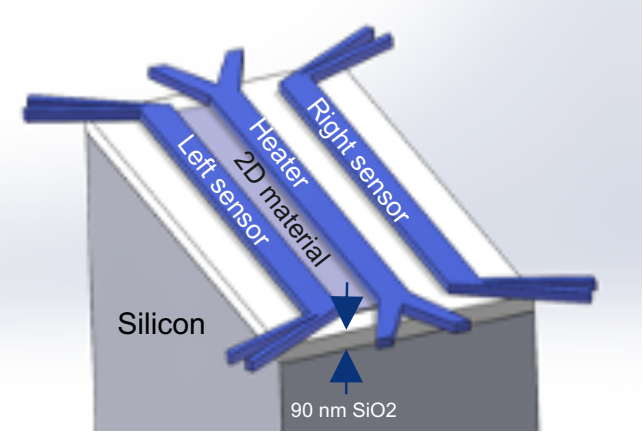
Activity 3

A nanoscale thermometry platform made by Dr. Estrada's group (see schematic) consists of a single crystal metal bar that is heated through Joule heating. The heater is made from an isomorphous binary alloy of 13.6 at.% Ni in 86.4 at.% Cu. The dimensions of the bar are 200 nm in width, 1000 nm in length, and 50.0 nm in height (thickness).



Note: at 300 K, $\rho_{Cu} = 17.1$ nΩ m and $\alpha_{Cu} = 4.00 \times 10^{-3}$ K^{-1}. The effective Nordheim coefficient of Ni dissolved in Cu is $C = 1310$ nΩ m. At 100 K, the carrier mean free path for the alloy is $\lambda = 65.0$ nm, the mean carrier speed is 1.60×10^{6} m/s, and the alloy's specularity parameter is 0.800.

$P = IV \quad V = IR \Rightarrow P = \frac{V^2}{R} \quad R = \frac{\rho L}{A} \quad P = \frac{V^2 A}{\rho L}$

When operating the device with an applied bias of 50.0 mV, the power dissipated in the heater must be 500 μW. Will the heater achieve the necessary power dissipation? If not, what recommendations would you make?

at 100K

Account for surface scattering ← Fuchs-Sondheimer
temperature dependence ← TCR
impurities ← Nordheim

$\rho_{total} = \rho_{bulk}^{100K}\left[1 + \frac{3\lambda}{8\delta}(1-p)\right]$

$\rho_{bulk}^{100K} = \rho_{Cu}^{100K} + \rho_{impurity} = \rho_{Cu}^{200K}\left[1 + \alpha_{Cu}(\Delta T)\right] + CX(1-X)$

$T - T_0$; $\Delta T \approx -200K$; $X \approx 0.136$

$\Rightarrow \rho_{bulk}^{100K} = 157.35$ nΩm

$\rho_{total}^{100K} = 172.69$ nΩm $= 172.69$ Ω nm

$\text{Power} = \frac{\Delta V^2}{\rho L} = \frac{(200\text{nm})(50\text{nm})(5\times10^{-2}\text{V})^2}{(172.69\ \Omega\text{nm})(10^3\text{nm})} = \boxed{145\ \mu W}$

This is too low. At constant voltage, we need to decrease R. Remove Ni, make bar wider, thicker and shorter.