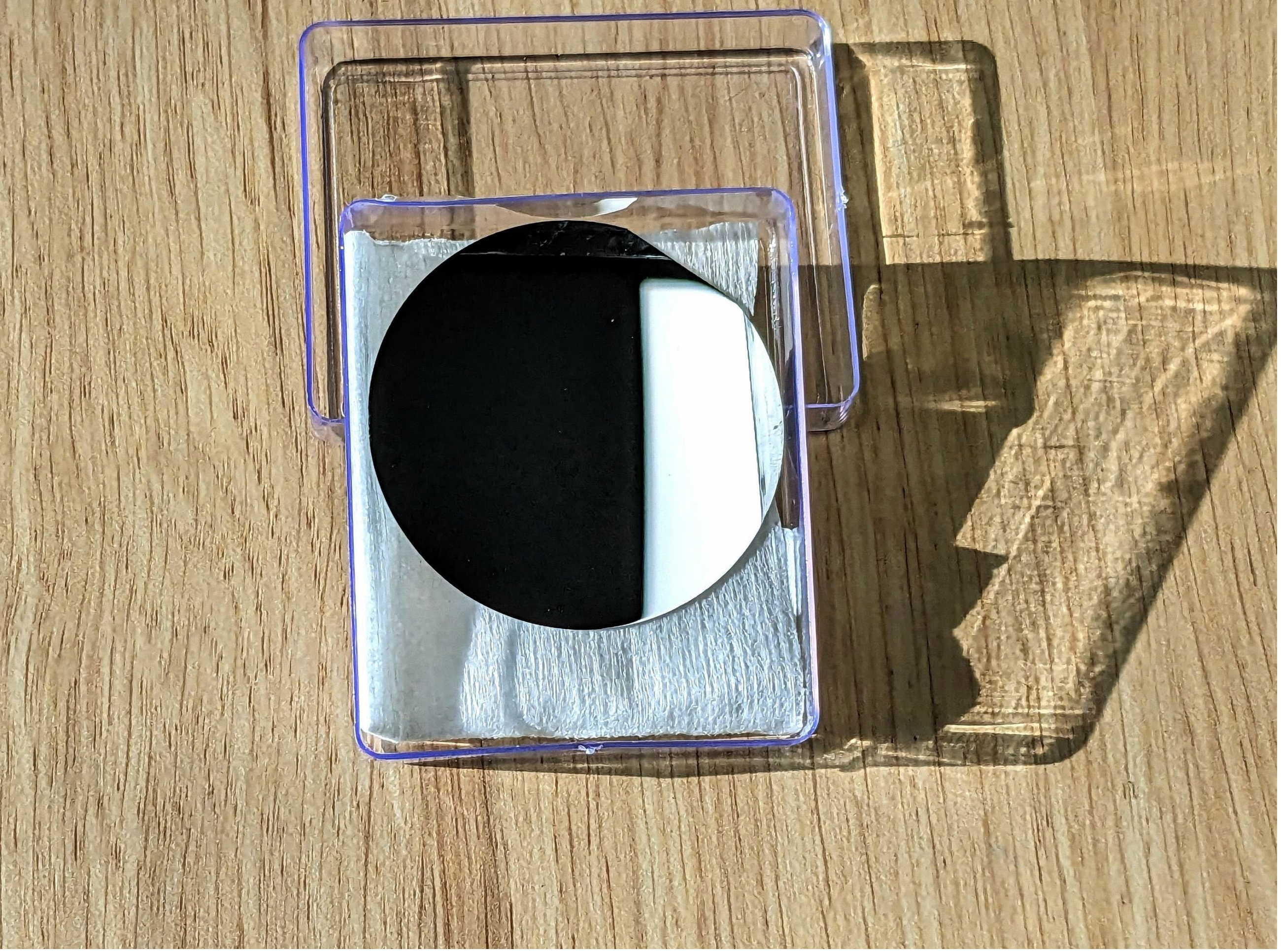
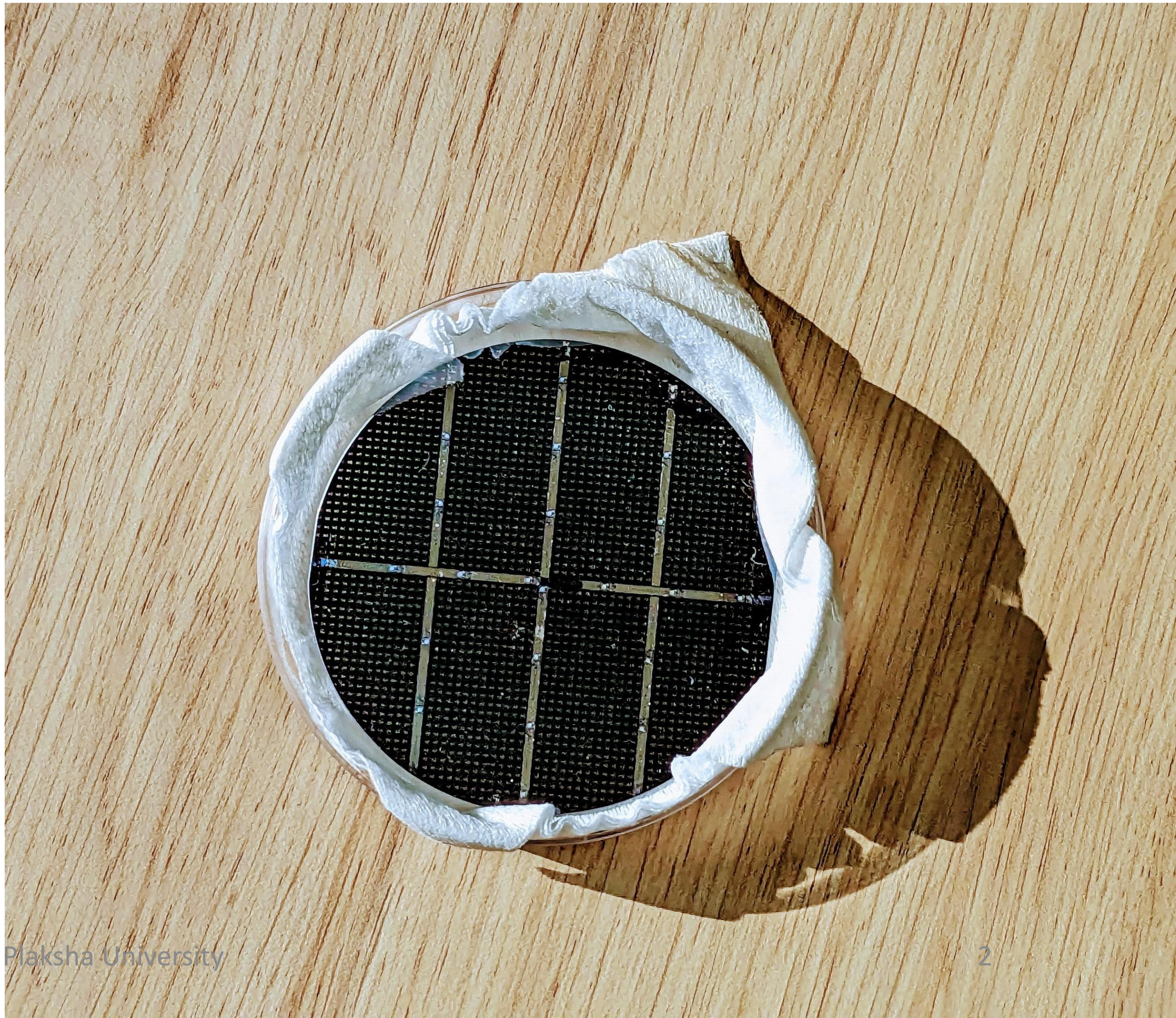
Electrical Basics II

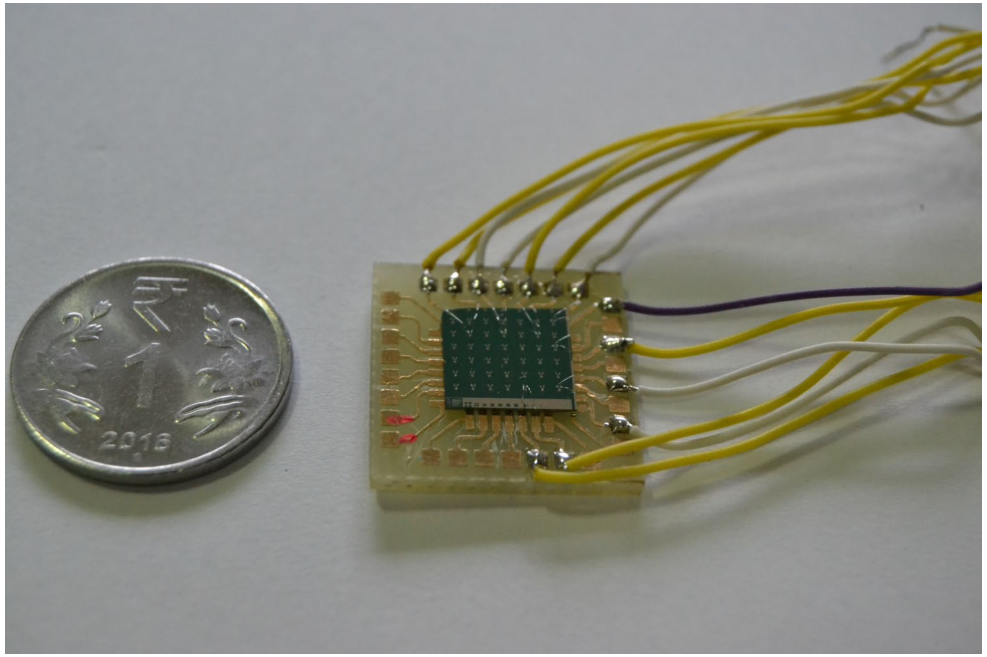
Conductivity and Resistivity

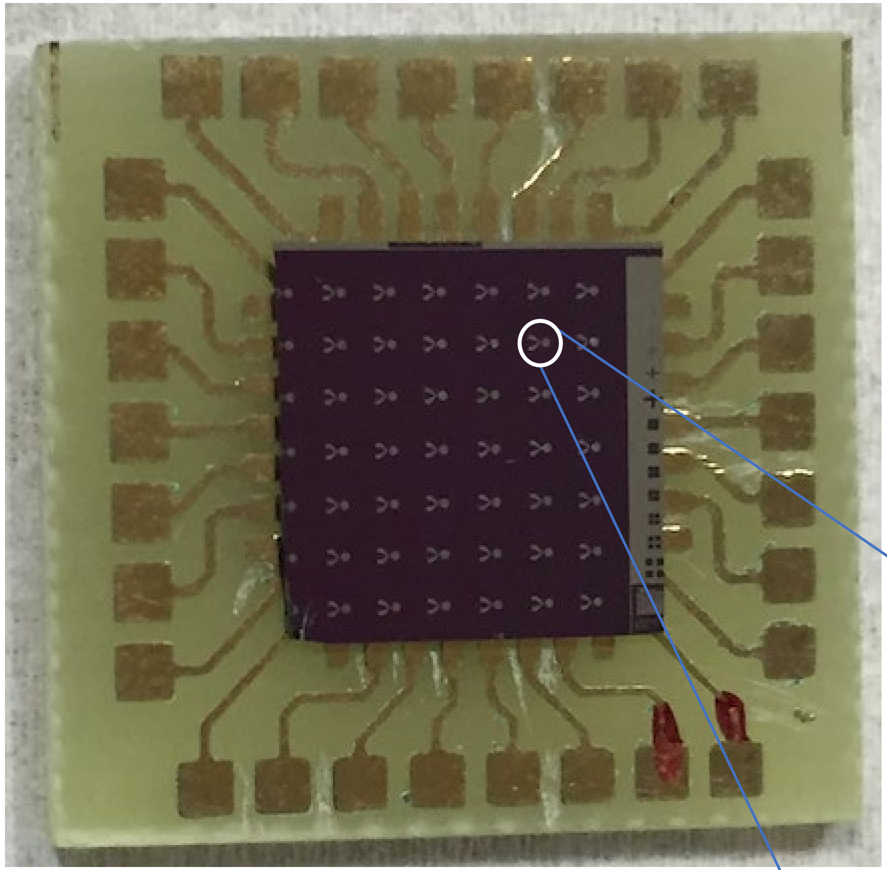
Demo of silicon wafer and microheater array

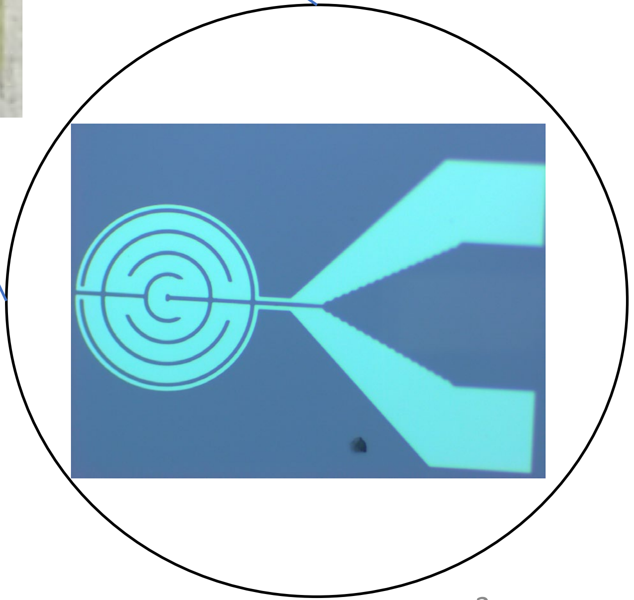




Picture credits: Suvrajyoti Paul







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Section 3.1.3: Conductivity and Resistivity,
Foundations of MEMS, Chang Liu

Example 1

The intrinsic carrier concentration (n_i) of silicon under room temperature is $1.5 \times 10^{10}/\mathrm{cm}^3$. A silicon piece is doped with phosphorus to a concentration of $10^{18}\ \mathrm{cm}^{-3}$. The mobility of electrons and holes in the silicon are approximately $1350\ \mathrm{cm}^2/\mathrm{V\text{-}s}$ and $480\ \mathrm{cm}^2/\mathrm{V\text{-}s}$, respectively. Find the resistivity of the doped bulk silicon.

Example 3.2, Foundations of MEMS, Chang Liu

$$n_0 = 10^{18}\,\text{cm}^{-3}$$

$$p_0 = \frac{n_i^2}{n_0} = 225\,\text{cm}^{-3}$$

The resistivity of the doped silicon is calculated by plugging in the following formula

$$\rho = \frac{1}{\sigma} = \frac{1}{q(\mu_n n_0 + \mu_p p_0)}$$

$$= \frac{1}{1.6 \times 10^{-19} \times (1350 \times 10^{18} + 480 \times 225)}$$

$$= 0.0046 \frac{V \cdot s \cdot \text{cm}}{C} = 0.0046 \frac{V \cdot \text{cm}}{A} = 0.0046 \Omega \cdot \text{cm}$$

Example 3.2, Foundations of MEMS, Chang Liu

Example 2

Determine the thermal equilibrium electron and hole concentrations in a compensated n-type semiconductor.
Consider a silicon semiconductor at $T = 300°K$ in which $N_d = 10^{16}$ cm^{-3} and $N_a = 3 \times 10^{15}$ cm^{-3}. Assume that $n_i = 1.5 \times 10^{10}$ cm^{-3}.

If the semiconductor is silicon, Find the resistivity of the doped bulk silicon.

The mobility of electrons and holes in the silicon are approximately 1350 cm^2/V-s and 480 cm^2 /V-s respectively.

Based on example 3, https://inst.eecs.berkeley.edu/~ee105/fa05/handouts/discussions/Discussion1.pdf

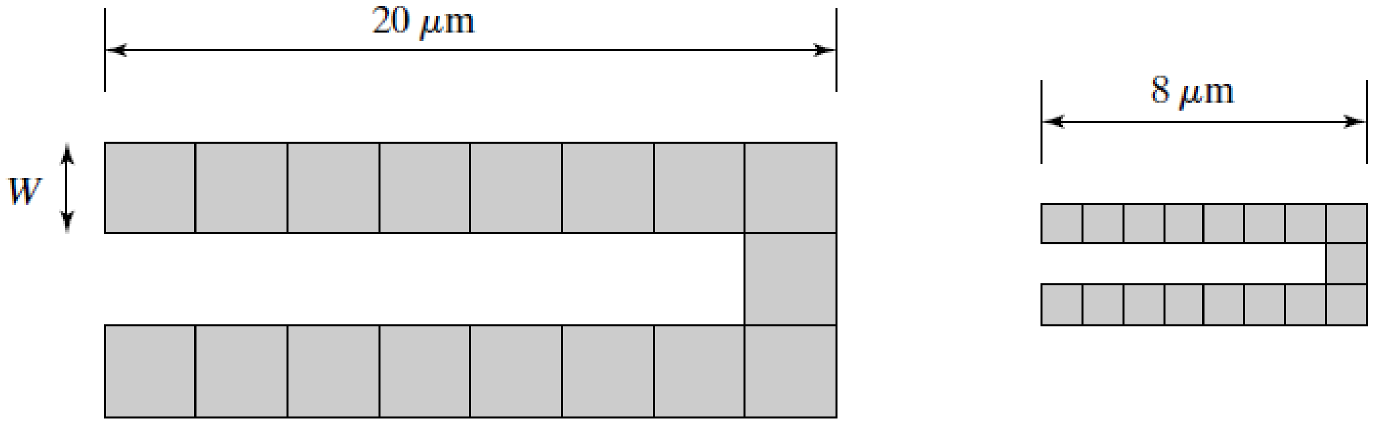
The majority carrier electron concentration is
$n_o = \frac{1}{2}\{(10^{16} - 3 \times 10^{15}) + ((10^{16} - 3 \times 10^{15})^2 + 4(1.5 \times 10^{10})^2)^{1/2}\} \cong 7 \times 10^{15}\ \text{cm}^{-3}$ The minority carrier hole concentration is
$p_0 = n_i^2 / n_0 = (1.5 \times 10^{10})^2/(7 \times 10^{15}) = 3.21 \times 10^4\ \text{cm}^{-3}$

<Resistivity ~ 0.6613 Ω.cm>

Observation:
If we assume complete ionization and if Nd - Na >> ni, the majority carrier electron concentration is, to a very good approximation, just the difference between the donor and acceptor concentrations.

Example 3

Continue with previous example (#2). If the doped layer is thick and has uniform doping thickness within the layer, find the sheet resistivity of the doped layer. A resistor is defined using the doped layer with geometries shown below in Figure (a).
What is the resistance of the resistor?
How much heat would be generated by the resistor when a 1 mA current is passed through it?
What is the resistance of the resistor shown in Figure (b)?



(a) (b)

Example 3.3, Foundations of MEMS, Chang Liu