AC Calorimetry
Principle, Schematic, Examples

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\[ I = I_0 \cos \left( \frac{1}{2} \omega t \right) \]

\[ P = I_0^2 R \cos^2 \left( \frac{1}{2} \omega t \right) \]

\[ T = T_{dc} + T_{ac} \cos(\omega t + \phi) \]

**Simplified model**

\[ T_{ac} = \frac{P_0}{2K_b} \left( 1 + \omega^2 \tau^2 \right)^{-1/2} \]

\[ \tau = \frac{C_s}{K_b} \]

Simple but requires knowledge of \( R(P, T) \)!
\[ C_h \dot{T}_h = \dot{Q}_h = \dot{Q}_0 \left( \cos \frac{1}{2} \omega t \right)^2 - K_h (T_h - T_s), \]
\[ C_s \dot{T}_s = \dot{Q}_s = K_h (T_h - T_s) - K_b (T_s - T_b) - K_\theta (T_s - T_\theta), \]
\[ \dot{Q}_\theta = K_\theta (T_s - T_\theta). \]

\[ T_\theta = T_{dc} + T_{ac} \cos(\omega t + \varphi) \]

If \( \omega^2 (\tau_\theta^2 + \tau_h^2) \ll 1 \)

and \( \omega \tau_s \gg 1 \)

\[ T_{ac} = \frac{P_0}{2\omega C} \left[ 1 + \frac{1}{\omega^2 \tau_s^2} + \omega^2 (\tau_\theta^2 + \tau_h^2) \right]^{-1/2} \]

\[ K_S = \infty \]

\[ Q = \dot{Q}_0 \left( \cos \frac{1}{2} \omega t \right)^2, \]

\[ \tau_1 = \tau_s \]
\[ \tau_2 = \tau_\theta^2 + \tau_h^2 + \tau_{int} \]

\[ T_{ac} = \frac{\dot{Q}_0}{2\omega C} \left[ 1 + \frac{1}{\omega^2 \tau_1^2} + \omega^2 \tau_2^2 + \frac{2K_b}{3K_s} \right]^{-1/2} \]

\[ T_{ac} = \frac{P_0}{2\omega C} \left[ 1 + \frac{1}{\omega^2 \tau_1^2} + \omega^2 \tau_2^2 \right]^{-1/2} \]

\[ \omega^2 \tau_2^2 \ll 1 \]

Slow enough for heater and thermometer to catch up sample temperature

\[ \omega \tau_1 \gg 1 \]

Quick enough for sample to decouple from thermal bath

\[ \tau_1 = 3sec, \tau_2 = 7 \times 10^{-4}sec \]

\[ f = \frac{\omega}{2\pi} \]

2Hz – 20Hz for this case

\[ T_{ac} \left( \frac{P_0}{2\omega C} \right)^{-1} \sim 1 \]
Sample: 20 µm  
Thermocouple: 12 µm  
Heating wire: 3 µm


Drawbacks
(i) Thermocouple calibration
(ii) Absolute value

Eichlerand Gey, Rev. Sci. Instrum. 50, 1445 (1979)
Current directly applied to sample $\text{CePd}_{2+x}\text{Ge}_{2-x}$

- $C(T)$ vs. $\rho(T)$
- $\nabla T$
- $\nabla P$

Antiferromagnetic transition $T_N$ vs $P$

For $x = 0.02$, open circle by ac calorimetry, filled circle by resistivity
For $x = 0$, open and filled square are two samples measured by resistivity


Unpressurized thermometer

Grain size 0.25 μm.

Kazunori Umeo, REVIEW OF SCIENTIFIC INSTRUMENTS 87, 063901 (2016)
Conclusion

• Sensitive to heat capacity change
• Absolute value not as accurate as adiabatic calorimetry
• Suitable in pressure cell

Thank you for attentions
Questions?