909. Outline the process of refining raw quartzite to electronic grade silicon (EGS).

910. How is EGS transformed into single crystal silicon? Describe the process in detail.

911. A collinear equidistant four point probe (4PP) is used as a fast and nondestructive test for the determination of a wafer’s resistivity.

Assume one of the outer probes of the 4PP in use has been damaged and is bent from its normal position, as shown below. Note that the points remain collinear.

\[ \begin{array}{cccc}
    a & c & d & b \\
    \downarrow & \downarrow & \downarrow & \downarrow \\
    |s + \delta s| & \\
\end{array} \]

a. Derive an expression for the voltage between the two inner probes of the damaged 4PP using the general form of the equation presented in lecture. Label this voltage \( V^* \).

b. Normalize this voltage as \( \left( \frac{V^*}{V} \right) \) where \( V \) is the value for \( \delta = 0 \).

c. What is the percent error in measured \( \rho \) if \( \delta = 0.05 \)?

912. A 100mm diameter, 475\( \mu \)m thick phosphorus doped silicon wafer is measured with a 4PP having a probe spacing \( s = 25 \) mils. The probes are centered over the wafer and a 1mA current is injected and collected with the two outer probes.

a. Calculate \( D/s \) and find the correction factor \( k \) from GT-3.

b. Calculate \( t/s \) and find the correction factor \( a \) from GT-2.

c. From the data sheet supplied by the manufacturer, \( \rho = 1 \, \Omega \cdot \text{cm} \). What would be the sheet resistance \( (R_s) \) of this wafer? What is the expected voltage reading from the two inner probes?

d. The actual measurement from the 4PP is 20 \( \Omega \). What is the resistivity? What is the voltage measured with the two inner probes?

e. The resistivity specified by your company when the wafers were ordered was 1 \( \Omega \cdot \text{cm} \) \( \pm 10\% \). Is this wafer in spec?

f. What is the doping concentration of the wafer? (use GT-1 and the measured resistivity)