

Zeitschrift: Helvetica Physica Acta
Band: 62 (1989)
Heft: 6-7

Artikel: The Corbino disk
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DOI: <https://doi.org/10.5169/seals-116079>

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THE CORBINO DISK

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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 CoSi_2 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

$\tau =$ relaxation time

$$\alpha^{-1} = \left(\frac{\eta \tau}{N_0 m} \right)^{1/2} = \text{adherence length}$$

with $\eta =$ viscosity coefficient

$$\delta^{-1} = \left(\frac{\epsilon_0 \epsilon \zeta}{N_0 e} \right)^{1/2} = \text{Debye length}$$

with $\epsilon_0 \epsilon =$ permittivity

$\zeta =$ 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 $z_0 = d/2$

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

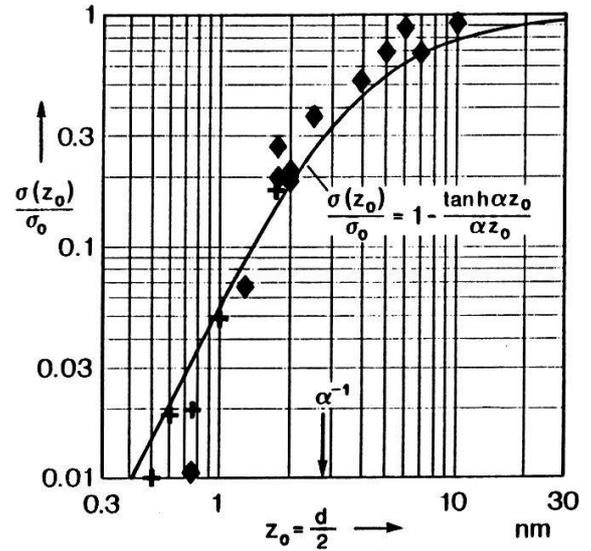
If we define an effective conductivity

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

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

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

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



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 $\sigma_0 = 4.255 \times 10^7 \Omega^{-1}\text{m}^{-1}$) of thin CoSi_2 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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