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Autor: Jaggi, R.
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THE CORBINO DISK

R. Jaggi, IBM Research Division, Zurich Research Laboratory
 CH-8803 RÜSCHLIKON, Switzerland

Abstract: The electrostatic field distributions in Corbino disk and film geometries have been investigated within the framework of a hydrodynamic model. Owing to the absence of space charge, the Corbino disk allows a simple treatment of this problem. The thickness dependence of the effective conductivity is derived and compared with recent experimental data for thin CoSi₂ films.

We analyze transport phenomena within the framework of an electron-fluid model in which the Navier-Stokes equation and Maxwell's equations lead to a generalized Ohm's law [1]. After linearization we obtain for stationary conditions and zero magnetic field the symmetric relation between current density \mathbf{J} and electric field \mathbf{E}

$$\mathbf{J} - \alpha^{-2} \Delta \mathbf{J} = \sigma_0 (\mathbf{E} - \delta^{-2} \Delta \mathbf{E}) , \quad (1)$$

where $\sigma_0 = N_0 \frac{e^2 \tau}{m}$ = bulk conductivity
 with N_0 = electron concentration
 e = electron charge
 m = effective mass
 τ = relaxation time

$\alpha^{-1} = \left(\frac{\eta \tau}{N_0 m} \right)^{1/2}$ = adherence length
 with η = viscosity coefficient
 $\delta^{-1} = \left(\frac{\epsilon_0 \epsilon \zeta}{N_0 e} \right)^{1/2}$ = Debye length
 with $\epsilon_0 \epsilon$ = permittivity
 ζ = electrochemical potential.

Exact solutions of equation (1) can be easily derived for simple geometries. The Corbino disk (inner and outer radius a and b , thickness $d = 2z_0$) allows an especially simple formulation since no space charge occurs. In short, we obtain for the conductance in the entire range of $z_0 = d/2$

$$G(z_0) = 4\pi\sigma_0 \frac{z_0}{\ln \frac{b}{a}} \left[1 - \frac{\tanh \alpha z_0}{\alpha z_0} \right].$$

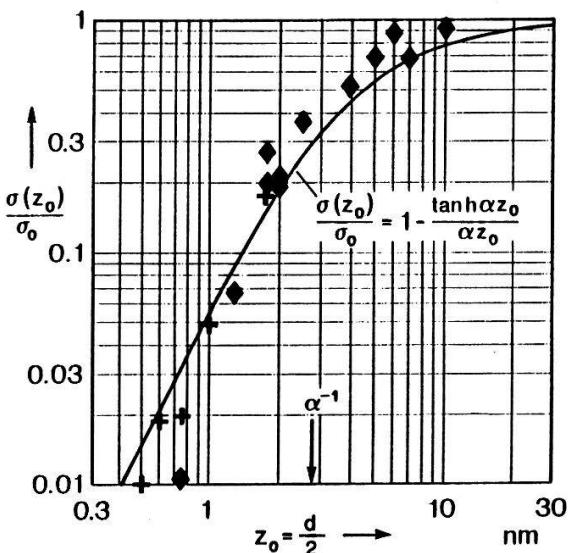
If we define an effective conductivity

$$\frac{\sigma(z_0)}{\sigma_0} = \frac{G(z_0)}{G(z_0 \rightarrow \infty)} = 1 - \frac{\tanh \alpha z_0}{\alpha z_0},$$

we obtain within the limits of thin and thick samples, respectively,

$$\alpha z_0 \ll 1: \frac{\sigma(z_0)}{\sigma_0} = \frac{\alpha^2 z_0^2}{3},$$

$$\alpha z_0 \gg 1: \frac{\sigma(z_0)}{\sigma_0} = 1 - \frac{1}{\alpha z_0} \quad (\text{Nordheim rule}).$$



The effective conductivity above is also a first approximation for the case of a rectangular plate of thickness $d = 2z_0$. As shown in the figure, this conductivity represented by the solid line is found to fit experimental data (total conductivity $\sigma(z_0)$ at $T = 4.2$ K normalized by the bulk residual conductivity $\sigma_0 = 4.255 \times 10^7 \Omega^{-1}m^{-1}$) of thin CoSi₂ films [2] for a value of the adherence length $\alpha^{-1} = 2.4$ nm.

We are now investigating the significance of our phenomenological approach (1) as compared to microscopic quantum-mechanical approaches [3].

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