

Semiconductor Materials Lab

Purpose:

Become familiar with basic semiconductor materials and characterization techniques.

Required Materials:

Nitrile gloves & safety glasses
Diamond scribe, tweezers, & glass slides
Soldering iron
Multimeter (4-wire sense capability)
Four point probe
Sourcemeater
Calipers or micrometer
Variable DC power supply (min 2 amp capability)
Surplus wafers for scribing (111 & 100 orientations)
9 or 12V incandescent bulb
1 Ω resistor

Prelab:

Review the “Wafer Specifications”, “Types of Wafer Substrates”, and “Fabrication of Bulk Semiconductor Crystals” sections provided in the following link:

http://www.cleanroom.byu.edu/everything_wafers.phtml

Review the following videos demonstrating how to scribe & cleave wafers by hand:

https://www.youtube.com/watch?v=Rv_wTEWFdU

<https://www.youtube.com/watch?v=kivkEir4RcM>

<https://www.youtube.com/watch?v=cA9Jydzp1PM>

Review the difference between 2 and 4 wire resistance measurements from the following link: <http://www.keithley.com/data?asset=57571>

Review the “Hot Probe” experiment as described on the following link:

<http://ecee.colorado.edu/~bart/book/hotprobe.htm>

Review the “Short Application Note” and “Basic Information” sections provided in the following link: <http://four-point-probes.com/technical-information-guide/>

Procedure:

1. Your TA will give your lab section a wafer to scribe. Take turns scribing and cleaving until the wafer has been reduced to chips approximately one square cm in size. **Be sure to wear gloves and safety glasses as small shards can be sent flying.** Dispose surplus wafer shards in the “broken glass disposal” receptacle.
2. Use a multimeter to make 2-wire resistance measurements on a 1Ω resistor and then again on just the multimeter leads (“short circuited” together). Now use the 4-wire resistance function to measure the same 1Ω resistor. Record these values.
3. Your TA will give you several “unknown” wafers to characterize. Use a hot point probe setup (soldering iron & multimeter) to determine whether each is n or p doped (for the epi wafer determine this for both the epi layer & the substrate). Note that some of the wafers are very lightly doped & will thus generate a very small current.
4. For these same wafers use a four point probe to measure the sheet resistance of each (for the epi wafer do this for both the epi layer and the substrate). You will need to use a sourcemeter to provide the current and a multimeter to measure the voltage (refer to the “Device Characterization” section of the lab manual for more details on this setup). Record these values as well as the probe tip spacing.
5. Measure the thickness of each wafer using the calipers or micrometer provided. Please do this gently as to not break the wafers. Record these values.
6. Use a variable DC power supply to collect data (min 10 data points) for creating IV curves of a tungsten wire (incandescent bulb) and of a silicon wafer (just alligator clipped across the diameter). For the incandescent bulb do not exceed 100 mA or it will burn out. For the silicon wafer record values up to the power supply’s maximum capability. **Be careful not to touch the wafer as it will get very hot** (pull back rubber protectors on alligator clips so they don’t melt). Don’t worry about getting exact data as these values will drift as the bulb and wafer heat up. We are just looking for general trends.

Post Lab:

1. Determine the crystal orientation of the wafer you scribed based on its tendency to break into a specific shape.
2. What was the 2-wire resistance of the 1Ω resistor you measured? What was resistance of the multimeter leads? Take the difference of these values to be the "true" resistance and calculate the % error of your 2-wire and 4-wire measurements.
3. What did you conclude to be the doping type of each of your sample wafers?
4. What sheet resistance values did you calculate for the unknown wafers? Is it necessary to apply correction factors for thickness or diameter based on our probe tip spacing?
5. Use these sheet resistances and the wafer thicknesses you measured to calculate the resistivity (in ohm-cm) for each wafer (list epi and substrate resistivities separately). Now calculate the majority carrier concentrations of each (use the mobilities given in section 2.1 of your lab manual and assume an intrinsic carrier concentration of $1.1 \times 10^{10}/\text{cm}^3$).
6. Plot the IV curves for the incandescent bulb and the semiconductor wafer. Describe what happens to the resistivity of each as temperature (current) increases and explain why this happens in your own words.
7. Use your incandescent bulb's IV curve to approximate the resistance of the tungsten filament when it is cold. Assuming the incandescent filament is a tungsten wire with a diameter of $50\mu\text{m}$, calculate the length of filament wire used inside the bulb.
8. Provide feedback about this lab citing any areas requiring clarification and/or suggestions for future improvements.