THE EFFECT OF HE-3 IMPURITY ON THE SUPERSOLID TRANSITION OF HELIUM-4

E. Kim (PSU, Physics); J. S. Xia (NHML, High B/T Facility); J. T. West (PSU, Physics); X. Lin (PSU, Physics); M. H. W. Chan (Penn State University, Physics)

Introduction

The supersolid phase of ^{4}He was reported in a series of torsional oscillator experiments [1]. The effect appears as a drop in the resonant oscillation period as the sample cell is cooled below about 0.2 K, indicating a fraction of solid helium decoupled from the oscillatory motion of the cell. One of the most striking features of the supersolid transition is the intriguing ^{3}He impurity effect. The addition of an extremely small amount of ^{3}He impurity broadens the transition and enhances the transition temperature T_c. We have studied the influence of ^{3}He impurity on the supersolid transition systematically by progressively diluting isotopically-pure ^{4}He (^{3}He impurity less than 2ppb) with ^{3}He.

Experimental

The torsional oscillator used in the measurement has a resonant frequency of 1297Hz and mechanical Q factor of 10^6. The torsion cell containing the helium sample has a cylindrical geometry of height=0.5cm and diameter= 1.0 cm. We used a blocked capillary method to grow the solid helium samples. Because the transition temperature is highly sensitive to the concentration of ^{3}He impurity in the solid, one may expect that the transition temperature of isotopically-pure ^{4}He to be less than 10mK. This makes the detection of NCRI in isotopically-pure ^{4}He extremely challenging. In order to observe the supersolid transition in isotopically-pure ^{4}He it is necessary to extend the measurements to ultra-low temperatures. This is realized by utilizing the high B/T facility in University of Florida.

Results and Discussion

While increasing the temperature of the solid helium sample the resonant period was measured with different amplitudes of oscillations. The amplitude is proportional to the linear velocity at the rim of the torsion cell. Fig. 1 shows the resonant period of the oscillator containing isotopically-pure solid ^{4}He samples as a function of temperature. Non-classical rotational inertia appears below 0.085 K as deviation of the resonant period from the expected linear temperature dependent behavior, (plotted as dotted lines in Fig. 1). The strong attenuation of the period drop with increasing velocity (or amplitude) of oscillation is also observed. We systematically diluted isotopically-pure ^{4}He by the addition of ^{3}He impurities. The inset of Fig.1 shows the transition temperature as a function ^{3}He concentration, plotted together with other ^{3}He dependence measurements performed so far. The transition temperature is monotonically enhanced with increasing ^{3}He concentration.

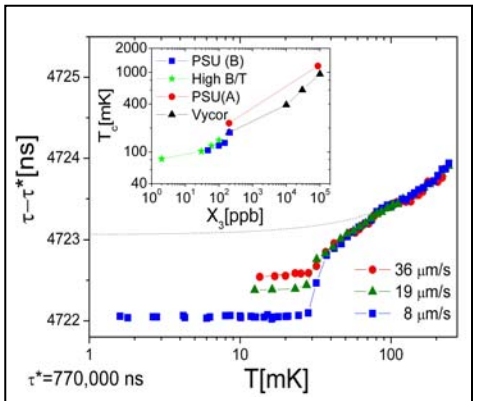

Fig.1 The resonant period of oscillation

Conclusions

We carried out torsional oscillator measurements to investigate the effect of ^{3}He impurity on the supersolid transition of ^{4}He. By diluting isotopically-pure ^{4}He with ^{3}He we found that the transition temperature is very sensitive to ^{3}He concentration. This result suggests that ^{3}He impurities are crucial for the appearance of the supersolid phenomenon. We are in the process of preparing the results for publication.

Acknowledgements

This work is partially supported by NSF Grant DMR 0207071.

References

[1] Kim, E., et al., *Science*, **305**, 1941 (2004); *Nature* **425**, 227 (2004); *J. Low Temp. Phys.* **138**, 859 (2005); *Phys. Rev. Lett.* **97**, 115302 (2006).