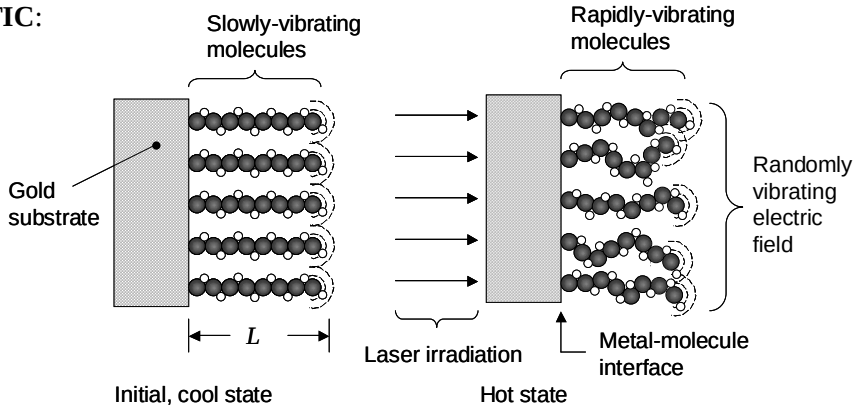
PROBLEM 5.21

KNOWN: Initial length, density and specific heat of self-assembled molecular chains. Time constant of the molecules' vibrational response.

FIND: Value of the contact resistance at the metal-molecule interface.

SCHEMATIC:



ASSUMPTIONS: (1) Molecules lose no thermal energy to surroundings. (2) Lumped capacitance behavior, (3) Constant properties, (4) Vibrational intensity represents temperature at the molecular scale, (5) Cylindrical molecule geometry.

ANALYSIS: From Equation 5.7, $\tau_t = R_{t,c}C_t = R''_{t,c}C_t / A_c$ where $C_t = \rho V c_p = \rho A_c L c_p$ is the lumped thermal capacitance and $R''_{t,c}$ is the thermal contact resistance. Combining the preceding two equations yields

$$R''_{t,c} = \frac{\tau_t}{\rho L c_p} = \frac{5 \times 10^{-12}\text{s}}{180\ \text{kg/m}^3 \times 2\times10^{-9}\ \text{m} \times 3000\ \text{J/kg}\cdot\text{K}} = 4.6 \times 10^{-9}\ \text{m}^2\cdot\text{K/W} \quad <$$

COMMENTS: (1) The contact resistance is very small, compared to values typical of larger systems. Nonetheless, the contact resistance may be larger than the conduction resistance within the moledule or thin gold film. (2) The time response is very fast, as expected at these length scales. This suggests that computational speed using such devices will be correspondingly fast. (3) See Z. Wang, J.A. Carter, A. Lagutchev, Y.K. Koh, N.-H. Seong, D.G. Cahill, and D.D. Dlott, "Ultrafast Flash Thermal Conductance of Molecular Chains," *Science*, Vol. 317, pp. 787-790, 2007, for details.