Chapter 1

Introduction

Though comprising a variety of experiments using several different nanomaterials and involving various physical effects involving a range of different branches of physics, this thesis is unified by several common themes. All of the projects described use nano-scale materials that generally have a wire or tube-like geometry. In some cases, the nanowires are the key element in the device, while in one situation the nanowires play an important part in the fabrication of the device. Another unifying theme is the hybrid fabrication techniques employed in these projects. The nanowires or nanotubes are fabricated using bottom-up techniques, which result in random distributions of the nanomaterials. A recent challenge has been to integrate these materials with top-down fabrication techniques common to the semiconductor industry such as lithography, etching and deposition.

It is important to investigate methods to bridge top-down fabrication and bottom-up materials, to make useful devices. To be useful, nano-signals have to be transduced to the scale of humans and their machines.

As material and device dimensions shrink, the surface area to volume ratio decreases linearly. An increasing percentage of the atoms are at surfaces or junctions, causing properties to deviate from bulk.

The next chapter describes the fabrication and properties of the metallic nanowires used for several projects. We made basic measurements of their electrical transport properties using a four probe measurement. Finally, several unsuccessful projects are described as well as some unexplored ideas.

Chapter three details the most successful of my experiments, the study of a nanowire based very-high-frequency mechanical resonator. This device exhibits nonlinear behavior, which becomes increasingly important as the size of resonators continues to shrink.

Chapter four describes another nanomaterial I gained experience in—carbon nanotubes. The history and properties of carbon nanotubes is described, then several projects involving this material are described, each of which had interesting issues with fabrication and integration. One project is an attempt to create an integrated CNT field-emission device. Finally, I will describe attempts to create and measure a CNT mechanical resonator, an effort that is still in progress by my collaborators.

The appendix covers a seemingly unrelated project of the fabrication and measurement of photonic crystal laser defect cavities. However, the integration of photonic crystal structures and nanomaterials could yield tantalizingly interesting devices for completely new applications.