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Can we reduce thermo-elastic damping by cooling?

Brag. et al

$$x^2(\omega) = \frac{8}{\sqrt{2\pi}} \alpha^2 (1+\sigma)^2 \frac{k_b T^2}{\rho C} \frac{a^2}{r_0^3} \frac{1}{\omega^2}$$

$$\left\{ a^2 = \frac{K_{th}}{\rho C} \right\}$$

1) • Need values for $\alpha(T)$, $C(T)$, $K_{th}(T)$

2) n.b. formula is valid for condition $\omega \gg \frac{a^2}{r_0^2} \cong \frac{1}{\tau}$

$$x^2(\omega) \propto \frac{\alpha^2 T^2}{C} \frac{1}{r_0} \frac{a^2}{r_0^2} \frac{1}{\omega^2}$$

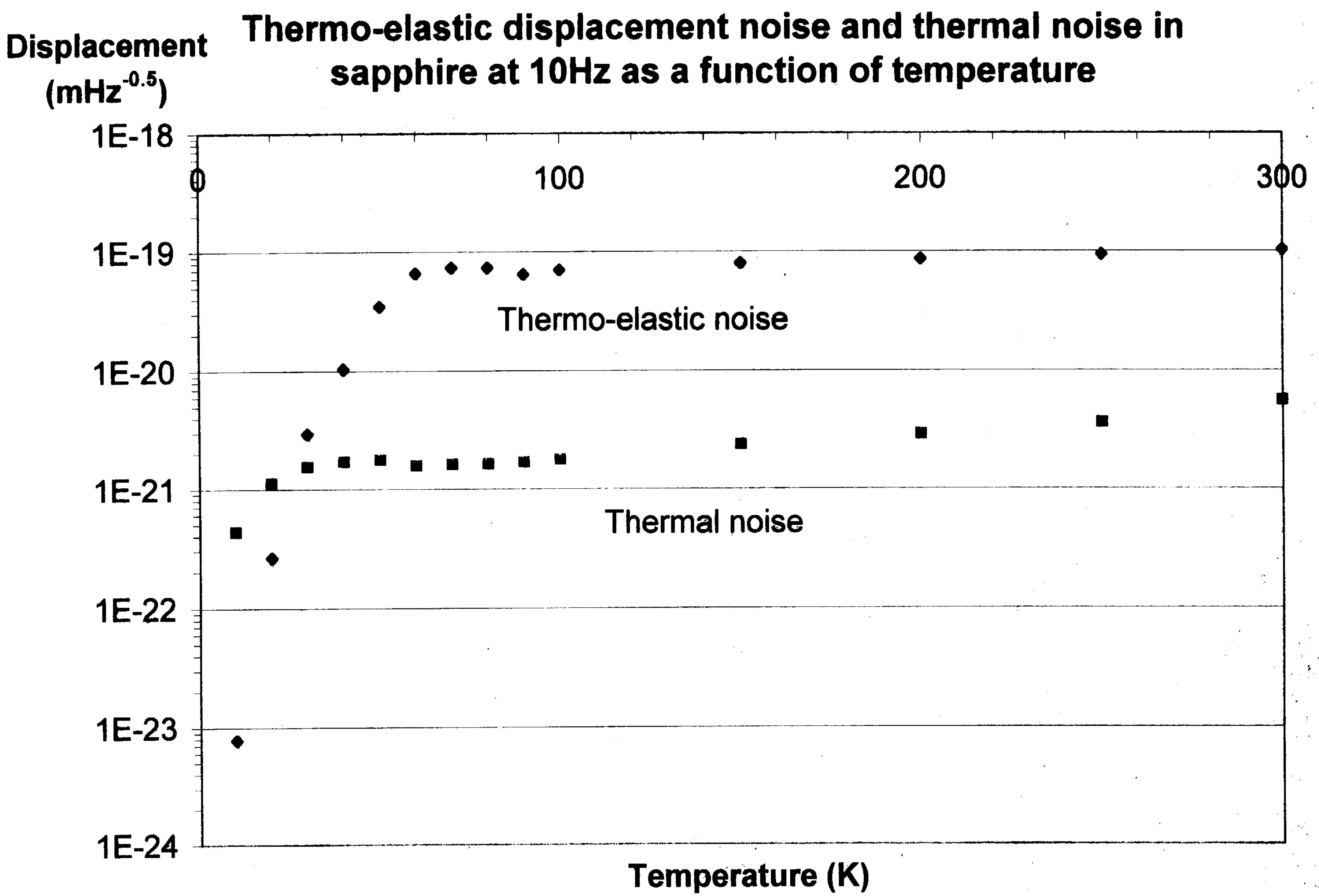
$$= \frac{\alpha^2 T^2}{C} \frac{1}{r_0} \frac{1}{\omega\tau} \frac{1}{\omega}$$

Following classical treatment of thermo-elastic damping to extend more generally replace $\frac{1}{\omega\tau}$ by $\frac{\omega\tau}{1+\omega^2\tau^2}$

→ Evaluate $x^2(\omega)$ as a function of temperature

$$x(\omega) \propto \frac{\alpha T}{\sqrt{K}}$$

$$x(\omega) \propto \frac{\alpha T \sqrt{K}}{C} \frac{1}{\omega}$$



Thermo-elastic displacement noise and thermal noise in sapphire at 10Hz as a function of temperature
Displacement (mHz^-0.5)
1E-18
1E-19
1E-20
1E-21
1E-22
1E-23
1E-24
0
100
200
300
Thermo-elastic noise
Thermal noise
Temperature (K)

Silicon : similar to sapphire <u>but</u>
coefficient of thermal expansion = 0
at ~ 120K , ~ 20K

⇒ <u>Thermo-elastic</u> noise → zero at these temperatures

→ silicon looks very interesting

McGuigan et al, J. Low Temp. Phys. (1978)

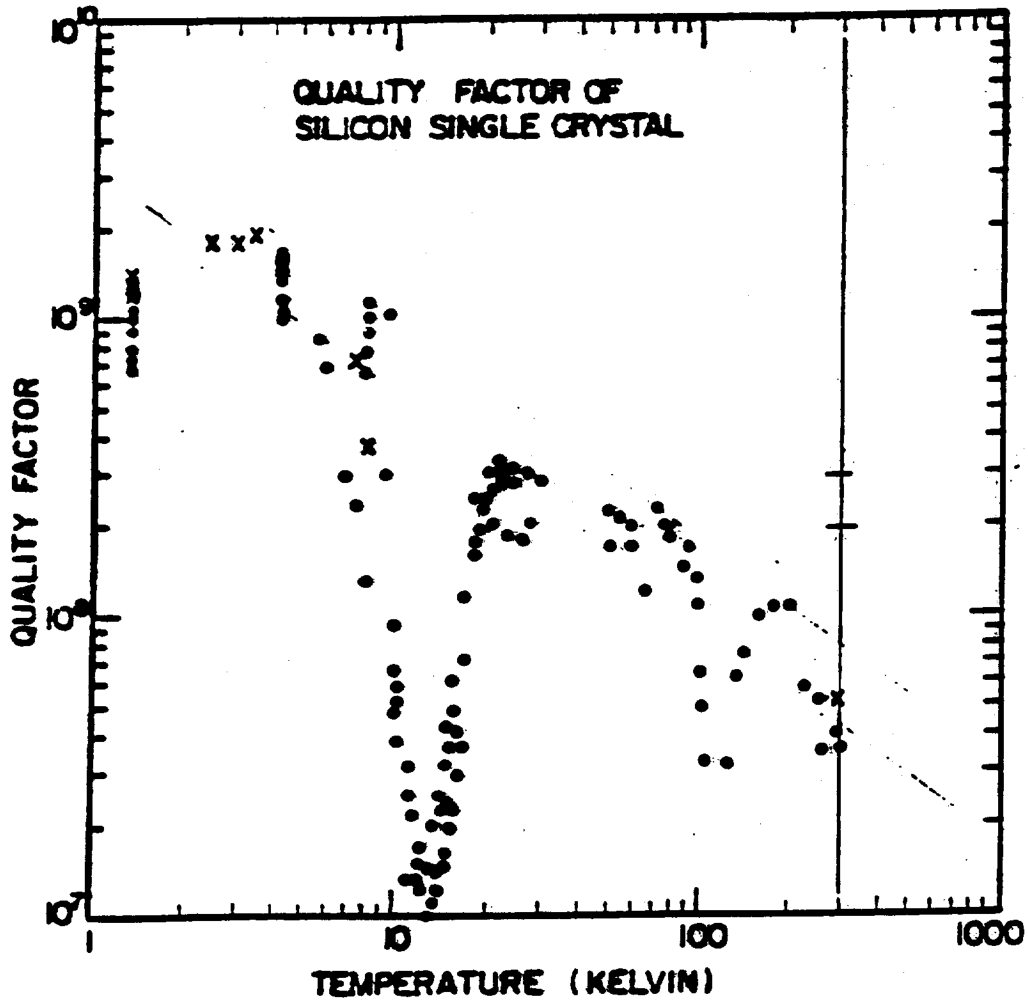
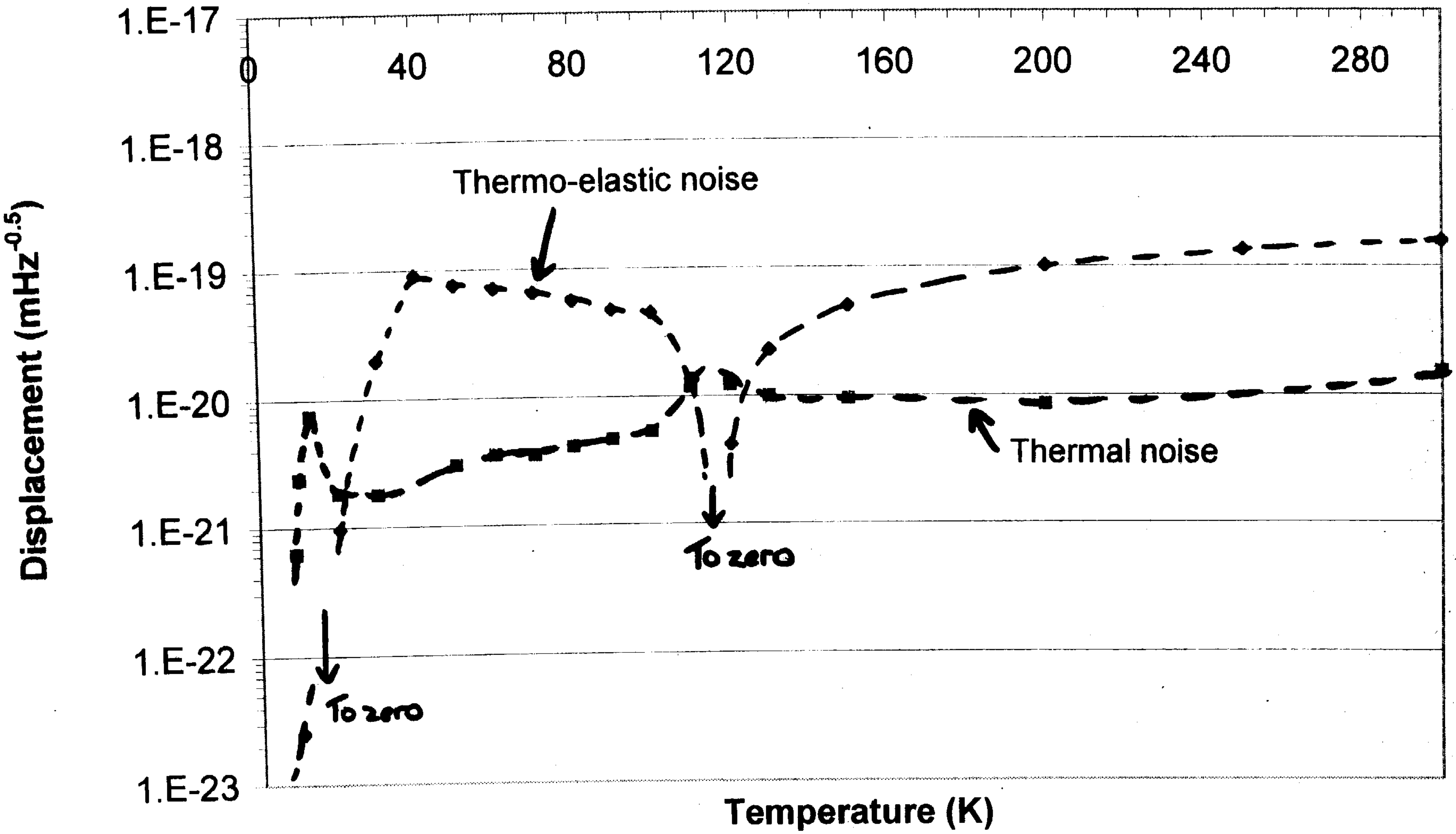


Fig. 6. Quality factor of silicon vs. temperature. The solid dots (data points) were obtained during several runs with aluminum films evaporated on the faces. The data points indicated by × were obtained in a later run after chemical polishing; no metal film was evaporated onto the face.

'Thermo-elastic' displacement noise and 'thermal' noise in silicon at 10Hz as a function of temperature



Conclusions

We can reduce thermo-elastic noise by cooling, but best to cool to < 20K

Silicon - interesting - sources of dissipation need further investigation.

(nb: must always remember work needs done)
to take care of SQL

Note 1, Linda Turner, 05/09/00 01:44:07 PM
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