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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 **J** and electric field **E**

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

where $\sigma_0 = N_0 \dfrac{e^2\tau}{m}$ = bulk conductivity

with N_0 = electron concentration

e = electron charge

m = effective mass

τ = relaxation time

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

with η = viscosity coefficient

$$\delta^{-1} = \left(\frac{\varepsilon_0\,\varepsilon\,\zeta}{N_0 e}\right)^{1/2} = \text{Debye length}$$

with $\varepsilon_0\,\varepsilon$ = permittivity

ζ = electrochemical potential.

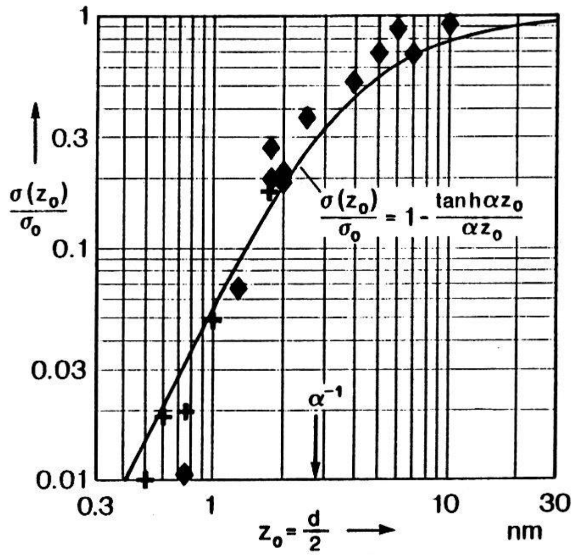
Exact solutions of equation (1) can be easily derived for simple geometries. The Corbino disk (inner and outer radius a and b, thickness $d = 2z_0$) allows an especially simple formulation since no space charge occurs. In short, we obtain for the conductance in the entire range of $z_0 = d/2$

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

If we define an effective conductivity

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

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 $T = 4.2\,\mathrm{K}$ normalized by the bulk residual conductivity $\sigma_0 = 4.255 \times 10^7\,\Omega^{-1}\mathrm{m}^{-1}$) of thin $CoSi_2$ films [2] for a value of the adherence length $\alpha^{-1} = 2.4\,\mathrm{nm}$.

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

References

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