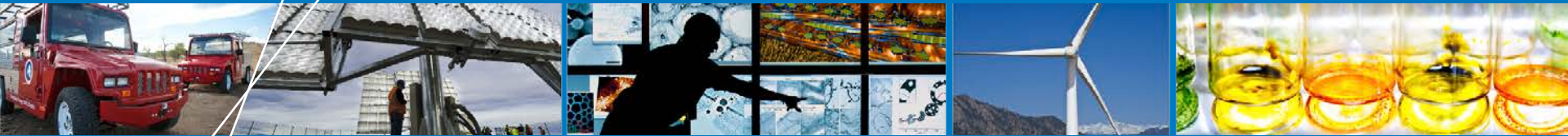


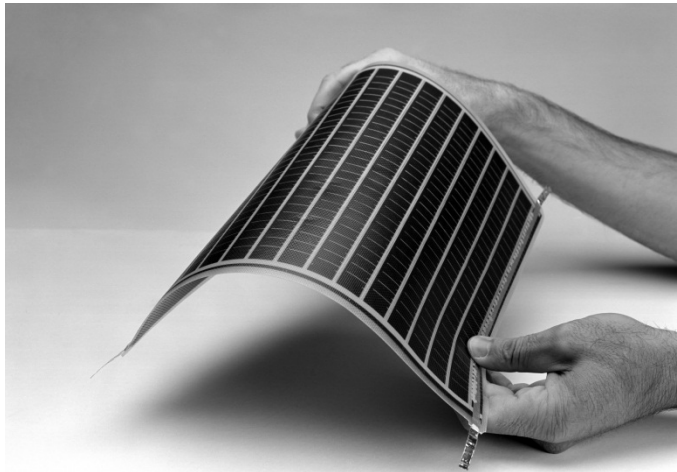
EERE QC Workshop: Overview of Relevant Processes



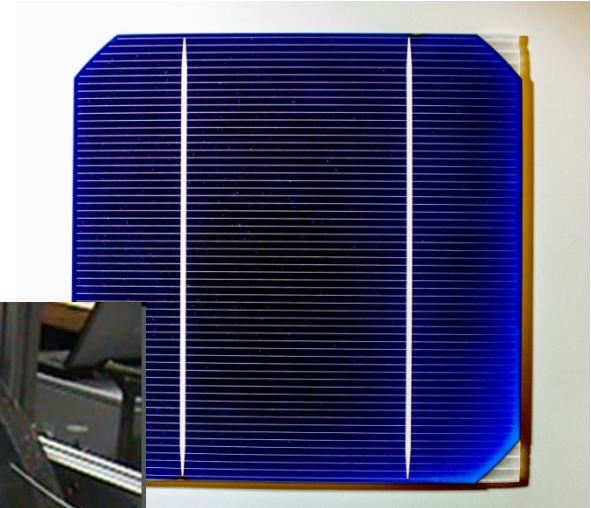
Michael Ulsh, NREL

December 9, 2013

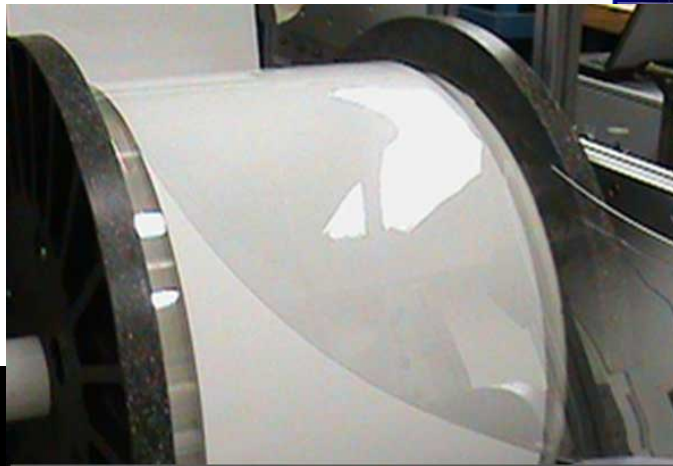
Materials



NREL Image Gallery #03541



NREL Image Gallery #27981



Corning, Inc. Courtesy of Sean Garner



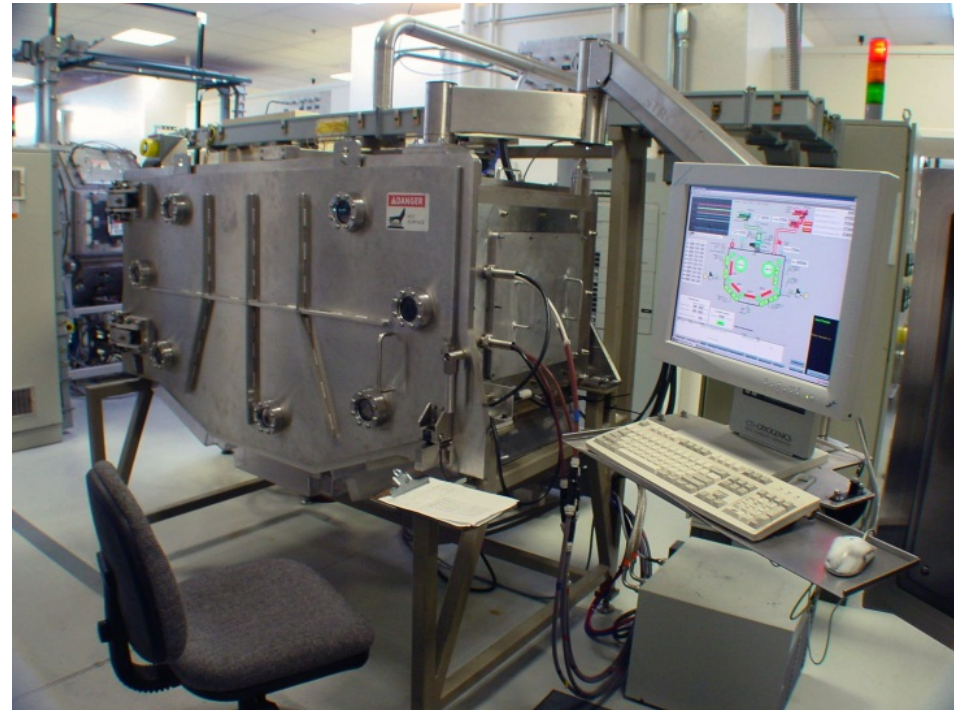
NREL Image Gallery #18745



J. Morgan, "Reduction in Fabrication Costs of Gas Diffusion Layers," DOE Hydrogen Program Annual Merit Review, May, 2011.

Outline

- **Line types**
 - Continuous sheet
 - Continuous part
- **Process types**
 - Atmospheric coating
 - Vacuum coating
 - Sawing/surfacing
 - Drying/curing



NREL Image Gallery #13414



D. Wood, "Advanced Materials Processing for Lithium Ion Batteries," ECS PRIME 2012, October, 2012.

Line Types

- **Continuous sheet**
 - Roll-to-roll
 - Float
 - Belt

Used with permission, Sonotek Corporation



Used with permission, Ballard Power Systems



NREL Image Gallery #08527

Line Types

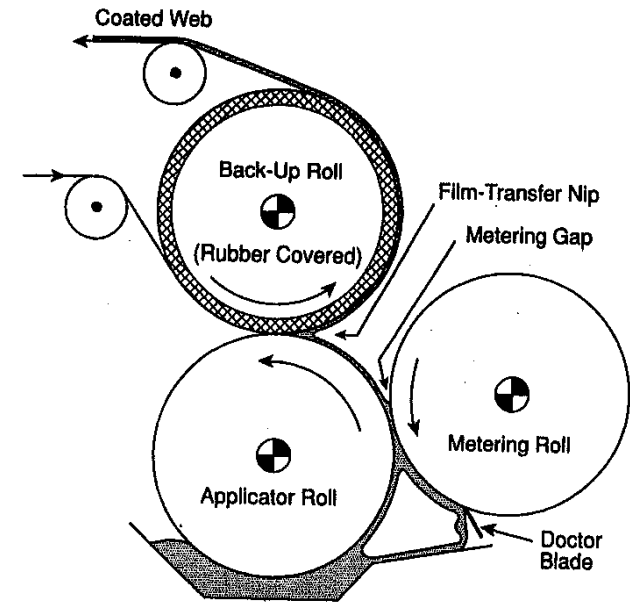
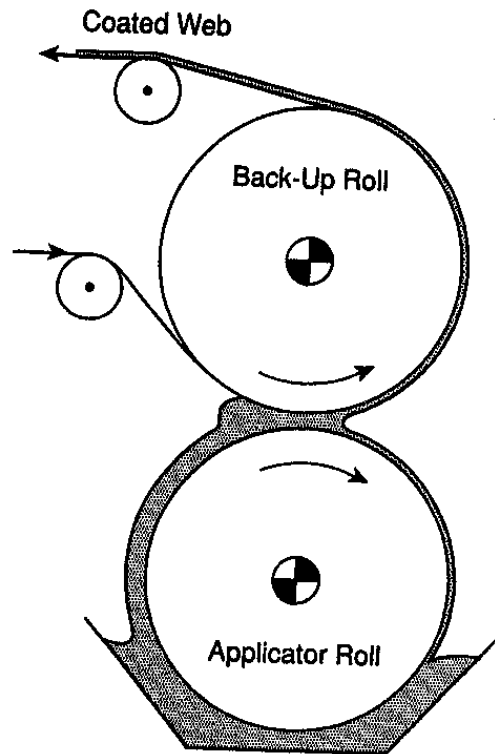
- **Continuous part**
 - Conveyor



L. Thrun, "Manufacturing System Design Analysis of Solid Oxide Fuel Cell Stacks," final report under DOE contract number DE-SC0004845, April, 2011.

Process Types

- Atmospheric coating
 - Roll



E. Cohen, E. Guttoff, "Modern Coating and Drying Technology,"
John Wiley & Sons, 1992.

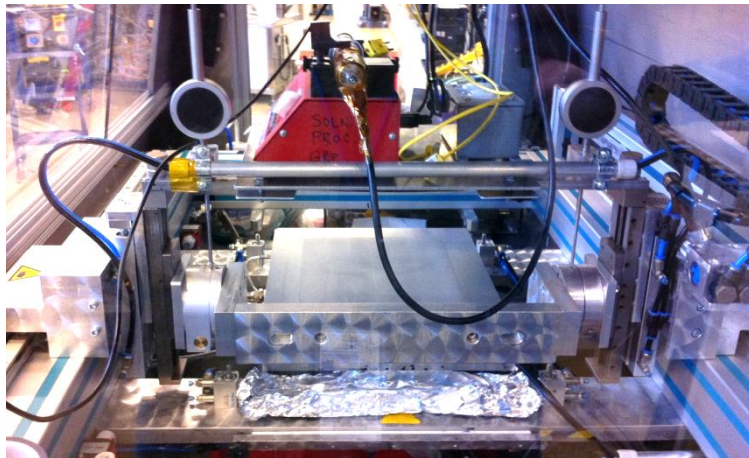
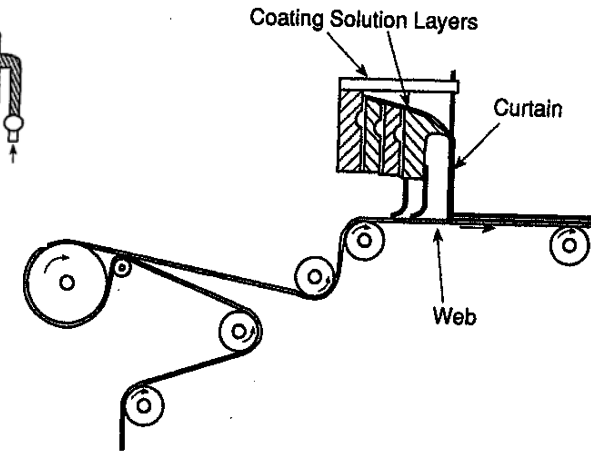
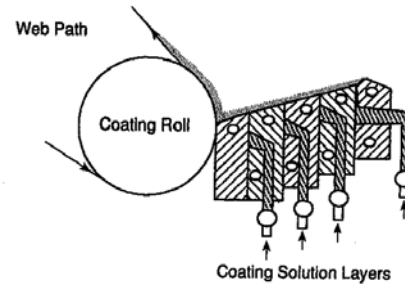
Process Types

- **Atmospheric coating**

- Knife/die

- Multi-layer / slide
 - Curtain
 - Screen printing

E. Cohen, E. Guttoff, "Modern Coating and Drying Technology," John Wiley & Sons, 1992.

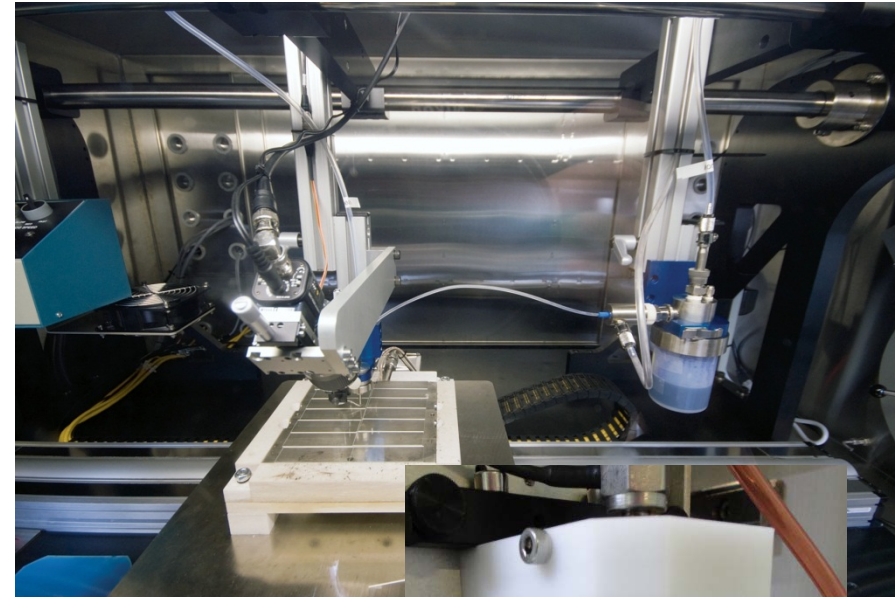


M. Richards, "Solid Oxide Fuel Cell Manufacturing Overview," DOE/NREL Hydrogen and Fuel Cell Manufacturing R&D Workshop, August, 2011.

Process Types

NREL Image Gallery #17120

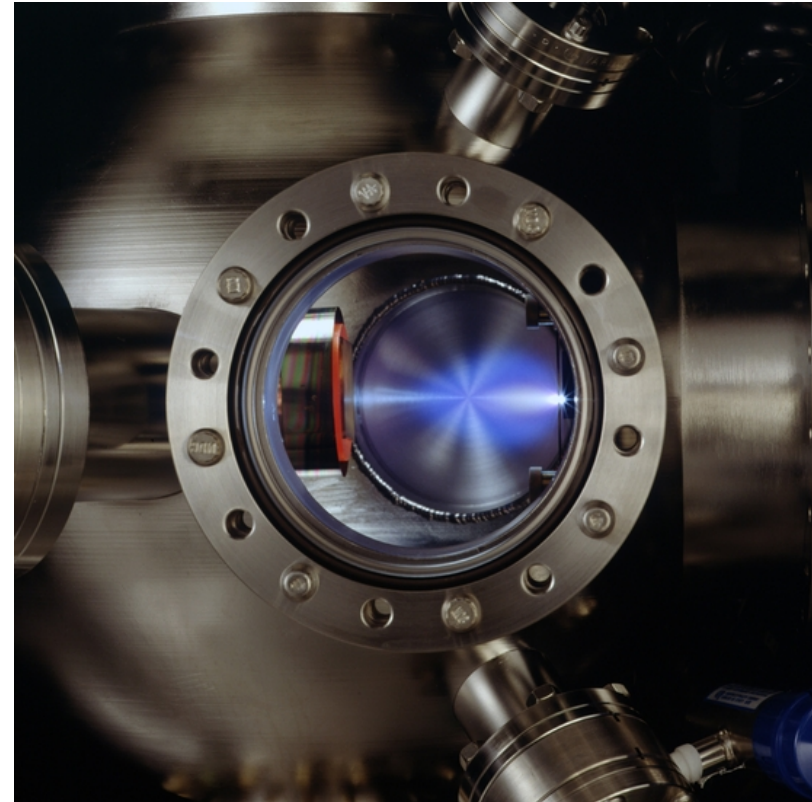
- **Atmospheric coating**
 - Spray
 - Low temperature (jet, ultrasonic)
 - High temperature (arc, plasma)



<http://www.directindustry.com/prod/afs-gmbh/plasma-thermal-spray-guns-61471-575137.html>

Process Types

- **Vacuum coating**
 - Sputter
 - Vapor deposition
 - Evaporation



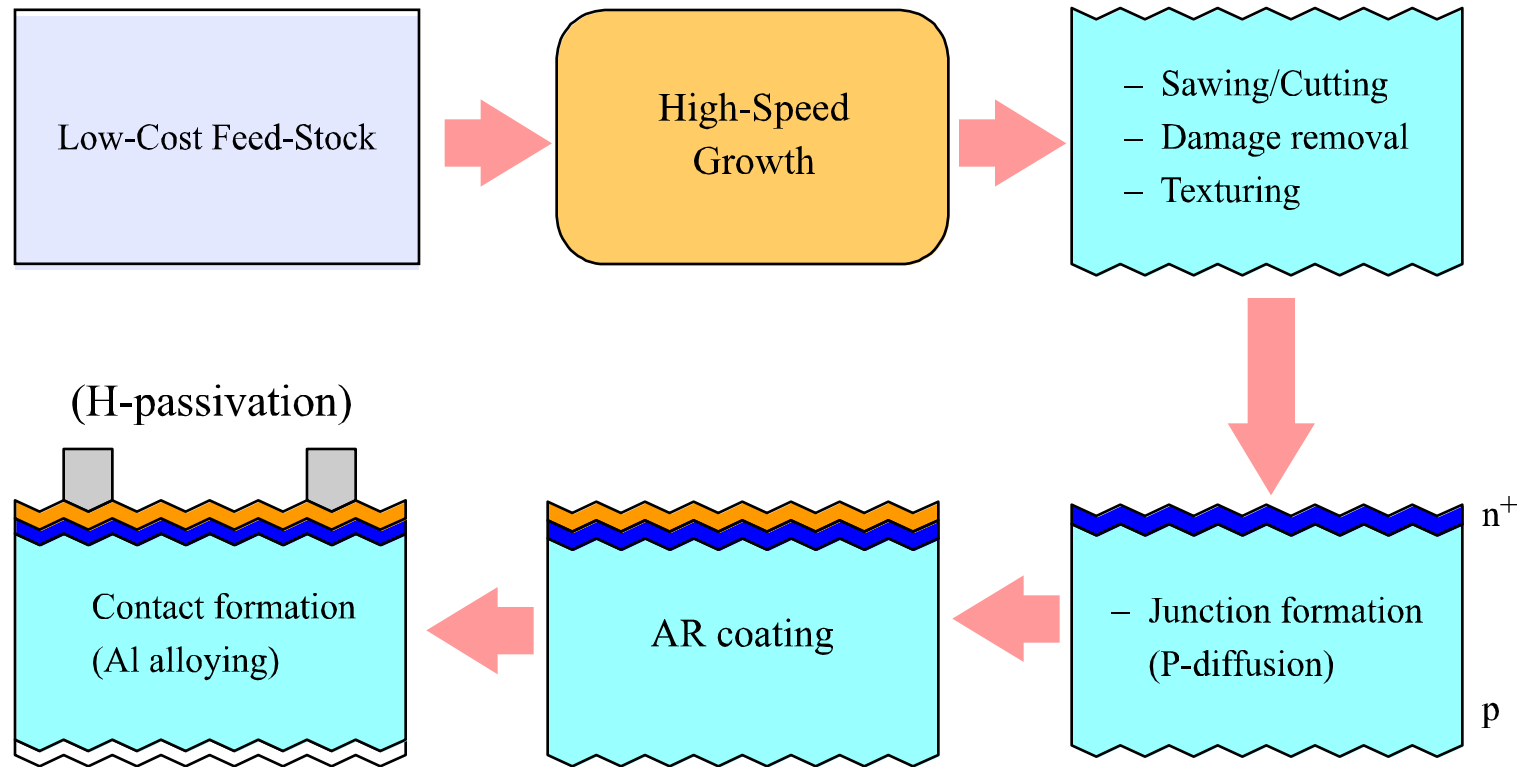
NREL Image Gallery #03837-FP



NREL Image Gallery #13419

Process Types

Schematic of Various Process-steps for Si Solar Cell Fabrication



Process Types

J. Morgan, "Reduction in Fabrication Costs of Gas Diffusion Layers," DOE Hydrogen Program Annual Merit Review, June, 2010.

- **Drying/curing**
 - Oven
 - Convective, IR
 - Air, inert, reactive
 - Sintering



M. Richards, "Solid Oxide Fuel Cell Manufacturing Overview," DOE/NREL Hydrogen and Fuel Cell Manufacturing R&D Workshop, August, 2011.

Process Types

- **Drying/curing**
 - Radiation
 - UV, IR, electron-beam
 - Air, inert