NMR STUDY OF CORRELATED ELECTRON BEHAVIOR IN SINGLE-WALLED CARBON NANOTUBES

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Introduction

Single-walled carbon nanotube (SWNT), cylindrical tubules formed by wrapping a graphene sheet, exhibit novel mechanical and electronic properties. The unique electronic properties of SWNTs, make them an ideal system for studying correlated electron behavior in one-dimension [1]. A breakdown of the Fermi liquid theory is generally expected in 1D systems [2] and a Luttinger liquid can be used to calculate the ground state and low-energy excited states of such 1D systems. There is some evidence, based on transport experiments, that a Luttinger behavior may be present in SWNTs [3]. Because the spin degree of freedom has characteristic properties and plays a key role in a Luttinger liquid, the study of the spin degree of freedom in such systems can shed further light on this matter and NMR is well suited for this purpose. There are theoretical predictions on how the nuclear spin relaxation times (T_1) would behave in the presence of correlations [4,5]. These studies predict a deviation from Korringa's law with $1/T_1$ deviating from linearity at low temperature. Some studies also suggest the possibility of a magnetic field dependence of T_1 [6].

Experimental

To study the spin relaxation, we run two NMR experiments using a saturation recovery/CPMG technique in the 24.6 T, 32mm bore, higher homogeneity facility at the NHMFL. In the first experiment, we measured T_1 vs. temperature. For the second experiment, we kept the temperature constant, and swept the field in order to study the field dependence of T_1.

Results and Discussion

The first round of experiments show a T_1 dependence on the field at low temperatures (<120K) whereas the dependence seems to vanish at room temperature. On the other hand, the values for T_1 obtained at fixed field (22T), do not seem to show a significant deviation from Korringa's law down to 80K. However, the precision of the data obtained in the first set of experiments is not enough for us to say conclusively that such a deviation does not occur. Furthermore, experiments carried out at 4.7 Tesla in our Lab at UNC-CH, show a clear deviation from Korringa's law at 80K (and perhaps higher temperatures), suggesting that the field strength may be playing an important role in determining the relaxation mechanisms.

Conclusions

The results of the first set of experiments clearly show deviations from the behavior expected if interactions were ignored. However, the quality of our data isn't yet good enough to allow us a univocal characterization of this deviation. Further experiments are planned and will be carried out, that will allow us to characterize the low temperature behavior with more confidence.

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