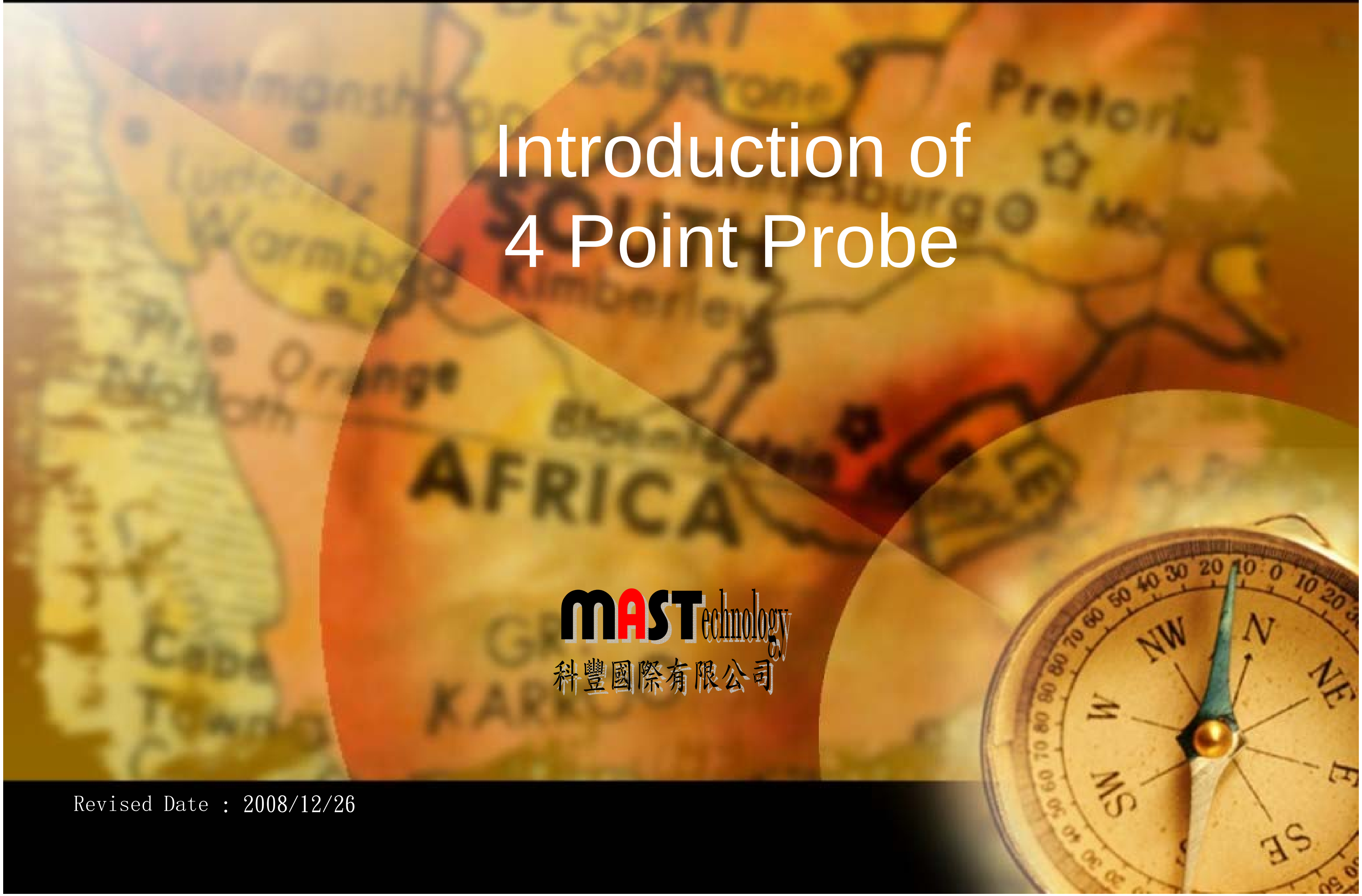

Introduction of 4 Point Probe

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Revised Date : 2008/12/26

Outline

1.Resistance?Resistivity?Sheet Resistance?

2.What is 4pp?

3.Two Configurations?

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9.Models of CDE ResMap

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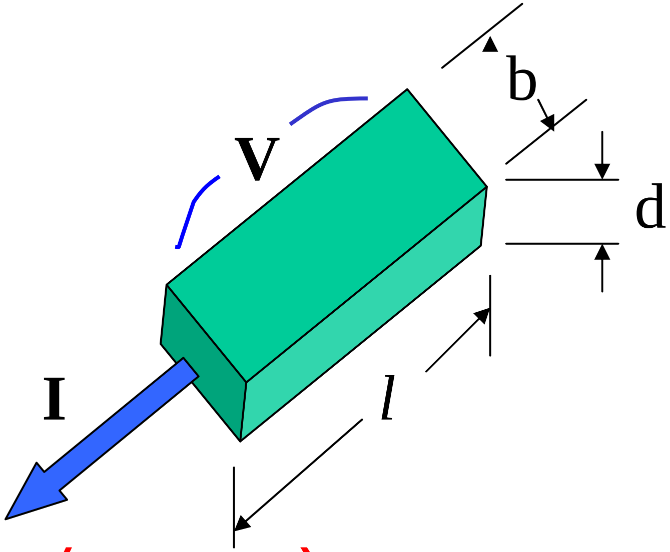
Resistance? Resistivity? Sheet Resistance?

- *Resistance(ohm)*

$$R = \frac{V}{I}$$



- *Resistivity(ohm-cm)*

$$\rho = R * \frac{bd}{l}$$

- *Sheet resistance(ohm/square)*

$$R_S = \frac{\rho}{d} = \frac{\pi}{\ln 2} * \frac{V}{I}$$

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What is 4pp?

- **Compare to 2 Point Probe**

  $R_T = V / I = 2R_P + 2R_C + 2R_{SP} + R_S$

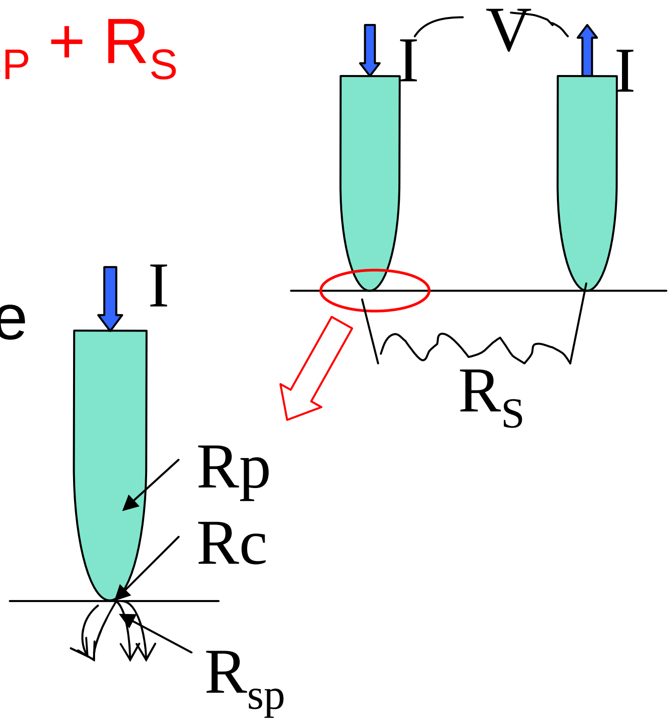
  R_S:sheet resistance

  R_C:contact resistance

  R_{SP}:spreading resistance

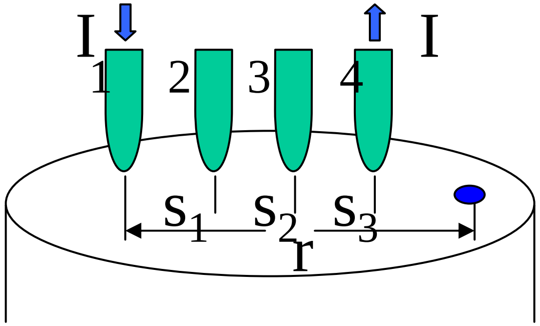
  R_P:pin resistance

- **R_C & R_{SP} can't measure**
- **ρ can not get from V**



What is 4pp?

- **For 4pp :Separate the pins of Voltage & Current**

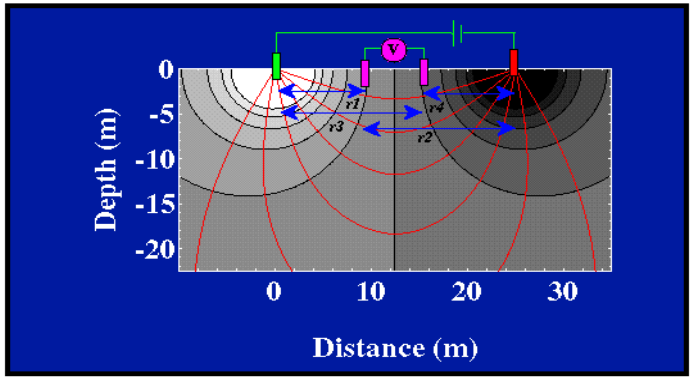


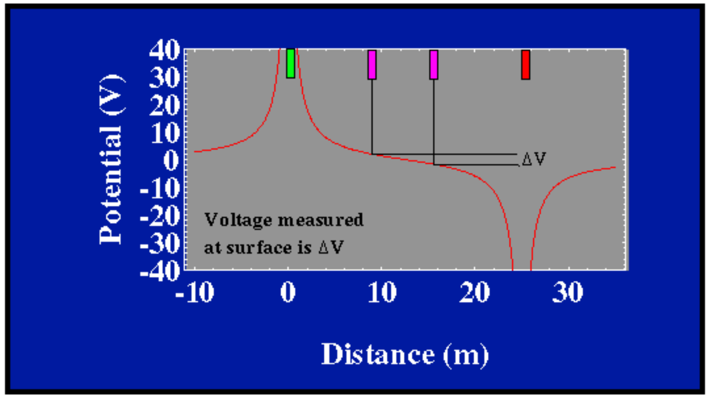
$V=V_2 - V_3$

$$V = \frac{\rho I}{2\pi}\left(\frac{1}{S_1} - \frac{1}{S_2+S_3} - \frac{1}{S_1+S_2} + \frac{1}{S_3}\right)$$

$$\rho = 2\pi S\left(\frac{V}{I}\right)$$ If $S=S_1=S_2=S_3$

$$\boxed{\rho = 2\pi s F\left(\frac{V}{I}\right)}$$





What is 4pp?

- **Correction Factor($F=F_1F_2F_3$)**

F1: Correction Factor in Thickness

F2: Correction Factor in lateral

F3: Correction Factor in distance between pin and edge

$$F_{11} = \frac{t/s}{2\ln\{[\sinh(t/s)]/[\sinh(t/2s)]\}}$$

$$F_2 = \frac{\ln(2)}{\ln(2) + \ln\{[(D/s)^2 + 3]/[(D/s)^2 - 3]\}}$$

$$F_{31} = \frac{1}{1 + \frac{1}{1+(2d/s)} - \frac{1}{2+(2d/s)} - \frac{1}{4+(2d/s)} + \frac{1}{5+(2d/s)}}$$

$$F_{32} = \frac{1}{1 + \frac{2}{[1+(2d/s)^2]^{1/2}} - \frac{1}{[1+(d/s)^2]^{1/2}}}$$

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What is 4pp?

- **When thin film & t << S/2** $F_1 = \frac{t/s}{2\lambda n 2}$

$$\rho = \frac{\pi t}{\lambda n 2}\frac{V}{I} = 4.532\, t\frac{V}{I}$$

$$\boxed{R_s = \frac{\rho}{t} = \frac{\pi}{\lambda n 2}\frac{V}{I} = 4.532\frac{V}{I}}$$

- **ρ is usually constant**
- **Film thickness t = ρ / R_S**

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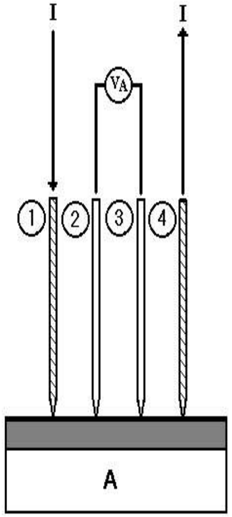
Two Configurations

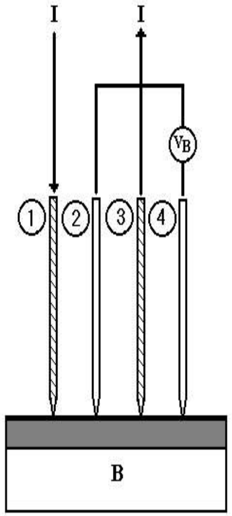
Single Configuration

$R_S = (\pi/\ln 2)x(V_{23}/ I_{14}) = 4.532Ra$

Dual Configuration

$R_S = \{-14.696 + 25.173\ (Ra/Rb) - 7.872(Ra/Rb)^2\}Ra$





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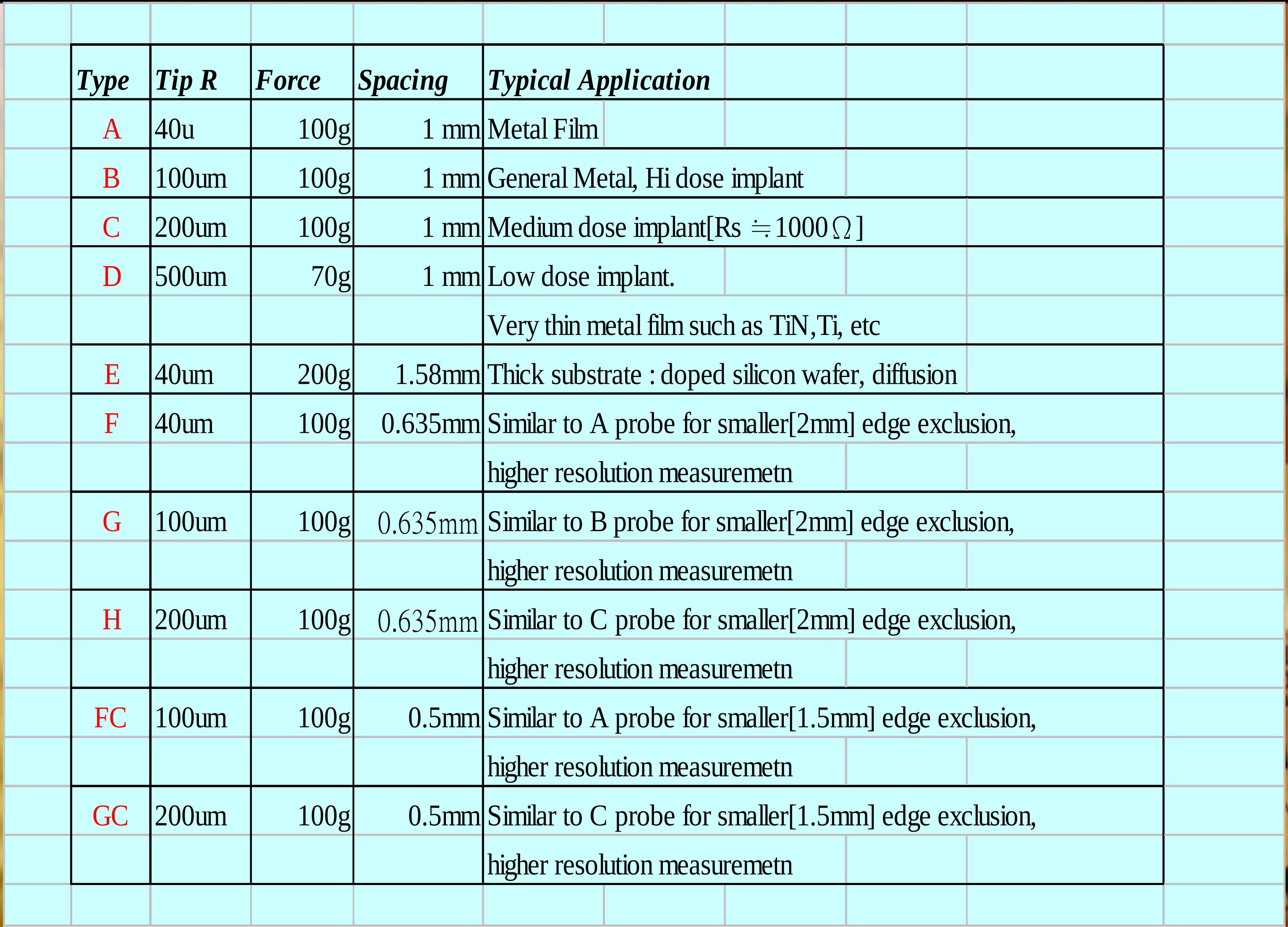
Probe Type



Type	*Tip R*	*Force*	*Spacing*	*Typical Application*
A	40u	100g	1 mm	Metal Film
B	100um	100g	1 mm	General Metal, Hi dose implant
C	200um	100g	1 mm	Medium dose implant[Rs ≒1000Ω]
D	500um	70g	1 mm	Low dose implant. Very thin metal film such as TiN,Ti, etc
E	40um	200g	1.58mm	Thick substrate : doped silicon wafer, diffusion
F	40um	100g	0.635mm	Similar to A probe for smaller[2mm] edge exclusion, higher resolution measuremetn
G	100um	100g	0.635mm	Similar to B probe for smaller[2mm] edge exclusion, higher resolution measuremetn
H	200um	100g	0.635mm	Similar to C probe for smaller[2mm] edge exclusion, higher resolution measuremetn
FC	100um	100g	0.5mm	Similar to A probe for smaller[1.5mm] edge exclusion, higher resolution measuremetn
GC	200um	100g	0.5mm	Similar to C probe for smaller[1.5mm] edge exclusion, higher resolution measuremetn
]

What can the 4pp do?

- **4pp measure :**
  - Sheet resistance
  - Resistivity
  - Thickness of thin film ($\rho = R_S \times t$)
- **4pp measure wafer :**
  - Thin Film wafer (Metal ,Alloy, ITO…)
  - Ion Implanted wafer (High,medium,and low dose implanted wafer, normally dopant with Boron or Phosphorus)
  - Thin Film wafer with CMP process
  - Diffusion wafer
  - Epitaxy wafer (But cross type)

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Resistivity of General Metal

Metal	***Bulk Resistivity***	***Film Resistivity***
	(micron-ohm-cm)	(micron-ohm-cm)
Al	2.75	4
Cu	1.72	2.5
Cr	17	20~50
Ni	7.24	50
Ti	55.4	200
Mo	5.33	50
Mo-Ta		50
Alpha-Ta	13.1	25
Bata-Ta		200
Mo-W		15

How important is the R_S in semiconductor

- Resistivity, is a particularly important semiconductor parameter because it can be related directly to the impurity content of a sample; The four point probe is the apparatus typically used to determine bulk resistivity
- In semiconductor layers, resistivity is a strong function of depth. For circuit design, it is often convenient to work with a parameter called the "sheet resistance" (Rs).

Application of 4pp

- Know something of the sample
- Is the sample clean and fresh?
- Is the sample homogenous?
- If the sample has a layer it must be of the opposite conductivity type to the substrate
- If the layer is thin, one must avoid puncturing the layer by needle loading, by sharp needle tips, or too rapid descent velocity of probe, excessive current can also inject minority carriers.
- The smallest sample :If the spacing between probes is constant ,and the thin film THK is less than 50% of the spacing,and the edges of the film are more than 4 times the spacing distance from the measurement point->Rs =4.53V/I

Limitation of Measurement

- The material must be capable of being probed,i.e.the probes must be able to make ohmic-contact with the material
- Very low resistivity material (like Al, Au, Pt) requires the maximum current from current source to achieve a reading
- Current source is restricted because of heating effects and excessive current density at the probe tips.That means blunt tips are desirable for thinner film.
- High resistivity material (e.g. ion-implanted Si wafer, Si on sapphire) can be measured using very low current and trying to avoid a greater voltage. Probably sheet resistance up to 10^7 ohm/sq can be measured.
- Some potential problem :electrical noise due to poor contact,thermally induced voltage, actinic effect, offset voltages produced by devices in current source, and leakage in plugs,lead etc.

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