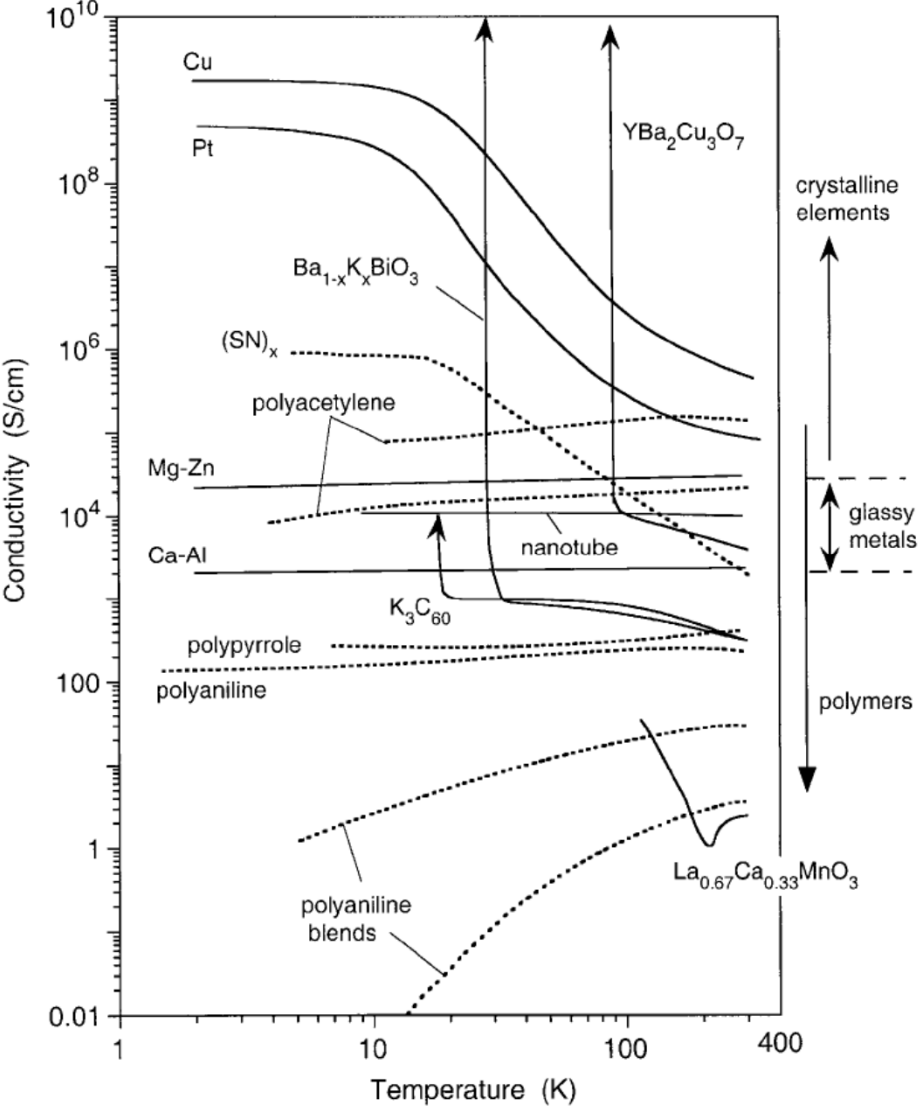


Metal-Insulator Transitions

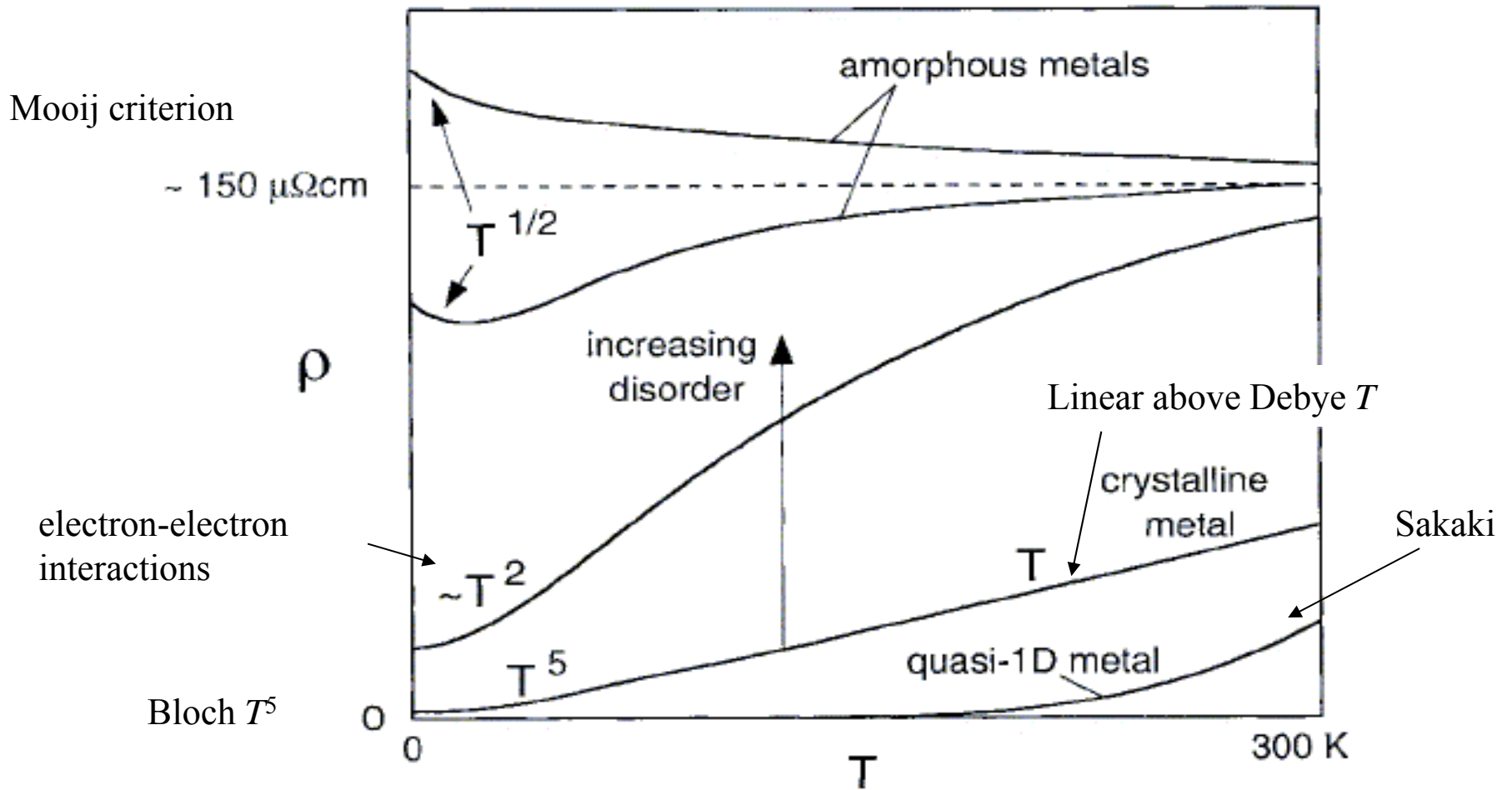
Temperature dependence of the conductivity



σ vs T tells us about the electron - electron and electron phonon interactions

A B Kaiser 2001 *Rep. Prog. Phys.* **64** 1

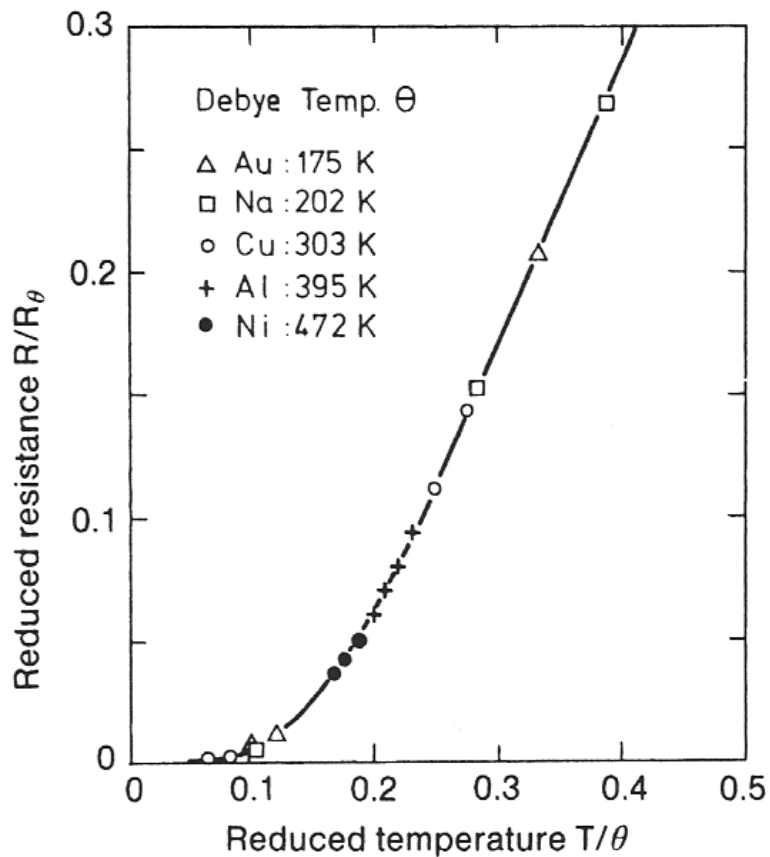
ρ vs. T



Temperature dependence of conductivity

Grueneisen model

$$\rho_{phonons} = A \left(\frac{T}{\Theta_D} \right)^5 \int_0^{\Theta_D/T} \frac{x^5}{(e^x - 1)(1 - e^{-x})} dx$$



for $T > \theta_D$, the number of phonons is proportional to T

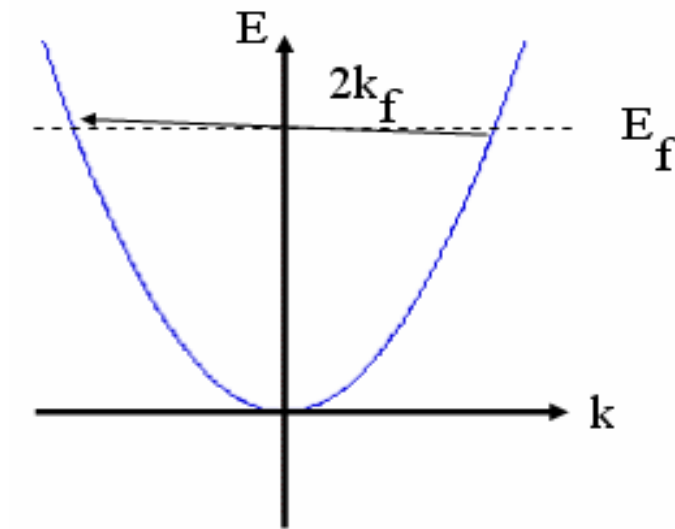
$$\rho_{phonons} \propto T$$

Low T : Only phonons with small $q \rightarrow$ small angle scattering

$$\rho_{phonons} \propto T^5$$

$$k + q = k' + q' + G$$

Suppression of backscattering in 1-D



There are no phonons with momentum $2k_f$ at low T

H. Sakaki, Jpn. J. Appl. Phys. Vol. 19 (1980) L735-L738

Peierls Transition

A quasi-one dimensional metal will undergo a transition to an insulator at low temperature

Predicted in the 1930's

Accidentally observed in the 1970's in TTF-TCNQ



Rudolf Peierls

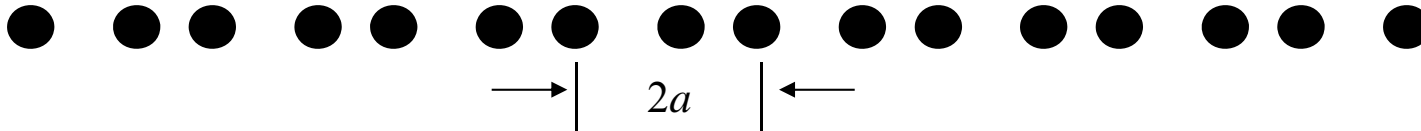
Quantum Theory of Solids
Surprises in Theoretical Physics
More Surprises in Theoretical Physics

Peierls Transition

Consider a 1-d lattice of atoms with spacing a .

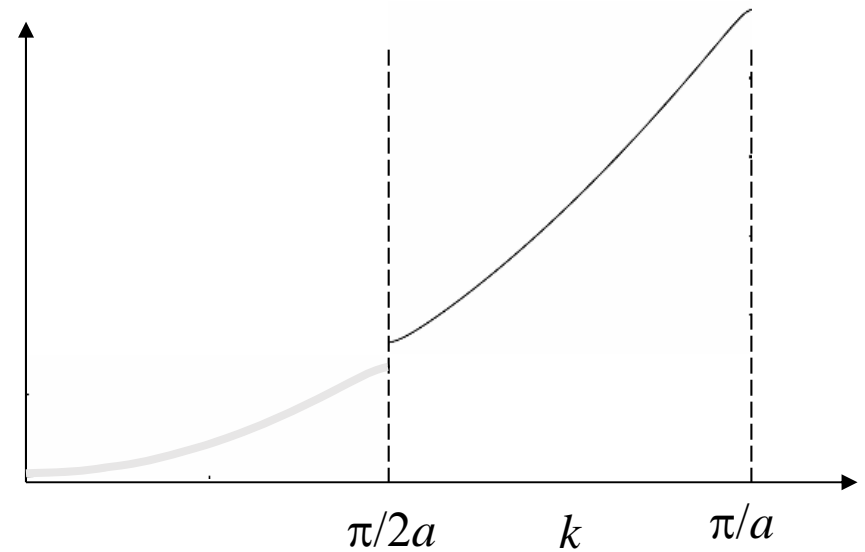
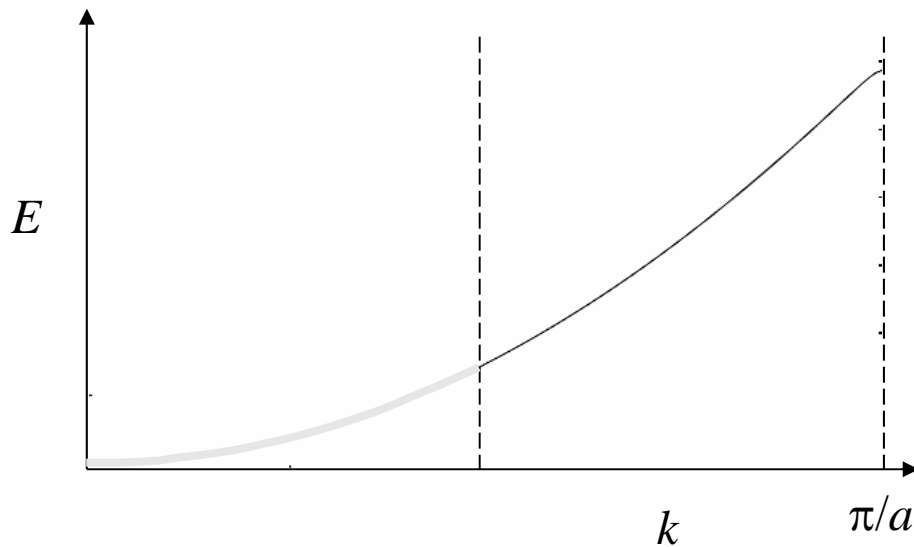
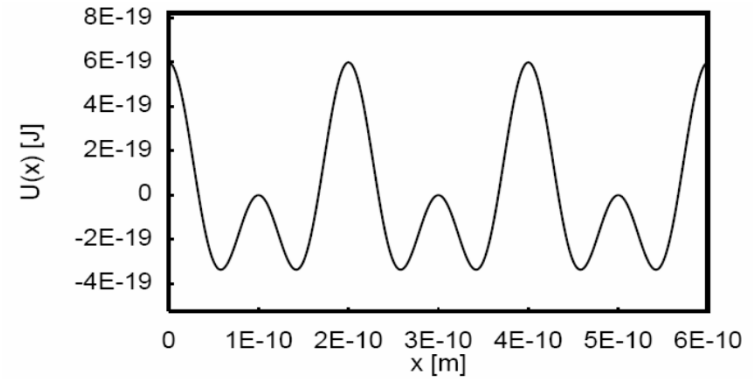
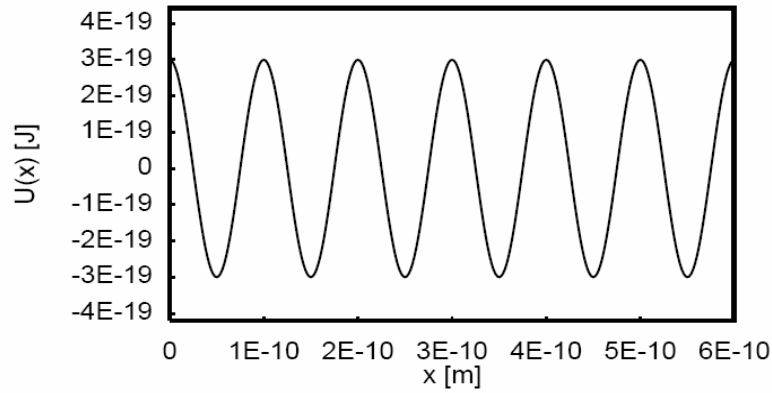


A periodic distortion of a 1-d lattice increases the periodicity to $2a$



There are $2N$ states in each band. (N is the number of unit cells in the crystal)

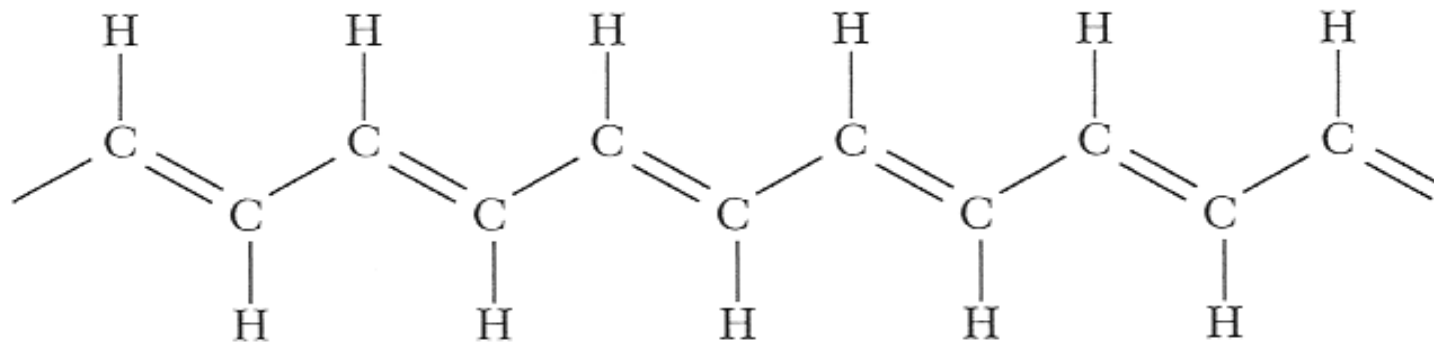
Rudolf Peierls, *More Surprises in Theoretical Physics*, Princeton University Press.
G. Grüner, *Density Waves in Solids*, Addison-Wesley Publishing Company, 1994.



For a distortion of the lattice $\Delta \cos(2k_F x)$, the elastic energy increases like Δ^2 while the electronic energy decreases like Δ .

<http://lamp.tu-graz.ac.at/~hadley/ss1/bloch/bloch.php>

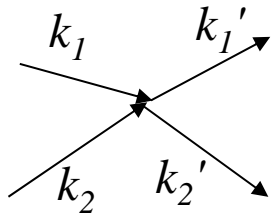
Peierls transition in polyacetylene



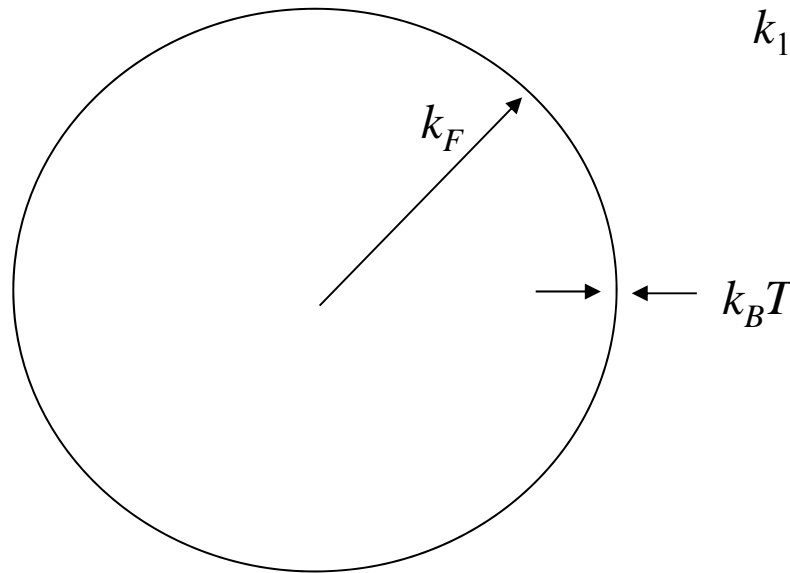
e 12 Structure of polyacetylene. Due to the Peierls distortion, the lattice is dimerized, atoms joined by double bonds in the diagram closer together than those linked by single bonds. The Peierls distortion opens a semiconducting gap of approximately 1.5 eV.

$\rho \sim T^2$ for electron-electron scattering

$$\Gamma = \frac{2\pi}{\hbar} \left| \langle \psi_{k_1} \psi_{k_2} | H | \psi_{k_1'} \psi_{k_2'} \rangle \right|^2 \delta(E_{k_1} + E_{k_2} - E_{k_1'} - E_{k_2'})$$

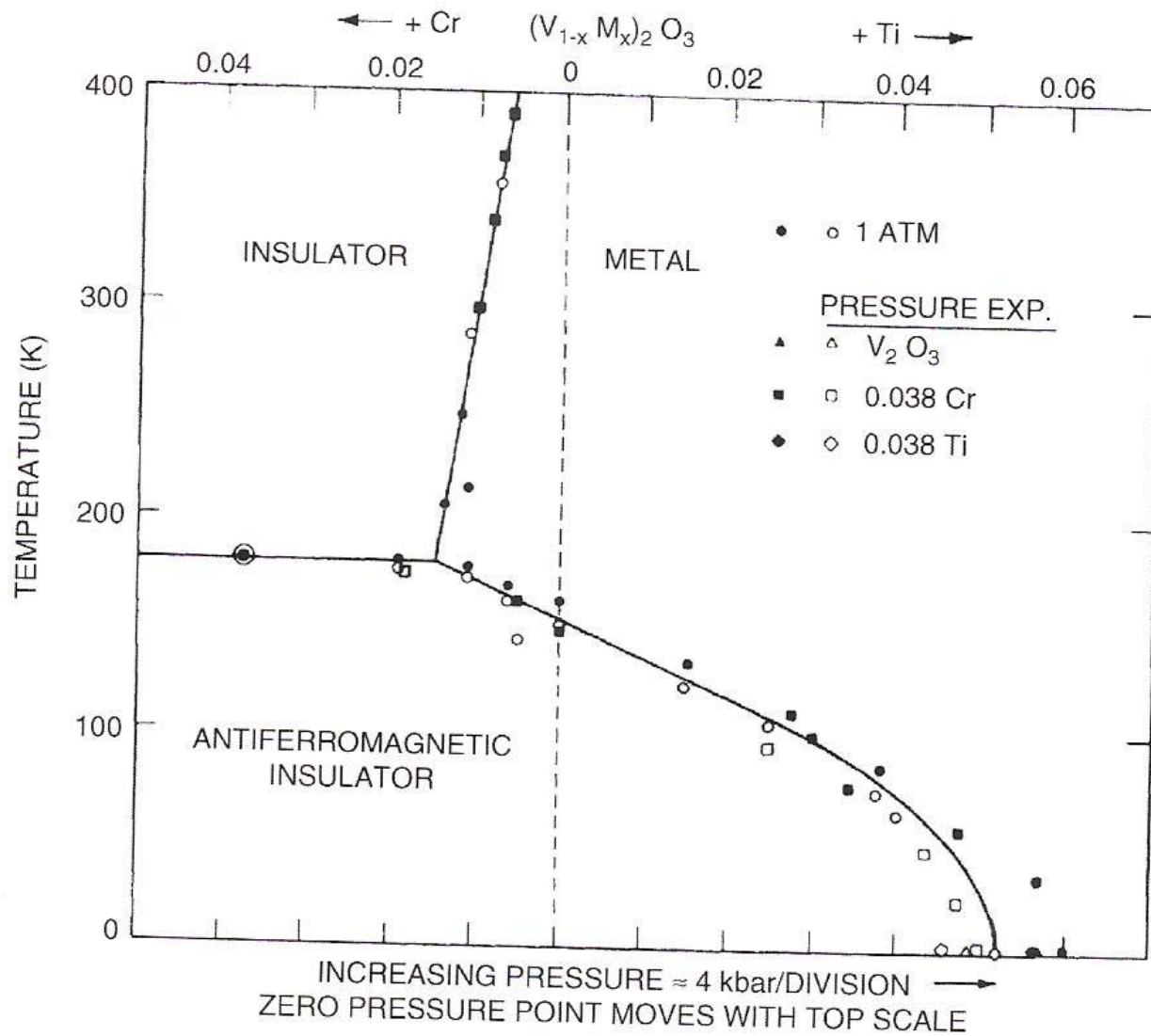


$$k_1 + k_2 = k_1' + k_2' + G$$

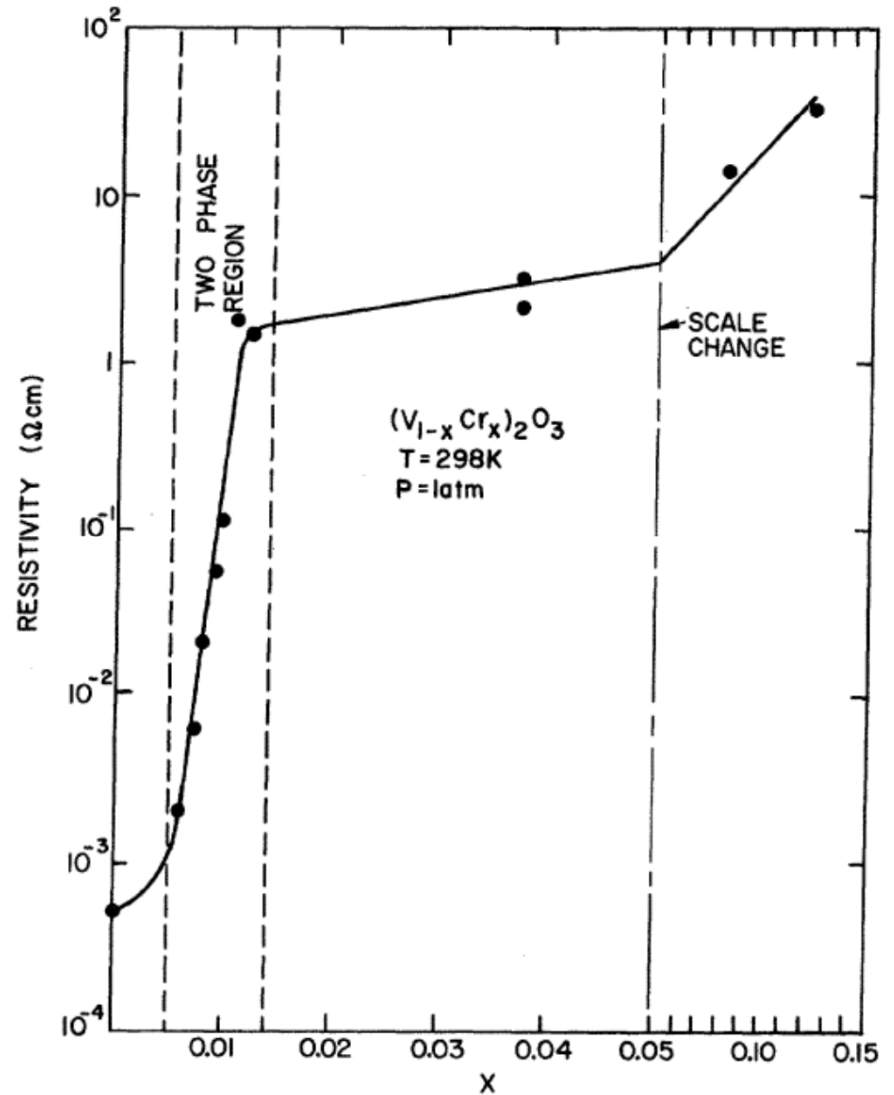
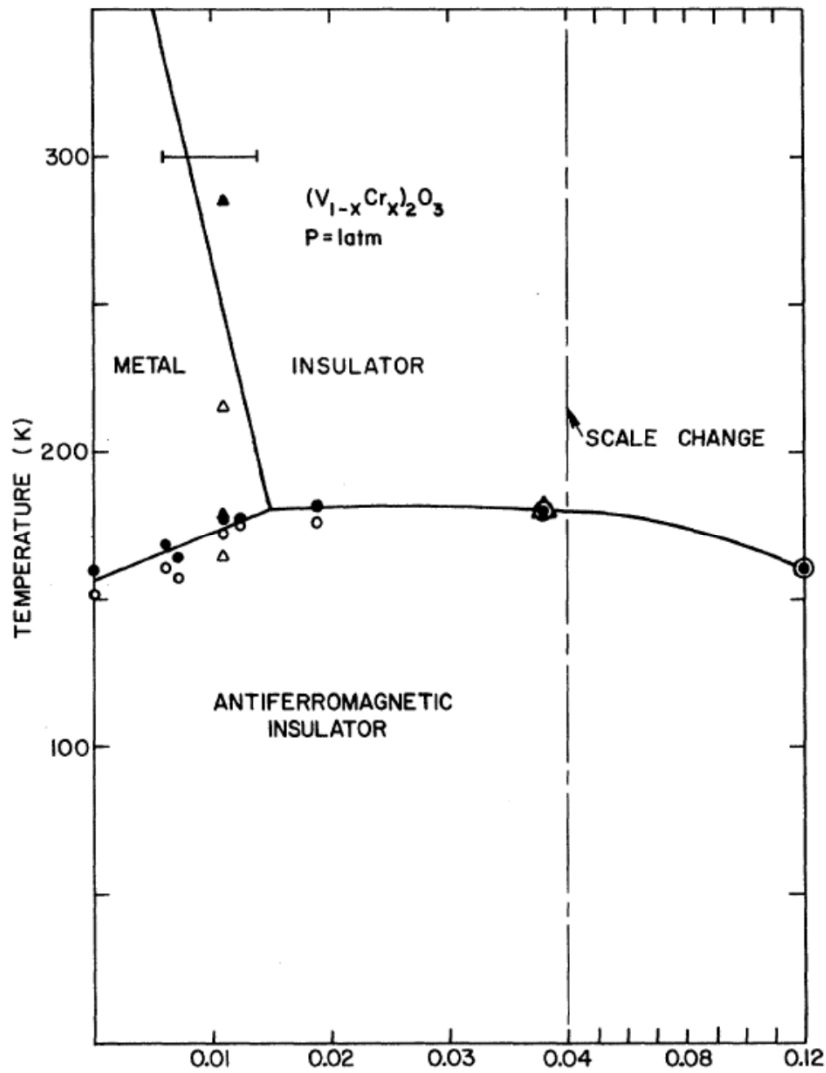


The number of available states depends on the temperature

$$\rho \sim T^2$$

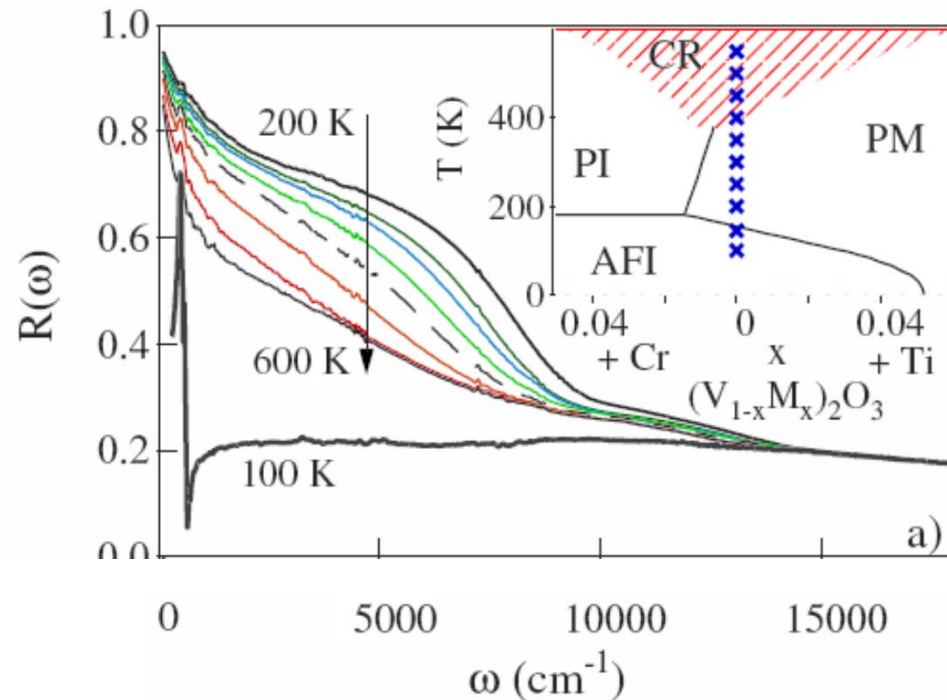
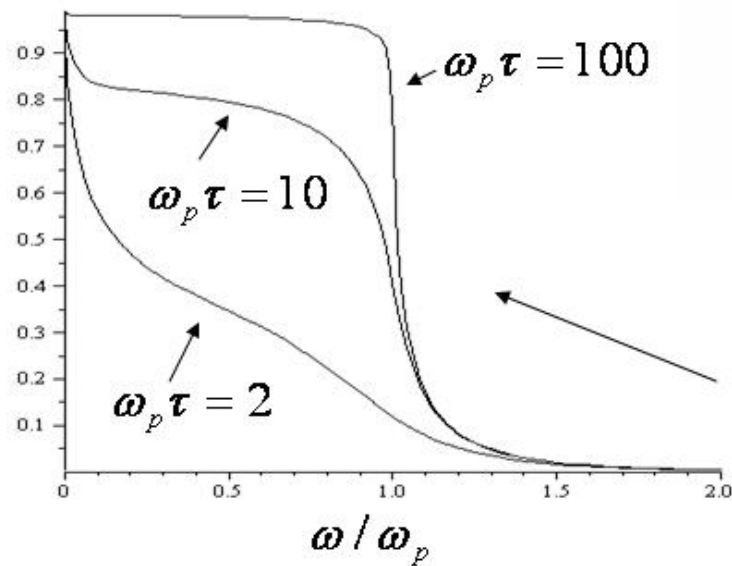


Dynamics at solid state surfaces and interfaces, Editors: U. Bovensiepen, H. Petek, and M. Wolf



D. B. McWhan and J. P. Remeika, PRB 3 p. 3734 (1970)

Vanadium sesquioxide V_2O_3



$$R = \frac{(n-1)^2 + K^2}{(n+1)^2 + K^2}$$

PM paramagnetic metal

PI paramagnetic insulator

AFI Antiferromagnetic insulator

CR crossover regime (poor conductor)

Landau theory of a Fermi liquid

The free electron model = 'Fermi gas' is very successful at describing metals but it is not clear why this is so since electron-electron interactions are completely ignored.

Landau first considered the "normal modes" of an interacting electron system. The low lying excitations he called quasiparticles.

The quasiparticles have as many degrees of freedom as the electrons. They can be labeled by k .

Quasiparticles can have the same spin, charge, and k vectors as the electrons.

It is not easy to calculate $E(k)$.

Concepts like the density of states refer to quasiparticles.