Advanced

Do Not Forget the Temperature Dependence of the Specific Resistivity!

- The discovery of high temperature superconductors in **1986** immediately lead to proposals to use these materials for interconnects on chips instead of the **Al** that was common than (and for about **15** more years).
  - The reason was that the finite resistivity of **Al** together with parasitic capacitances (e.g. between two conducting lines on a chip) limits the maximum frequency to

$$f_{max} = \frac{1}{R \cdot C}$$

  - With R **=** resistance of the longest connection line on the chip and C **=** parasitic capacitance "seen" by this line.
  - For $R = 0\ \Omega$ as we have it for a superconductor, the maximum frequency is no longer limited by $R \cdot C$, no matter how large the parasitic capacitances are. Instead, the limit comes from
    $f_{max} = (L \cdot C)^{-1/2}$
    with L **=** inductance of the line, and this is just another way of saying that the signal propagation is limited by the speed of light.

$$f_{max} = (L \cdot C)^{-1/2}$$

- Given the resistivity of **Al** (at room temperature!), a sizeable advantage was seen for the integrated circuits then envisioned.
  - However, comparing the performance of a chip run with **Al** at room temperature to a chip run at liquid N_2 temperature (**77 K**), is not the right comparison. After all, you can cool down the conventional chip, too - and that will decrease R_{Al} by a factor of **6 - 8**.
  - The comparison then is quite different. The graph shows the minimum switching time $\tau = 1/f_{max}$ as a function of the length of a standard interconnect line about **1 µm²** cross section.
- Whereas superconductors would already make an interesting difference for lengths of a few **mm** (typical line length) in the *wrong* comparison, the correct comparison only shows an advantage for about **1 cm** and larger - line lengths easily avoided by clever design.