ELECTRON SPIN RESONANCE SPECTROSCOPY OF A SINGLE CARBON NANOTUBE

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Carbon nanotubes provide an ideal one-dimensional system in which to study exotic quantum mechanical behaviors of electrons. In particular, metallic single-walled carbon nanotubes are predicted to possess some unique properties arising from electron-electron interactions under extreme quantum confinement. Although previous electrical transport and optical studies of carbon nanotubes have revealed novel phenomena, not much is understood about their magnetic properties. Here we use electron spin resonance, or ESR spectroscopy, to elucidate electronic states of carbon nanotubes in magnetic fields. Theory predicts that so-called 'spinons' and 'holons' show different amounts of Zeeman splitting, leading to splitting of an ESR peak, which, if observed, can be taken as direct evidence of spin-charge separation of a Luttinger liquid. Our carbon nanotubes were dispersed onto a Si/SiO_2 substrate by spin-coating. Two titanium electrodes were then created and attached to a single nanotube by photolithography and chemical vapor deposition. After bonding gold wire to each electrode to complete our resistance setup, the sample's resistance was taken while being subjected to a varying magnetic field and constant microwave radiation. We have already observed ESR due to an ensemble of nanotubes, and data analysis is underway. Our next step is to attempt to observe ESR in a single carbon nanotube by monitoring the sample's resistance using a lock-in technique.

Electron Spin Resonance Spectroscopy of a Single Carbon Nanotube

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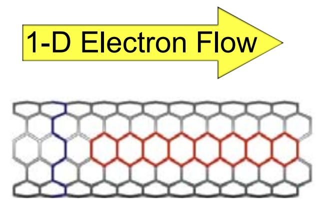
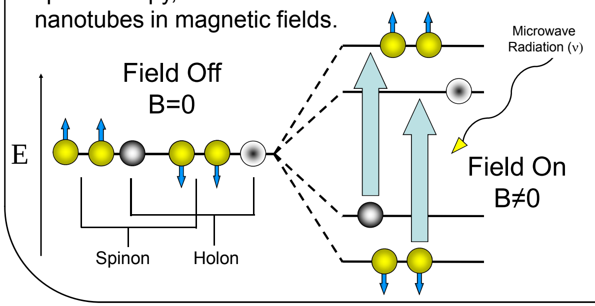
Introduction

Carbon nanotubes provide an ideal one-dimensional system in which to study exotic quantum mechanical behaviors of electrons. In particular, metallic single-walled carbon nanotubes are predicted to possess some unique properties arising from electron-electron interactions under extreme quantum confinement. Here we use electron spin resonance, or ESR spectroscopy, to elucidate electronic states of carbon nanotubes in magnetic fields.



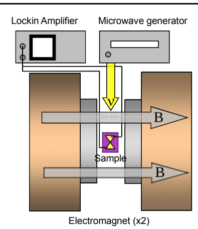


Theory predicts that so-called 'spinons' and 'holons' show different amounts of Zeeman splitting, leading to splitting of an ESR peak, which, if observed, can be taken as direct evidence of spin-charge separation of a Luttinger liquid. Our goal was to confirm this theory experimentally.

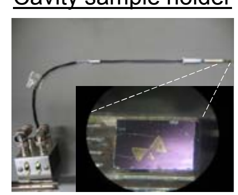
Apparatus

<u>ESR Spectrometer</u>

A varying applied magnetic field (B) of under 1 Tesla causes degenerate free electrons to split in energy. Constant microwave radiation (ν) causes electrons to jump states equal to the energy difference.

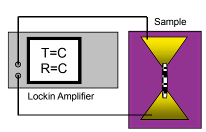


<u>Cavity sample holder</u>

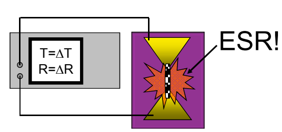


<u>Lockin amplifier</u>

A change in temperature and resistance allows us to detect the CNT ESR resistively using an eLockin 204 Amplifier.



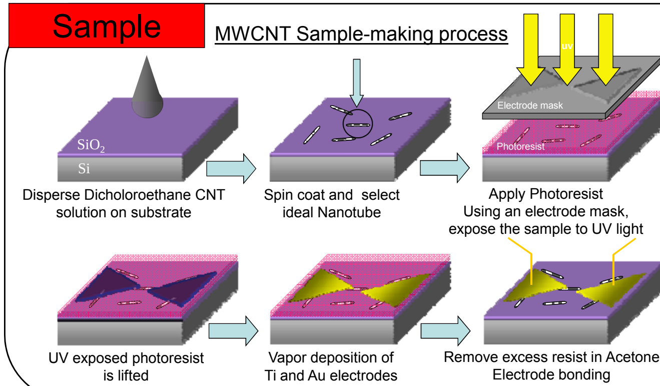
Before Resonance: Temperature and Resistance remain constant

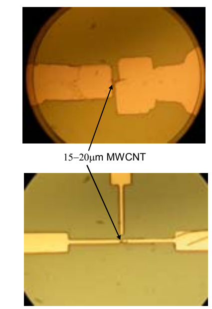


During Resonance: Temperature will increase resulting in a change in Resistance

Sample

<u>MWCNT Sample-making process</u>





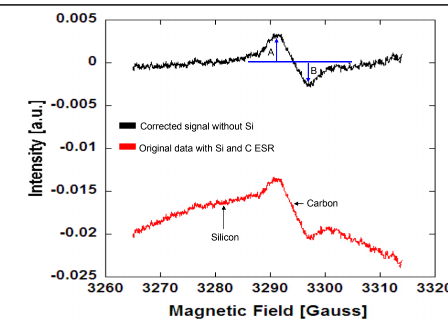
Finished Samples (Magnification x100)

Results

The weak ESR signal of the bulk CNT directly correlated to the defined signal of the Si/SiO₂ sample. The symmetric (A=B) lineshape appears to be Lorenztian with the following parameters:

g-value = 1.982537

Linewidth ~ 30 gauss



Discussion

The obtained results above are from a small ensemble of nanotubes dispersed throughout the surface of the substrate. The broad lineshape was confirmed to be the resonance signal from Si and the sharp and defined lineshape that of the nanotubes. The ESR resistance measurement was not completed due to equipment and sample difficulties but will be continued in hope to confirm the spin-charge separation prediction of SWCNT and MWCNT.

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