R&D on Shell Solar's CZ Silicon Product Manufacturing

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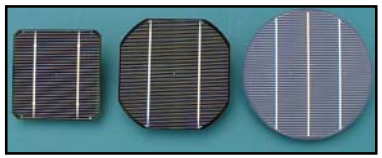
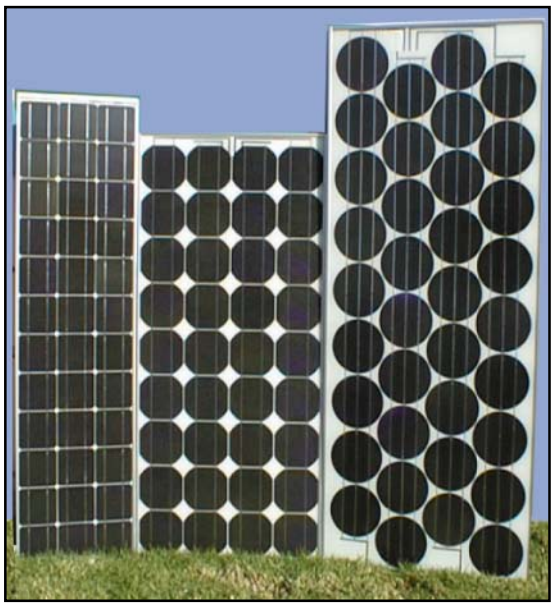
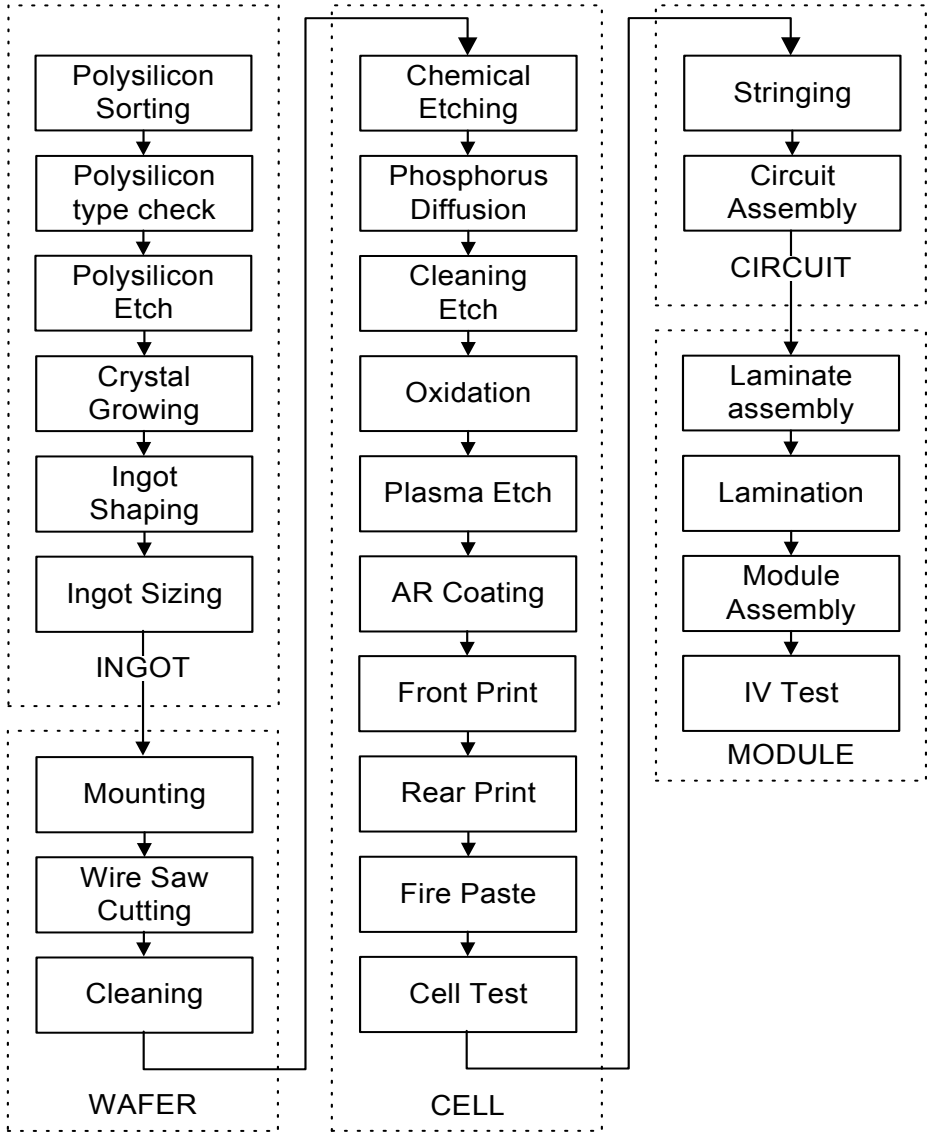
Shell Solar Industries

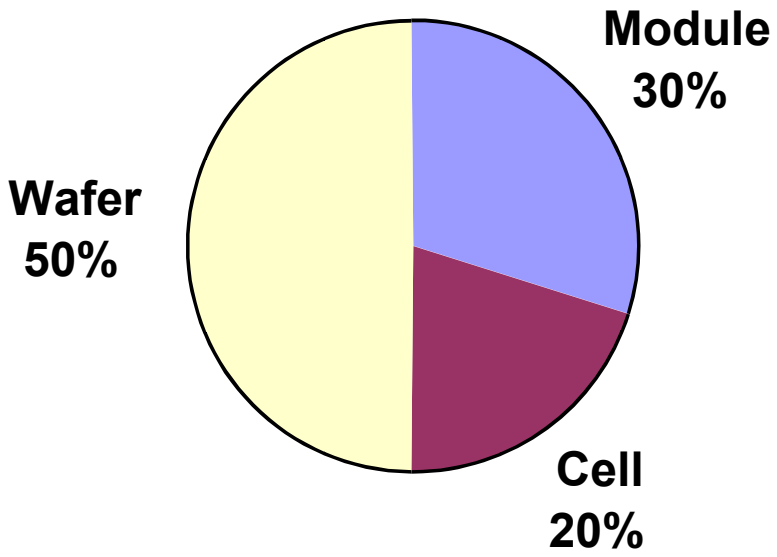
Crystalline Process Flow



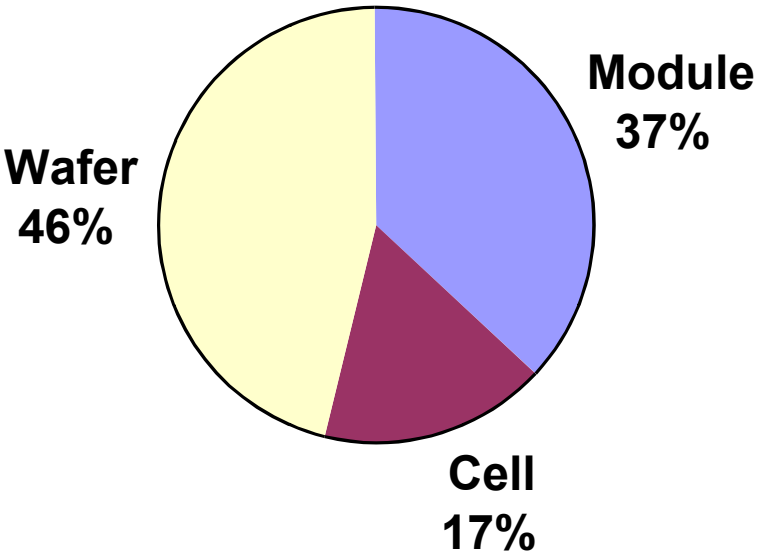




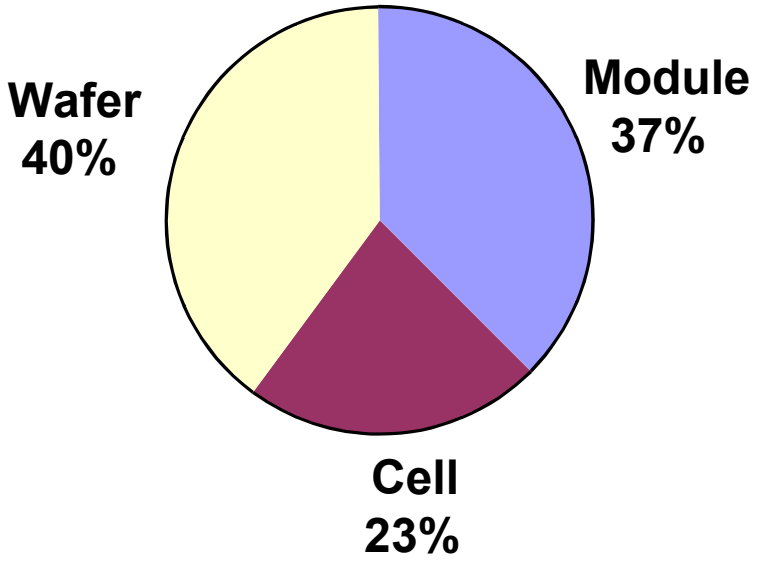
Components of Module Cost- Start of PVMat Programs

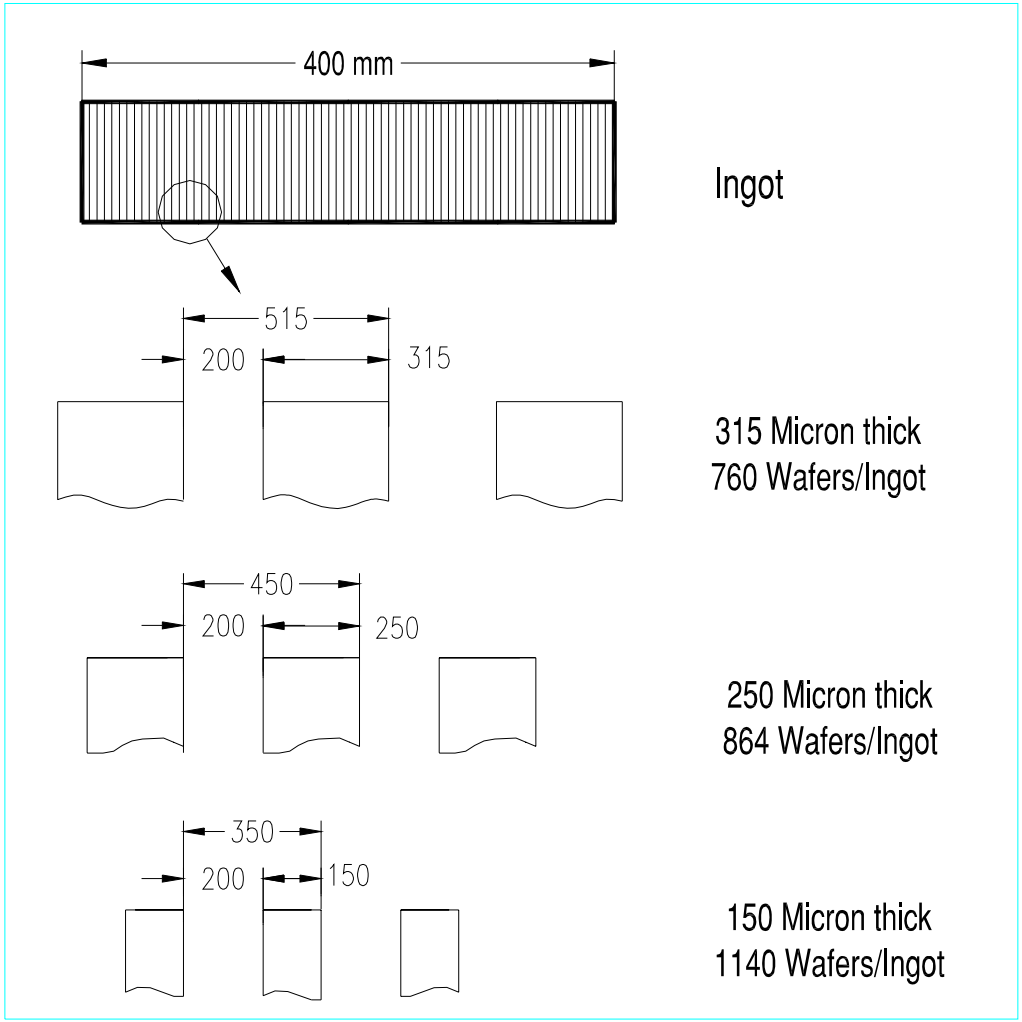


Components of Module Cost-Current Costs



Components of Module Cost- Thin Wafer/High Efficiency Cell





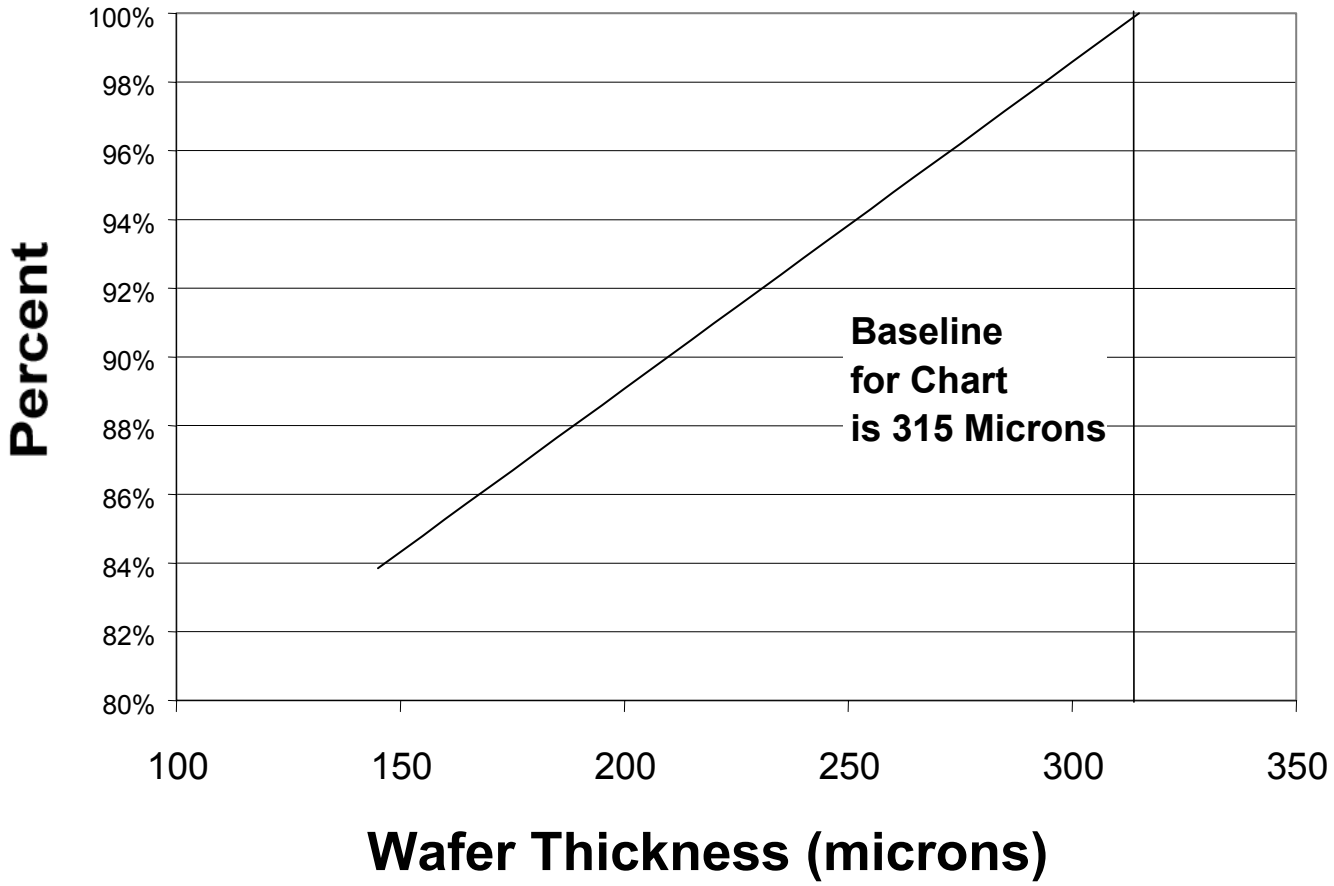
Thinner wafers increase silicon utilization

315 microns- +15%

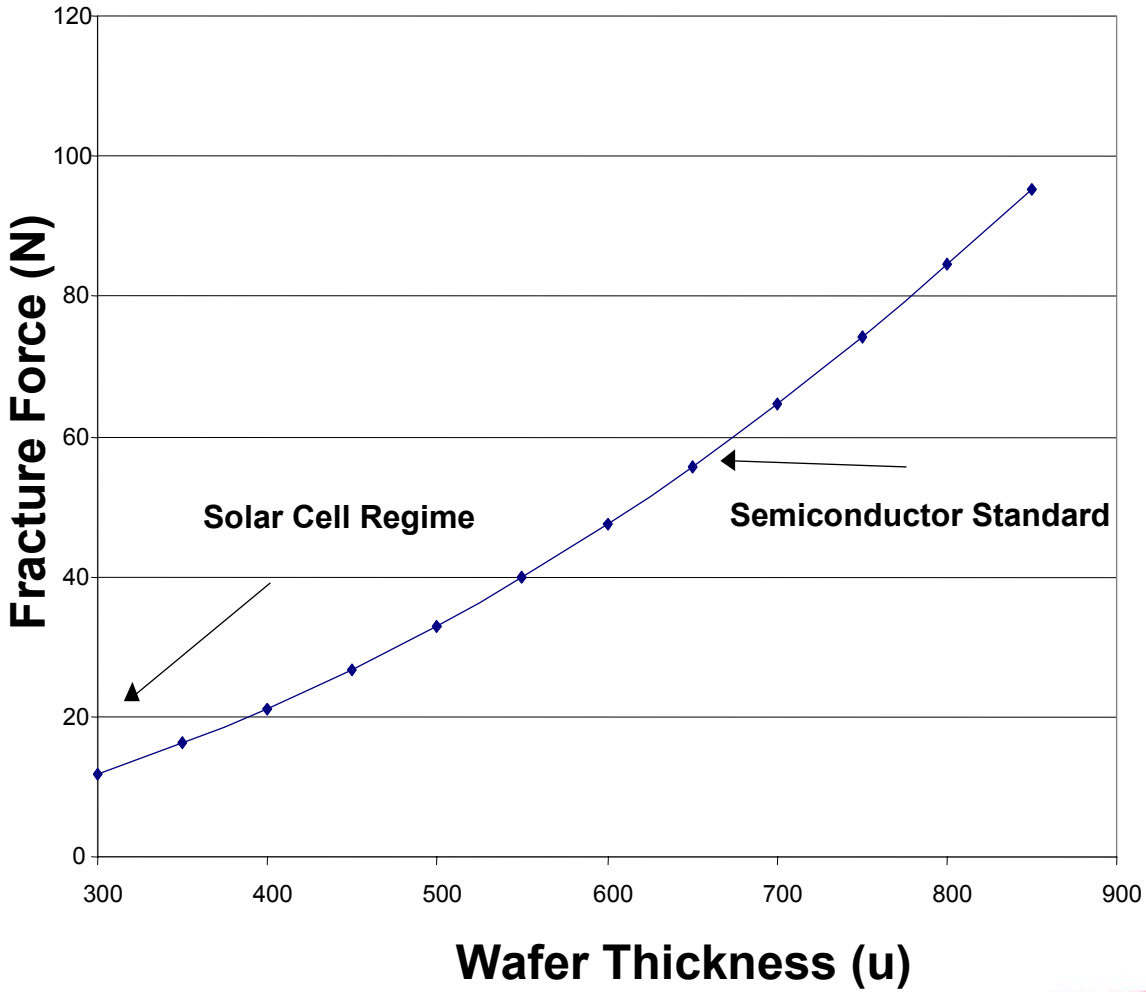
250 microns- +15%

150 microns- +25%

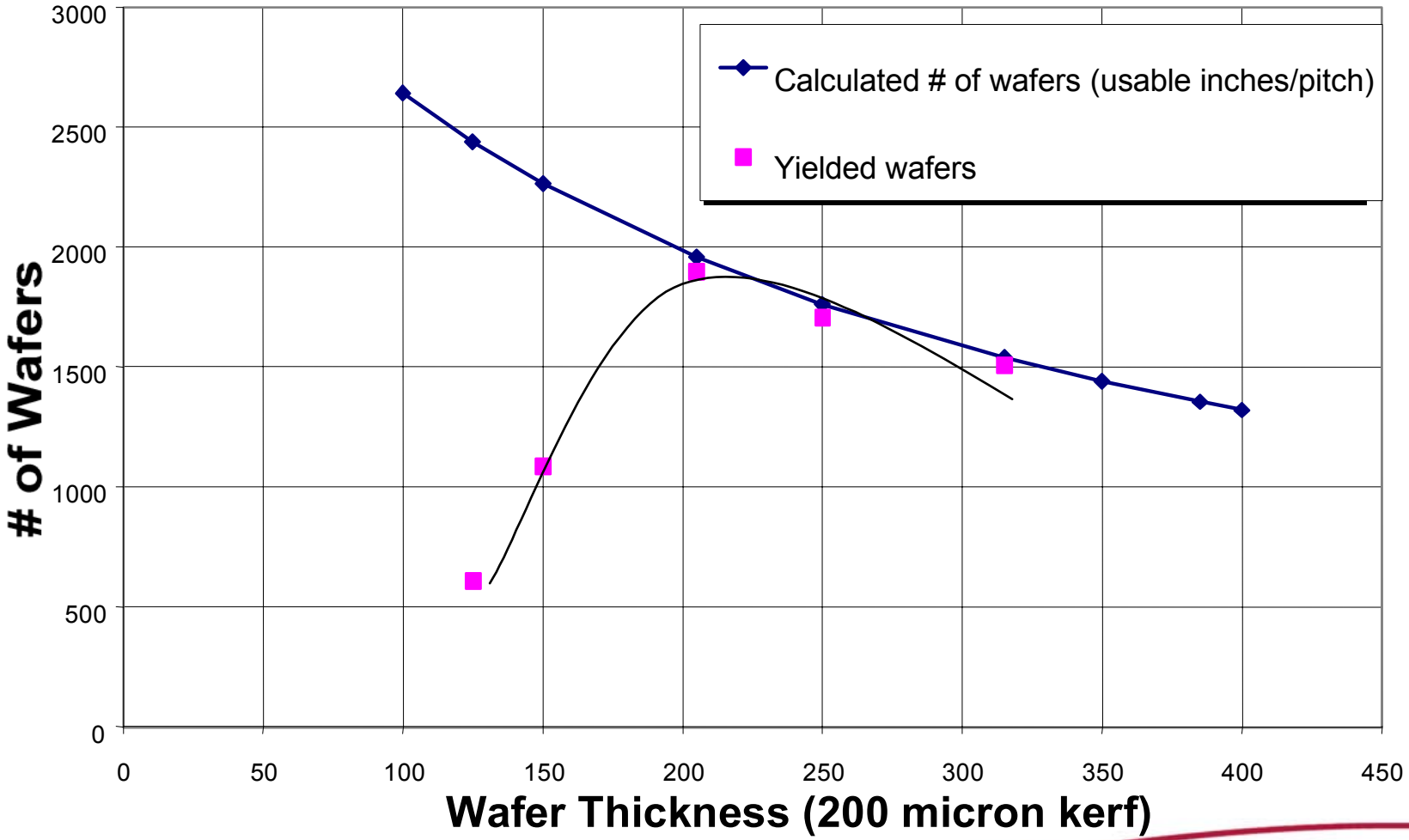
Percent Reduction of Current Cost



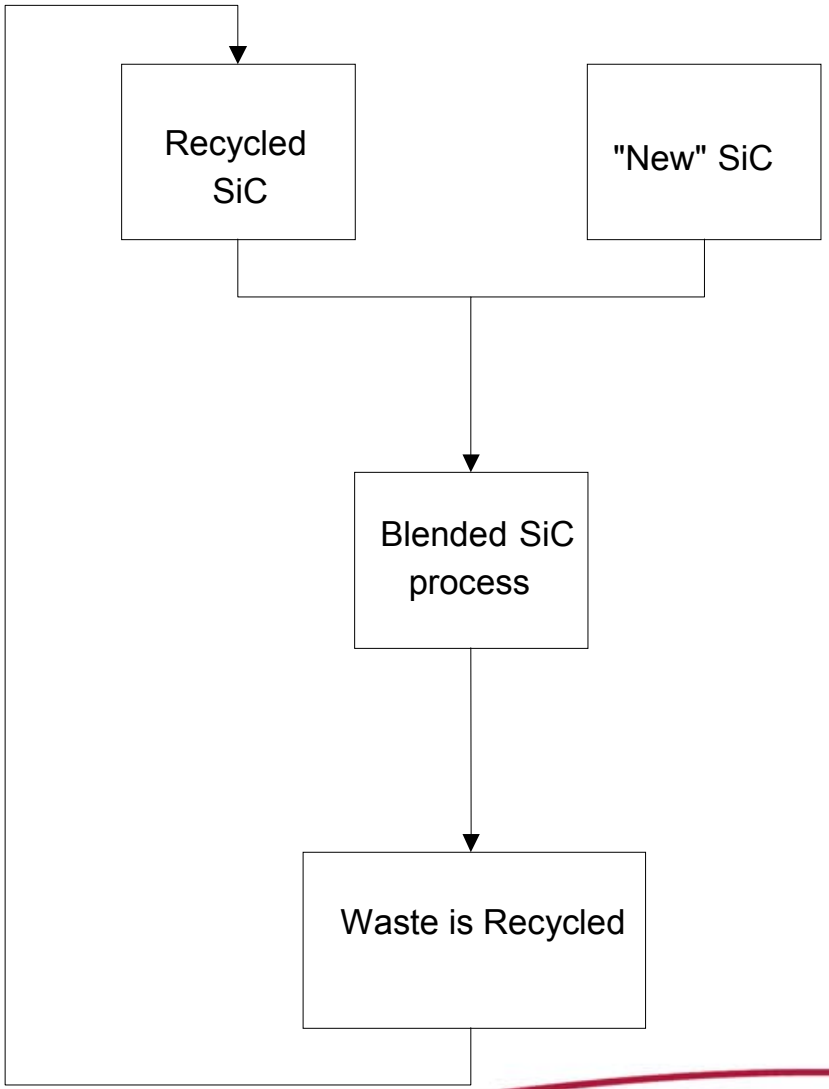
Fracture Force vs Thickness



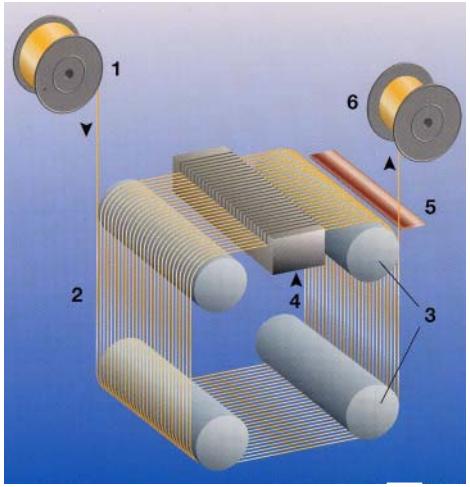
Wafer Yield vs. Thickness



Silicon Carbide Recycle and Re-use Process

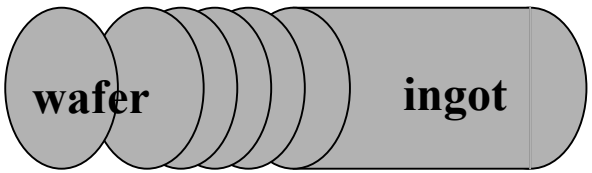


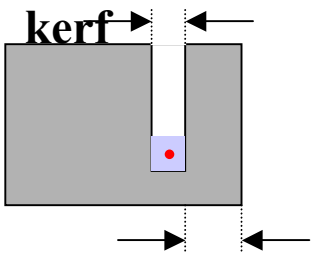
Wafer Slicing - Ingots are mounted and sliced using advanced wire saw technology. Wafers are loaded into cassettes and prepared for cleaning and etching.



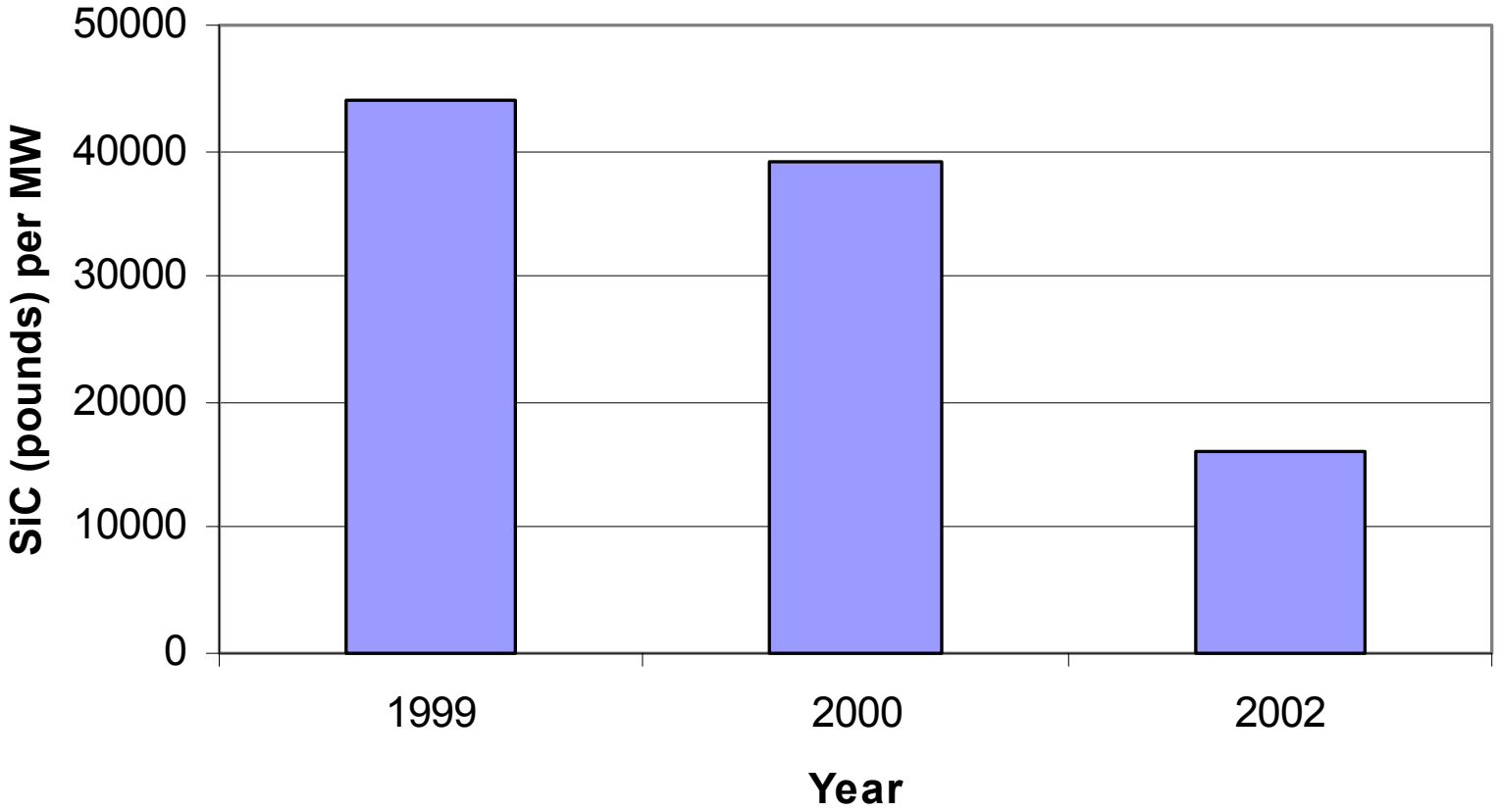
wire

abrasive

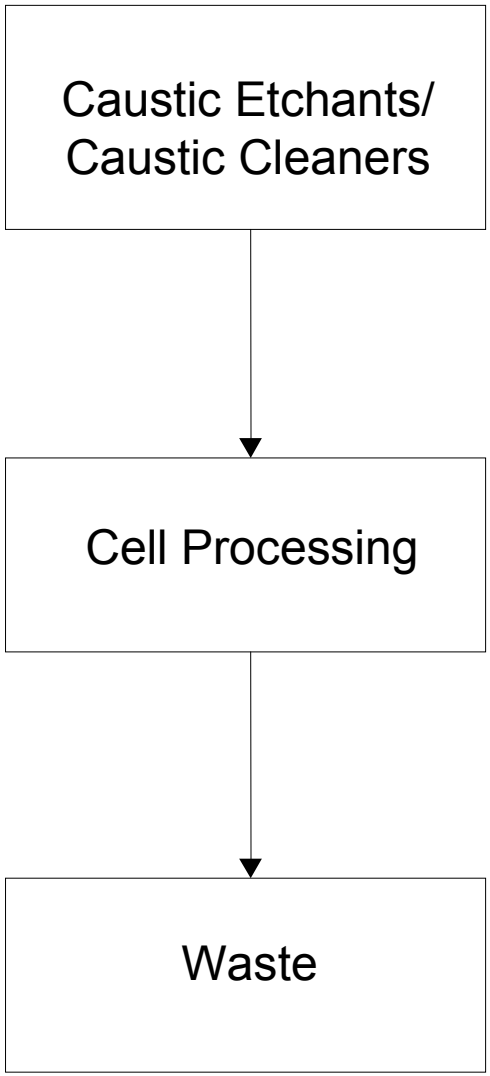




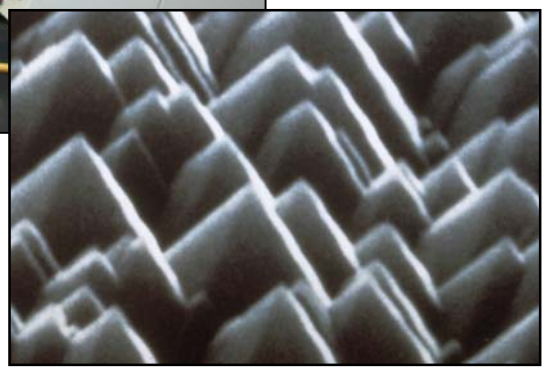
Silicon Carbide Waste Reduction Program
PVMat



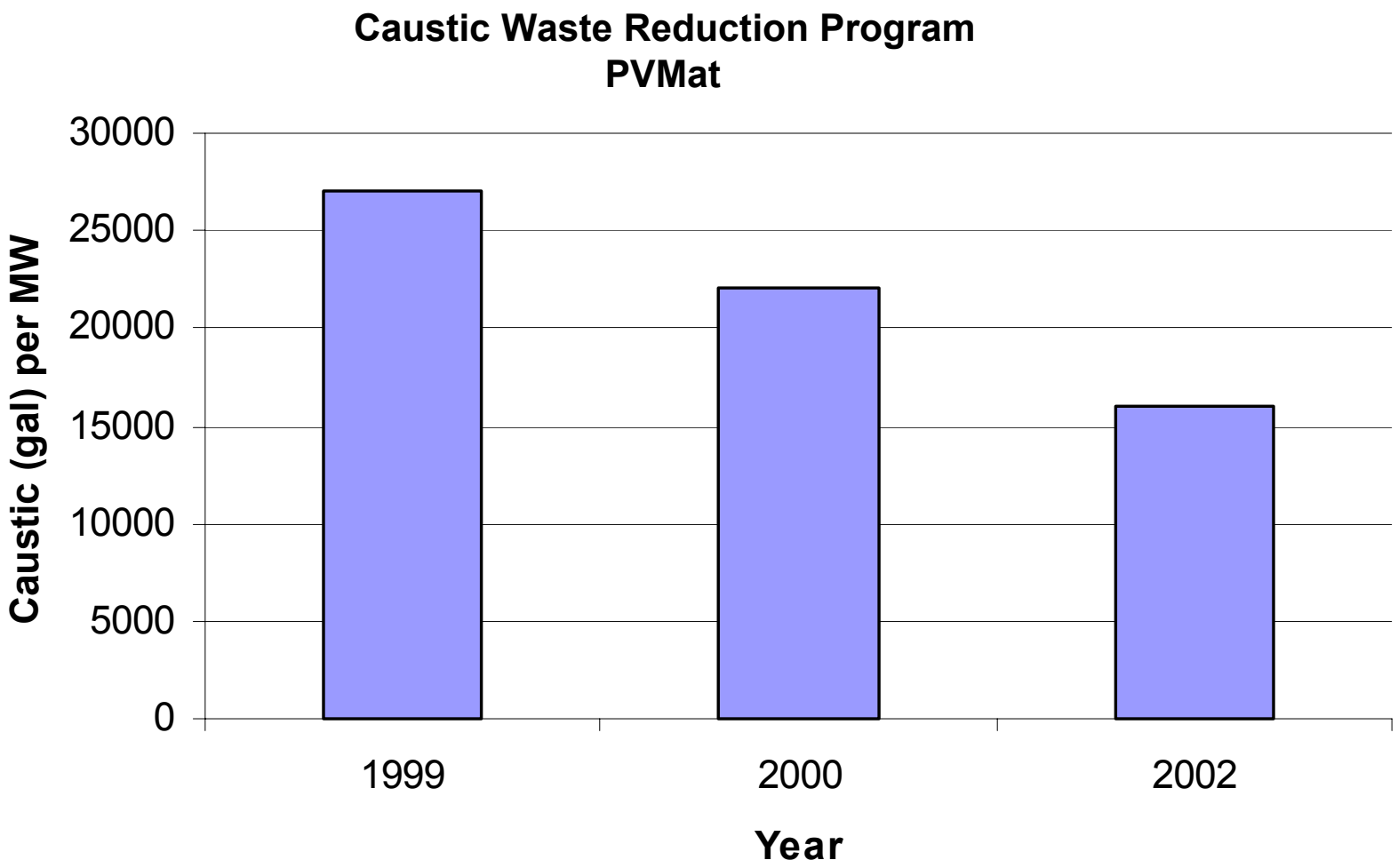
Caustic Use in Cell Processing



Cleaning and Etching - Wafers are cleaned, damage-etched and texture etched prior to diffusion and oxidation.

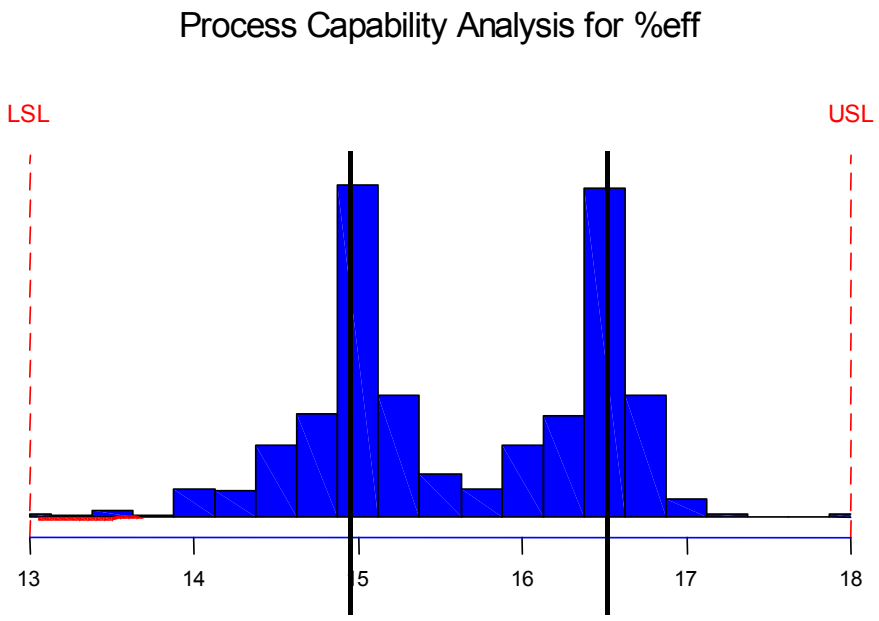


Wafer substrate

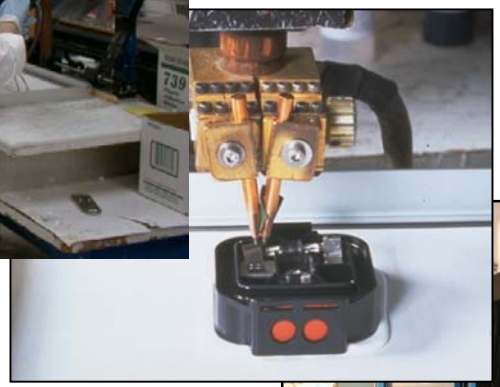

Caustic Waste Reduction Program
PVMat
Caustic (gal) per MW
30000
25000
20000
15000
10000
5000
0
1999
2000
2002
Year

10 % Efficiency Improvement

(Boron Back Surface Field and Silicon Nitride)



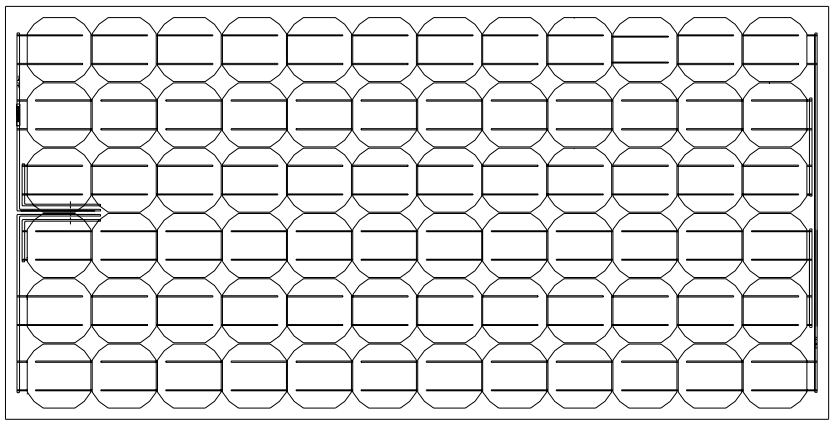
14.8% **16.5%**



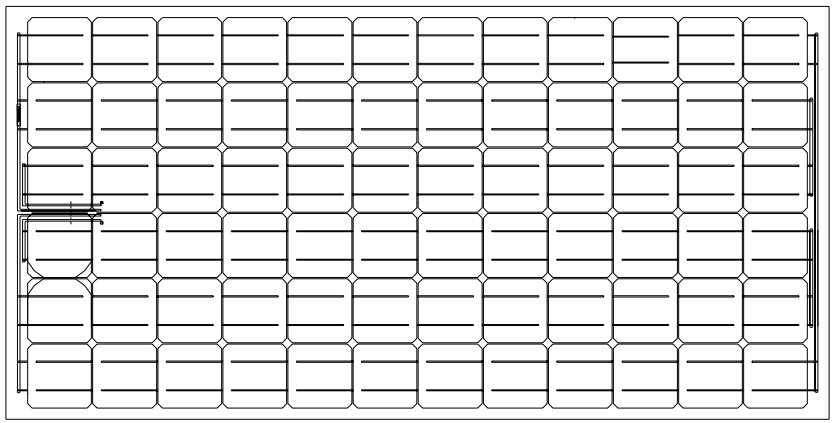
Module Assembly and Test - Laminates are framed, junction box and diodes are added. Modules are tested with a solar simulator, inspected, labeled, serialized and packaged for shipment.

Module Efficiency Improvement

10% Power Increase

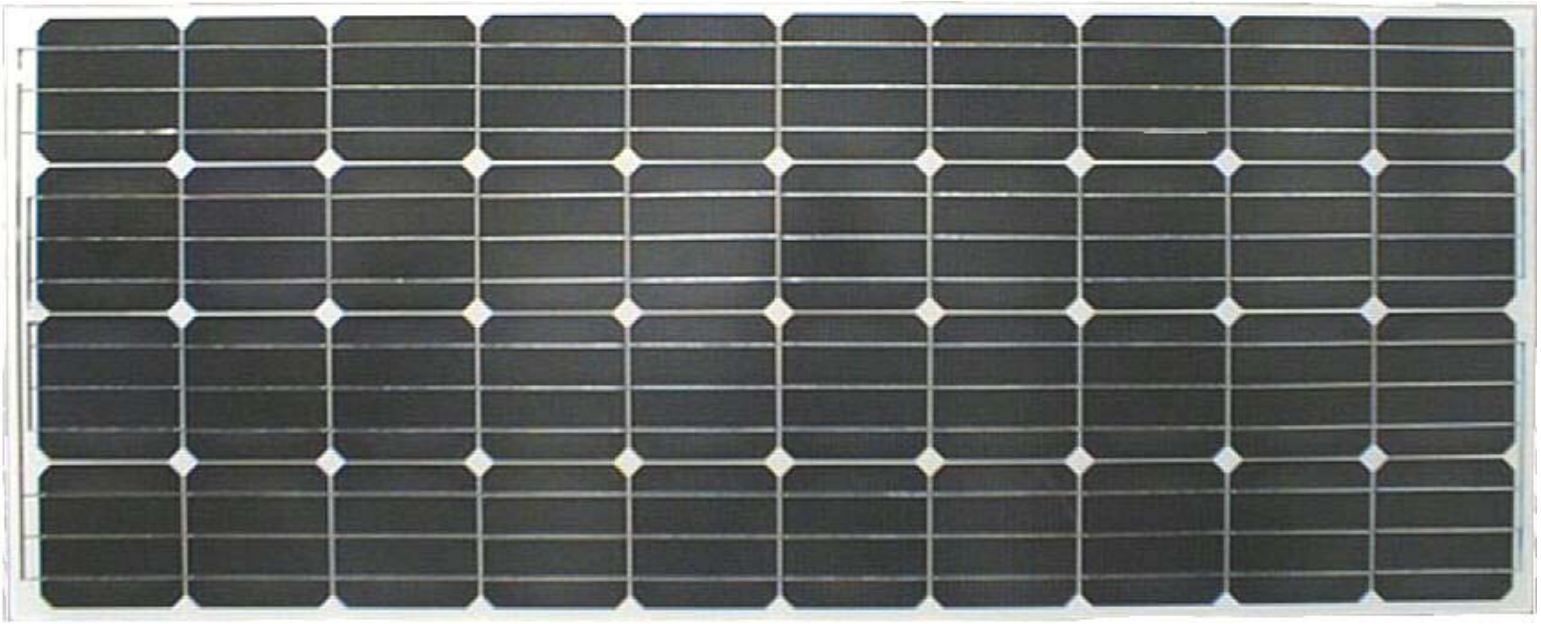


145-150 Watt Average Power

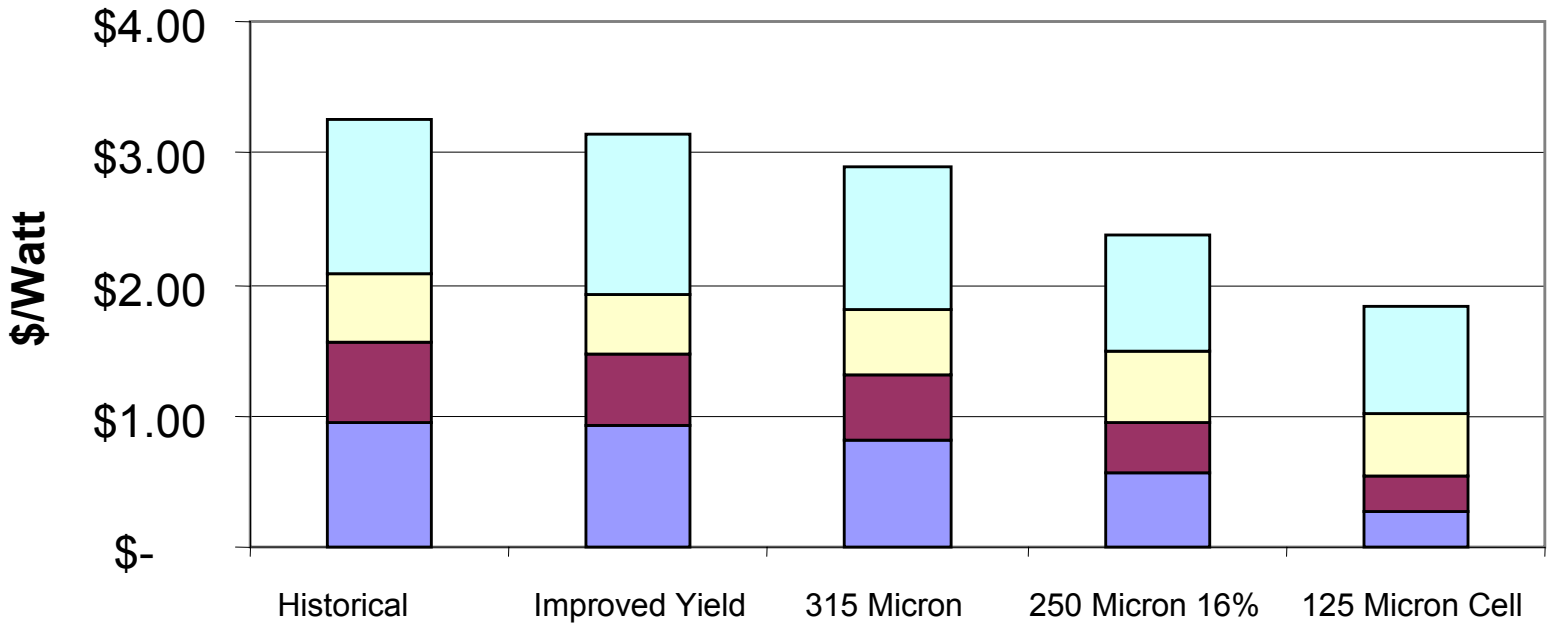


160 Watt Average Power

80 Watt Module with 125 mm Cells



Cost per Watt at Module-Camarillo



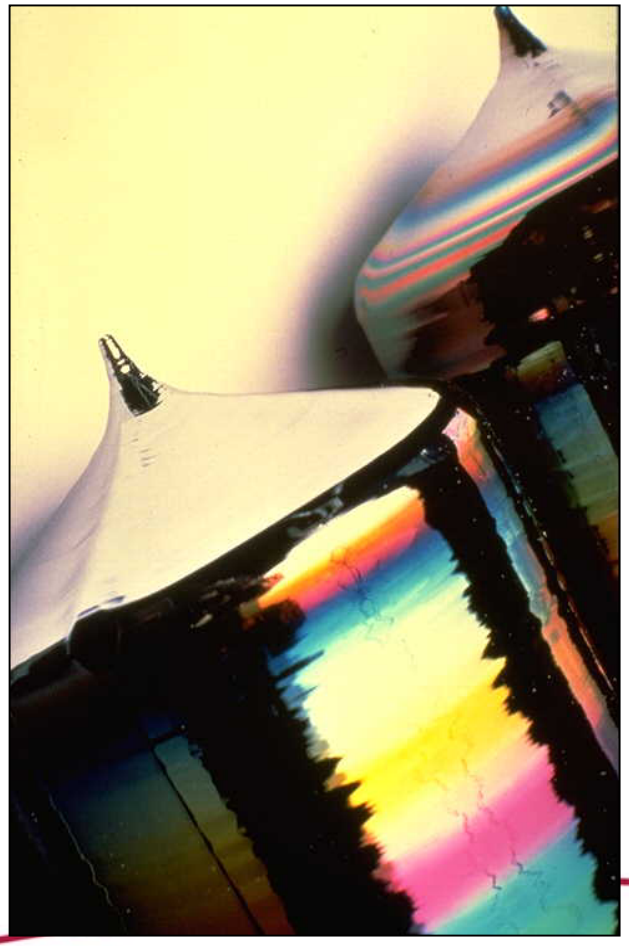
Cost Reduction Summary

- Wafer cost contributions reduced from 50% to 40% of total cost of production
- Cell costs increased as a result of added process steps for efficiency improvement
- Module costs now represent the highest portion of cost reduction opportunity for both Silicon and Thin Film

What does the future hold for PV Manufacturing?

Silicon-based technologies

- Silicon will remain the dominant technology for some time
  - Market acceptance
  - Proven reliability
  - Wide array of products
- Mature technology
- Can expect to see
  - More automation
  - Better material utilization-
    - Need better slicing technology
    - Thinner wafers
  - Better cell performance
    - Increased Efficiency
- Will still suffer from
  - Process complexity
  - High material cost- particularly in module assembly
  - Solar grade silicon quality and cost



What does the future hold for PV Manufacturing?

Thin film-based technologies

- Thin films will gradually overtake silicon
- Many issues must be addressed
  - Market acceptance
  - Proven reliability
  - Product offering
- Emerging technology
- We can expect to see:
  - Monolithic structure will prove more reliable
  - Lower cost of material (particularly indirect)
  - Fewer process steps
  - Improved efficiency
  - Better cycle times
  - Lower capital cost per watt peak
  - Ultimately lower prices
- All thin films share many common steps
  - Cost per sq. ft is comparable
  - **Efficiency per sq. ft. will determine value in the market**

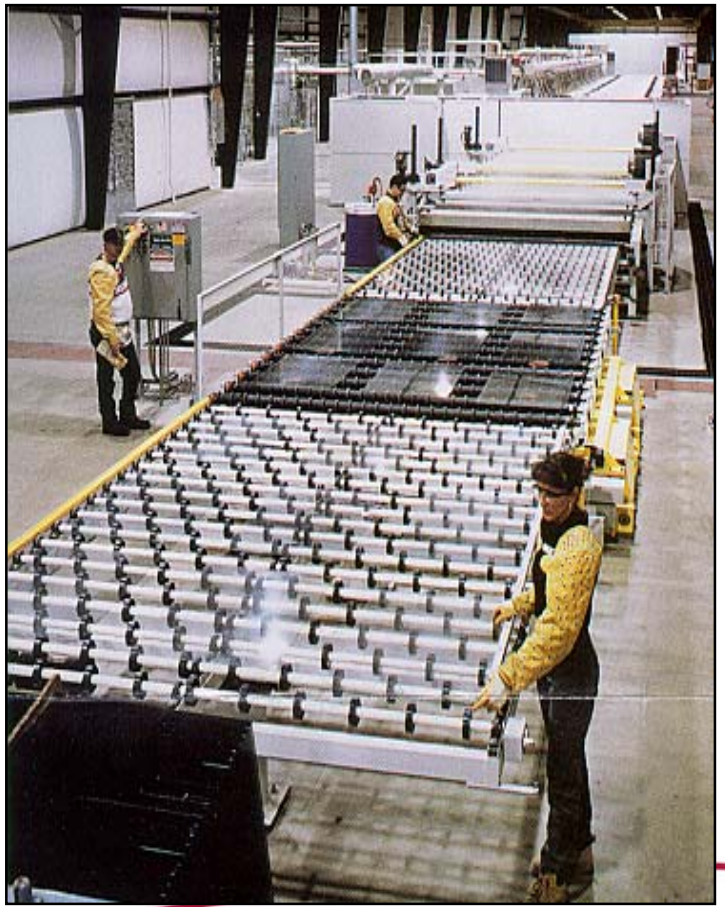


Photo courtesy of GL Coating Corp