EELE408 Photovoltaics

Lecture 16: Silicon Solar Cell Fabrication Techniques

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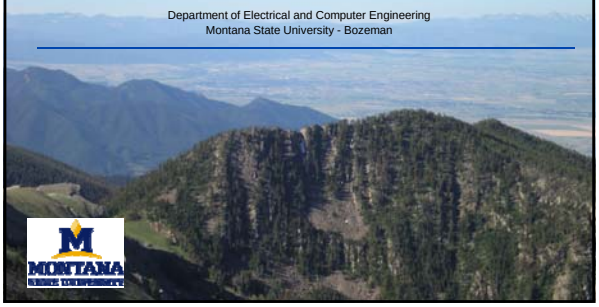


Screen Printed Solar Cells

- Starting wafer is about 0.5 mm thick and 10 x 10 cm^2. The wafer is p-type and lightly doped with Boron ($10^{16}/cm^3$)

Screen Printed Solar Cells

- Saw Damage Etch
  - The starting wafer is uneven due to saw damage and coated in cutting fluid
  - A strong alkaline etch cleans the wafer and removes the damaged outer layer of silicon

Screen Printed Solar Cells

- Junction Formation by Doping
  - Heating the wafer (800 -1000ºC) in a phosphorus atmosphere cause the outer surface to be doped to n-type silicon

Phosphorus atoms produce an external skin of n-type silicon

p-type bulk

Screen Printed Solar Cells

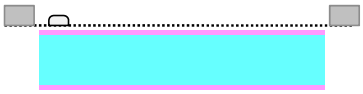
- Edge Isolation
  - Wafers are stacked on top of each other for removal of the junction at the edge of the wafer

Screen Printed Solar Cells

- Edge Isolation
  - The edges of the cells are etched by a highly reactive plasma gas to remove the edge junctions

Screen Printed Solar Cells

- Screen Printing the Rear Contact
  - A screen is lowered onto the rear of the cell along with the metal paste



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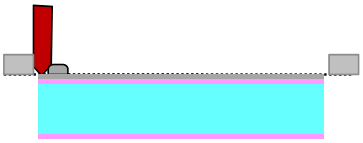
Screen Printed Solar Cells

- Screen Printing the Rear Contact
  - A squeegee drags across the screen forcing the metal past through the holes in the screen
  - The screen is removed leaving a thick layer of wet metal paste



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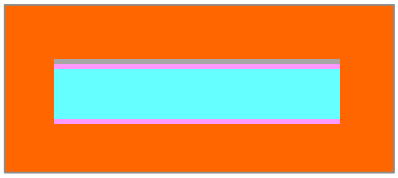
Screen Printed Solar Cells

- Screen Printing the Rear Contact
  - The paste is dried in an oven to drive off the organic solvents and binders



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Screen Printed Solar Cells

- Firing the Rear Contact
  - The wafer is placed in a second furnace at a much higher temperature to diffuse the metal into the silicon

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Screen Printed Solar Cells

- Firing the Rear Contact
  - The firing destroys the rear n-layer and makes contact with the p-type bulk silicon
  - The wafer is flipped over for printing on the front

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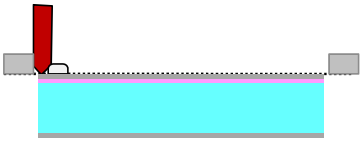
Screen Printed Solar Cells

- Printing the front contact
  - The front contact is printed in a similar manner to the rear contact
  - A pattern of fine lines is used to prevent shading of the cell



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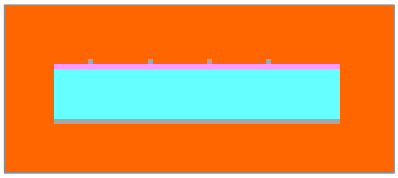
Screen Printed Solar Cells

- Firing the contacts
  - The furnace heats the cell to a high temperature to diffuse the metal into the silicon
  - The finished cell is ready for encapsulation into a module



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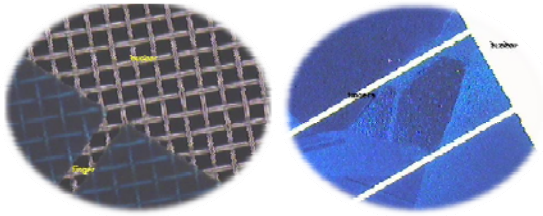
Screen & Metal Closeup



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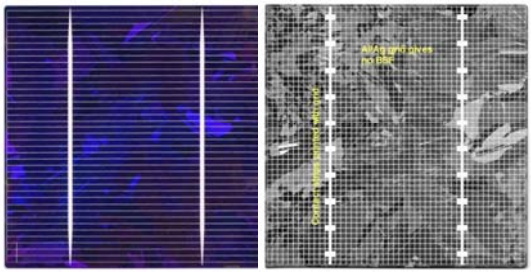
Front and Back of Screen Printed Solar Cell



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Crystallization Furnace for Ingot Production

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Sawing Ingots into Blocks

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Automated Loading of Diffusion Furnace

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Diffusion Furnace

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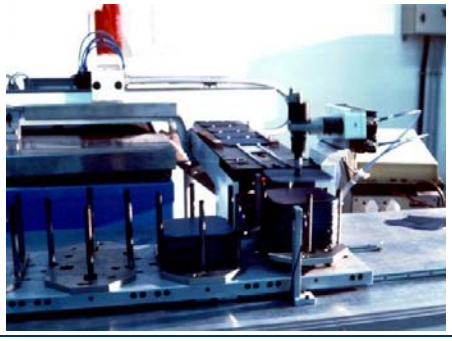
Diffusion Furnace Unloading



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Camera Aligned Screen Printing Machine

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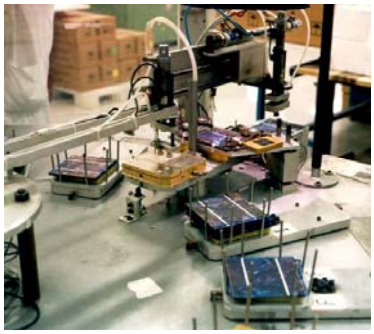
Testing and Sorting by Efficiency



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Rear Panel before Lamination

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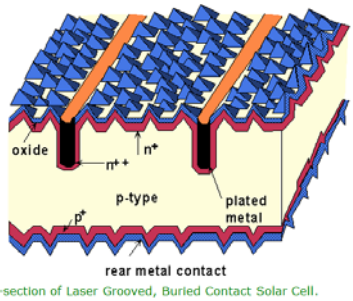
Buried Contact Solar Cells

- High Efficiency
- Laser groved then plated to fill groves
- High aspect ratio
- High density of fingers
- Textured front surface



Cross-section of Laser Grooved, Buried Contact Solar Cell.

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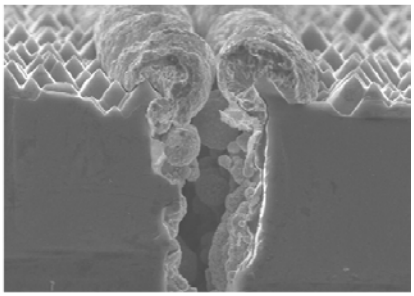
Laser Groove



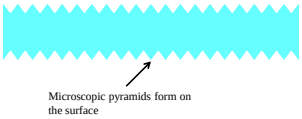
Cross section of a partially plated laser groove.

Buried Contact Solar Cell

- Saw Damage Etch
  - The starting wafer is uneven due to saw damage and coated in cutting fluid
  - A strong alkaline etch cleans the wafer and removes the damaged outer layer of silicon

Buried Contact Solar Cell

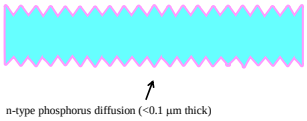
- Texturing
  - A flat silicon wafer has a high reflectivity but this can be reduced by texturing the wafer
  - A second chemical bath etches preferentially along crystal planes



Microscopic pyramids form on the surface

Buried Contact Solar Cell

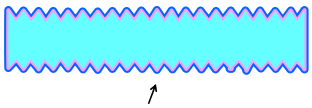
- Junction Forming by Doping
  - Heating the wafer (800 -1000^{0}C) in a phosphorus atmosphere cause the outer surface to be doped to n-type silicon



n-type phosphorus diffusion (<0.1 μm thick)

Buried Contact Solar Cell

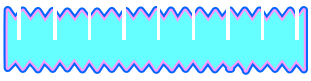
- Growth of Masking Oxide
  - Heating the wafer in the presence of water vapor causes the outer layer to oxidize and turn to silicon dioxide



Thin layer of oxide (<0.5 mm thick)
n-type phosphorus diffusion (<0.1 mm thick)

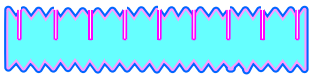
Buried Contact Solar Cell

- Cutting Grooves
  - A series of trenches are laser cut or sawn into the top surface (30μm wide by 80μm deep)



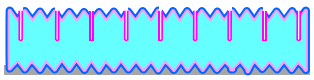
Buried Contact Solar Cell

- Grove Diffusion
  - A second heavier phosphorus diffusion is confined to grooves by the masking oxide



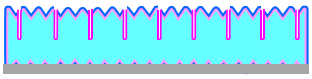
Buried Contact Solar Cell

- Application of Aluminum Back Surface Field
  - A layer of aluminum is applied to the rear of the cell by either evaporation or screen printing



Buried Contact Solar Cell

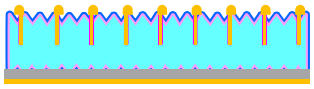
- Sintering
  - The wafer is held at a high temperature for a long period to diffuse the aluminum in to the silicon and drive-in the phosphorus



Buried Contact Solar Cell

- Copper Plating
  - A thin barrier layer of nickel and then copper is plated to exposed areas of silicon by immersion in a bath with metal salts

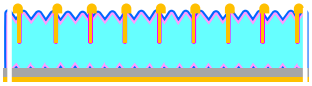
Copper completely fill the surface grooves



A thin layer of copper covers the entire back of the wafer

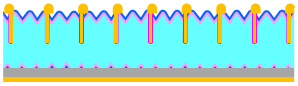
Buried Contact Solar Cell

- Edge Isolation
  - The sides are cut from the cell to isolate the front junction from the rear contact



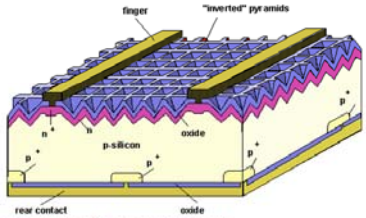
Buried Contact Solar Cell

- Completed
  - The finished cell is ready for encapsulation into a module



PERL Solar Cell

- Passivated Emitter with Rear Local Diffusion
- Near 25% efficiency under AM1.5

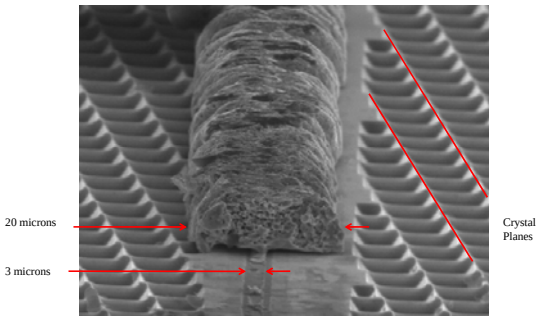


Schematic of high efficiency laboratory cell.

PERL Solar Cell

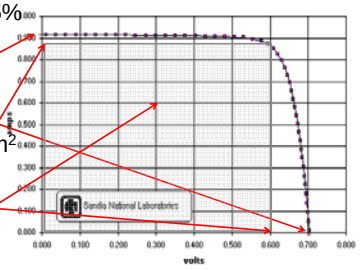
- Passivated Emitter refers to high quality oxide on front surface that significantly lowers surface recombination
- Rear Local is heavily doped only at metal contact regions to minimize recombination at the rear

PERL CELL Image



I-V Curve

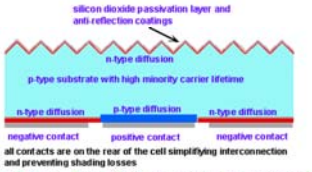
- Efficiency: 23.5%
- Area: 22cm^2
- I_{sc}: 914 mA
- V_{oc}: 703 mV
- J_{sc}: 41.3 mA/cm^2
- I_{mp}: 868 mA
- V_{mp}: 600 mV
- FF: 0.81



IV curve for a solar car cell.

Rear Contact Solar Cells

- Eliminates shading losses by placing both contacts on rear
- Thin high quality material used
- Especially useful for concentrator applications
- Easier to make contact with cells closer together



Back Contact Solar Cell as used in commercial production.