Workshop on Supersolid 2008

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Pressure relaxation on annealing in solid helium

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X-ray scattering experiments on Solid helium

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Pressure drops on annealing

Shah/Simmons
Grigor’ev et al.
What can we learn?

• We know the compressibility of the “clean” solid.

• From $\Delta P$ we can find $\Delta V$, the extra volume that became available on annealing.

• If we know the “volume per defect” we can find the number of defects.
For example:

• Assume there is a glassy component with a density about 10% lower than the crystal.

• The pressure drops 4 bar on annealing

→ 10% of the solid was in the glassy state before we annealed it
Pressure cell

15 mm diameter
8 mm width

Two transducers facing each other
Temperature “quench”
What is in the cell?

- It cannot be a perfect crystal.
- It is a glass
- It’s all in the grain boundaries
- Dislocations, dislocations!
- Liquid “droplets”, “channels” etc.
X-ray diffraction set-up

- Point detector
- Ccd camera
- Beamstop
- Cell
- Incident beam
“All these experiments take a long time.”

H. Kojima

“Let me get this right. We must do a low temperature experiment and an x-ray experiment, and we have five days to do it?”

J. T. West
I. Experiments on crystals

All crystals were grown at constant pressure,

\[ P = 60 \text{ bar}, \quad T_M = 2.6 \text{ K} \]
Mapping a crystal

Typically, crystals span the tube diameter and are a few mm wide.
Looking at “strain”
Waiting and watching

20 snapshots
5 minutes apart

$T = 1.75 \, \text{K}$
Crystal in motion

And gone!
Conclusions I

• Constant pressure crystals are fairly large but severely strained.

• Some mobility $1.75 \, \text{K} < T < 2.15 \, \text{K}$ (60 bar, $T_M = 2.6 \, \text{K}$),

rapid motion at larger temperature
II. Solid helium in aerogel

Motivation?

R&R: NCRIIf $\rightarrow$ 20%

"due to disorder"

Logical step: Build in disorder
But also

1. Shear modulus and NCRIf track

2. Shear modulus drops because dislocation lines become mobile?

→ Pin the dislocations and both shear modulus and NCRIf will remain high up to some high temperature???
Aerogels ???

Very porous silica glass,
90% --- 99% open space

Large surface area,
1000 $m^2/g$

→ Small primary particles,
2 – 5 nm diameter

TEM picture of 5% dense silica aerogel

Herman and co-workers,
U. Alberta
The large surface-to-volume ratio, $100 \text{ m}^2/\text{cm}^3 \rightarrow \sim 3\%$ of the solid helium is within 3 Å of a silica surface.

No helium is more than $\sim 200 \text{ Å}$ away from silica.

The mean free path, the mean distance between pinning sites $\sim 500 \text{ Å}$. 
Aerogel

SAXS

scattering intensity

$q (\text{Å}^{-1})$
We observe a transition similar to the good/pure samples!

What sort of sample do we have?
X-ray powder diffraction

rings from Be windows

rings from solid helium

liquid

crystal

solid
Solid - liquid

(100)
(101)
(102)
(110)
(002)

-liquid ring
Clearly, we observe rings, not isolated Bragg spots

→ we have a “powder” not a single crystal

We can index the rings, finding an HCP structure

Can we learn more?
From the diffraction peak width, we can obtain the grain size:

\[ D = \frac{S \lambda}{W_{FWHM} \cos \theta} \]

\[ D \sim 1000\text{Å} \]
Connection with NCRIIf?

A crystallite size of 1000 Å

→ 30 m²/cm³ of grain boundaries

→ ~1% of the solid within 3 Å
   a much larger fraction than the actually observed NCRIIf
Conclusions II

We have made very disordered samples, consisting of 1000 Å diameter HCP crystallites.

We observe a super solid transition similar to that in “high quality” samples.

???
Ambition
TO results

Josh West, PSU

All 10 μm/s
Blocked Capillary

35 - 65 bar

95% aerogel

NCRIF [%]

Temperature [K]