# Transmission Line Method

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# What is TLM?

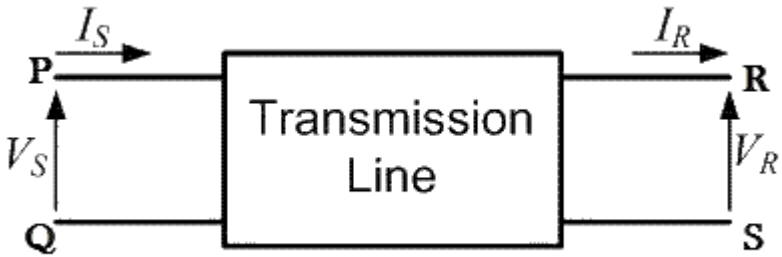
TLM : **T**ransmission **L**ine **M**ethod or
**T**ransfer **L**ength **M**ethod

A method of calculating the contact resistance using a horizontal electrode.

Described by H.H. Berger's “Models for contacts to planar devices” Solid State Electronics, Vol. 15 pp. 145 (1972)

In 1970s, it was widely known that a mathematical calculation was made by constructing an equivalent circuit similar to a transmission line. → introduced to analyze electrical contact of semiconductors → TLM

Transmission line picture




Transmission line equivalent circuit

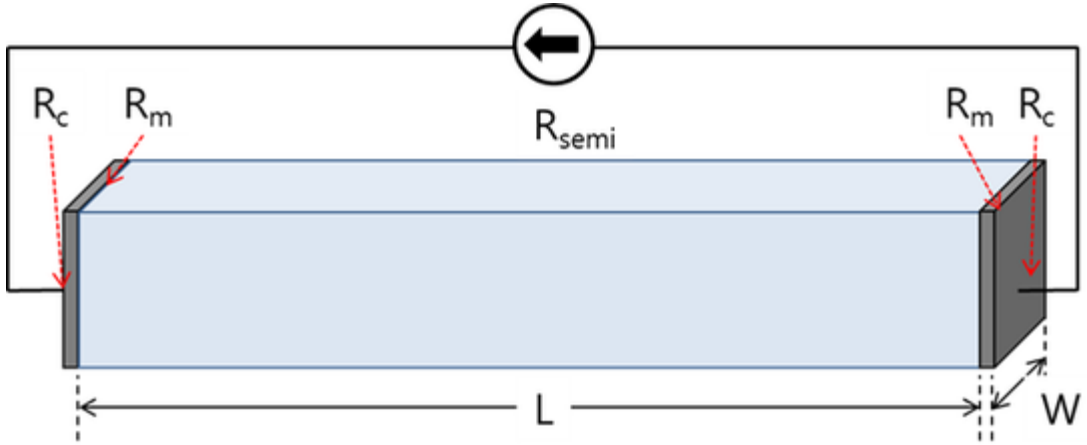
# Principles of TLM measurement

Ignored in most cases

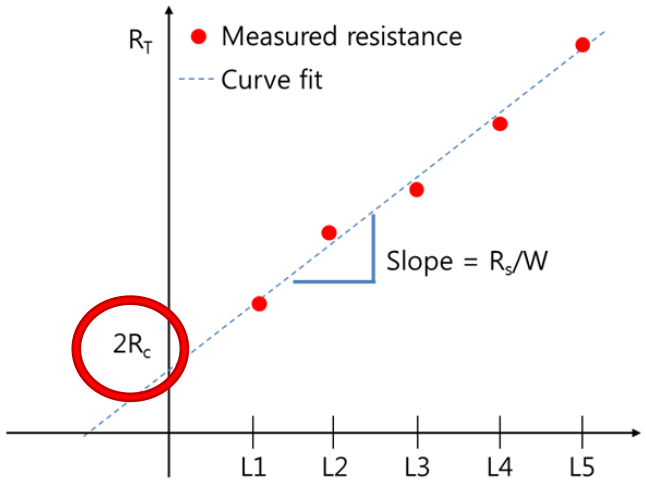
$$R_T = 2R_m + 2R_c + R_{semi}$$

$$R_{semi} = R_s \frac{L}{W}$$

$$R_T = \frac{R_s}{W} L + 2R_c$$

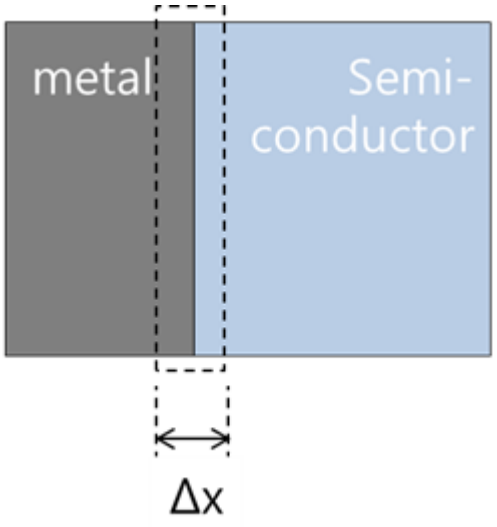



Simple resistor geometry(vertical contact)




TLM measurement graph

# Contact resistivity




$$R_c = \rho' \frac{\Delta x}{A_c}$$

$$\rho_c = \lim_{\Delta x \to 0} (\rho' \Delta x) = R_c A_c$$ (Generally $10^{-3} \sim 10^{-8} \Omega \cdot cm^2$)

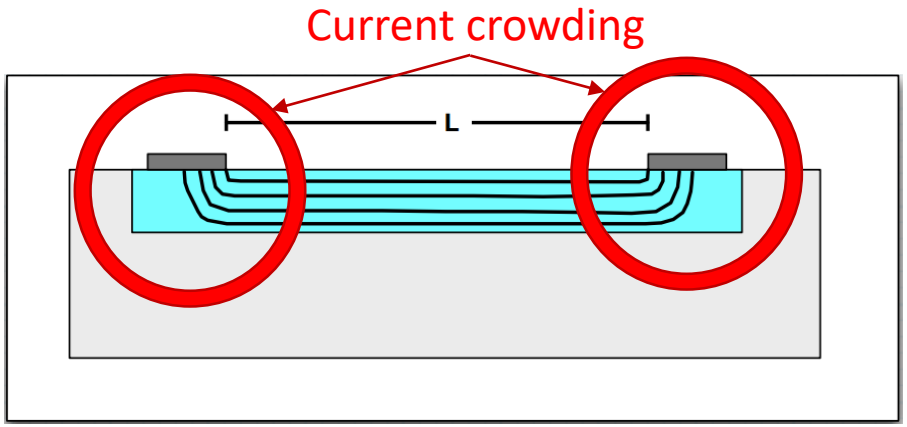
vertical contact

Lateral contact

# Lateral contact geometry & current crowding

$$I(x) \propto \exp\left(-\frac{x}{L_T}\right)$$

$$L_T = \sqrt{\frac{\rho_c}{R_s}}$$




Lateral contact geometry

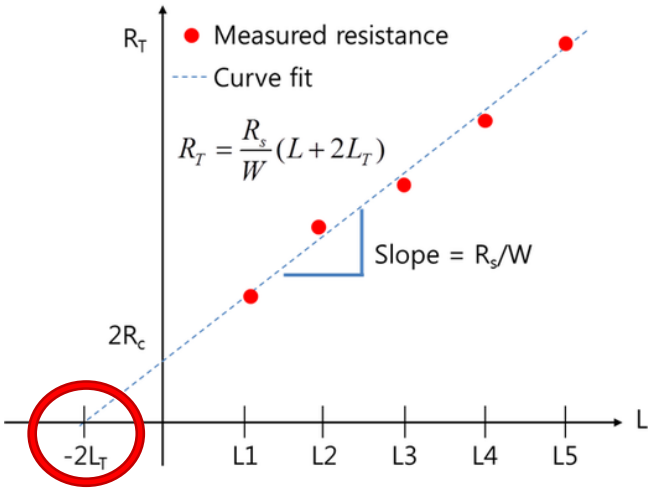
➡ Effective area of contact $A_c = L_T \cdot W$

We know $\rho_c = R_c A_c$,

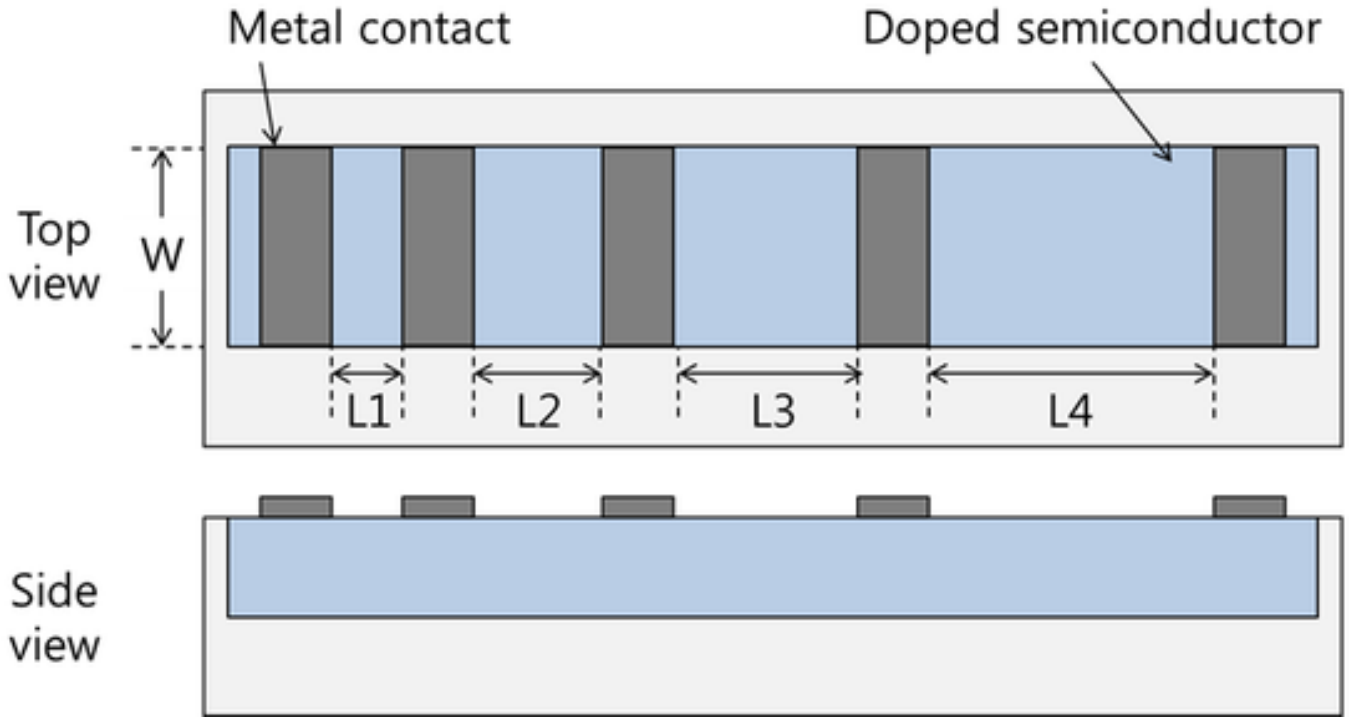
$$R_c = \frac{\rho_c}{L_T W} = \frac{R_s L_T}{W} \Rightarrow R_T = \frac{R_s}{W} L + 2R_c$$

$$= \frac{R_s}{W} L + \frac{2R_s L_T}{W}$$

$$= \frac{R_s}{W} (L + 2L_T)$$

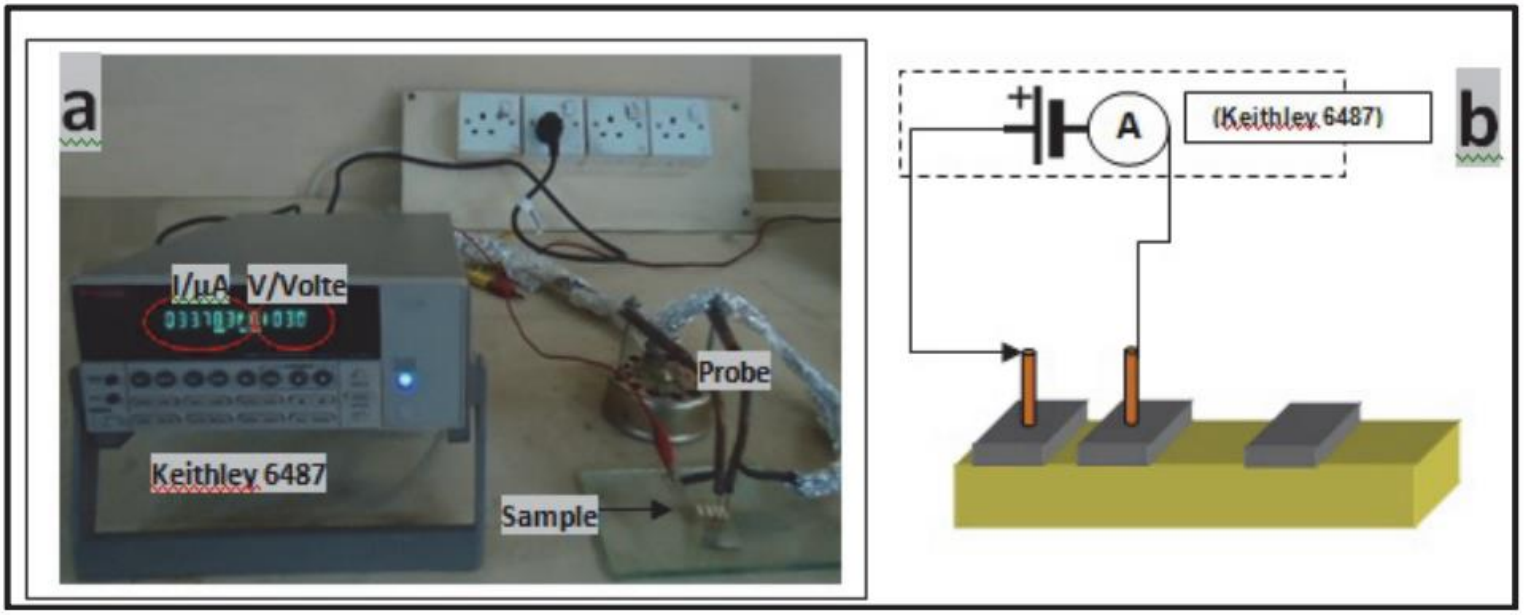


# TLM test pattern



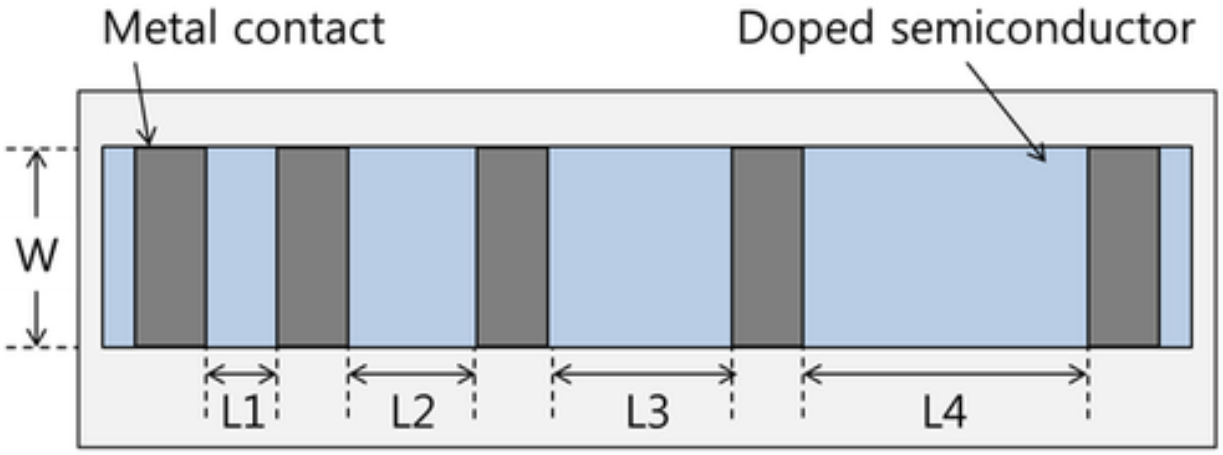
# Example

- Measurement



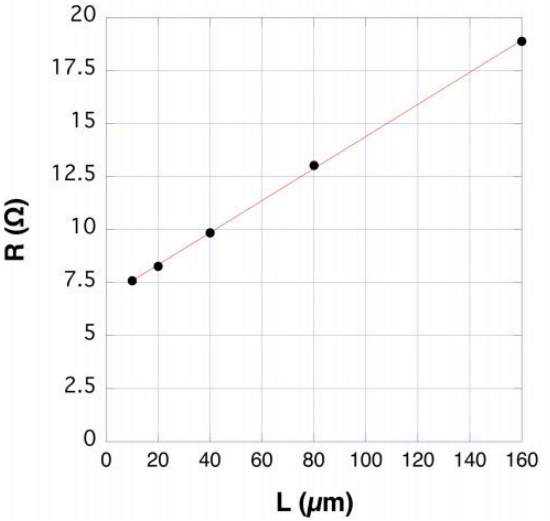
# Example

- Calculation




W = 100um,
L = 10um, 20um, 40um, 80um, 160um

Measurement results give the following resistances:
R1 =7.59 Ω, R2 = 8.26 Ω, R3 = 9.85 Ω, R4=13.02 Ω, R5= 18.87 Ω




$R = 6.829\ \Omega + (0.0756\ \Omega/\mu m)L$
$R_c = 6.829/2\ \Omega = 3.415\ \Omega$
$R_s$ =slope x W = 0.0756 Ω/μm x 100 μm = 7.56 Ω/□
$0 = 6.829\ \Omega + (0.0756\ \Omega/\mu m)(-2L_T)$
$L_T$= 6.829 Ω /(2x0.0756 Ω/μm) = 45.2 μm
$\rho_c = R_c L_T W = (3.415\ \Omega)(0.00452\ cm)(0.01\ cm) = 1.54 \times 10^{-4}\ \Omega \cdot cm^2$

# Reference


- S.S. Cohen “Contact resistance and methods for its determination, Thin Solid Films, 104, 361 (1983)
- D.K. Schroder, Semiconductor material and device characterization, Wiley, New York, 1998
- T. Abbas* , L. Slewa , Transmission line method (TLM) measurement of (metal/ZnS) contact resistance, 2015

# Q&A