Pulsed NMR Studies of ^{3}He Exchange on Atomically Smooth Surfaces

N. S. Sullivan (UF Physics), C. Park (UF-Physics), P. Stachowiak (Institute for Low Temperature Physics, Wroclaw, Poland)

Introduction

Nuclear magnetic resonance studies of ^{3}He on atomically smooth surfaces with well-defined geometries are of special interest in demonstrating quantum exchange of particles in two dimensions and the dynamics of vacancies for near perfect monolayer coverages. As one approaches the perfect monolayer coverage at low temperatures for different coverages one expects to see a strong minimum in the relaxation time at the perfect monolayer coverage. The value of the nuclear spin relaxation rate at the minimum is the most reliable data point for determining the ^{3}He-^{3}He quantum exchange rate.

Experimental

The experiments were carried out using powdered boron nitride powder which has been shown to consist of microcrystalline platelets that are atomically smooth. Furthermore, the material has very low diamagnetism compared to exfoliated graphite which is often used for studies of thin films and monolayers of ^{3}He. The latter leads to uncertainties in the interpretation of the NMR data because of the substrate diamagnetism, especially in high magnetic fields.

We used pulsed NMR techniques to measure the nuclear spoon-spin relaxation rates at 204 MHz for samples with different coverages and for temperatures $0.1<T<2.0$K. Some results have been previously reported for pure ^{3}He coverages[1,2]. We report here results for mixed ^{3}He-Ne coverages. The purpose of adding Ne is to interrupt the exchange narrowing process and to determine if 2 or 3-particle exchange dominates the exchange process.

Results and Discussion

Figure 1 shows the change observed in the values if the spin-spin relaxation rate at 0.8 K for coverages ranging form 0.6 to 1.3 monolayers. The sharp minimum at 1.0 monolayers is consistent with the model that coverages slightly less or slightly larger than monolayer coverages have highly mobile atoms due the presence of effective vacancies (holes) or adatoms (second layer) with respect to a perfect monolayer. What is most remarkable is the dramatic change is this minimum for a mixture of ^{3}He and Ne because three particle exchange would be reduced appreciably as the number of three particle paths is dimished in the diluted system. The dilution of the two particle exchange paths would not be as dramatic.

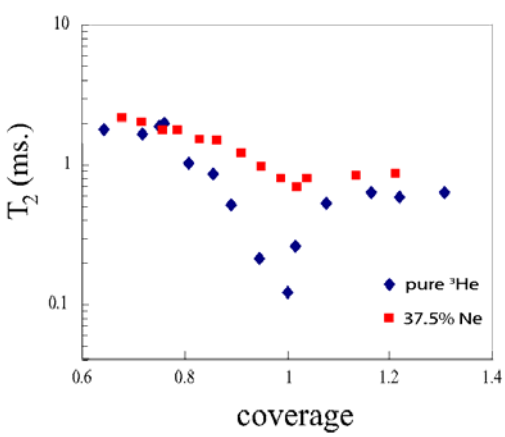

Figure 1. Observed values of the spin-spin lattice relaxation time (T_2) for pure ^{3}He and a mixture of ^{3}He and Ne containing 37.5% Ne.

Conclusions

The large change in the relaxation rate at one layer coverage for ^{3}He films on a two-dimensional hexagonal surface with dilution by 37.5% ^{3}He is strongly supportive of the assumed dominance of three-particle exchange over two-particle exchange on the this lattice structure.

References

[1] Parks, C., et al., J. Low Temp. Phys. 121, 489-493 (2000).
[2] Parks, C, et al., Physica B 329-333, 140-141 (2003).