



**CALIFORNIA STATE SCIENCE FAIR  
2009 PROJECT SUMMARY**

<b>Name(s)</b> <b>Abhejit Rajagopal</b>	<b>Project Number</b> <b>S1915</b>
<b>Project Title</b> <b>Selective Isolation and Manipulation of Single-Walled Carbon Nanotubes using AFM Lithography</b>	
<p style="text-align: center;"><b>Abstract</b></p> <p><b>Objectives/Goals</b> The goal of this project is to determine a general set of parameters for moving, manipulating, and cutting single-walled carbon nanotubes with and without a charged tip that can be used on a world-wide scale as a standard for nanochip fabricators.</p> <p><b>Methods/Materials</b> Materials: - Pacific Nanotechnology Atomic Force Microscope - Pacific Nanotechnology Standard AFM tip and Charged AFM tip - Dell 2350 computer - Silicon dioxide plated chip with electrodes and nanotube growth (94-S)</p> <ol style="list-style-type: none"><li>1. Obtain a sample with abundant carbon nanotube growth (AKB 94-S )</li><li>2. Place sample onto puck and into AFM (Pacific Nanotechnology), calibrate, and image a particular tube.</li><li>3. Open the LPM software (Pacific Nanotechnology) and collect image from AFM, enter scan settings and start lithography.</li><li>4. Verify cut using the AFM data.</li></ol> <p><b>Results</b> It was practically impossible to consistently move around SW CNT's. This can be explained by the complex nature of both Columbic and Van der Waals forces acting on the nanotubes and the AFM tip acting on an atomic level. However, efficient parameters were established for cutting tubes at different scan rates, set points, and tip voltages. With no tip voltage, a quadratic relation was discovered between the scan rate and set point. With tip voltage, a direct relation was observed.</p> <p><b>Conclusions/Discussion</b> It was observed that SW carbon nanotubes were cut by an uncharged AFM tip at a lower set point voltage when the scan rate was small, around 4 <math>\mu\text{m/s}</math>. As the scan rate increased, the required set point also increase, as expected because a larger force would have to be present to cut the tube originating from the moving AFM tip. However, an interesting outcome that was overlooked in the begging was discovered; as the scan rate becomes very small, below 4 <math>\mu\text{m/s}</math>, the required set point voltage to cut the nanotube increases. This can be explained by the fact that very slow scan rates will tend to 'push' the tube rather than cut it, as well as the friction and stickiness of the tube.</p>	
<b>Summary Statement</b> This project provides a general set of parameters for moving, manipulating, and cutting SW CNTs with and without a charged tip that can be used on a world-wide scale as a standard for nanochip fabricators.	
<b>Help Received</b> Worked in lab at University of California at Irvine (UCI) under Prof. Phil Collins, mentored by grad student Steven Hunt	