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Ultrasonic Study for Superfluidity ^{4}He filled in a nano – porous glass

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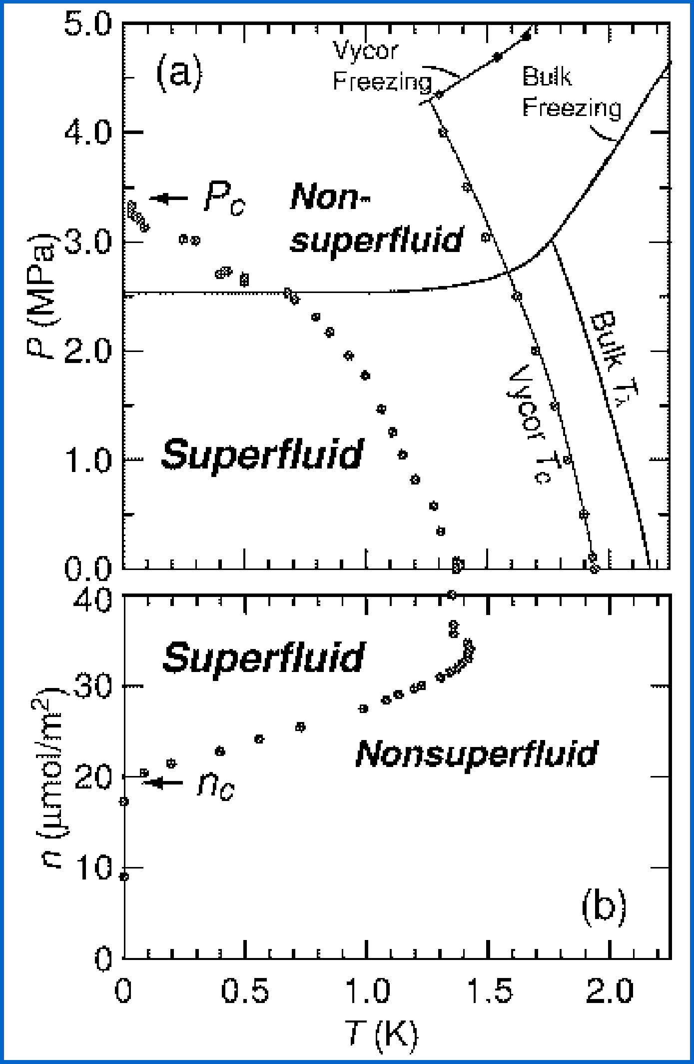
Introduction

・Yamamoto et al. have performed torsional oscillator measurements of a nano – porous glass (Gelsil).

・The superfluidity is suppressed largely as the pressure is increased.

Yamamoto et al. , Phys.Rev.Lett. **93**. 075302 (2004).



Ultrasound Technique

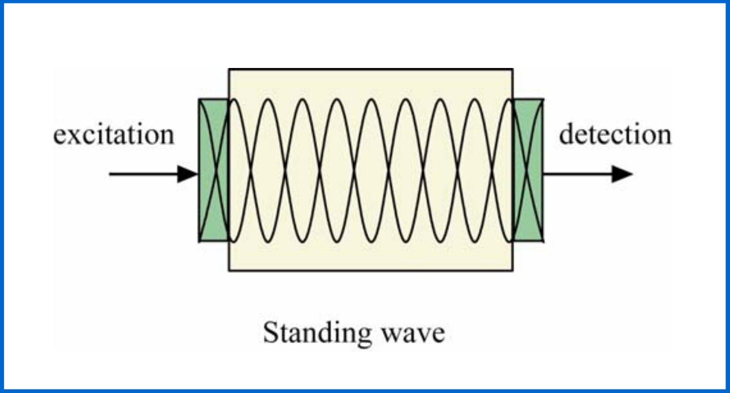
(a) Resonance technique

・Sound velocity increases when the superfluidity takes place in the sample.

$$\frac{\Delta v}{v} = \frac{1}{2}(1 - \chi_n)\frac{\rho_s}{\rho}$$

・The change in resonant frequency is related to the change in sound velocity.

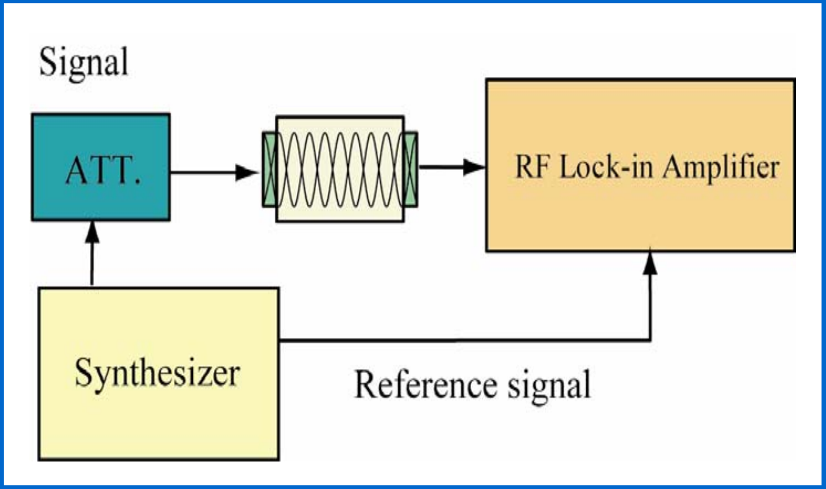
$$\frac{\Delta f}{f} = \frac{\Delta v}{v}$$



MHz ~ 10MHz range

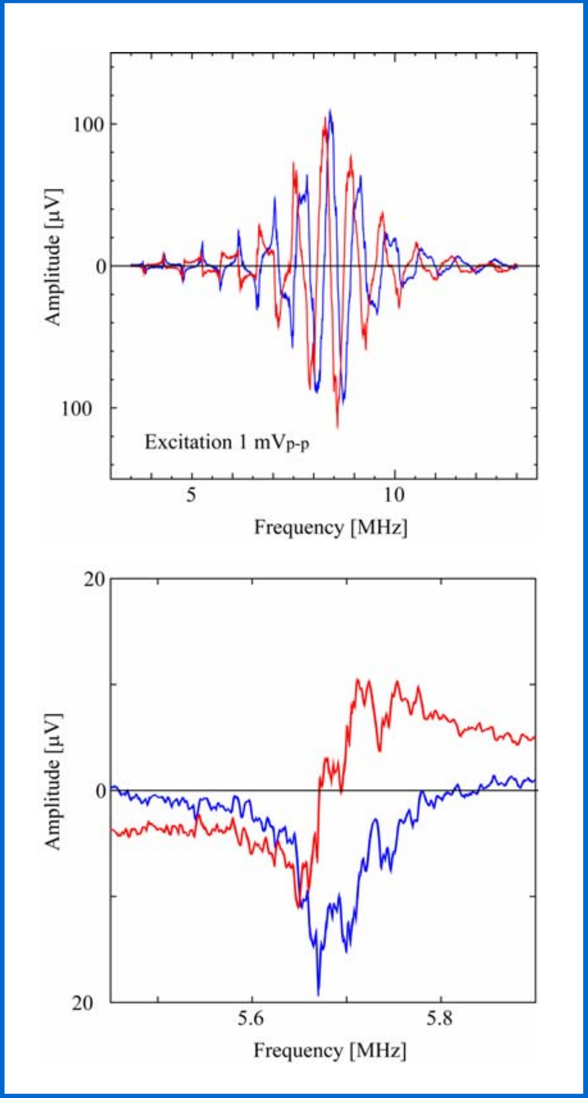
(b) Experimental Setup

Block diagram



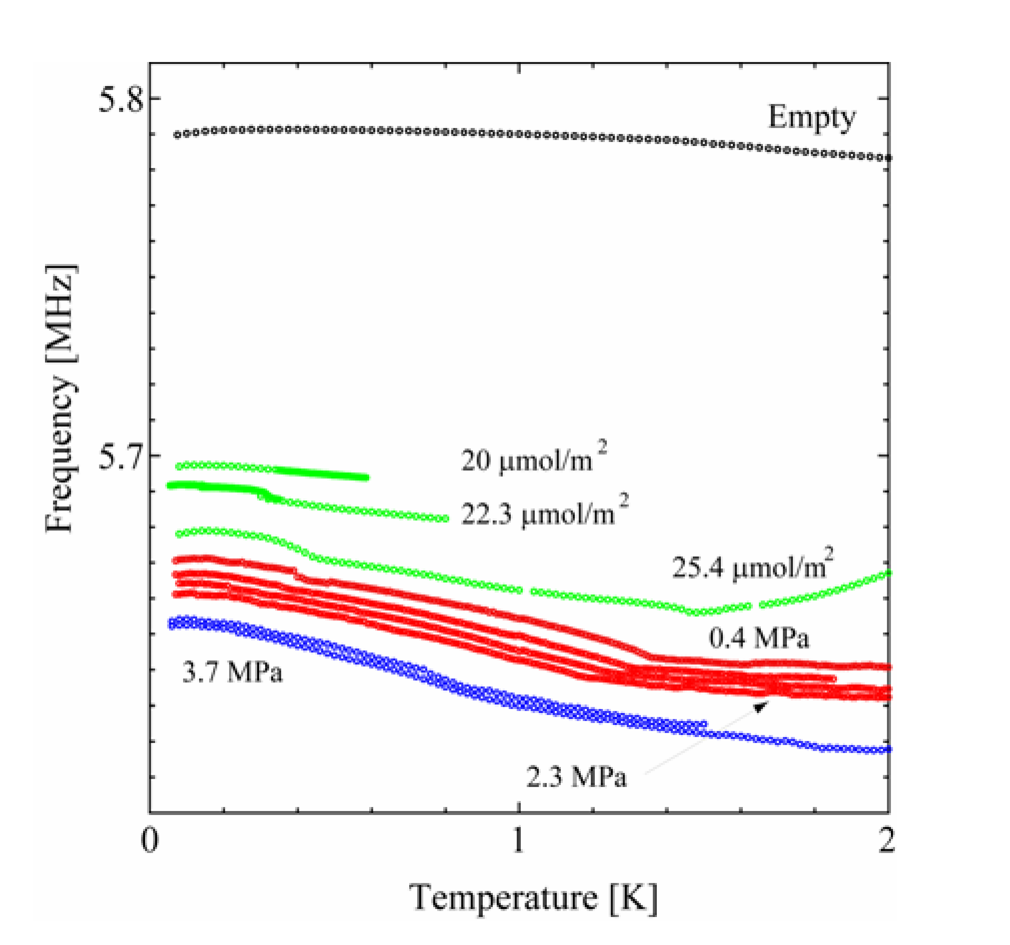
・The transmitted signal of the sample (Gelsil) was measured. When the sample resonates, the transmitted signal becomes large.

Resonance curve



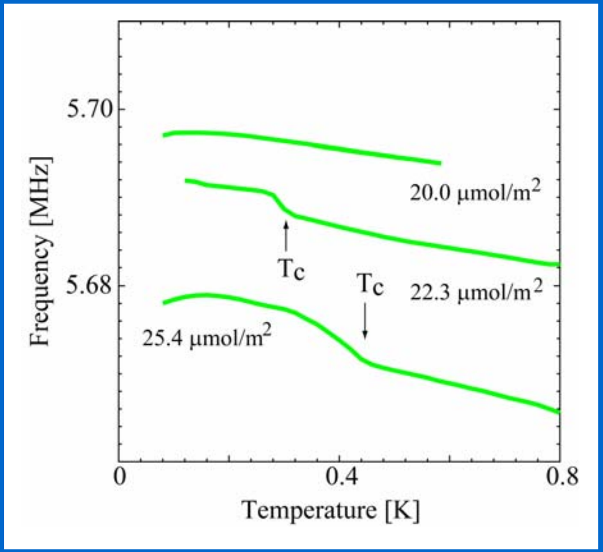
Results

（a） Pressure Dependence & Temperature Dependence

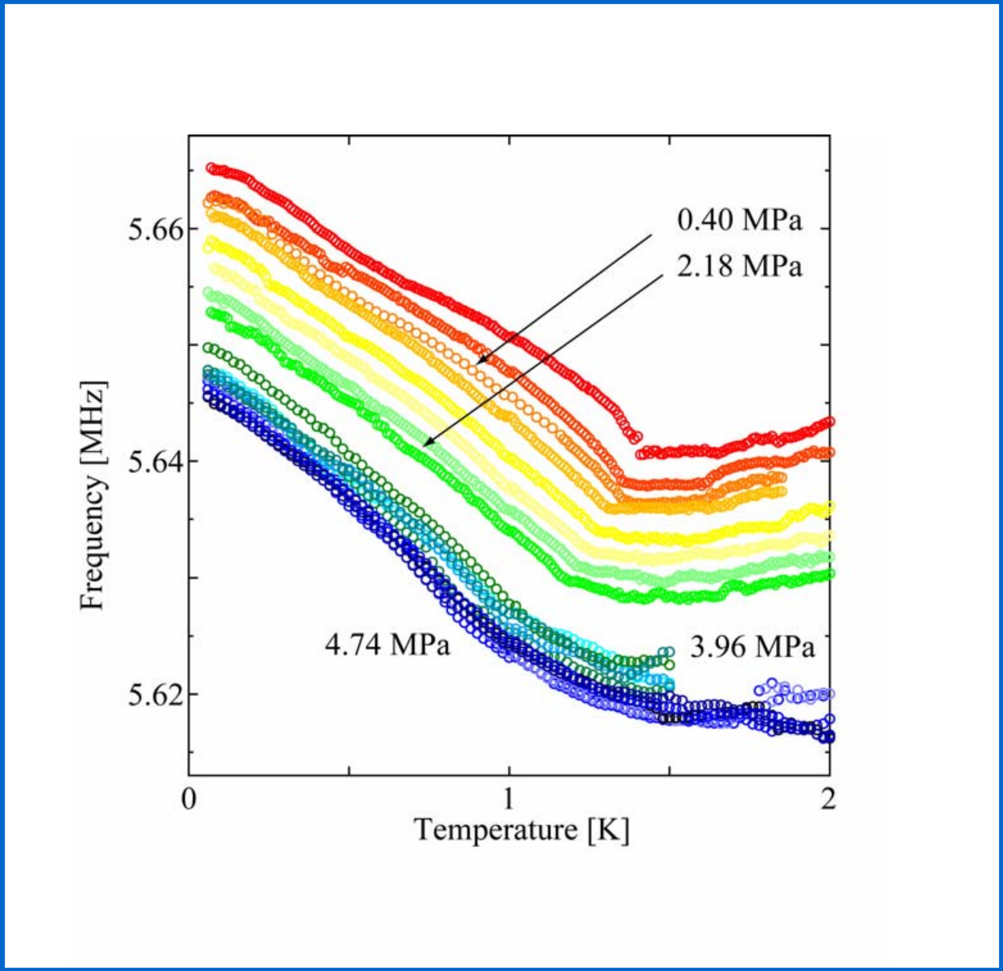


・The sound velocity decreases form the empty.

Film

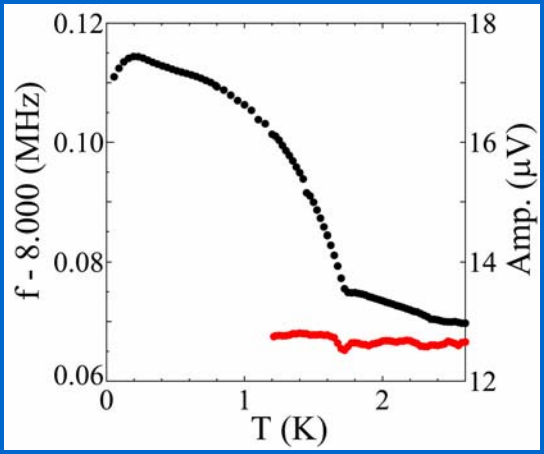


（a）Pressure Dependence & Temperature Dependence

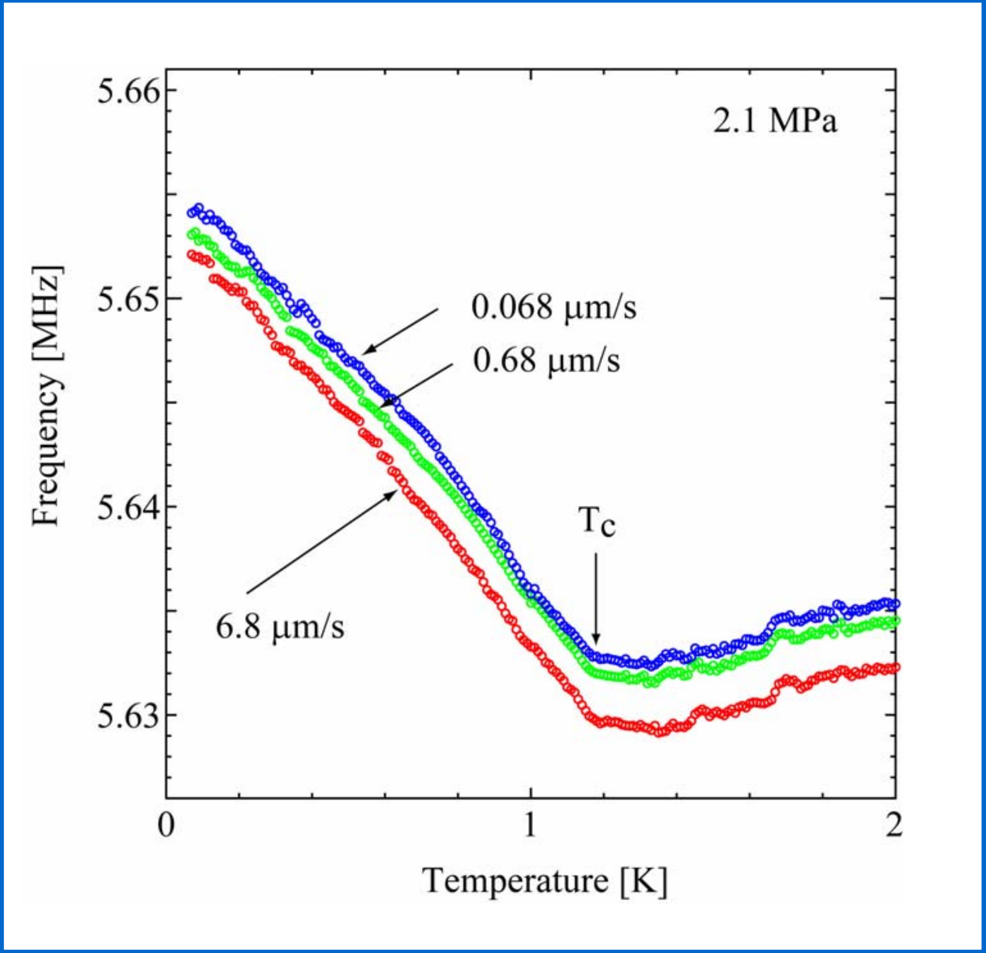


・The sound velocity increases at a certain temperature.

Cf. Vycor glass



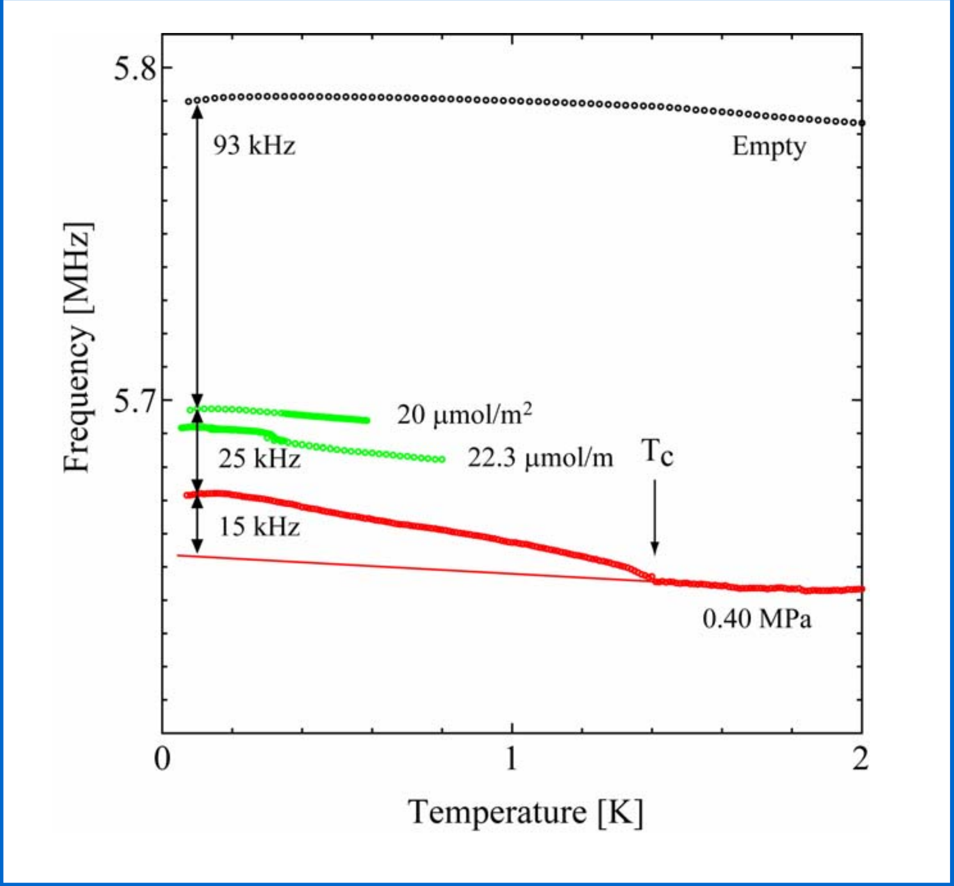
（b） Amplitude Dependence



・The Amplitude dependence is not observed in the present experimental condition.

・The critical velocity is larger then about 10 μm/s.

（c） Superfluid fraction

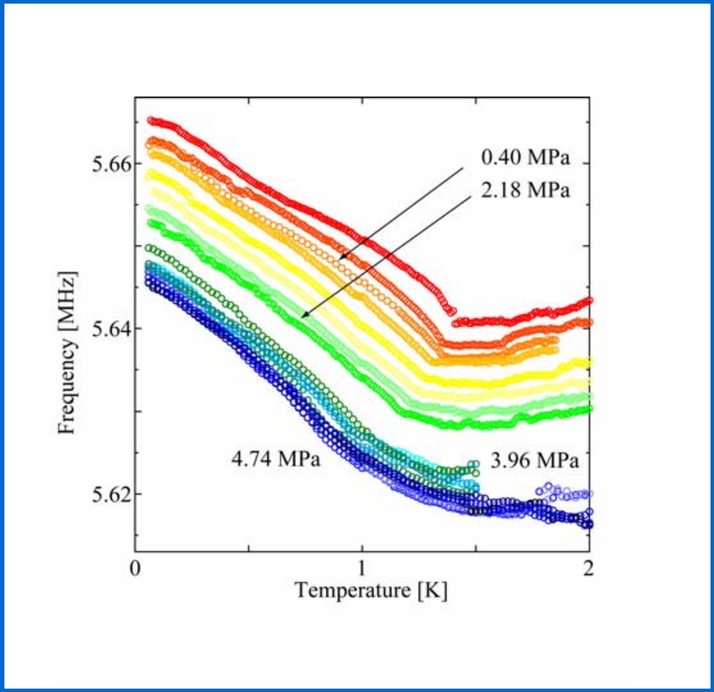


- The observed superfluid fraction is more than 35%.

$$1-\chi_n=\frac{15\ \mathrm{kHz}}{25\ \mathrm{kHz}+15\ \mathrm{kHz}}$$
$$=0.375$$

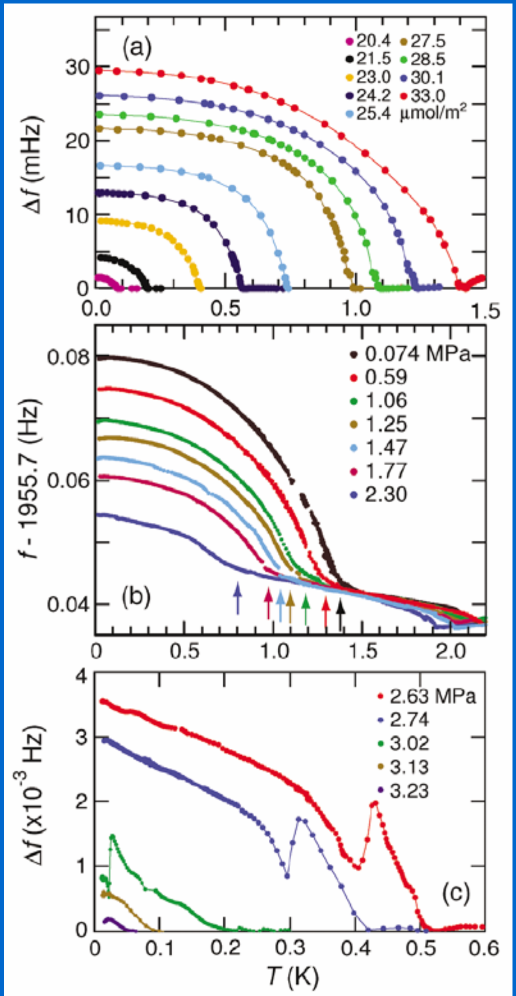
（d） Comparison between US and TO

Ultrasound （MHz range)



・The sound velocity has a strong temperature dependence at low temperatures.

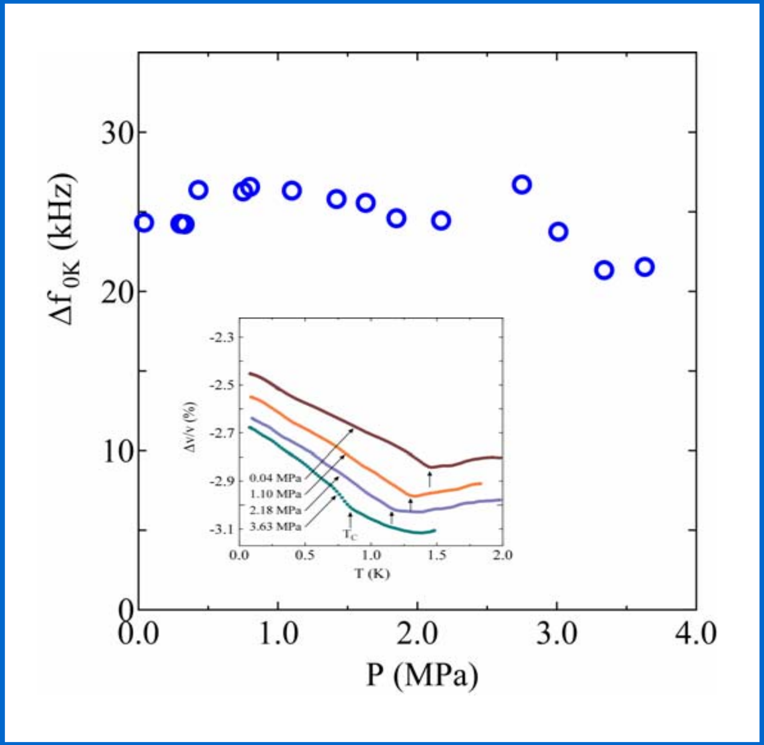
Torsional oscillator (kHz range)



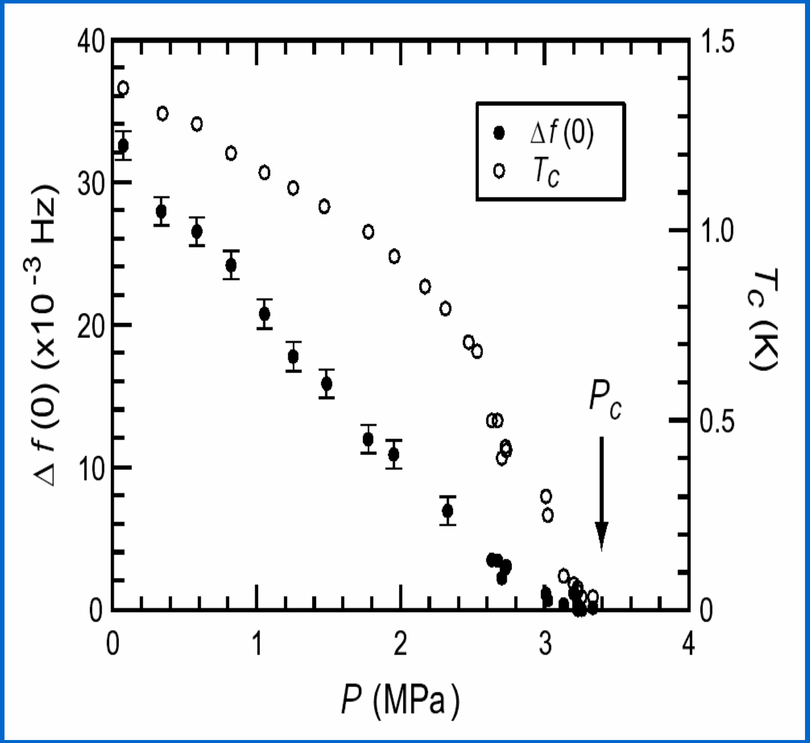
K.Yamamoto et al. ,
Phys.Rev.Lett. **93**. 075302 (2004)

(e) Comparison between US and TO

Ultrasound (MHz range)

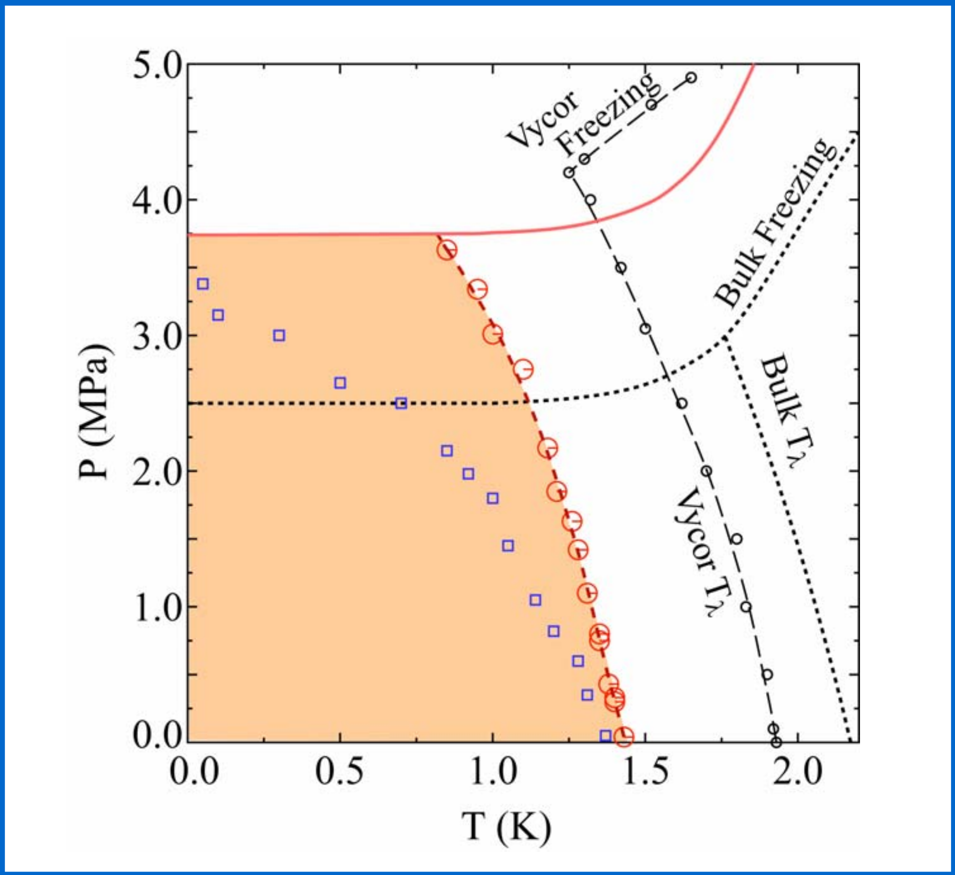


Torsional oscillator (kHz range)

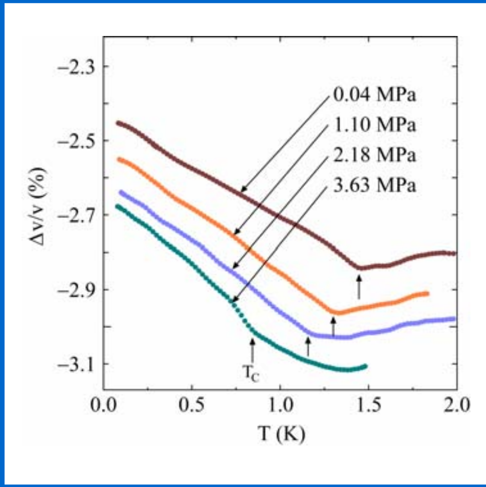


・The increase at 0K form Tc shows a weak pressure dependence.

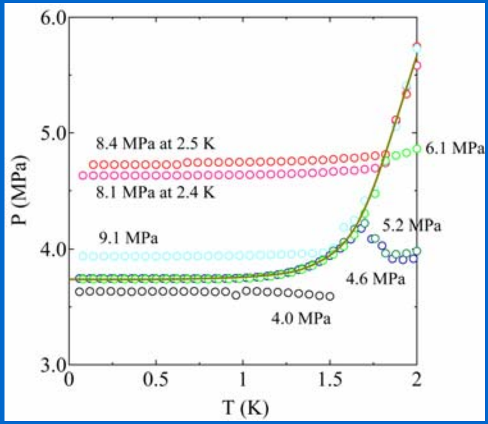
（e）Phase diagram



1) Sound velocity vs. Temperature



2) Pressure vs. Temperature



- Compared with TO, the Tc –line has a weak pressure dependence .

Summary and future plan

From ultrasound measurements,

- Superfluid onset Tc is suppressed largely.
- Tc decreases monotonously as the pressure increases.
- The Tc -line has a weak pressure dependence.

There are some differences between US and TO.

1. Simultaneous measurement of US and TO
2. Other porous substrates

Hectorite