Thermal Design of Piezoresistive Cantilevers

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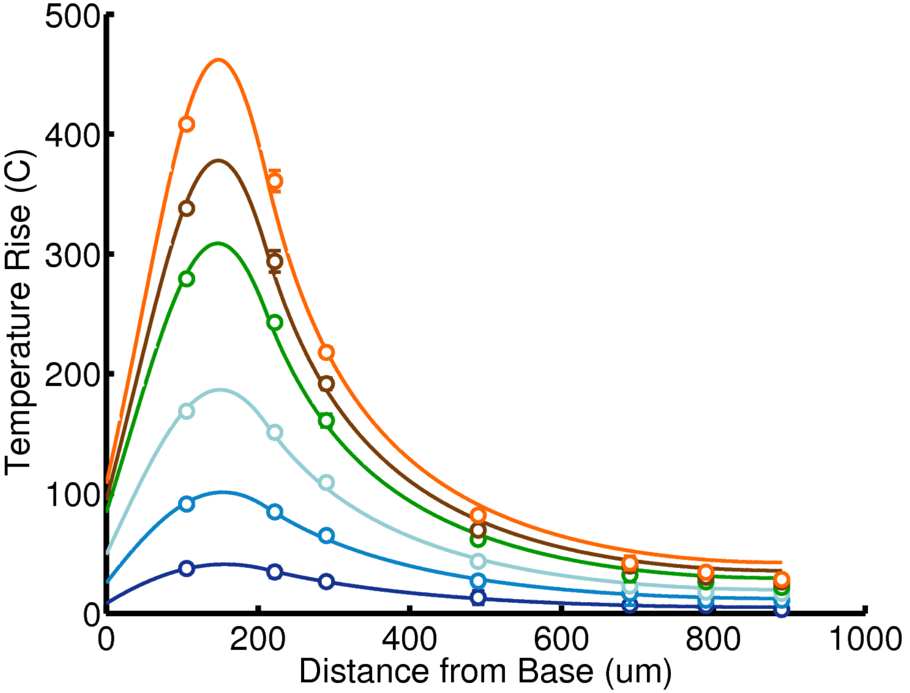
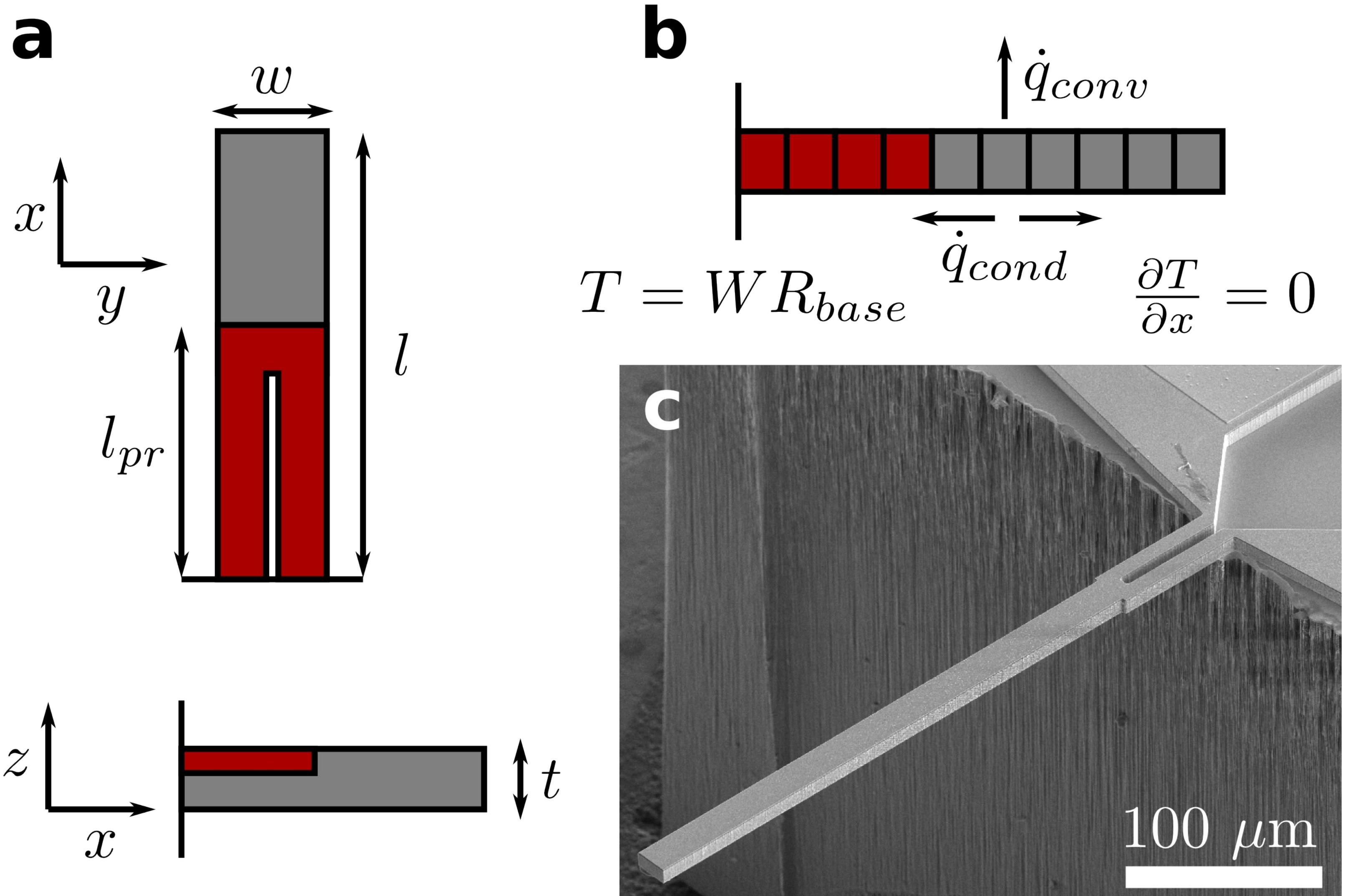


A Model for Cantilever Self-Heating



Mechanical Scaling Laws

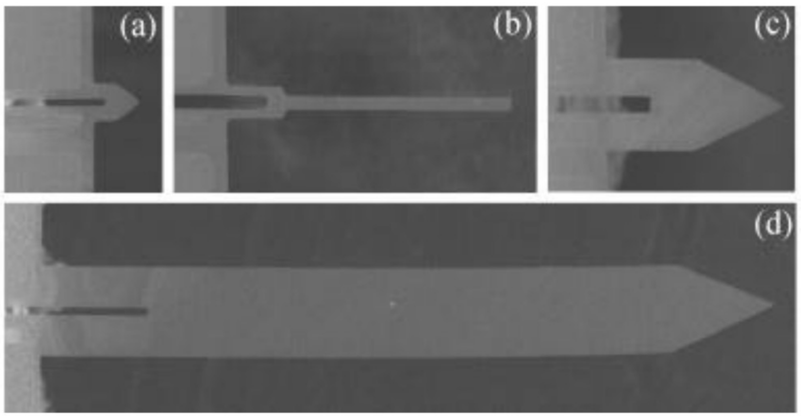
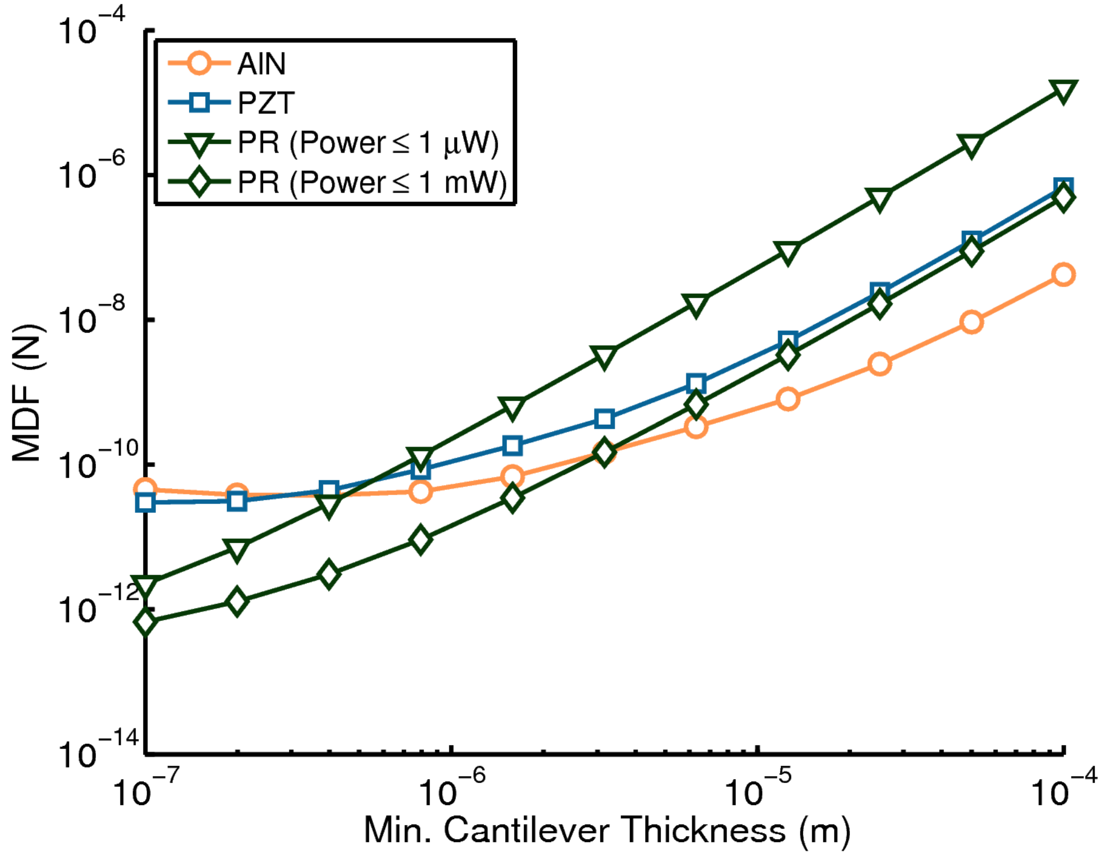


Figure 4-3. SEM of 87-91 nm-thick cantilevers. (a) 10 μm× 8 μm (b) 50 μm× 2 μm (c) 40 μm× 20 μm (d) 350 μm× 44 μm. Cantilever (d) is at a 40% scale compared to the others.

$$S_F \propto \frac{l}{wt^2} \propto [L]^{-2}$$

$$\frac{f_0}{k} \propto \frac{l}{wt^2} \propto [L]^{-2}$$

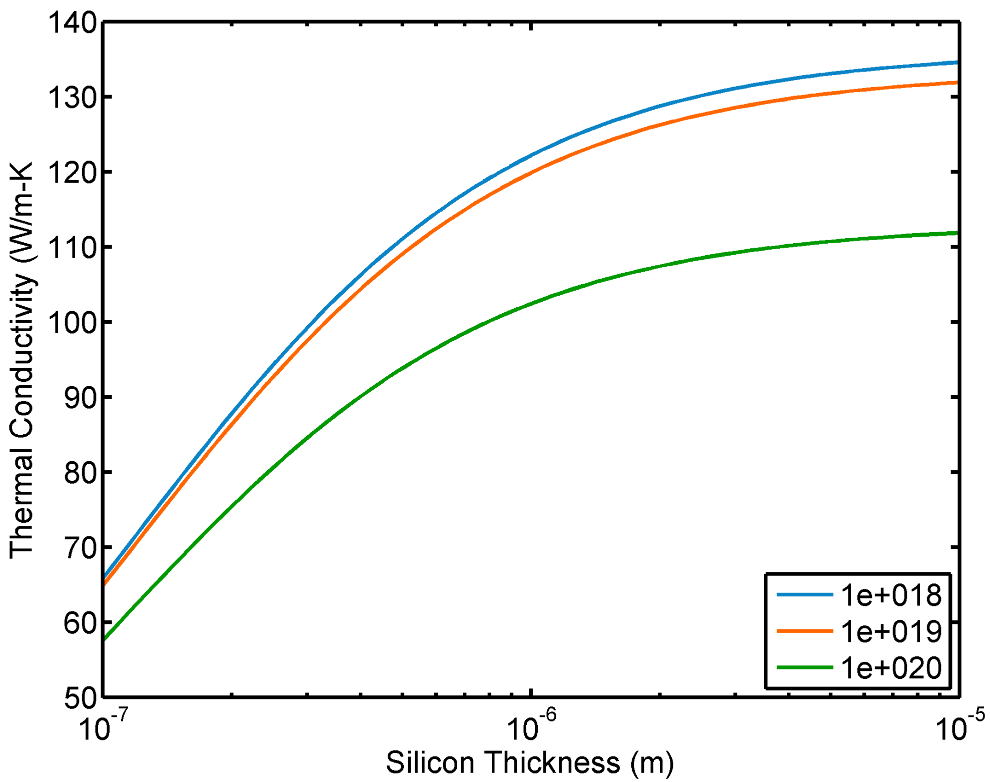


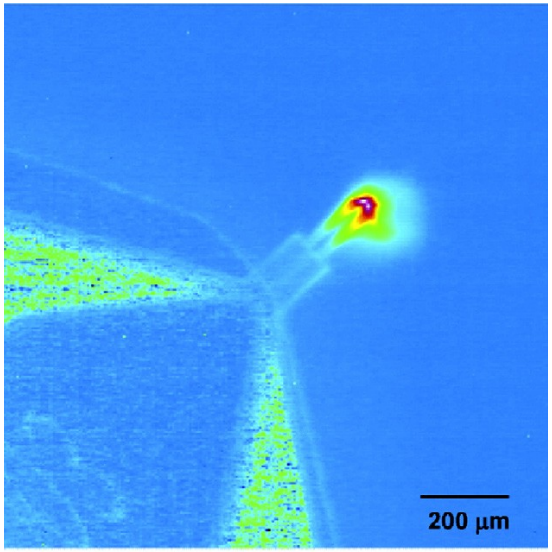
From "Advances in Piezoresistive Probes for Atomic Force Microscopy", Harley, 2000.

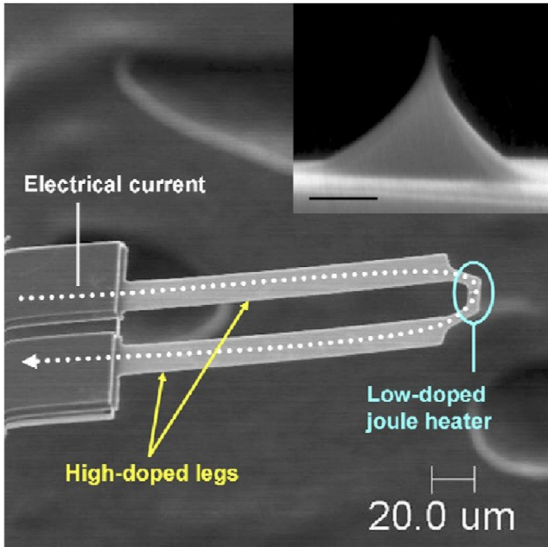
Thermal Scaling Laws

$$R_{cond} \propto \frac{l_{pr}}{2wtk} \propto [L]^{-1}$$

$$R_{conv} \propto \frac{1}{2hl(w+t)} \propto [L]^{-2}$$

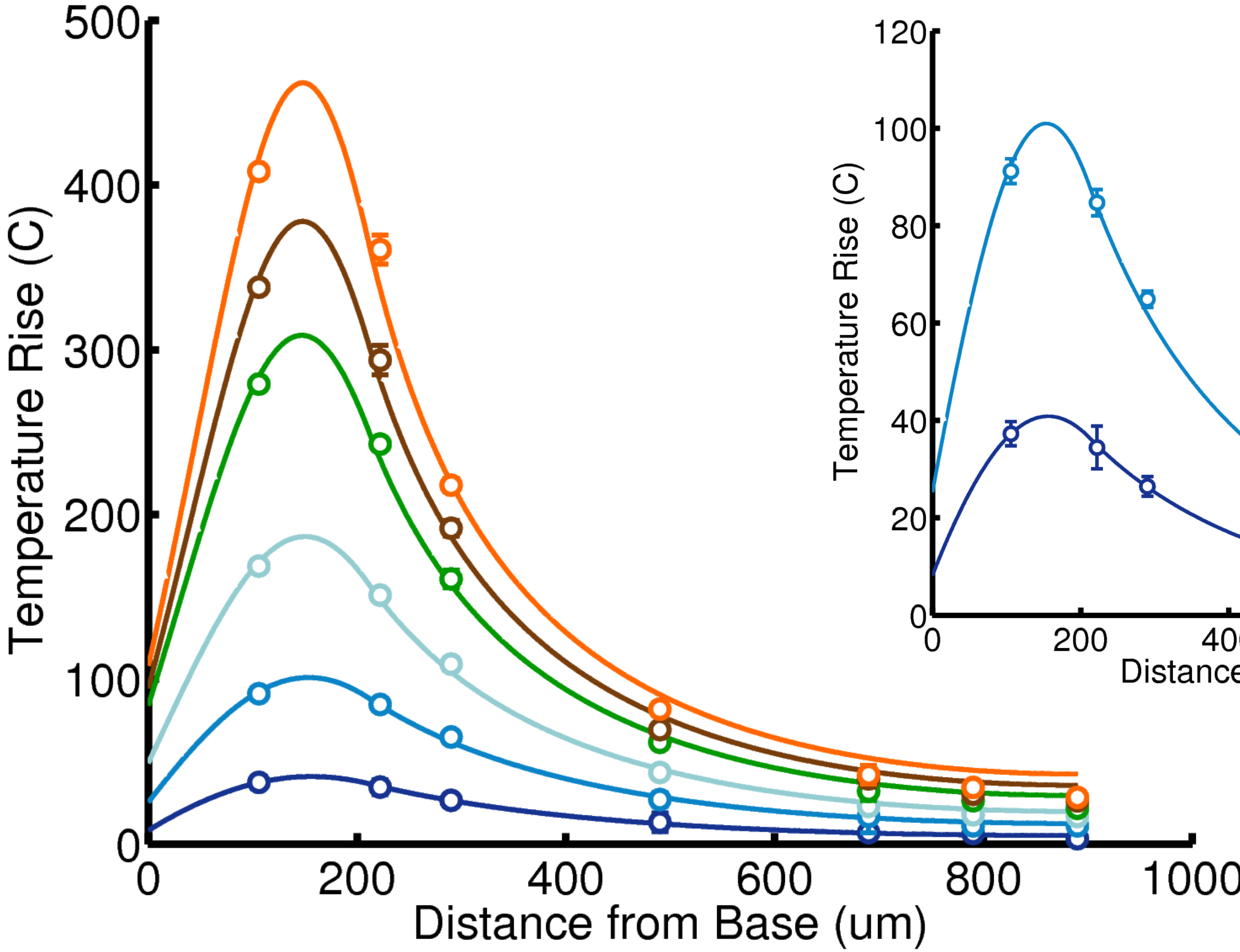


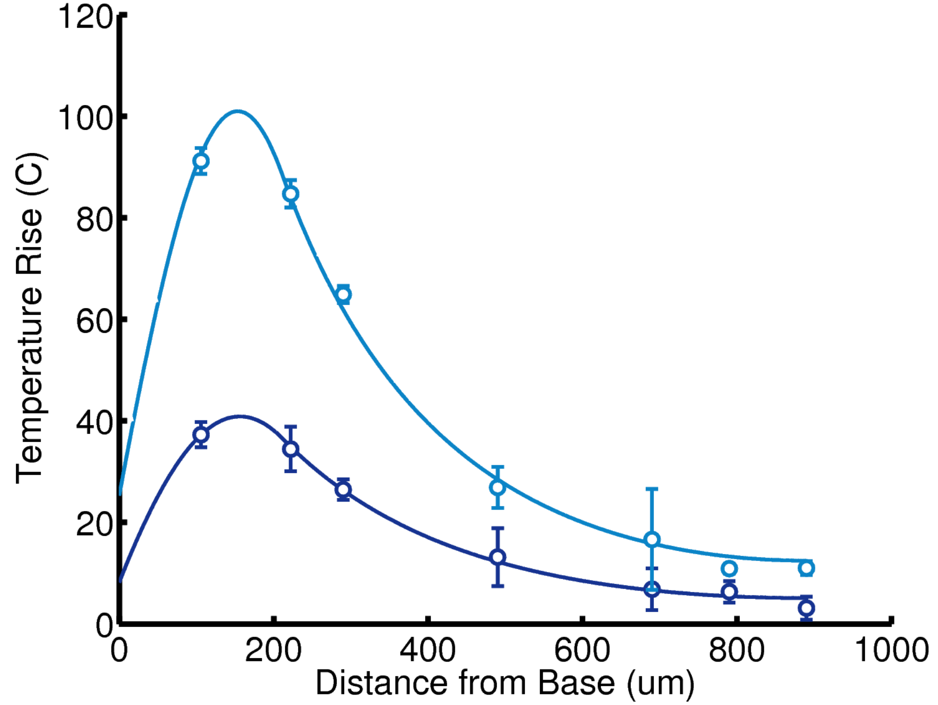




From "Temperature calibration of heated silicon atomic force microscope cantilevers", Nelson and King, 2007

Model vs. Experiment



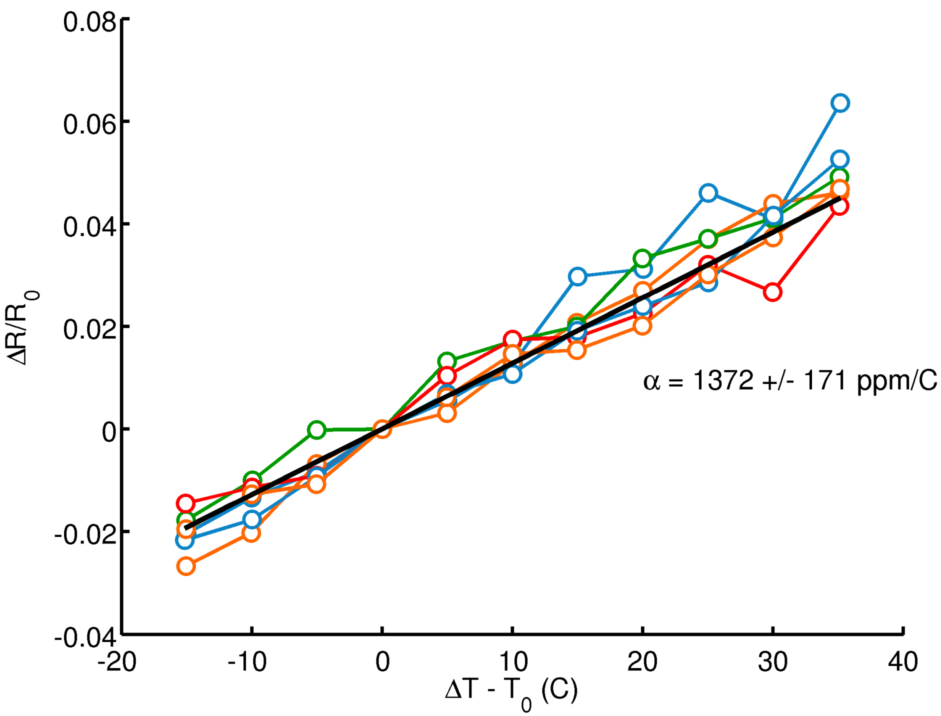


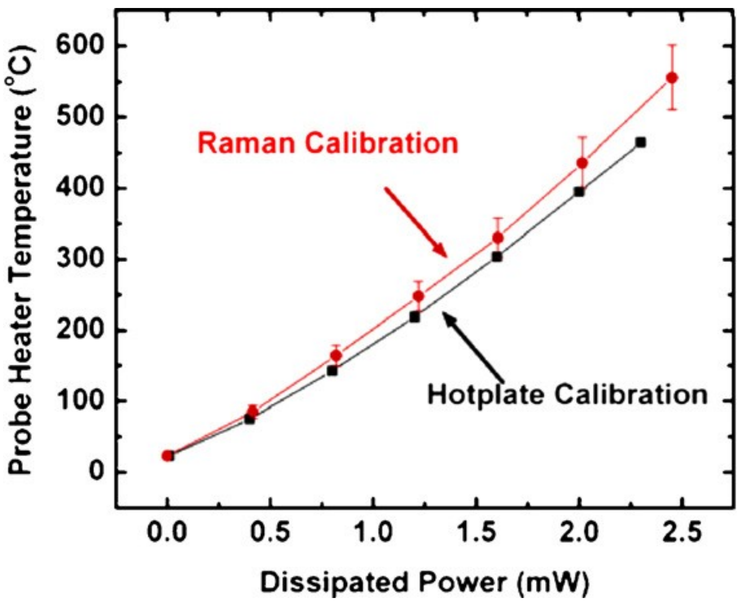
Cantilever = 2um x 10um x 890um
Piezoresistor = 220um long

Temperature measured using Raman Thermometry
By Elise Corbin, UIUC
Powers = 1-12 mW

Temperature Calibration

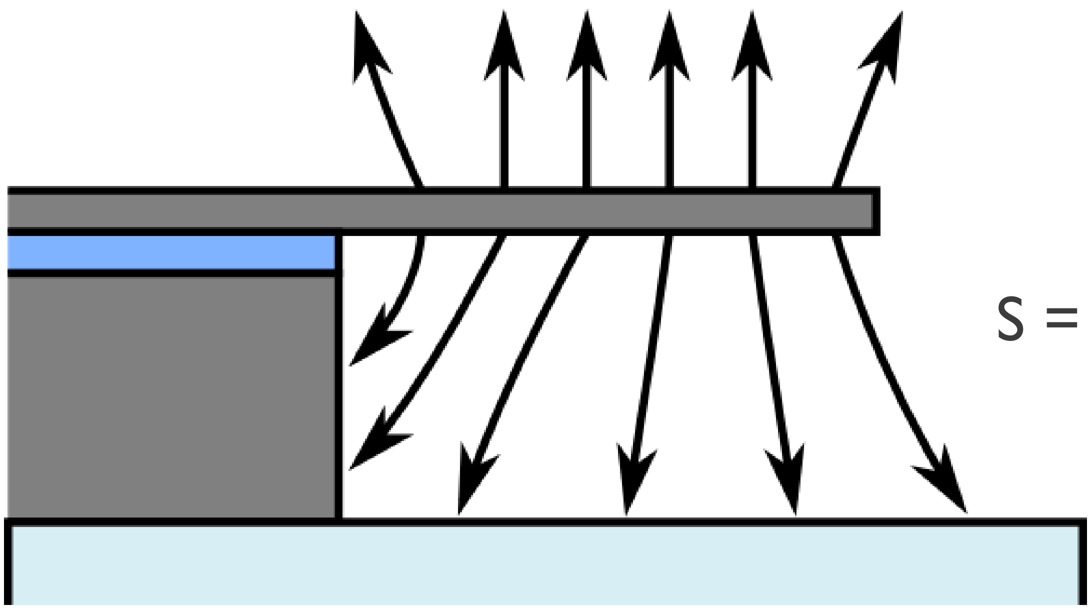
- Probe wavelength
  - Raman vs IR
- In-situ calibration
- Two parameters





From “Temperature calibration of heated silicon atomic force microscope cantilevers”, Nelson and King, 2007

Calculating the Convection Coefficient



$$h_{eff} = \frac{k_f S}{P}$$

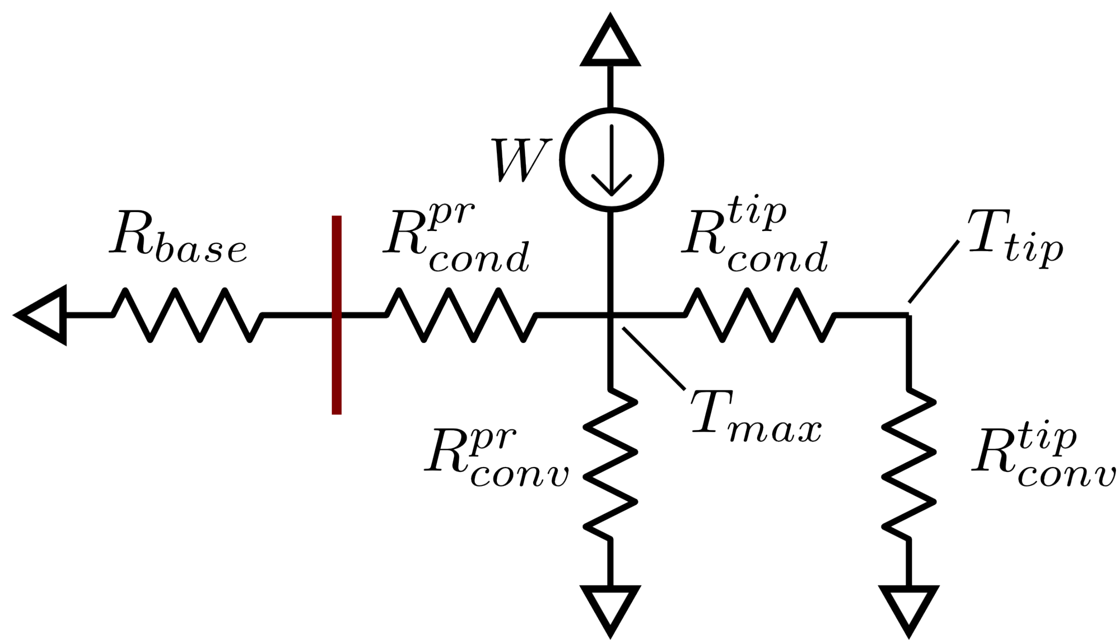
S = Shape factor from FEA or tables

Approximate Temperature Models

$$T_{max} \approx W(R_{base} + \frac{l_{pr}}{2wtk})$$

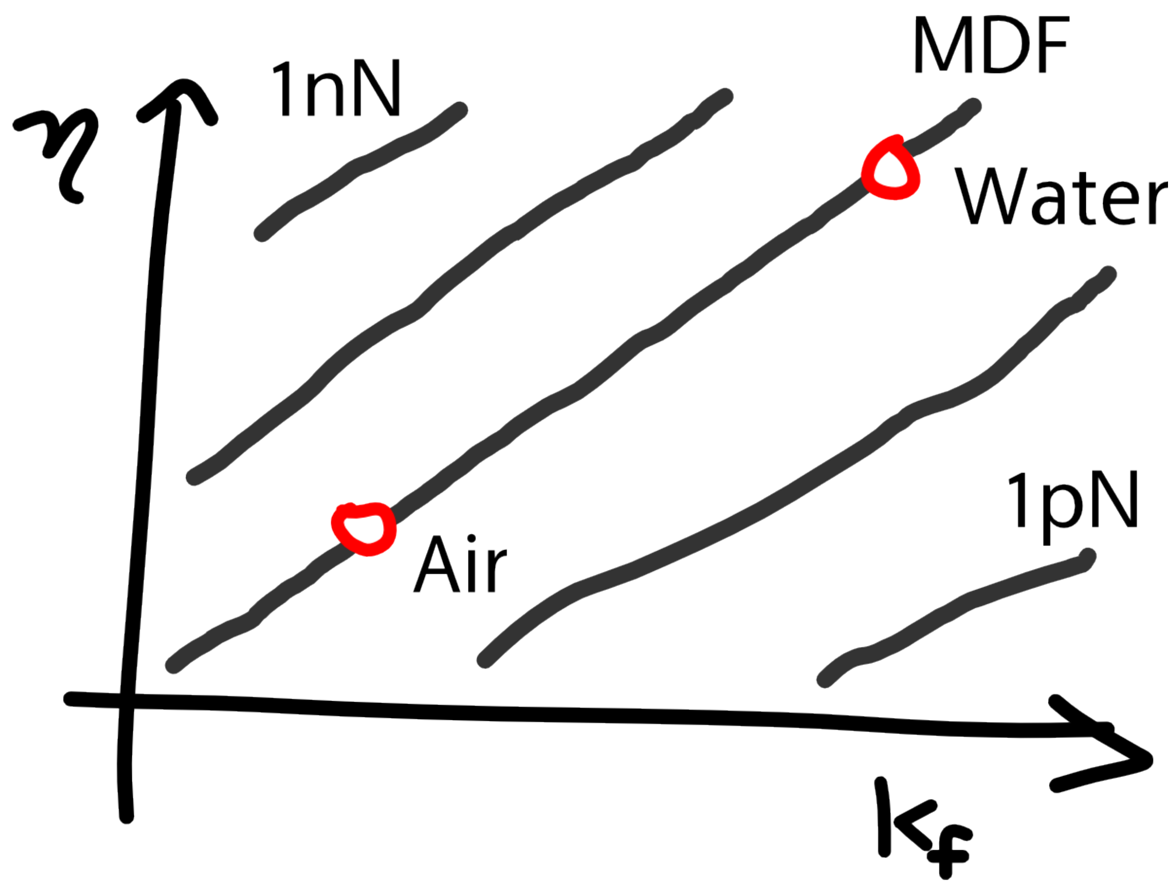
$$T_{tip} \approx T_{max} e^{-(l-l_{pr})/\Lambda}$$

$$\Lambda = \sqrt{\frac{kA}{hP}}$$



Implications for Cantilever Design

- Scaling cantilever design
  - PR length, resistance, power, voltage
- Die layout for good thermal contact
- Fluid thermal conductivity, viscosity
- Small cantilevers to date have been hot



Thanks for Listening!