch that has uniform height have so proved difficult. They key variables of this process have been identified to be the temperature of the gas and its composition when encountering the growth substrates. The objective of this project is to develop an automated controls system to minimize and compensate for deviations in the driving variables, thus ensuring even growth across the batch. It is also necessary to give the user control over the batch growth. This is to be done by implementing a real-time *in situ* growth measurement device as well as an automated furnace system.

EXECUTIVE SUMMARY

Professor Hart currently has a furnace system set up to create CNT films using Chemical Vapor Deposition (CVD). However, this process is sensitive to the gas and substrate temperatures as well as the time of exposure to heat for the gas. This results in uneven heights of the CNT films grown. Furthermore, the current setup is also unable to measure the height of the CNT film during the growth process.

The main objectives for this project are thus to maximize uniform growth across the furnace, introduce an *in situ* height measurement method during the CNT growth process and automate the entire growth process. The engineering specifications that are related to these objectives are as follows: 1) To withstand 900 ˚C, 2) temperature variation of ±5˚C for 600-900 ˚C and ±2˚C for 750-850 ˚C, 3) length of uniform height region of more than 8cm, 4) instantaneous height accuracy of 10 microns and 5) vertical height growth of 0-0.5cm. Other specifications can be found in this report. Further ranking of these specifications were made in relation to the main objectives using a QFD, which gave us insight to our engineering targets.

Our final design includes three sub-systems: A heating sub-system, a furnace motion system and an optical measurement system. Each sub-system has been analyzed to provide optimal performance with respect to its desired functionality. The heating sub-system has multi-zone heating capabilities with independent feedback control. The furnace also has thick insulation that is made up of alumina and Duraboard. Our oscillation system is able to control the distance moved by the furnace. This will allow for continuous CNT height readings along the growth region and providing a wide range of experiments in our sponsor's interest. The camera selected for the optical system has good resolution and good compatibility with the motion of the furnace. The optical system also runs on a separate rail. We have also considered the compatibility of these systems with each other and have made the necessary modifications to come up with a cohesive final design.

Our current prototype turned out slightly different from our final design and we have made some recommendations to rectify this. These issues involving the inaccuracy of product dimensions provided to us, the overlooking of some design aspects and some parts that could be better designed for easy machining. More information is detailed in the Discussion section.

The current prototype is not complete due to the complexity of our design and component lead times. Most of the mechanical components have been manufactured and assembled, which allowed us to simulate a successful oscillation of the furnace. We are left with assembling the optical system and insulation, fabricating the Duraboard insulation and designing the control systems for the heater plates and oscillation system. Due to time constraints, we were unable to conduct any specific validation. However, we hope certain members of the project team will be able to work on this during the summer of 2009. Even so, this report has a segment that gives sound guidance on what we perceive to be the best manner to conduct the evaluation.

We took the current CVD recipe to be most ideal and we recommend further looking into the current CVD recipe such as increasing the concentration of ethylene. Furthermore, we recommend containing and recycling the heat deliver for gas decomposition to improve the efficiency of the system.