Instruction Sheet

DESIGN AND FABRICATION OF A THIN FILM RESISTOR

I. Objective

Thin film resistors are becoming important subject of research because of their better electrical properties particularly in microwave technology and low dimensional circuit fabrication. The aim of this experiment is to deposit a resistor material (nichrome) over an insulating substrate (glass), making proper contacts for a desired total resistance (R in ohm).

II. Necessary theory

In order to design a thin film resistor the first electrical quantity to be known is the **sheet resistance**. The sheet resistance is a measure of resistance of thin films that have a uniform thickness. Sheet resistance is measured in ohms/square , and is applicable to two-dimensional systems where the thin film is considered to be a two dimensional entity. It is equivalent to resistivity as used in three-dimensional systems.

In a regular three-dimensional conductor, the resistance can be written as

$$R = \rho \frac{L}{A} \text{ ---------- (1)}$$

where ρ is the resistivity, *A* is the cross-sectional area and *L* is the length. The cross-sectional area can be split into the width *W* and the sheet thickness *t*.

By grouping the resistivity with the thickness, the resistance can then be written as

$$R = \frac{\rho}{t}\frac{L}{W} = R_S \frac{L}{W} \text{ --------- (2)}$$

R_s is then the sheet resistance. Because it is multiplied by a dimensionless quantity, the units are ohms. The term ohms/square is used because it gives the resistance in ohms of current passing from one side of a square region to the opposite side, regardless of the size of the square. For a square, $L = W$. Therefore, $R = R_s$ for any size square (Fig. 1).

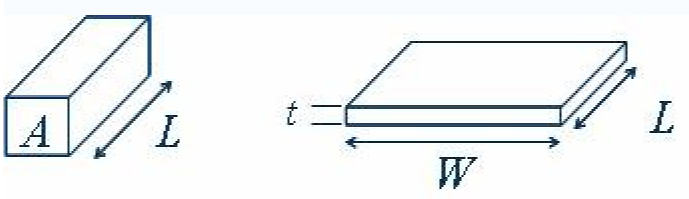

Fig. 1

Physical resistor sizes are easily calculated by dividing the resistor value required by the sheet resistance desired and then based upon power handling requirements and available space, choosing a convenient size.

III. Experimental steps

In order to design a resistor of some desired resistance, the following experimental steps are to be followed:

i. Calculate the required dimensions based on the theory
ii. Plan your own layout of the film (with connection) [Ref: study material]
iii. Draw this layout in computer aides design software and take a print on a transparency sheet.
iv. Cut the layout with utmost care from the transparency sheet, which is to be used as a mask during deposition
v. Load the material to be deposited on a filament/boat in the vacuum chamber.
vi. Obtain the lowest possible pressure using a rotary and diffusion pump combination (lower the pressure you achieve, better is the film quality)
vii. Keep the mask in front of the substrate during deposition note down the thickness in the thickness monitor.
viii. Vent the deposition chamber slowly and take out the film.
ix. Make contacts with Ag paste (making good contact is the most important requirement)
x. Do transport measurement (as per your knowledge in the Ist sem. Lab and Appendix 1).

IV. Task of this experiment

A] Make theoretical calculations (design parameters) for five desired resistances (say 50, 100, 150, 200 and 250 ohm)

B] Design and fabricate a resistor of 175 ohm

C] Compare the above two and furnish a **detail analysis and discussion (independently).**

Appendix 1:

Thin film resistivity by van der Pauw method

Consider the following figure:

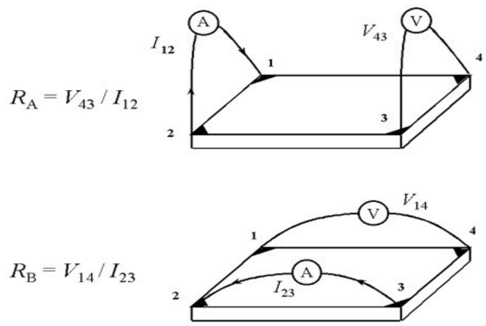

Figure 1

In order to determine the sheet resistance and the resistivity of the film follow the following steps:

Apply the current I_{21} and measure voltage V_{34}
Reverse the polarity of the current (I_{12}) and measure V_{43}
Repeat for the remaining six values (V_{41}, V_{14}, V_{12}, V_{21}, V_{23}, V_{32})

Eight measurements of voltage yield the following eight values of resistance, all of which must be positive:

$$\begin{aligned} &R_{21,34} = V_{34}/I_{21},\ R_{12,43} = V_{43}/I_{12},\\ &R_{32,41} = V_{41}/I_{32},\ R_{23,14} = V_{14}/I_{23},\\ &R_{43,12} = V_{12}/I_{43},\ R_{34,21} = V_{21}/I_{34},\\ &R_{14,23} = V_{23}/I_{14},\ R_{41,32} = V_{32}/I_{41}. \end{aligned} \quad (7)$$

Note that with this switching arrangement the voltmeter is reading only positive voltages, so the meter must be carefully zeroed.
Because the second half of this sequence of measurements is redundant, it permits important consistency checks on measurement repeatability, ohmic contact quality, and sample uniformity.

Measurement consistency following current reversal requires that:

$$\begin{aligned} &R_{21,34} = R_{12,43} \qquad && R_{43,12} = R_{34,21}\\ &R_{32,41} = R_{23,14} \qquad && R_{14,23} = R_{41,32} \end{aligned} \quad (8)$$

The reciprocity theorem requires that:

$R_{21,34} + R_{12,43} = R_{43,12} + R_{34,21}$, and
$R_{32,41} + R_{23,14} = R_{14,23} + R_{41,32}$. (9)

If any of the above fail to be true within 5 % (preferably 3 %), investigate the sources of error.

Resistivity Calculations

The sheet resistance R_S can be determined from the two characteristic resistances

$R_A = (R_{21,34} + R_{12,43} + R_{43,12} + R_{34,21})/4$ and
$R_B = (R_{32,41} + R_{23,14} + R_{14,23} + R_{41,32})/4$ (10)

via the van der Pauw equation

$\exp(-\pi R_A/R_S) + \exp(-\pi R_B/R_S) = 1$

[For numerical solution of the above equation see the routine belo or use the software.

If the conducting layer thickness *d* is known, the bulk resistivity $\rho = R_S d$ can be calculated from R_S.

Set the error limit $\delta = 0.0005$, corresponding to 0.05 %

Calculate the initial value of z_i, or $z_o = 2\, ln(2)/[\pi(R_A + R_B)]$

Calculate the i^{th} iteration of $y_i = 1/\exp(\pi z_{i-1} R_A) + 1/\exp(\pi z_{i-1} R_B)$

Calculate the i^{th} iteration of z_i where

$$z_i = z_{i-1} - [(1-y_i)/\pi] / [R_A/\exp(\pi z_{i-1} R_A) + R_B/\exp(\pi z_{i-1} R_B)]$$

When $(z_i - z_{i-1})/z_i$ is less than δ, stop and calculate the sheet resistance $R_S = 1/z_i$

The resistivity ρ is given by $\rho = R_S d$, where d is the thickness of the conducting layer