Contactless Electron Mobility Evaluation of Semi-Insulating GaAs and InP Wafers

R. Stibal, S. Müller, W. Jantz
Fraunhofer Institut Angewandte Festkörperphysik

U. Kretzer
Freiberger Compound Materials

Fraunhofer IAF Institut Angewandte Festkörperphysik

Motivation

- Routine GaAs and InP ingot resistivity and mobility evaluation required
- Conventional Hall procedure is
  - slow
  - destructive
- COntactless REsistivity MApping is (COREMA)
  - fast
  - nondestructive
- But mobility evaluation requires Hall measurement

⇨ Upgrade COREMA procedure for mobility evaluation !

Fraunhofer Institut Angewandte Festkörperphysik

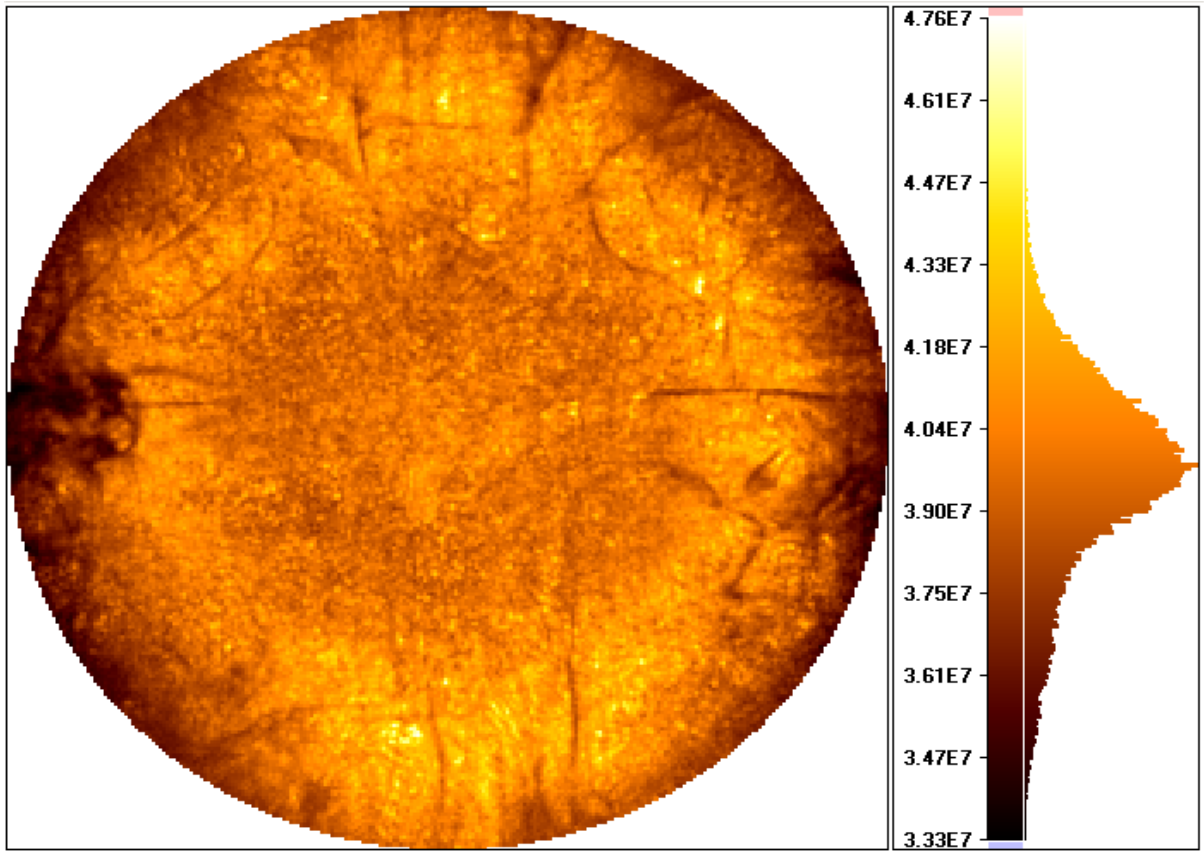
Contactless Resistivity Mapping COREMA

Resistivity Topogram of

150 mm GaAs Wafer

Mean: 3.96E7 Ωcm

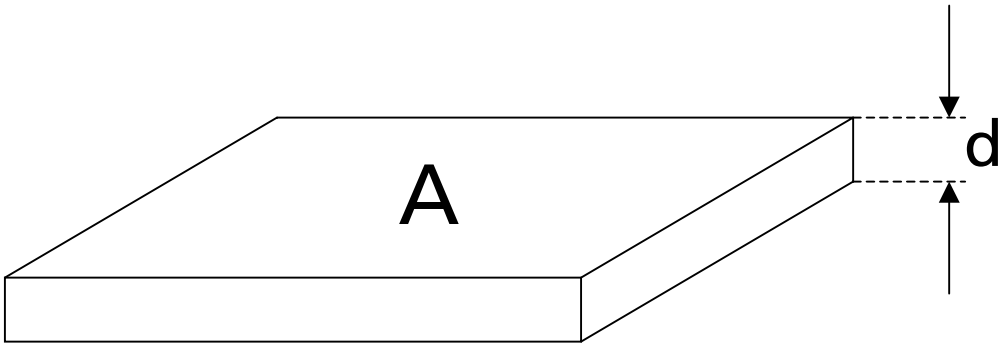
Stdv: 4.27 %



Fraunhofer Institut Angewandte Festkörperphysik

Capacitive Resistivity Evaluation (I)

Definition of Resistance and Capacitance



$$R_s = \rho\, d/A$$

$$C_s = \varepsilon\, A/d$$

$$R_s C_s = \rho\, \varepsilon = \tau$$

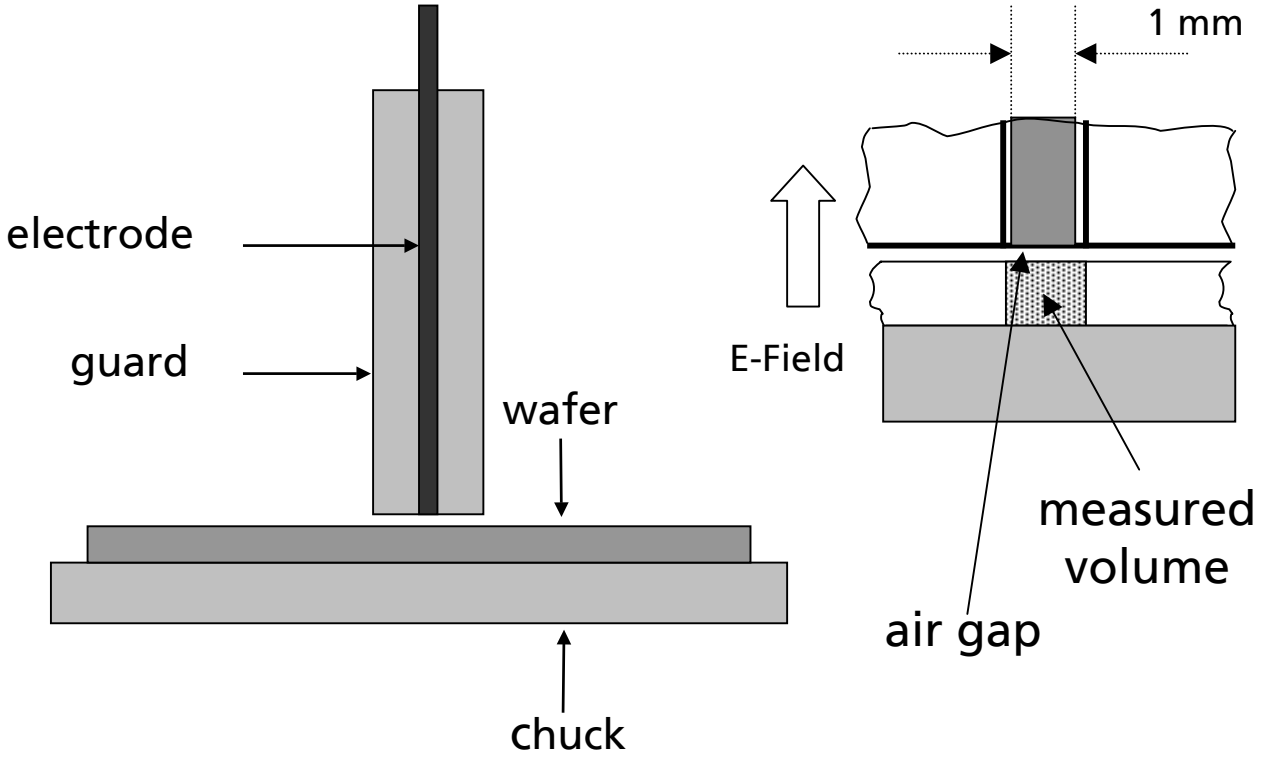
Semi-insulating Semiconductor

$$\rho = \tau / \varepsilon$$

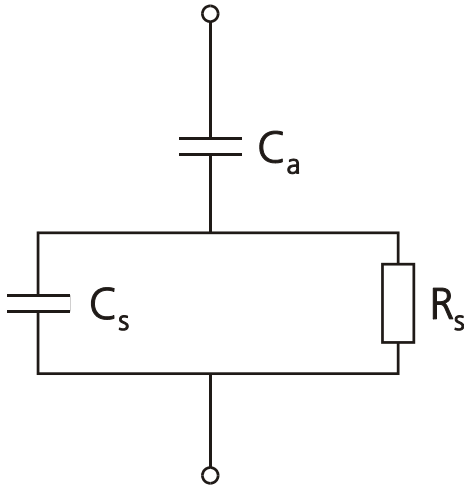
Fraunhofer Institut Angewandte Festkörperphysik

Capacitive Resistivity Evaluation (II)

Capacitive Probe



Equivalent Circuit

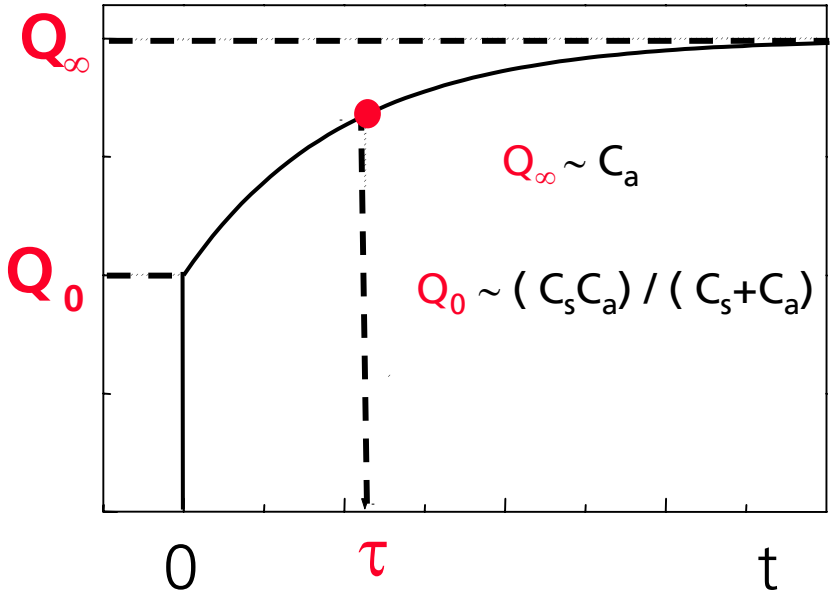


$$\tau = R_s(C_s+C_a)$$

Fraunhofer IAF Institut Angewandte Festkörperphysik

Capacitive Resistivity Evaluation (III)

Charge Transient after Voltage Step Application



Evaluation of Resistivity

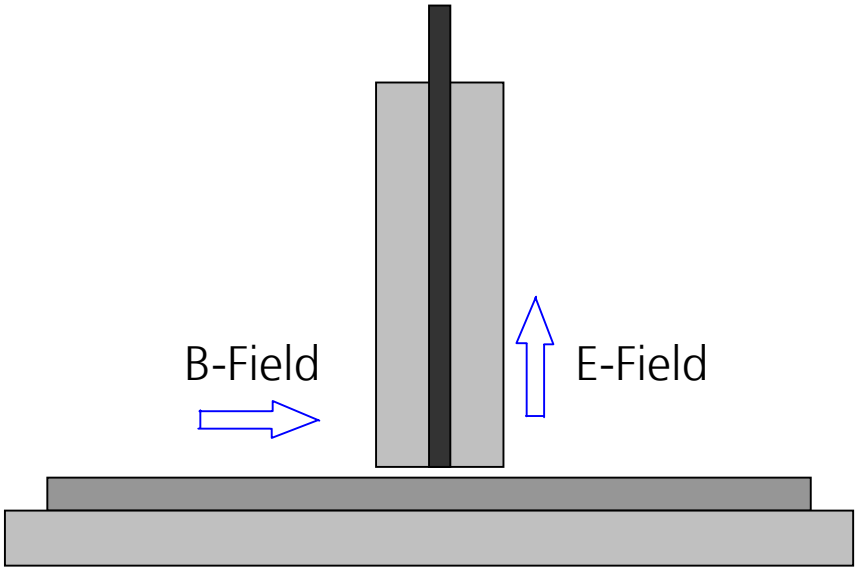
$$\tau = R_s(C_s + C_a)$$

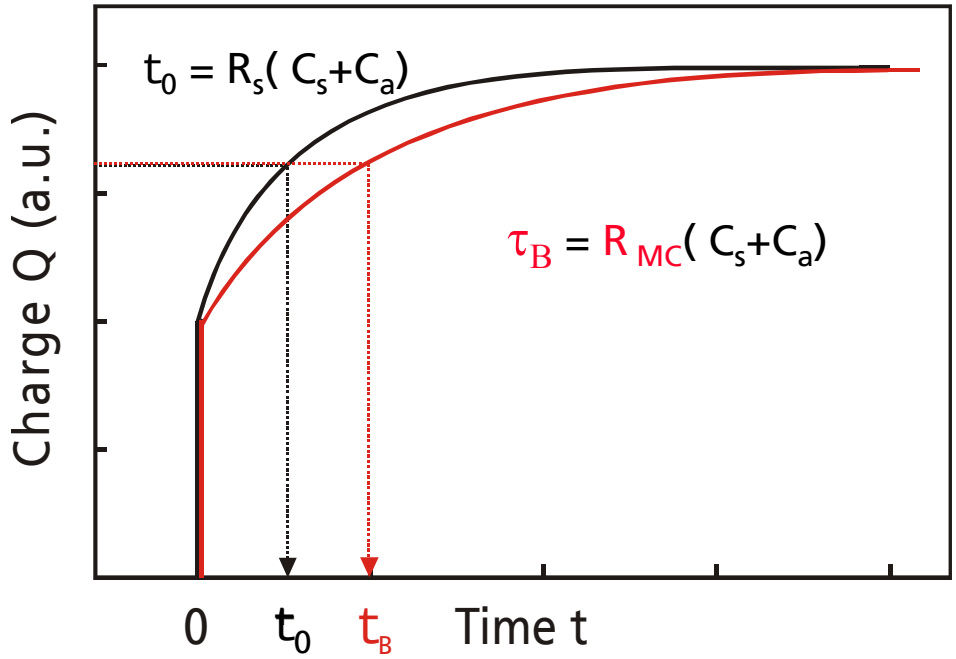
$$\rho = Q_0 \, \tau \, (Q_\infty \, \varepsilon \, \varepsilon_0)^{-1}$$

$\tau \approx 20$ µsec @ 10^7 Ωcm

Fraunhofer Institut Angewandte Festkörperphysik

Capacitive Mobility Evaluation (I)





Fraunhofer Institut Angewandte Festkörperphysik

Capacitive Mobility Evaluation (II)

Drude formula:

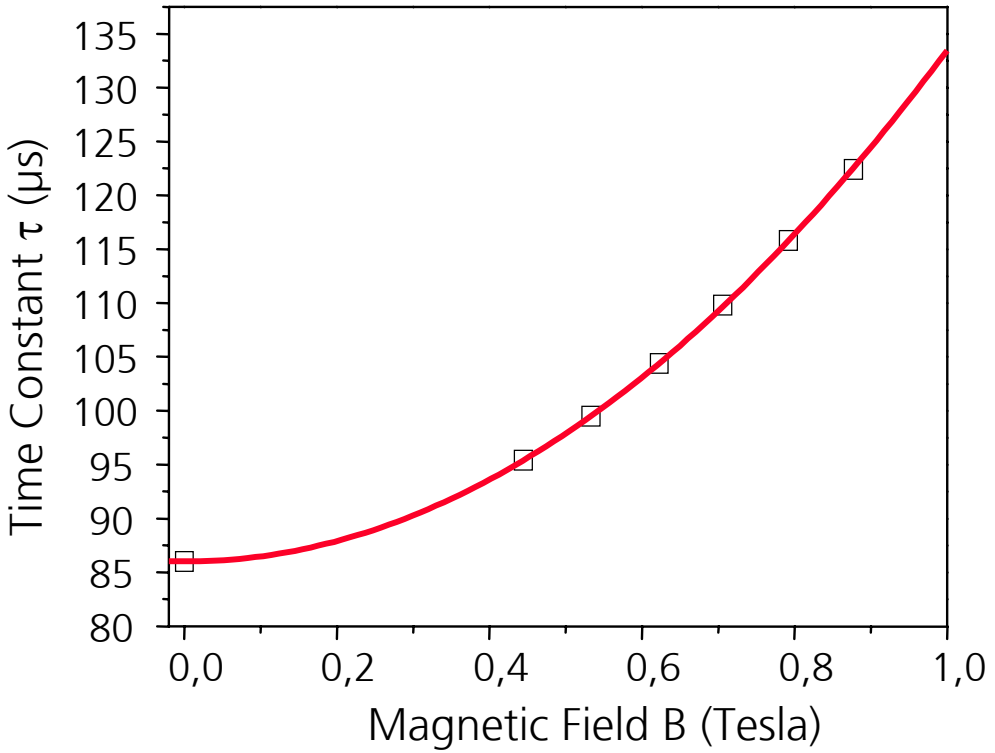
$$\sigma(B) = \sigma(0)\,[1 + (\mu B)^2]^{-1}$$

Expected ρ dependence:

$$\rho(B) = \rho(0)\,[1 + (\mu B)^2]$$

Expected t dependence:

$$\tau(B) = \tau(0)\,[1 + (\mu B)^2]$$



Fraunhofer Institut Angewandte Festkörperphysik

Capacitive Mobility Evaluation (III)

Measurement of time constant τ **at B = 0 and B = 0.843 Tesla**

$$\mu = \frac{\sqrt{\tau(B)/\tau(0) - 1}}{B}$$

Fraunhofer Institut Angewandte Festkörperphysik

Verification of COREMA generated Mobility Data

Comparison with

1. Values measured conventionally with Hall probes
2. Drift mobility values calculated with measured carbon content data (acc. Brooks-Herring formalism)

Fraunhofer IAF Institut Angewandte Festkörperphysik

Freiberger

Correlation (I)

Comparison with Hall Data

Hall Measurement:

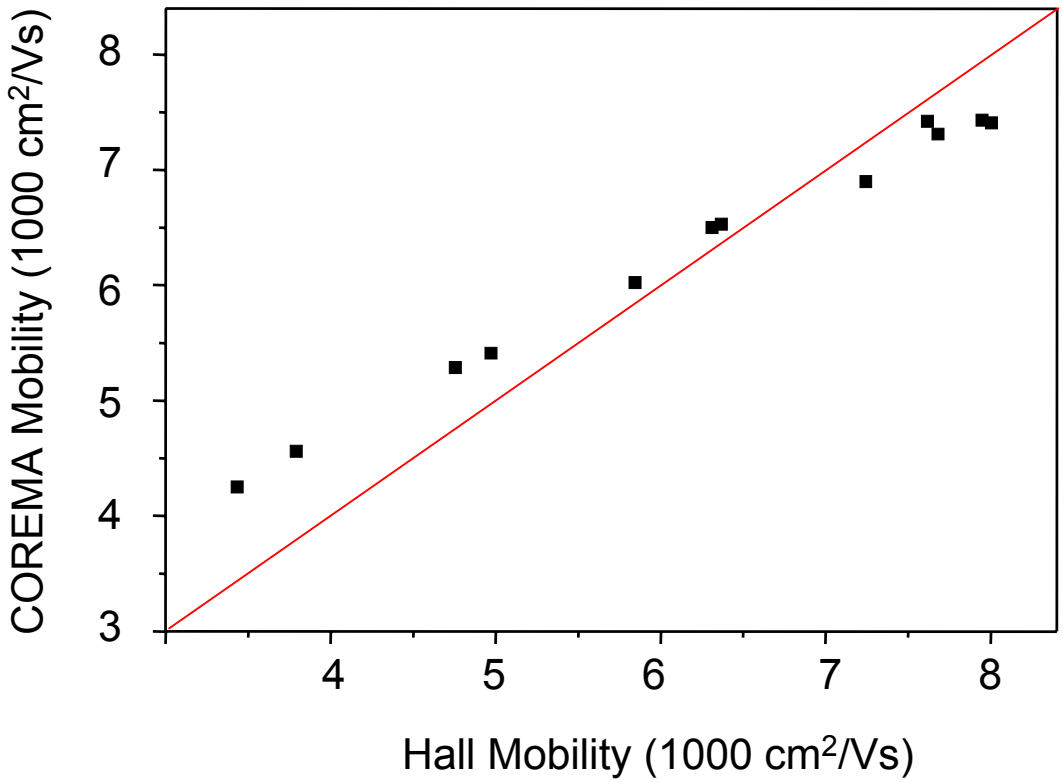
Sample size: 27x27 mm

B = 0.4357 T

Corema Measurement:

Center of sample: Ø 2.5 mm

B = 0.843 T



Fraunhofer IAF Institut Angewandte Festkörperphysik

Freiberger

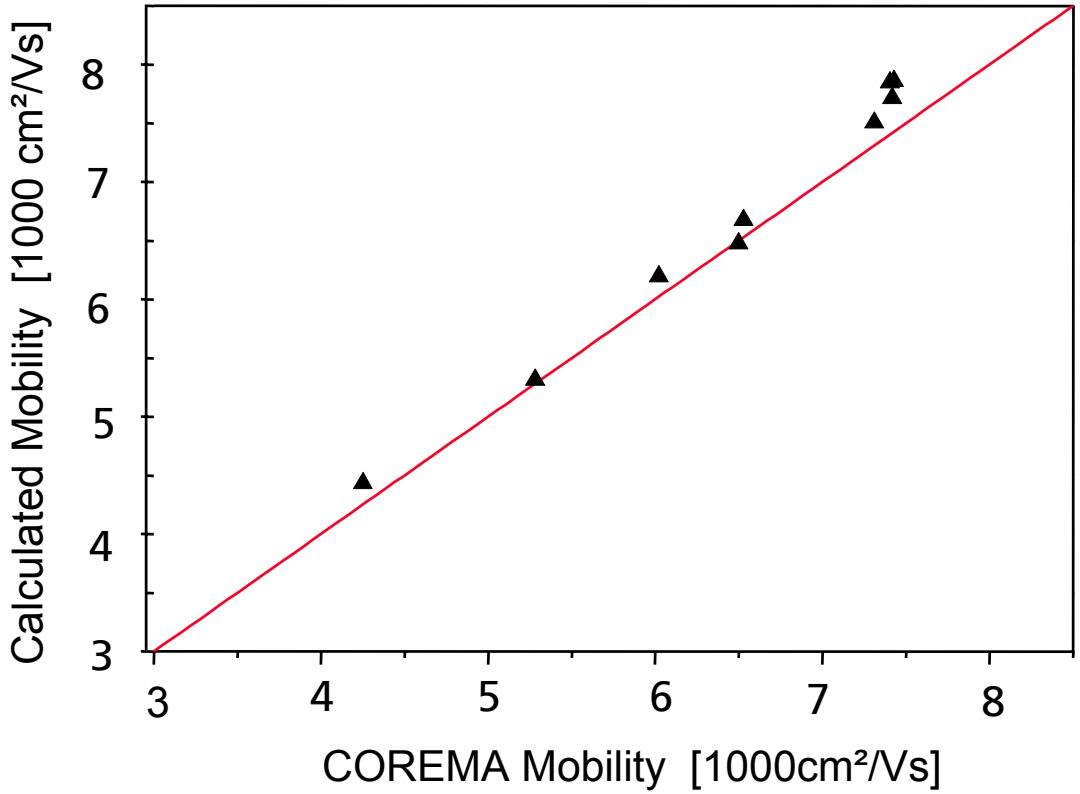
Correlation (II)

Comparison with calculated Drift Mobility

$$\frac{1}{\mu_D} = \left[\frac{1}{8000} + \frac{1}{\mu(Ion)}\right]\frac{Vs}{cm^2}$$

Concentration of ionized scattering centers:

$$[Ion] \cong 2[C]$$

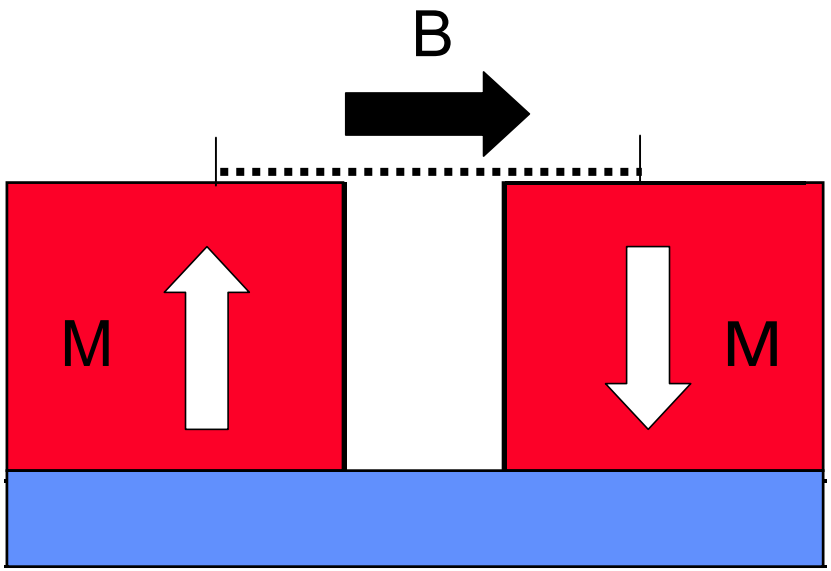


Fraunhofer IAF Institut Angewandte Festkörperphysik

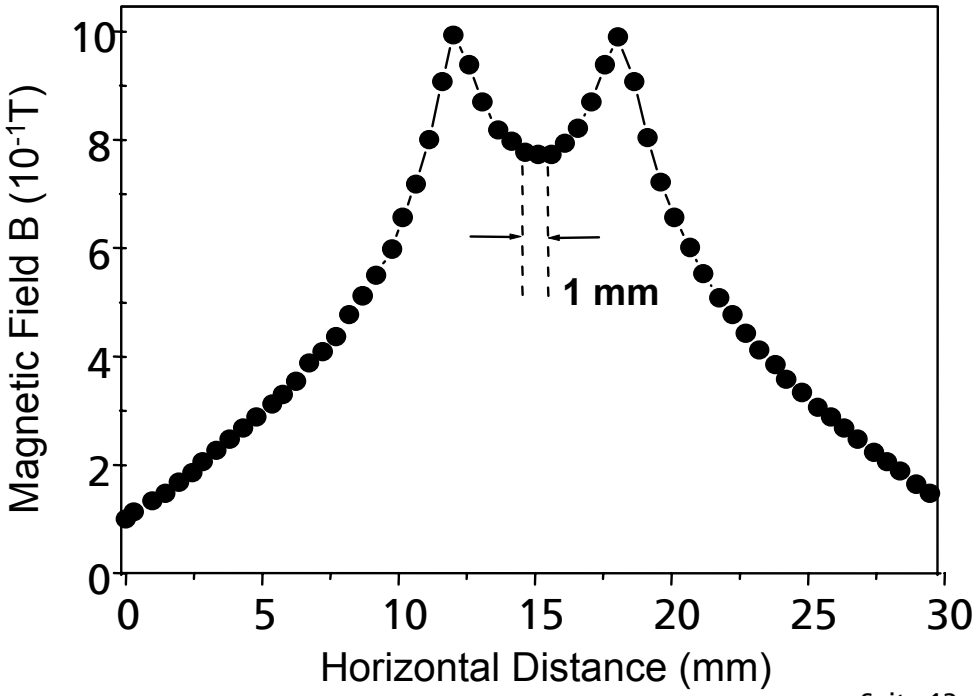
Freiberger

Permanent Magnet System Design

Arrangement of Magnets



Horizontal Field Component



Fraunhofer Institut Angewandte Festkörperphysik

SUMMARY

Contactless Resistivity Mapping (COREMA)

- Wafer Ø ≤ 200 mm
- Resistivity Range 10^5 – 10^{12} Ω cm
- Repeatabilty 1%
- Lateral Resolution 1 mm

Contactless Mobility Evaluation (Patent pending)

- Magnetoresistance based Method developed
- Permanent Magnet System designed
- Good Agreement with Hall Data
- Very good agreement with calculated Drift Mobility

Fraunhofer IAF Institut Angewandte Festkörperphysik

Freiberger