EECE5606 Laboratory Template

Student Name: Pavan Umesh **NUID:** 002831632 **Date: 03/14/2024**

Title: Metrology and Dicing **Lab week: 6**

1. Lab Description (10 points) ***(What is this lab about?)***

In this lab lesson, the students were introduced to the process of measuring wafer and thin film resistivity with 4-point probes, silicon wafer dicing and Liftoff.

2. Lab Objective (10 points) (*Why are you doing this lab?)*

This laboratory class was aimed at training the students to use the probe stations to measure resistivity of different materials, silicon wafer dicing and Liftoff in the George J. Kostas Nanoscale Technology and Manufacturing Research Center
cleanroom facility.

3. Methods (20 points)

1. Measuring the resistivity of a silicon wafer using the 4-Point Probe:

The Miller FPP-5000 4-Point Probe is an instrumentation tool used to measure the resistive properties of semiconductor wafers and thin films. The tool is a versatile instrument that can be utilized to measure parameters such as V/I, resistivity, and thickness, with its primary function being the measurement of sheet resistance. The instrument performs the measurement using the 4-Point Probe which consists of four sharp probes spaced 1.26 mm apart. In the 4-Point Probe, the first and third probes are input probes whereas the second and fourth probes are output probes.

The measurement ranges for the tool are as follows:

- Sheet resistance can be measured from 1.1 mΩ/square to 450 kΩ/square.
- V/I from 0.25 mΩ to 99.9 kΩ.
- Slice resistivity from 41.2 µΩ cm to 17.1 kΩ cm.
- Thickness from 2 nm to 24.3 µm

The tool is calibrated to ensure high accuracy of 0.5% on all readings between 5 mΩ to 5 kΩ, with a maximum deviation of 8.0% at the extreme limits of the range.

The various steps involved in resistivity measurement using the 4-point probe are as follows:

I. The lid is opened after ensuring that the system is on.
II. The desired measurement mode is selected.
III. A clean silicon wafer is placed on the plate face down.
IV. The wafer is positioned at the desired measurement location using the lines as guides.
V. The lid is pressed and held closed.
VI. After 2 seconds, the measurement starts automatically, and the results are displayed.
VII. After recording the results, the lid is opened, and the wafer is removed.

2. Silicon wafer dicing:

In this laboratory class, the instrument used for silicon wafer dicing process was the Dicing Saw Model 1006 from Micro Automation, Inc. This system is a precision machine designed for cutting semiconductor wafers (maximum size: 6 inch) into individual integrated circuit IC) die. The dicing saw consists of a spindle assembly, which turns a diamond saw blade. A vacuum huck acts as a carrier for the material to be sawed. Four motor driven assemblies (designated X, Y, Z, and θ) control the movement between the saw blade and the chuck. The wafer dicing saw can be sed to accurately cut devices or structures out of processed silicon, sapphire, and gallium arsenide wafers as well glass substrates and other materials.

The tool uses a simple preprogrammed microcontroller to run the dicing process. The various steps involved in the dicing process are as follows:

1. The wafer is first prepared by placing it face down carefully on cleanroom-grade soft paper while the back is covered with a layer of air-tight blue colored plastic sheet. Care must be taken to avoid the formation of bubbles in the air-tight layer. Then the sheet is cut around the edges of the wafer to produce a circular shape using a razor blade.
2. A silicon blade is installed in the dicing saw and the portable water valve, vacuum valve, DI water valve, and compressor valves are turned on (for compressor valve, value must be 80 to 85).
3. The machine is turned on by pressing the red “Stop” button and then the microscope and TV are turned on using the remote.
4. In the keypad, “PROG” is pressed and the following values are entered (by pressing the “ENTER” key) for the parameters: “1st INDEX” (width in mm) is set to “15”, “2nd INDEX” (length in mm) to “HEIGHT” (in mm) to 0.175, “THICKNESS” (in mm) to 2, “ANGLE” (in degrees) to 90, “SPEED” to “2”, and “DIA” (diameter in mm) to “100”. The values are checked once more, and then “PROG” is pressed again to confirm.
5. Then, in the settings to the right, “RESET” is pressed, and the cover is put on the tool. Then “SPINDLE” is pressed to start the rotation of the spindle. It is checked whether the spindle is operating smoothly (there will be some noise if working properly) and it slowly ramps up in speed.
6. The chuck is placed carefully to calibrate the saw. It is locked in by pressing “LOCK” under the “CHUCK” section and the zero value is set by pressing “CHUCK ZERO” (a beep sound is produced). Then it is removed by pressing the “UNLOCK”. The wafer is then inserted in and locked by applying vacuum (the “CHUCK VACUUM” pressure gauge should read a value above “15”).
7. Then, “AUTO CUT” mode is selected (“INDEX” mode must be selected before this) and the system will start cutting. The saw will stop cutting after it has moved the length of the wafer diameter programmed.
8. After the wafer has been cut, the nitrogen gun is used to blow-dry the wafer.

1. Performing the lift-off process on the aluminum coated silicon wafer:

The lift-off process in micro-fabrication is the method of patterning structures on the surface of a substrate. It is an additive process as opposed to a subtracting process like etching. In the process of lift-off, the photoresist (PR) layer, which acts as a sacrificial stencil, is initially patterned in an inverse manner during lift-off by creating etched openings that allow the target material to reach specific regions of the substrate. The target material is then deposited over the entire wafer surface, adhering to the substrate in the etched regions and remaining on top of the PR layer in the unetched regions. Upon washing away the PR layer with a solvent, the material on top is lifted-off and removed with the PR layer underneath. As a result, the target material is left only in the areas where it had direct contact with the substrate after the lift-off process. In this laboratory class, the following steps were used to perform the lift-off process:

a. A previously produced aluminum coated (100 nm Al thickness) silicon wafer was cleaved into small pieces (samples) and then subjected to the lift-off process. For the lift-off process, the samples were placed in beakers with acetone for 20 minutes. This dissolves the PR layer along with the aluminum coated on top, while preserving the aluminum coated on the silicon wafer, producing microstructures or micro-scale devices. For lift-off, it is preferable to place the wafer face down such that the PR and the aluminum coated on it dissolve away with gravity assist. However, the disadvantage of this method is that while removing the sample from the beaker it is likely to get scratched, but this can be prevented with the use of plastic holders. The beakers must be covered to prevent the acetone from evaporating.

b. Once the lift-off process is complete, the sample must be washed with isopropyl alcohol (IPA). Then the sample is immersed in a solution of deionized (DI) water and sonicated in an ultrasonic cleaner for a few minutes. The sample is then dried front and back using a nitrogen gun.

2. Outcomes and Measurements (15 points)

The outcome of this laboratory class was that the students were introduced to the process of measuring wafer and thin film resistivity with 4-point probes.

1. Measurement of the resistivity of a silicon wafer using the 4-Point Probe:
   The sheet resistance of the silicon wafer was found to be 254 Ω/square and its thickness was 525 µm. Therefore, the resistivity of the silicon wafer is calculated to be 13.33 Ω cm (The resistivity is given by the product of the sheet resistance with the thickness, i.e., 254 Ω/square * 525 µm 13.33 Ω cm).
2. Measurement of the resistivity of a aluminum silicon wafer using the 4-Point Probe:
   The sheet resistance of the silicon wafer was found to be 0.868 Ω/square and its thickness was 280 µm. Therefore, the resistivity of the silicon wafer is calculated to be 0.0243 Ω cm (The resistivity is given by the product of the sheet resistance with the thickness, i.e., 0.868 Ω/square 280 µm 0.0243 Ω cm).
3. Measurement of the resistivity of a high resistive silicon wafer using the 4-Point Probe:
   The sheet resistance of the silicon wafer was found to be out of range.

Comments (5 points)

The following were observed in this laboratory class:

• The resistivity of aluminum thin films is inversely proportional to the film thickness. Moreover, the resistivity of thin-film aluminum is slightly larger than that of its bulk counterpart due to contamination on the surface.

• The resistivity of silicon wafers can range from low (1 Ω cm to 100 Ω cm) to high (20,000 Ω cm) depending on the application. For example, MEMS resonators are built on high resistivity silicon wafers, whereas the silicon wafers used as test wafers have low resistivity.

4. Analysis Questions (30 points)

(a) What are the challenges of liftoff?

The hurdles associated with liftoff pertain to the phase wherein a layer of material, typically a photoresist, is eliminated after the formation of a pattern for microstructure development. These obstacles encompass ensuring thorough removal of undesired material while safeguarding the integrity of the underlying structures. Additional concerns may involve regulating the adherence of the photoresist, preventing residue formation, and handling the stresses on the wafer that could lead to cracking or peeling.

(b) What are the possible downsides of dicing? Why do you need to protect the wafer before dicing?

The potential drawbacks associated with dicing are linked to the procedure of slicing a wafer, housing microchips, into separate dice. Dicing can induce mechanical strain resulting in chip flaws, fractures, or impurities. Hence, safeguarding measures are imperative: a protective coating or tape is employed on the wafer surface to alleviate these potential hazards. Preserving the integrity of the wafer is paramount to avert harm to the intricate structures on the chips throughout the dicing operation. Moreover, minimizing contamination is vital, as particles generated during dicing could compromise the functionality of the chips.

5. Attendance (10 points)

Leave this answer blank – to be used by TAs.