Semiconductor Device Processing
Presentation

Transmission Line Model

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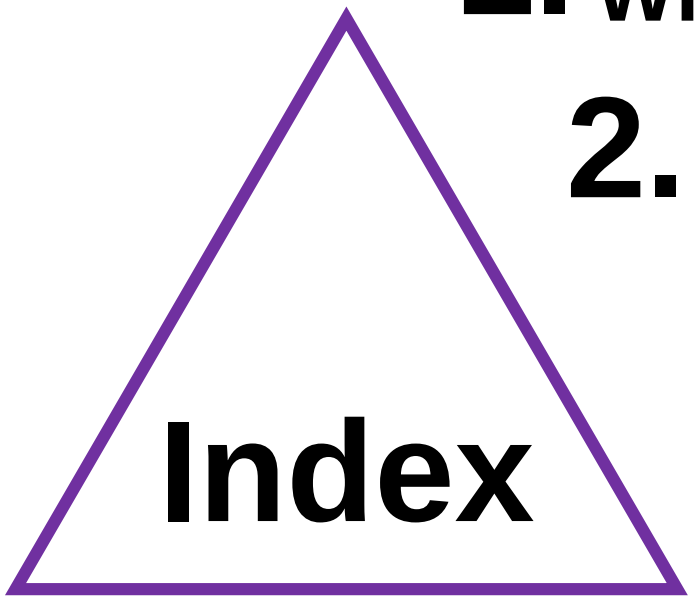
Ohmic Contact Measurement

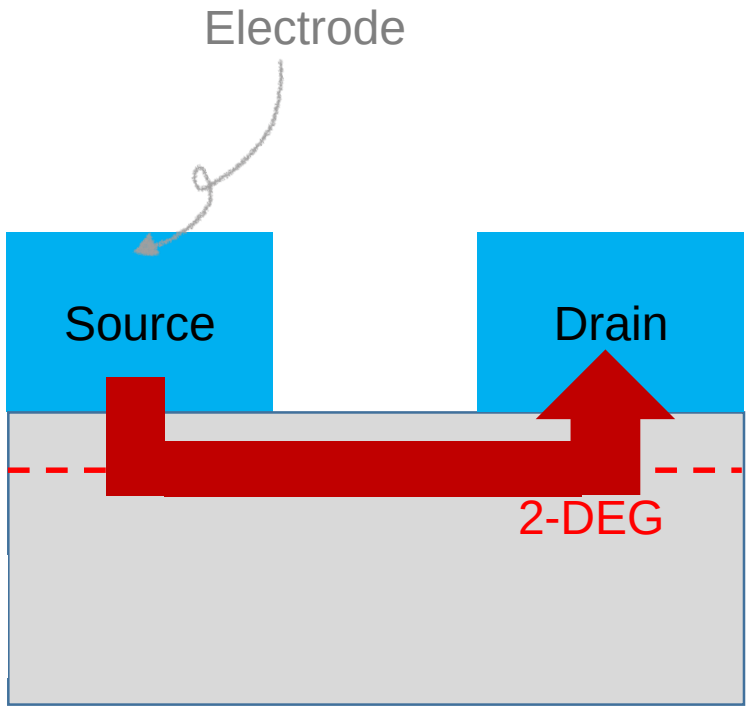


1. Why is TLM required?
2. Principle of TLM
3. TLM process
4. How to measure Contact resistance

1. Why is TLM required?

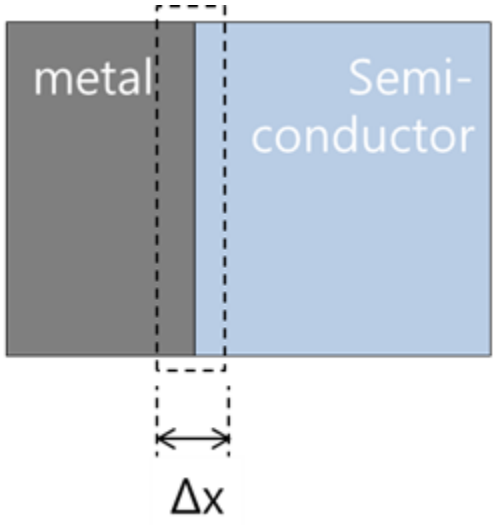
Current must flow in both direction between source and drain.

Ohmic contact is very important!



1. Why is TLM required?

Contact Resistance



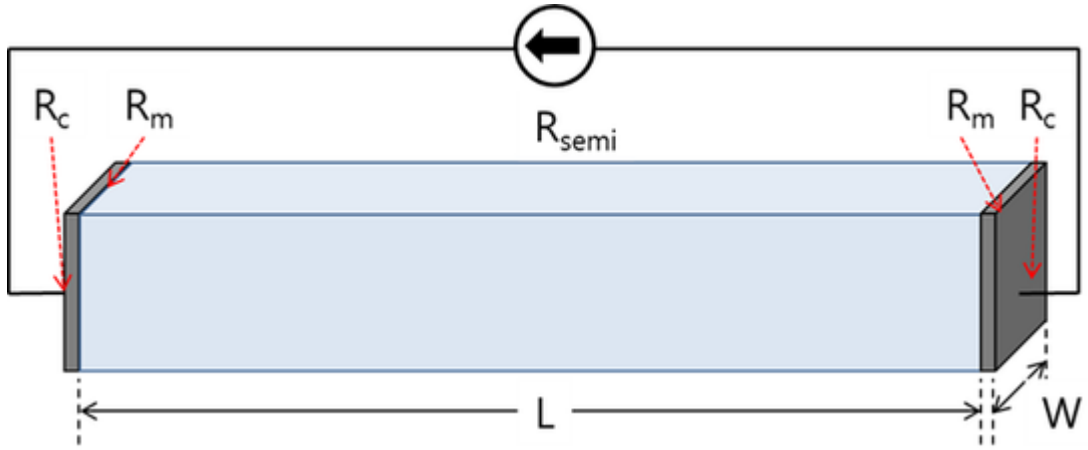
Small region in the vicinity of the contact

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

$$\rho_c = \lim_{\Delta x \to 0} (\rho' \Delta x) = R_c A_c$$

A_c: Contact area
R_c: Contact resistance
ρ_c: Contact resistivity

1. Why is TLM required?



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

Values caused by contact

Metal has very low resistivity

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

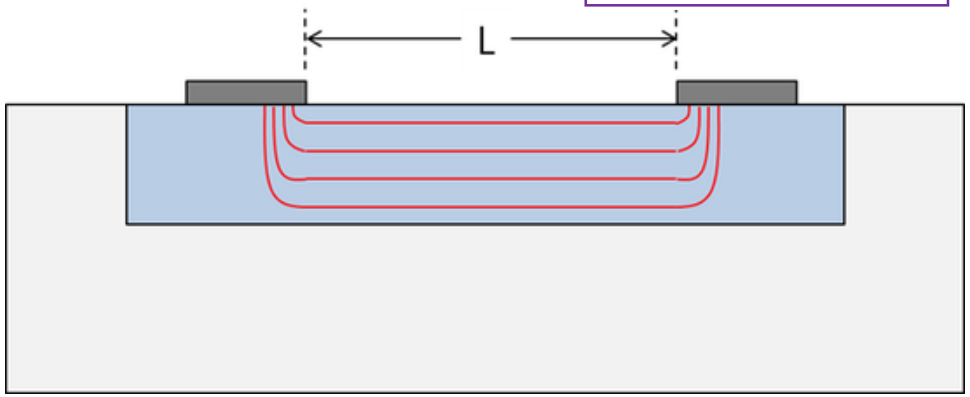
$$R_T = \frac{R_s}{W} L + 2R_c$$

Contact resistance may be obtained by measuring the total resistance.

2. Principle of TLM

Current Crowding

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



The physical length and width of the electrode should not be used directly to determine the contact resistance.

Effective area of contact: L_T

Called by transfer length

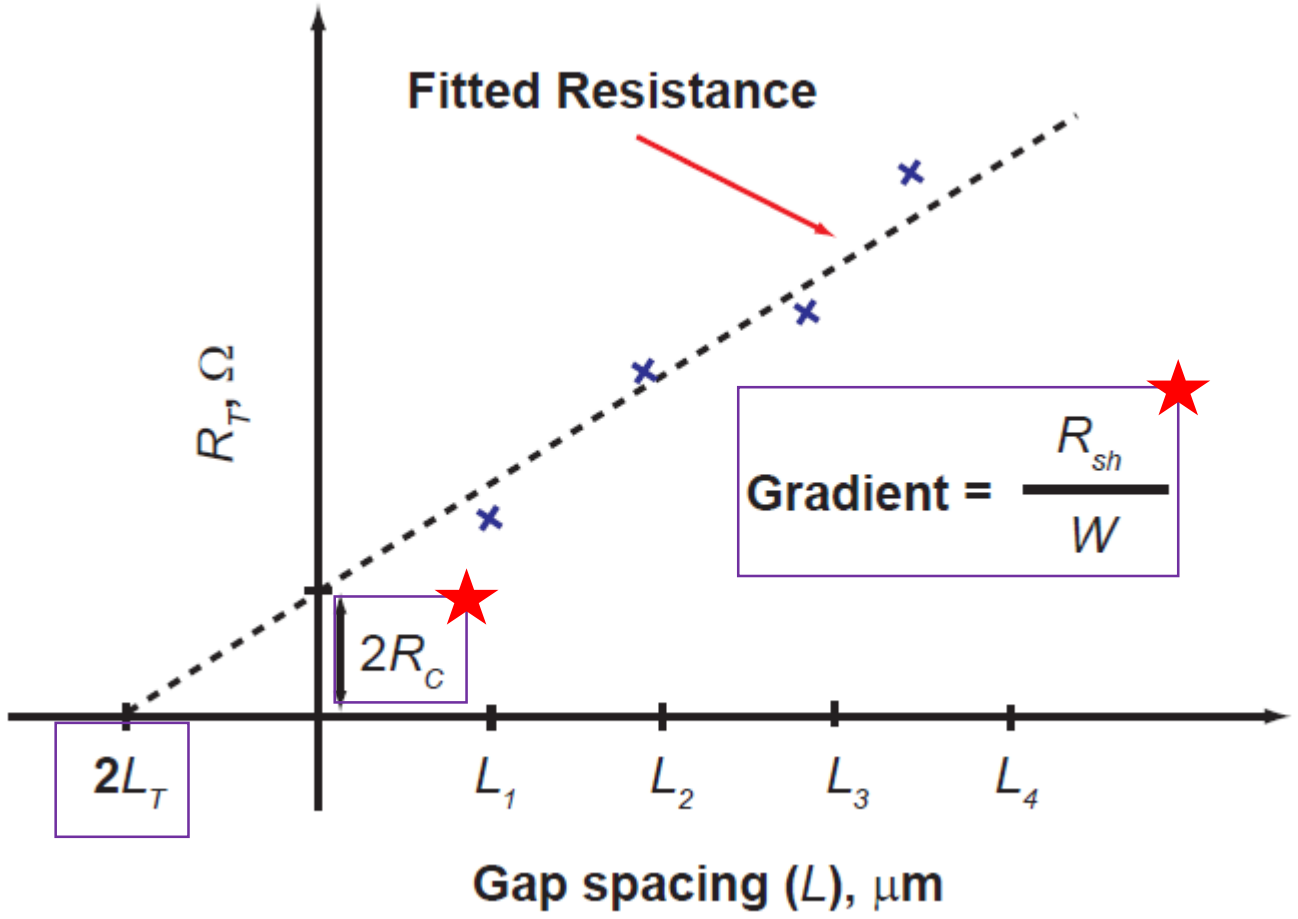
$$R_c = \frac{\rho_c}{L_T W} = \frac{R_s L_T}{W}$$

2. Principle of TLM

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

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

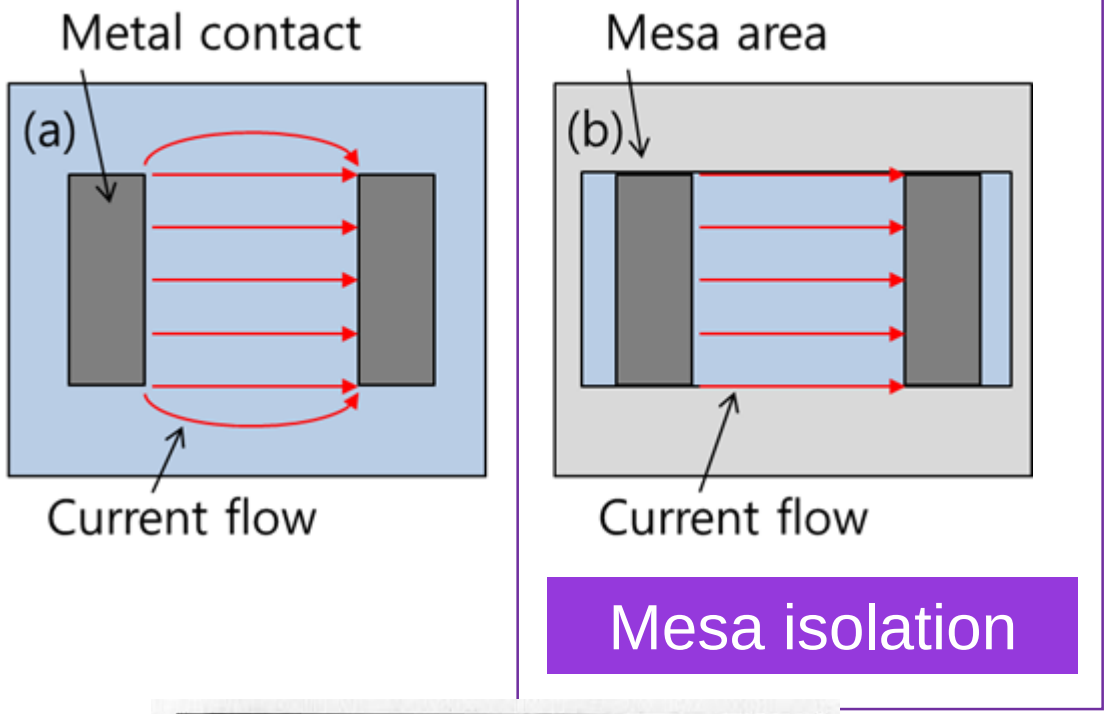
$$R_T = \frac{R_s}{W}(L + 2L_T)$$

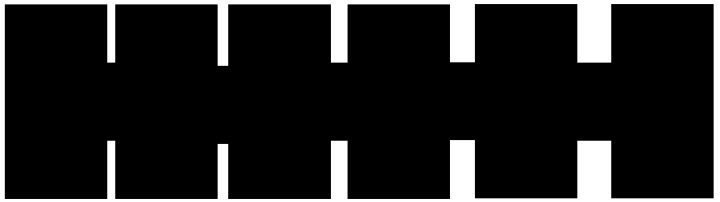


3. TLM process

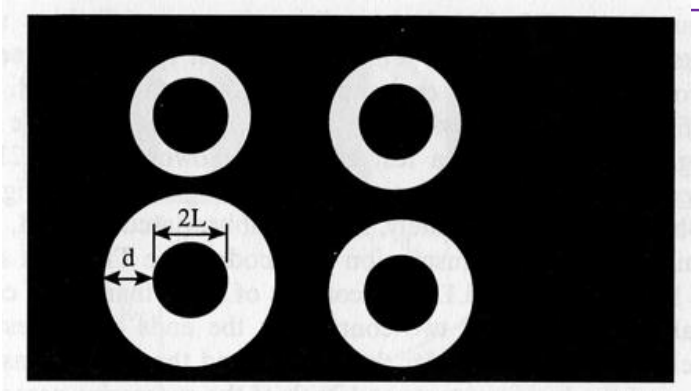
1. Patterning in a yellow room for Mesa-isolation
2. Mesa etching with ICP-RIE
3. Patterning in a yellow room for Ohmic metallization
4. Ohmic metallization with E-beam evaporator
5. Rapid Thermal Annealing

3. TLM process





Mask pattern for mesa etching



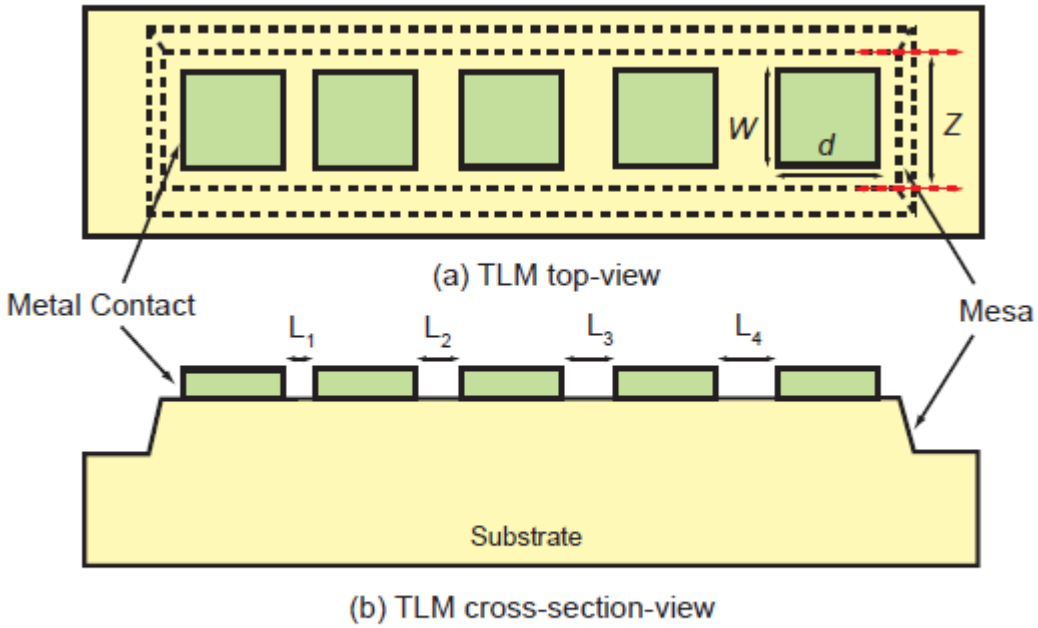


FIGURE 3.2: Schematic of TLM test structure

3. TLM process

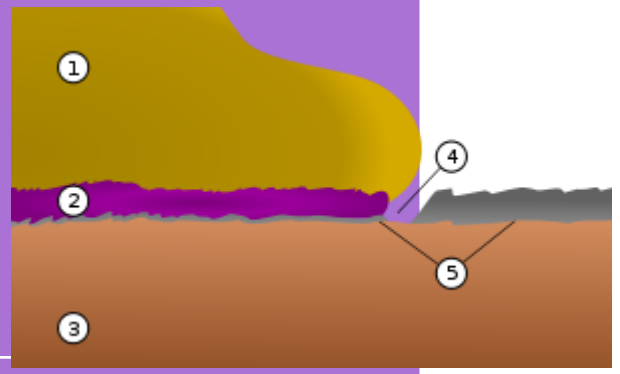
Metal Alloying

Work function is vital factor in ohmic contact!

- **Reduction of work function**
- **Increase of conductivity**

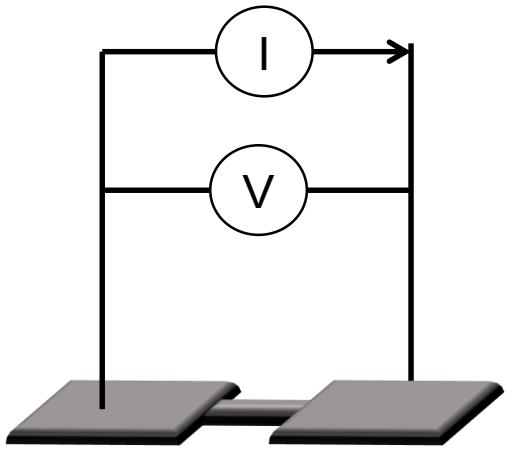
3. TLM process

Role of Metal	
Aluminum (Al)	**Gold (Au)**
• It is easy to deposit thin films of Al by vacuum evaporation. • It has good adherence to the silicon dioxide surface. • It forms good mechanical bonds with silicon by sintering at about 500°C or by alloying at the eutectic temperature of 577°C. • It forms low-resistance contacts with p-type silicon and with heavily doped n-type silicon.	• It improves ohmic contacts conductivity. • It prevents oxidation for other metals during high annealing temperature.
• During packaging operation if temperature goes too high, say 600°C, or if there is overheating due to current surge, Al can fuse and penetrate through the oxide to the silicon and may cause short circuit in the connection.	• It acts as a deep level trap and recombination center, i.e. charge carriers of opposite sign do recombine at Au defects in Si and get lost to the current. • It has poor adhesion.



4. How to measure Contact resistance

2 point probing



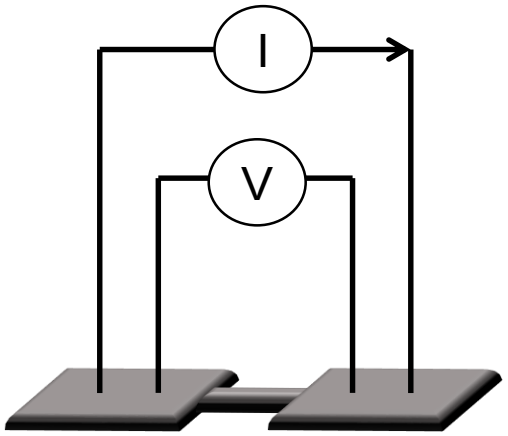
2 point probing

- **Advantages**
  - **Easy to measure contact resistance**
- **Disadvantages**
  - **Lots of assumptions**
  - **Low accuracy**

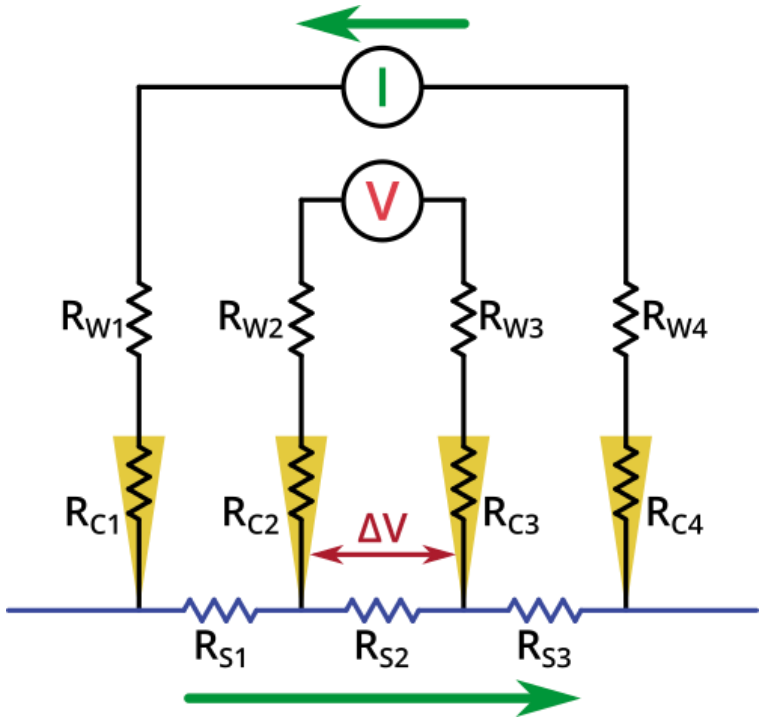
4. How to measure Contact resistance

4 point probing

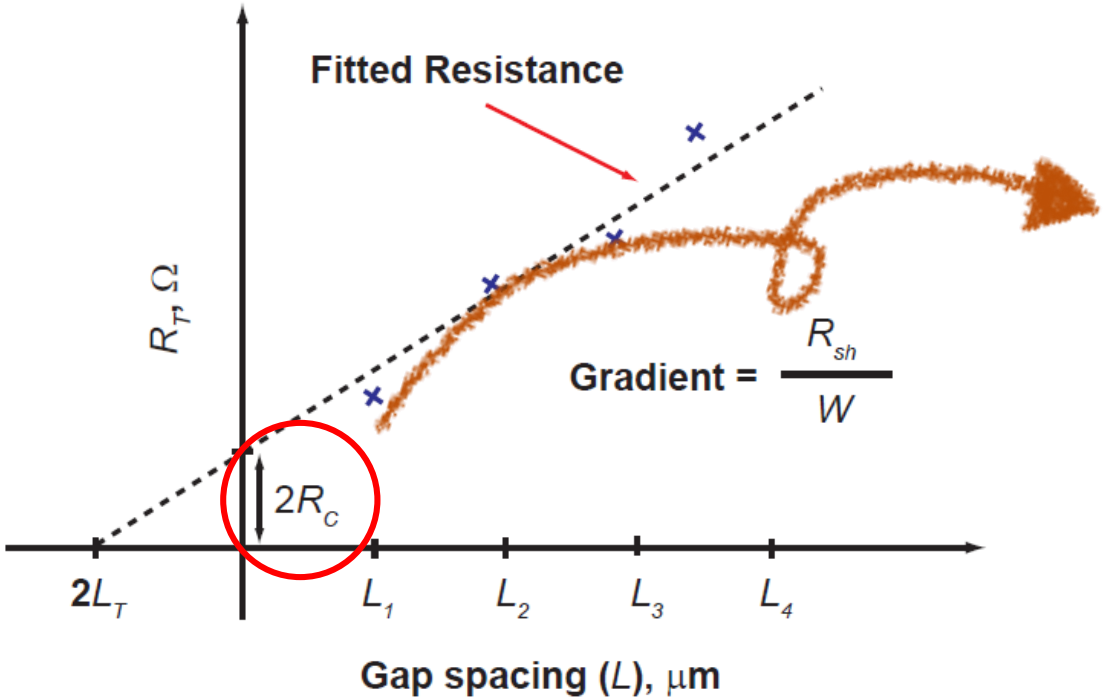
The elimination of resistances between contact and wire

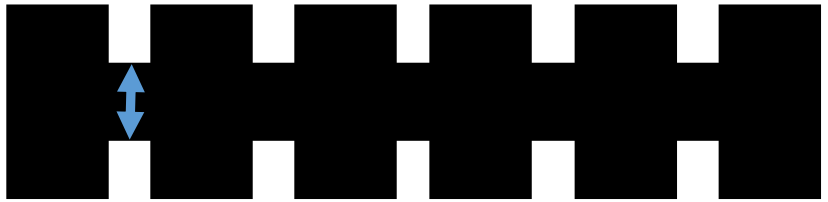


4 point probing



4. How to measure Contact resistance





Mask pattern for mesa etching

Rc(ohm*mm) = Rc(ohm) x width

Thank you for hearing my TLM presentation!