Cell Processing and Sheet Resistance

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15 November 2004
Outline

• Recap of Resistivity Equations
• Connection to Cell Geometry
• Discussion of Cell Processing and Geometry
• Series Resistance Effects Throughout
Series Resistance

- \( V = IR \)
- \( R = \text{sum of terms:} \)
  - Bulk silicon resistance
  - Sheet Resistance of top Layer
  - External Load
Basic Conductivity Relations

\[ \sigma = \frac{\Delta J}{\mathcal{E}} = q(n \mu_n + p \mu_p) \]

\[ \rho = \frac{1}{\sigma} = \frac{1}{q(\mu_n n + \mu_p p)} \]
Mobility vs. Doping

Red = n-type, Blue = p-type

Resistivity vs. Doping

Red = n-type, Blue = p-type

Sheet Resistance Equations

\[ R_s = \frac{\rho}{t} \]

\[ R = R_s \frac{L}{W} \]
Sheet Resistance vs. Doping

Red = n-type, Blue = p-type --- 14 mil Si wafer Thickness

Case Study on Single Crystal Cell Processing Sequence

• Credit to SJSU/Prof. David Parent
• Processing Sequence
• Data
Fabrication of Solar Cells

• Diffuse donor region
• Apply aluminum coating to front of wafer
• Photolithography to define solar cell pattern
• Etch aluminum to create solar cell pattern
• Apply anti-reflection coating *
• Apply aluminum coating to back of wafer
• Anneal wafers
• Remove outer edges of wafers
Diffuse Donor Region

• Spin on phosphorous doped silica glass
  ▪ Apply 3ml to front of wafer
  ▪ Spin @ 3000 rpm for 20 seconds

• Diffuse in furnace
  ▪ Heat furnace to 1100°c
  ▪ Push in wafers ½ inch per 15 seconds
  ▪ Diffuse for 1 hour
  ▪ Pull out wafers ½ inch per 15 seconds

• Makes wafer into a large diode
Apply Aluminum Coating

• Desire 2 microns thickness
• Sputter on the aluminum
  ▪ Accurate and precise
  ▪ Fast (2 microns onto 8 wafers in 15 min.)
  ▪ Prone to breaking down

- Or -

• Evaporate on aluminum
  ▪ Reliable
  ▪ Slow (2 microns onto 24 wafers in 3 to 4 hours)
  ▪ Not very precise
Photolithography

- Apply 3ml photo-resist; Spin for 20s @ 5000 rpm
- Soft bake for 90°C for 30 minutes
- Place solar cell mask on wafer
- Place both into wooden and glass holder
- Expose under lamp for 2 minutes
- Develop for 15 seconds
Etch Aluminum

- Etch exposed Al using hot sulfuric acid
- Rinse with DI water
- Remove remaining PR using plasma etch
Apply Anti-reflection Coating

- Apply 3ml Titaniumsilica film
- Spin @ 3000 rpm for 20 seconds
- Spreads film to thickness of 1000 angstroms
Anneal Wafers

- Anneal for 30 minutes in furnace
- Creates ohmic contact between Al and Si
Cleave Edges of Wafers

• Need to prevent shorting along edge of wafer
• Use scribe tool to score along edges of solar cell
• Cleave wafer along scoring
Testing the Solar Cells

- Scored, or roughened, back of cells
- Placed onto roughened aluminum wafer
- Used probes to make contacts
  - One probe onto the corner of the cell’s al grid
  - One probe onto the al wafer
- Tried various methods for making good contacts
  - Solder paste
  - Silver paste
  - Copper tape
Testing the Solar Cells

• Illuminated the cell
  ▪ Used 75W light bulb at 3cm distance

• Connected voltmeter to probe terminals
  ▪ Gives open circuit voltage

• Connected current source to probe terminals
  ▪ Ran current against that being generated by the cells
  ▪ Measured voltage for different current levels
IV Curves for One Half of Grid Solar Cells

Pmax S13A = 41.9 mW  Pmax S6A = 49.8
IV Curves for Small Grid Solar Cells

$P_{max} S21 = 61.4 \text{ mW}$ \hspace{1cm} $P_{max} S8 = 71.5 \text{ mW}$
Metal Contact Geometry on Cells
Sheet Resistance vs. Doping

Doping concentration [cm$^{-3}$]

Red = n-type, Blue = p-type --- 14 mil Si wafer Thickness