Electron Paramagnetic Resonance of Single-Walled Carbon Nanotubes

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Introduction

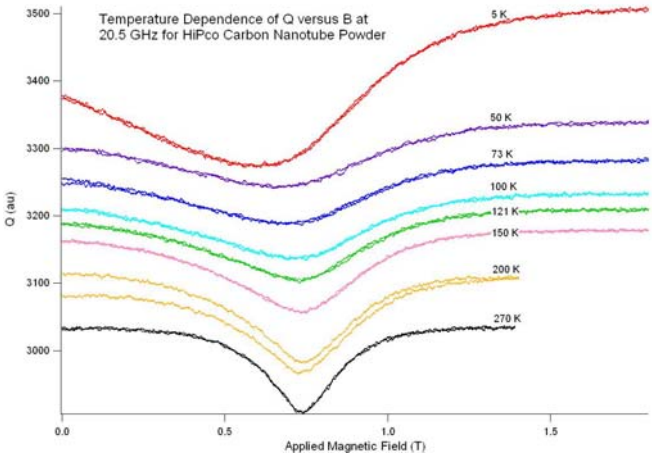
Due to their one-dimensional nature, single-walled carbon nanotubes (SWNTs) are predicted to have a variety of exotic behaviors. One of the most exotic physical manifestations of one-dimensionality, which is widely discussed by theorists, is spin-charge separation in Luttinger liquids. Luttinger liquids (LLs) are low-dimensional metals, whose Fermi surface has been so constrained that regular properties of metal are significantly altered. The disappearance of quasiparticles, due to the strong electron-electron correlations, provides such bizarre effects as spin-charge separation, which is when the boson particles of spin (spinons) and charge (holons) begin to act as separate entities under symmetry breaking operators like magnetic fields.

Over the past fifteen years, numerous electron paramagnetic resonance (EPR) experiments have been done on SWNTs attempting to observe the effect that LL physics has on lineshape, *g*-factor, and relaxation times [1–3]. All studies have been critically hindered by the existence of ferromagnetic catalyst particles, such as iron, cobalt, nickel, and magnesium.

Experimental

We tested a variety of different SWNTs in order to look at the effects of both nanotube type and purity on EPR lineshape. Previous experiments that we have performed using modulation-type X-band EPR machines had shown that the relaxation time becomes longer as the catalytic particle content of the SWNT is reduced. To look for different species within this wide resonance, we attempted to use three different frequencies: 11.3 GHz, 18 GHz, and 20.5 GHz. In addition, we varied the sample temperature from 5 K to 270 K in order to look for Curie and Pauli paramagnetic species.

Several samples were examined including mats of SWNTs (known as 'bucky paper'), HiPco powder, acid purified HiPco powder, and laser ablation nanotubes. The acid purified HiPco SWNTs had a catalyst concentration that was roughly six times less than that of the other samples. It was hoped that this sample would produce a signal that was distinguishable from the ferromagnetic resonance (FMR).



Results and Discussion

As Fig. 1 indicates, we saw an extremely broad resonance around $g = 2.07$. We believe that the resonance we are in fact observing has something to do with the iron in the samples. It is not clear currently, though, what form of iron we are looking at, since other forms of iron do not display this type of behavior. No conduction electron spin resonance (CESR) was seen in any of the samples. The width of the signal corresponds to a relaxation time in the tens to hundreds of picoseconds, far too short for CESR expected for SWNTs.

Figure 1. HiPco powder at 20.5 GHz as a function of temperature. Two lines at each temperature indicate sweep up and sweep down in magnetic field.

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