Measurement of resistance of thin film using Van der Pauw method

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Outline

- Van der Pauw method
- some results of our experiment

Van der Pauw method

From: http://en.wikipedia.org/wiki/Van_der_Pauw_method

The method was first propounded by Leo J. van der Pauw in 1958[1].

The **van der Pauw Method** is a technique commonly used to measure:

- the resistivity
- the Hall coefficient of a sample

Its ability:

- ✓any arbitrary shape
- ✓two-dimensional

1. The resistivity of the material
2. The doping type (P-type or N-type material)
3. Doping level can be found
4. The mobility of the majority carrier

[1] Van der Pauw, L.J. (1958). "A method of measuring specific resistivity and Hall effect of discs of arbitrary shape". *Philips Research Reports* **13**: 1–9.

Conditions

There are five conditions that must be satisfied to use this technique:[2]

1. The sample must have a flat shape of uniform thickness
2. The sample must not have any isolated holes
3. The sample must be homogeneous and isotropic
4. All four contacts must be located at the edges of the sample
5. The area of contact of any individual contact should be at least an order of magnitude smaller than the area of the entire sample.

[2] Webster, John G (1999). *The measurement, instrumentation, and sensors handbook*. New York: CRC Press LLC. pp. 43–1.

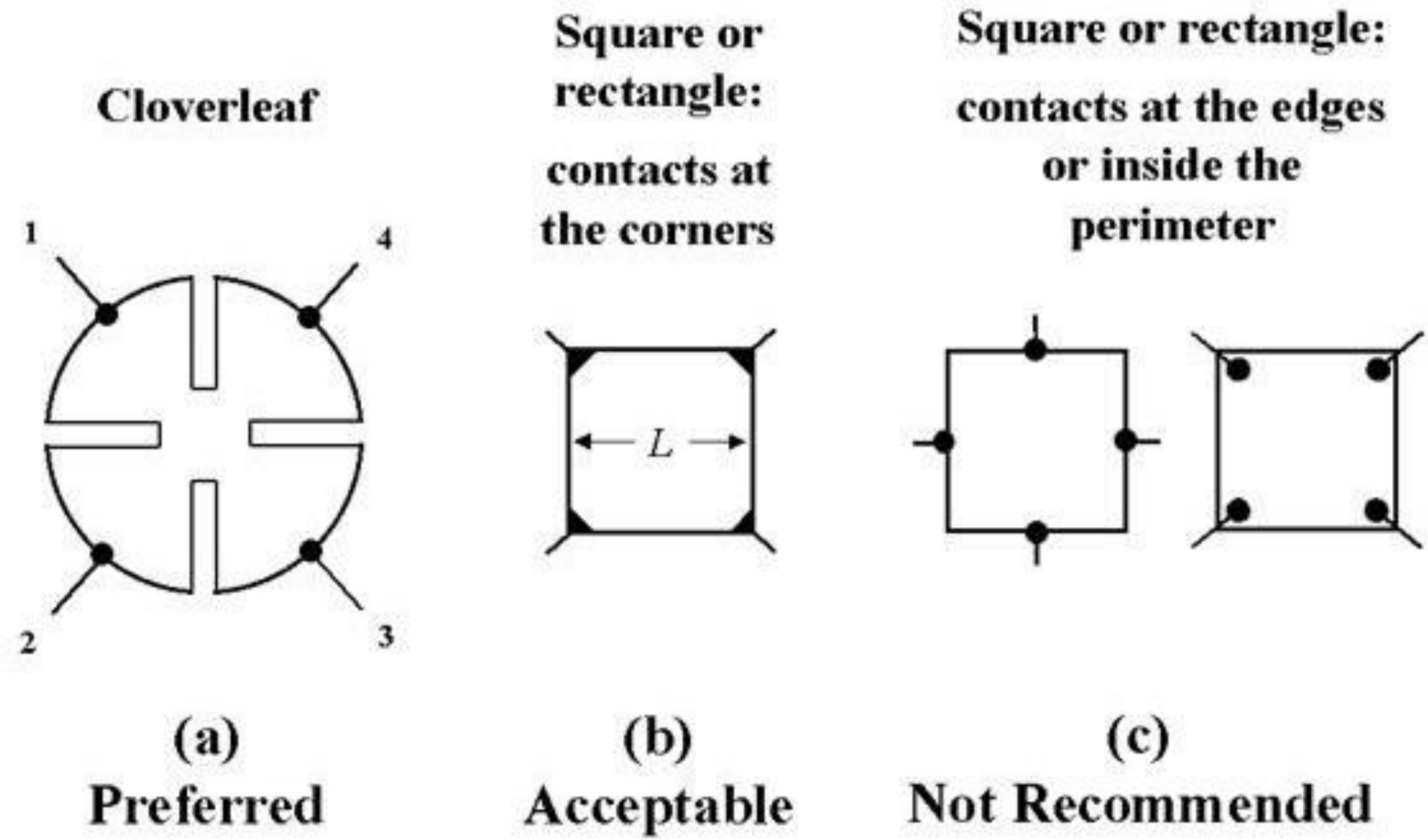
Sample preparation

- ✓ the sample thickness must be much less than the width and length of the sample.
- ✓ the sample is symmetrical.
- ✓ There must also be no isolated holes within the sample.

The measurements require that four ohmic contacts be placed on the sample. Certain conditions for their placement need to be met:

- ➢ They must be on the boundary of the sample.
- ➢ They must be infinitely small. (any errors given by their non-zero size will be of the order D/L, where D is the average diameter of the contact and L is the distance between the contacts.)

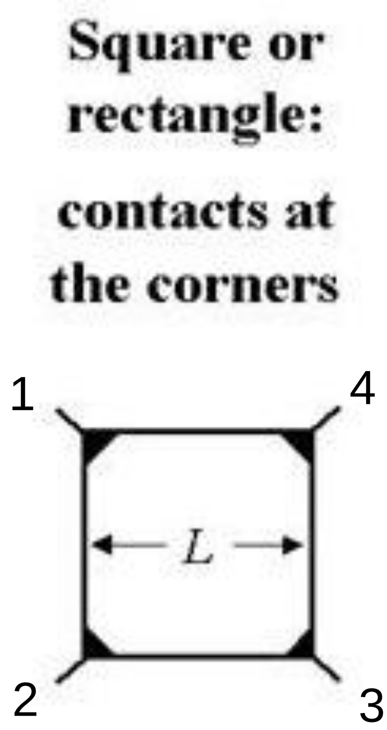
Some possible contact placements



Measurement definitions:

- The current I_{12} is a positive DC current injected into contact *1* and taken out of contact *2*, and is measured in amperes (A).
- The voltage V_{34} is a DC voltage measured between contacts *3* and *4* with no externally applied magnetic field, measured in volts (V).

- The resistivity ρ is measured in ohms·metres (Ω·m).
- The thickness of the sample t is measured in metres (m).
- The sheet resistance R_S is measured in ohms (Ω).



(b) Acceptable

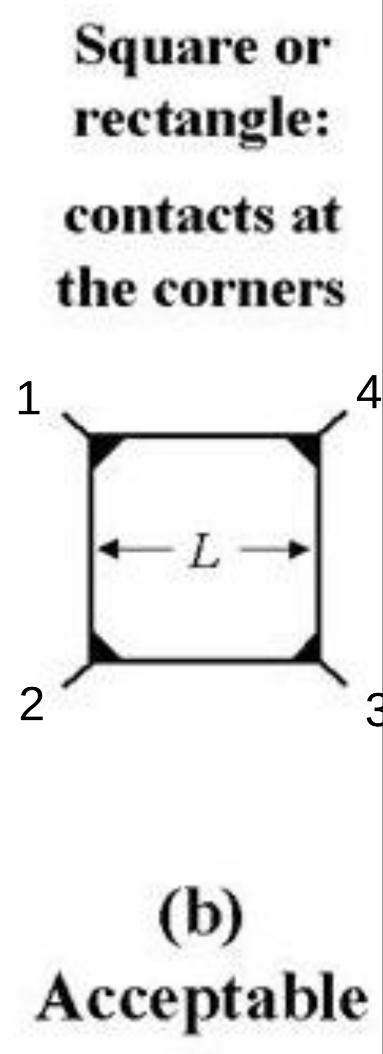
Resistivity measurements

The average resistivity of a sample is given by $\rho = R_S \cdot t$, where the sheet resistance R_S is determined as follows.

Basic measurements

To make a measurement, a current is caused to flow along one edge of the sample (for instance, I_{12}) and the voltage across the opposite edge (in this case, V_{34}) is measured. A resistance can be found using Ohm's law:

$$R_{12,34} = \frac{V_{34}}{I_{12}}$$

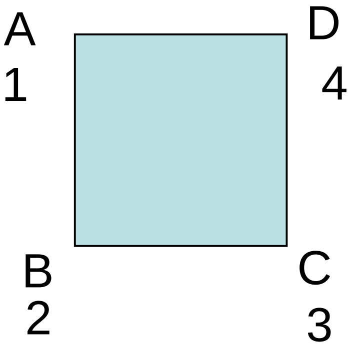


Van der Pauw showed that the sheet resistance of samples with arbitrary shapes can be determined from two of these resistances:

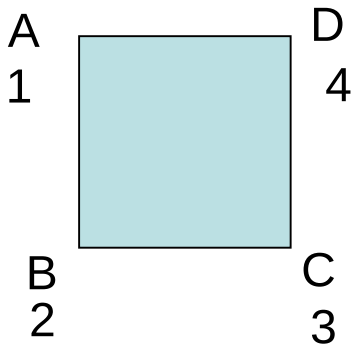
- one measured along a vertical edge, such as $R_{12,34}$,
- and a corresponding one measured along a horizontal edge, such as $R_{23,41}$.

The actual sheet resistance is related to these resistances by the van der Pauw formula

$$e^{-\pi R_{12,34}/R_s} + e^{-\pi R_{23,41}/R_s} = 1$$



Reciprocal measurements



The reciprocity theorem tells us that

$$R_{AB,CD} = R_{CD,AB}$$

To obtain a more precise value for the resistances $R_{12,34}$ and $R_{23,41}$

We define

$$R_{\mathrm{vertical}} = \frac{R_{12,34} + R_{34,12}}{2}$$

and

$$R_{\mathrm{horizontal}} = \frac{R_{23,41} + R_{41,23}}{2}$$

$$e^{-\pi R_{12,34}/R_s} + e^{-\pi R_{23,41}/R_s} = 1$$

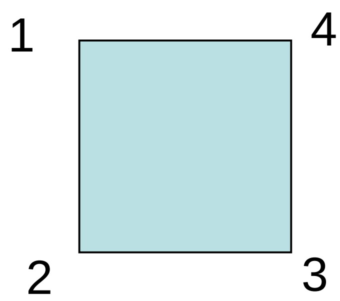
Then, the van der Pauw formula becomes

$$e^{-\pi R_{\text{vertical}}/R_S} + e^{-\pi R_{\text{horizontal}}/R_S} = 1$$

Reversed polarity measurements

A further improvement in the accuracy of the resistance values can be obtained by repeating the resistance measurements after switching polarities of both the current source and the voltage meter.

$$R_{\text{vertical}} = \frac{R_{12,34} + R_{34,12} + R_{21,43} + R_{43,21}}{4}$$



and

$$R_{\text{horizontal}} = \frac{R_{23,41} + R_{41,23} + R_{32,14} + R_{14,32}}{4}$$

The van der Pauw formula takes the same form as in the previous section.

Calculating sheet resistance

$$e^{-\pi R_{\text{vertical}}/R_S} + e^{-\pi R_{\text{horizontal}}/R_S} = 1$$

when $R_{vertical} = R = R_{horizontal}$

The sheet resistance is given by $$R_s = \frac{\pi R}{\ln 2}$$

Therefore, $\rho = R_S \cdot t = \dfrac{\pi R}{In2} t$

Here,R is the resistance, t is the thickness of the film.

Now take the thickness of our sample as 100 nm,

Therefore, $$\rho = R_s \cdot t = \frac{\pi R}{In2} \cdot t = R \cdot 4.53 \times 10^{-7}\,\Omega cm$$