

# Radio Frequency Lamination for Photovoltaic Panels

**Shawn M. Allan\***

Morgana Fall, Dr. Holly Shulman, Ceralink Inc

**Ceralink Inc.**

Rensselaer Technology Park  
Troy, New York

Materials Science & Technology 2009,  
and the 111<sup>th</sup> Annual Meeting of American Ceramic Society

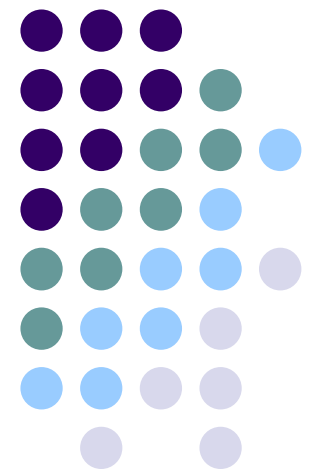
Energy Materials:  
Dielectric, Photovoltaic, and Other Energy Materials II

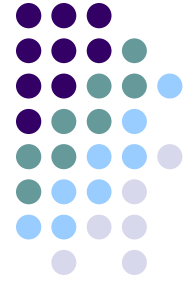


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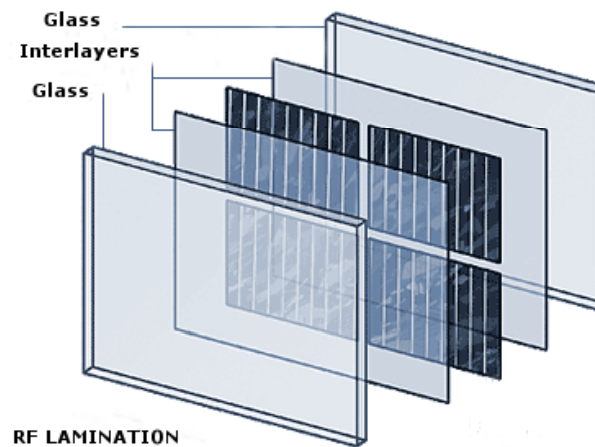
Pittsburgh, PA  
October 27, 2009





# Introduction

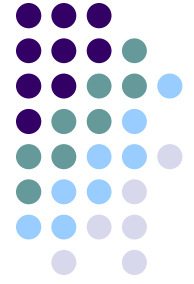
- Laminated Solar Panels
- Opportunities for manufacturing alternatives
- Application of low energy RF lamination to photovoltaics
- Conclusions



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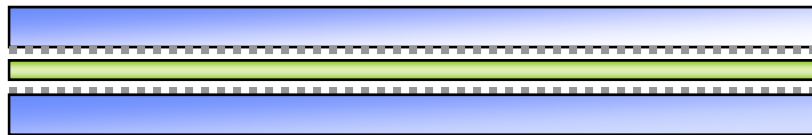




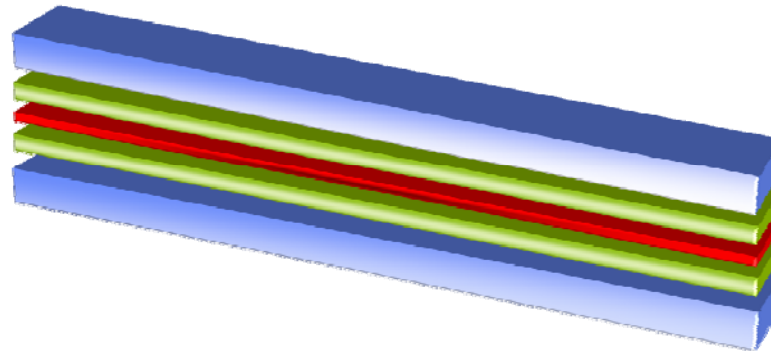
# Photovoltaic Lamination

- Delicate nature of most PV materials necessitates protection
- Lamination in glass common for Si, and thin film (eg., CdTe)
- Autoclave lamination is **very energy intensive**
- EVA materials for solar developed to lower cost → vacuum system compatible

Thin film PV  
on glass



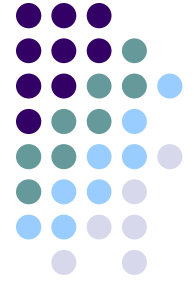
Silicon solar panel



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# State of the art glass lamination

- **Interlayers**
  - **EVA** - Ethylene vinyl acetate – **Solar, Decorative**
    - Clear, colored, opaque
  - **PVB** - Polyvinyl butyral – **Auto, Security**
    - Clear, printed
  - **TPU** - Thermoplastic Polyurethane - **Armor**
- **Methods**
  - Pre-processing rolling (de-airing)
  - Autoclave (PVB, TPU)
  - Vacuum oven (EVA)
- **Features**
  - Large batches, 1 to 6 hour processes
  - Slow process development
  - **Energy Intensive!!**



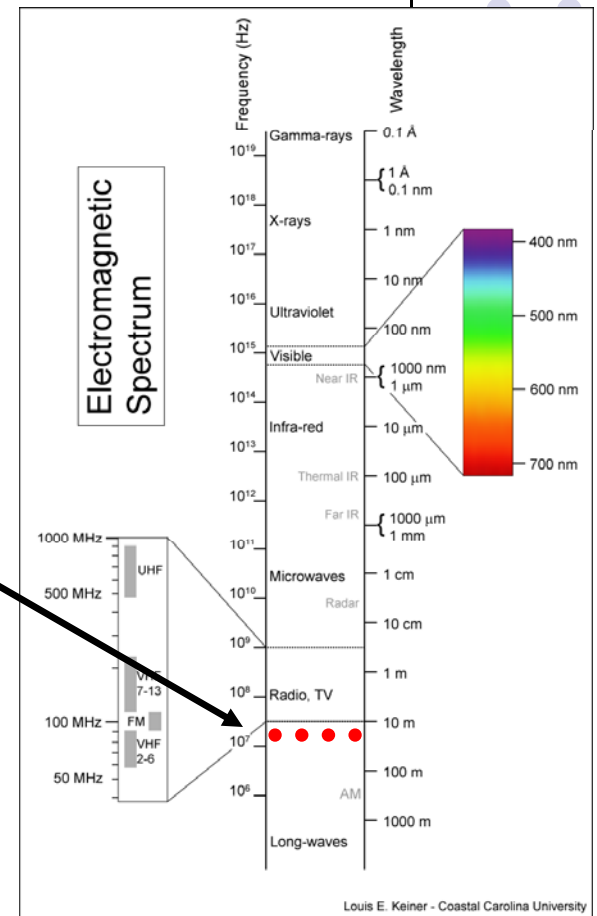
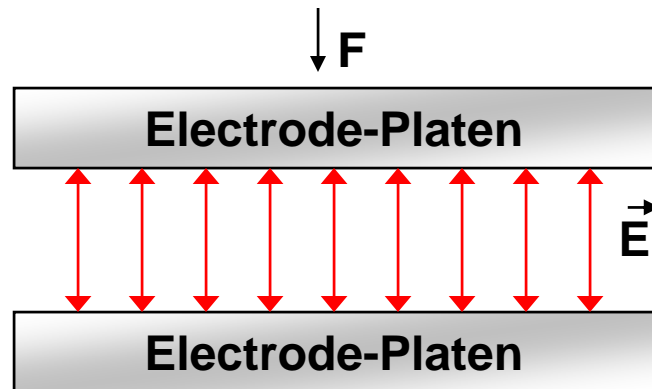
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# RF Technology

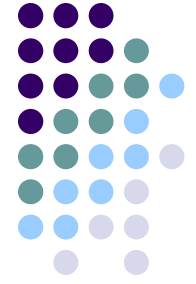
- We applied **RF heating** to **Glass Lamination**
- RF widely used for paper, wood, and plastics
- 27.12 MHz field between parallel electrodes
- Creates dielectric heating
- Press platens are RF source (electrodes)



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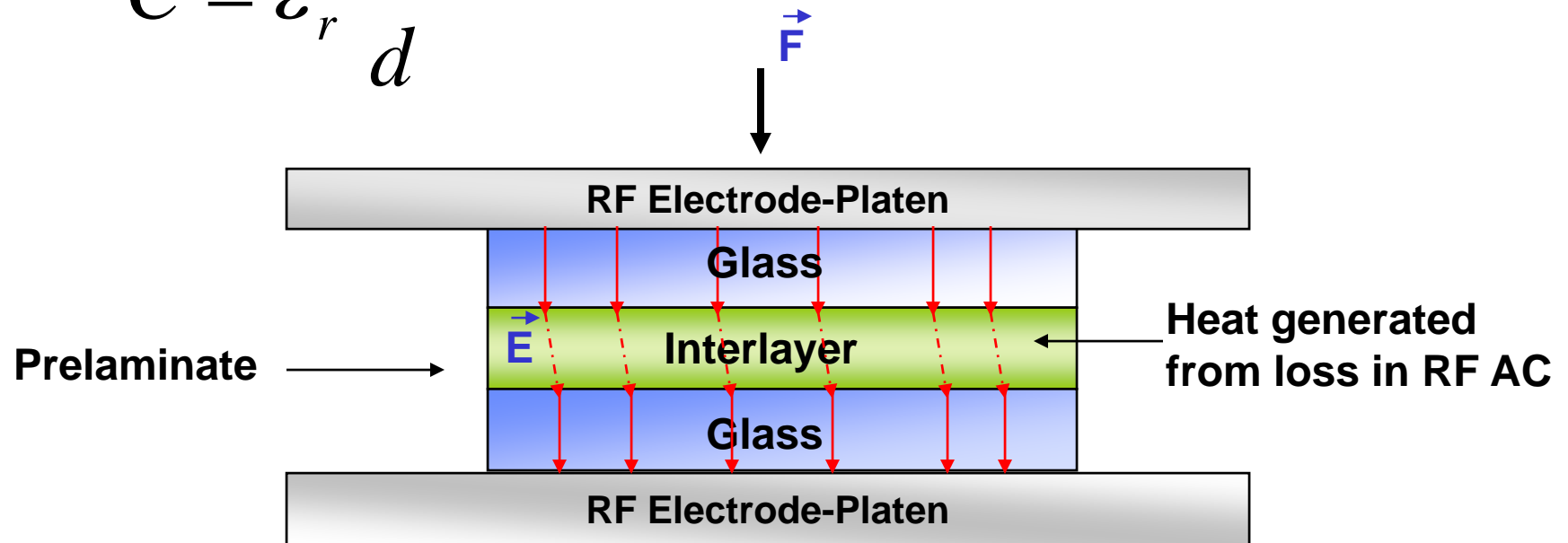
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# RF Lamination Technology

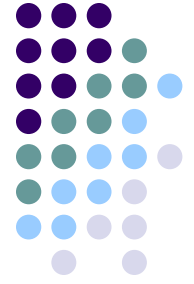
$$C = \epsilon_r \frac{A}{d}$$



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# RF Lamination Technology

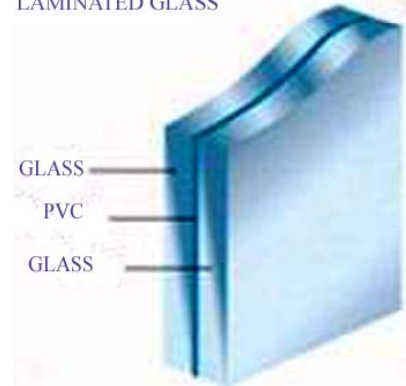
Method to make laminates faster and more efficient

- **0.5 to 3 minute cycle**
- Cuts energy over **90%**
- Heat interlayer directly
- Existing equipment
- Apply pressure
- **Fast development**
  - ♻️ 50+ experiments in 1 day



**Thermex Thematron  
RF Press with shuttle**

LAMINATED GLASS

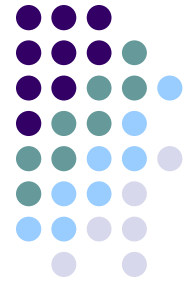


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# RF Presses



**4 ton, 18" x 20"**



**19 ton, 30" x 40"**



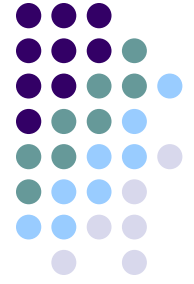
**700 ton, 48" x 120"**



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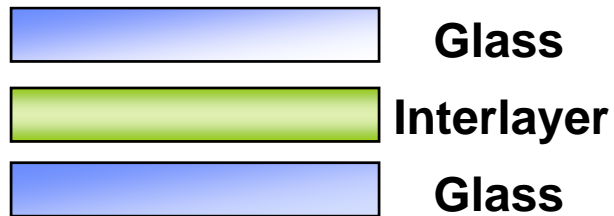
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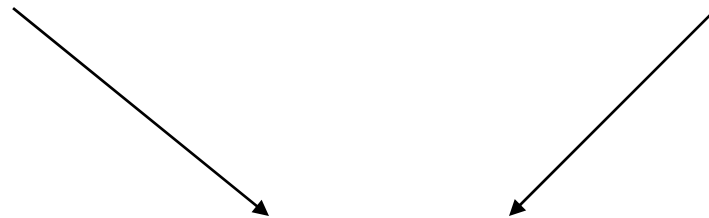
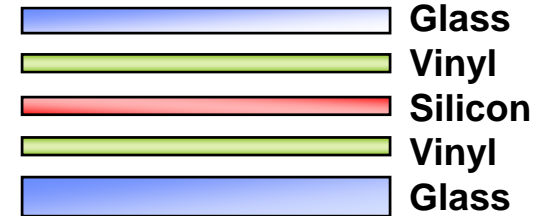


# RF Lamination Technology

## Basic – Autoglass



## Solar Laminate



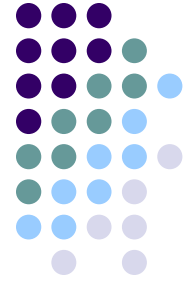
**Prelaminate**



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# Structural Layers & Interlayers

Ceralink has established feasibility for several materials used in laminated products:

- Clear & Colored Glass
- Metallized (Low-E) Glass
- Acrylic
- Polycarbonate
- Ceramics
- Silicon

## PVB – Polyvinyl butyral

- DuPont Butacite®
- Solutia Saflex®
- Sekisui S-LEC®

## Printed PVB

- DuPont SentryGlass Expressions®

## EVA – Ethylene vinyl acetate

- Sekisui S-LEC® EN
- Bridgestone EVASAFE™
- Kin Yong Fa
  - clear, colored, opaque

## TPU – Thermoplastic polyurethane

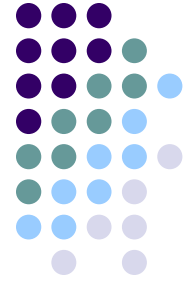
- Deerfield Urethane Dureflex®



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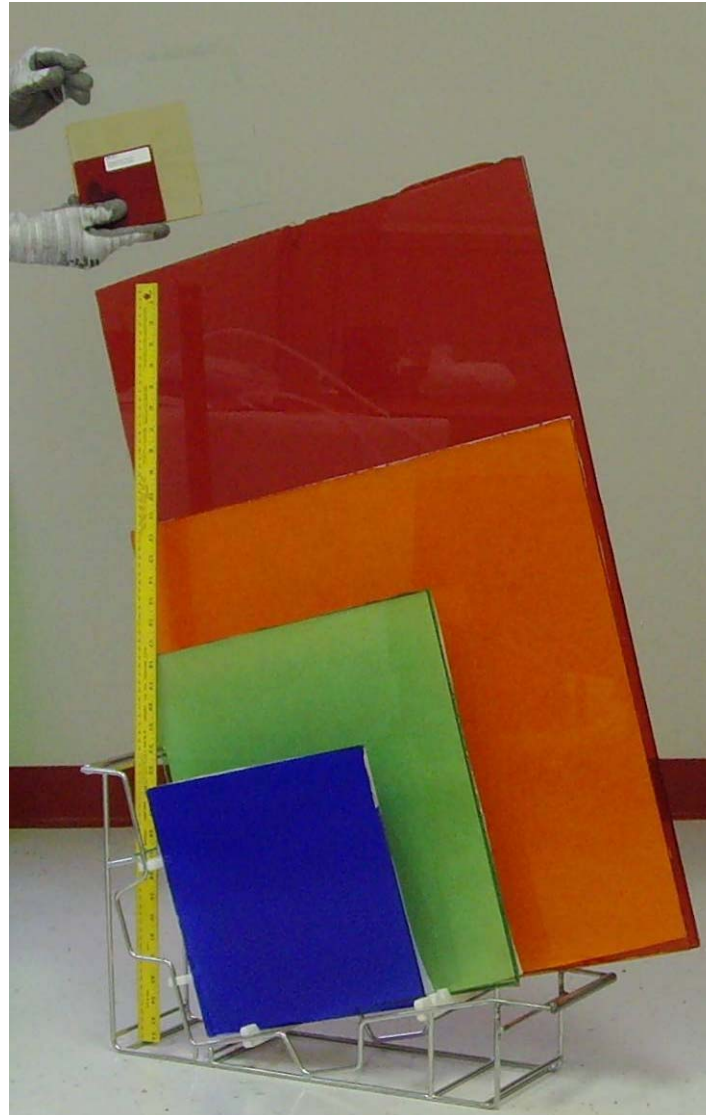




# RF Laminated Area

## Demonstrated sizes

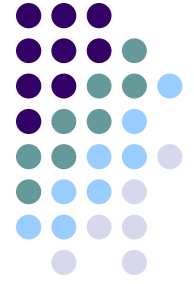
<b>36" x 24"</b>	<b>6 ft<sup>2</sup></b>
<b>24" x 24"</b>	<b>4 ft<sup>2</sup></b>
<b>18" x 16"</b>	<b>2 ft<sup>2</sup></b>
<b>12" x 12"</b>	<b>1 ft<sup>2</sup></b>
<b>9" x 9"</b>	<b>0.56 ft<sup>2</sup></b>
<b>6" x 6"</b>	<b>0.25 ft<sup>2</sup></b>
<b>4" x 4"</b>	<b>0.11 ft<sup>2</sup></b>



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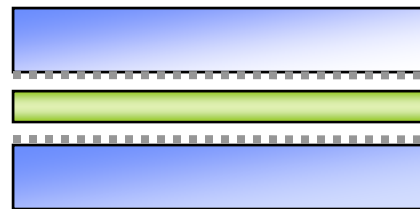
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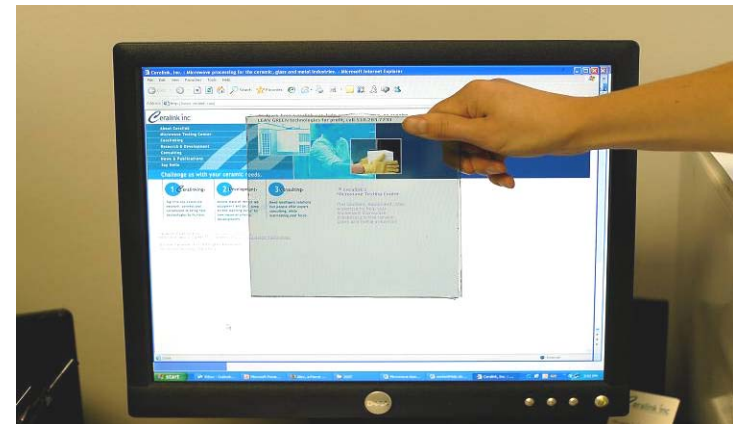


# Metallization

- Glass is metallized on one side for tinting, IR reflection
- Capacitive coupling transmits RF across metal layers
- Low-E Glass was laminated with EVA
- Applications:
  - RF shielding
  - Reflective coatings
  - Mirrors



**Metallized Glass**



**RF Laminated Low-e Glass**  
150 mm x 150 mm



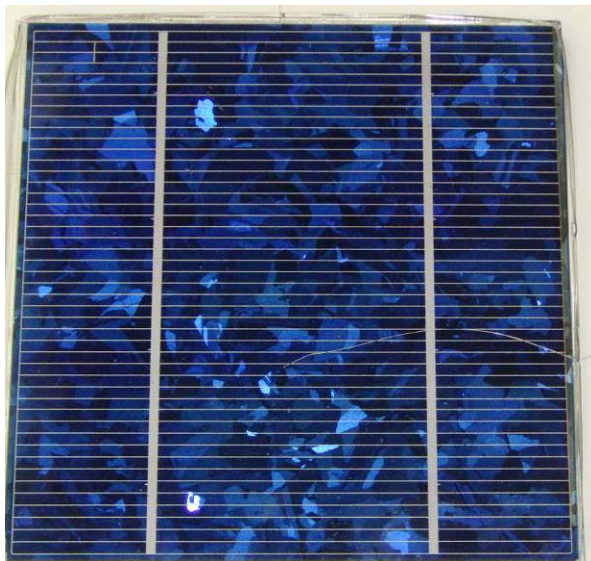
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# Solar Cell Lamination

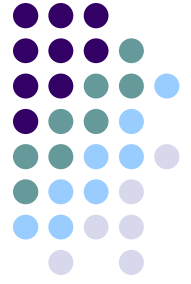
- Solar cells cover part or all of glass area
- Single and Polycrystalline Si laminated

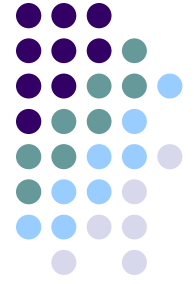


← 4.5" Polycrystalline  
Solar Cell  
RF Laminated  
45 seconds

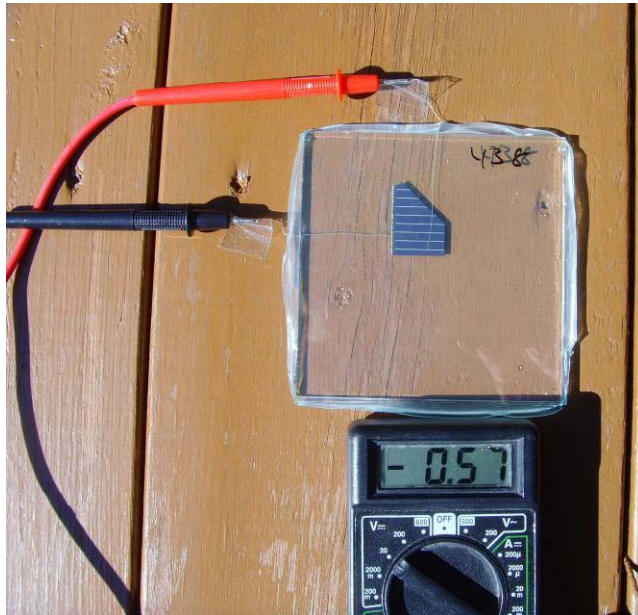


Conventionally  
Laminated Solar Cells  
at GlassTec 2006  
Functional & Aesthetic





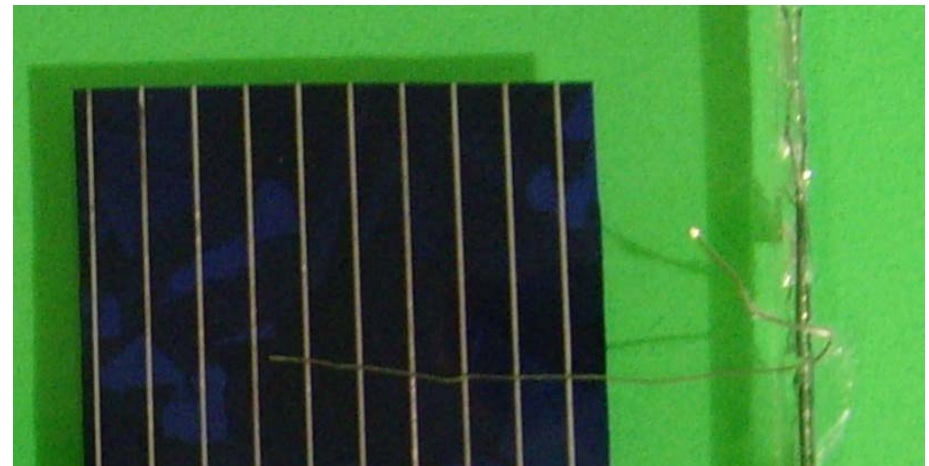
# Solar Cell Lamination



Solar cell laminated with RF Press

Rated for 550 mV

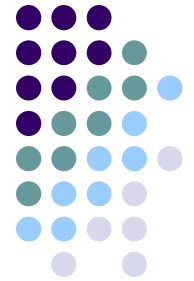
Measured output in full sun **570 mV**



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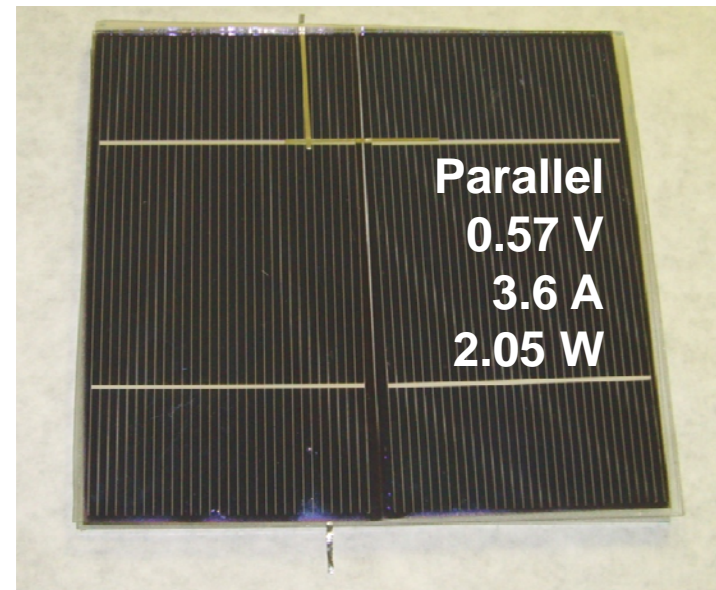
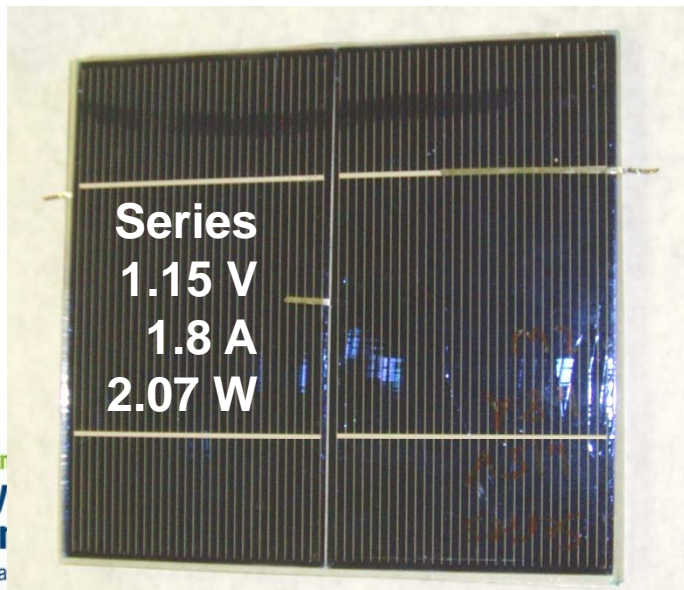
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# Building Solar Panels

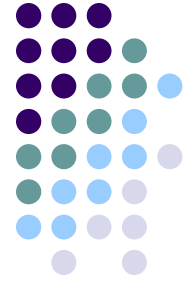
- Laminated multiple solar cells, series or parallel to control V, I output
- 45 seconds for 6" x 6.5" panel
- **Solderless** electrical contact between solar cells and leads



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Energy and Reliability

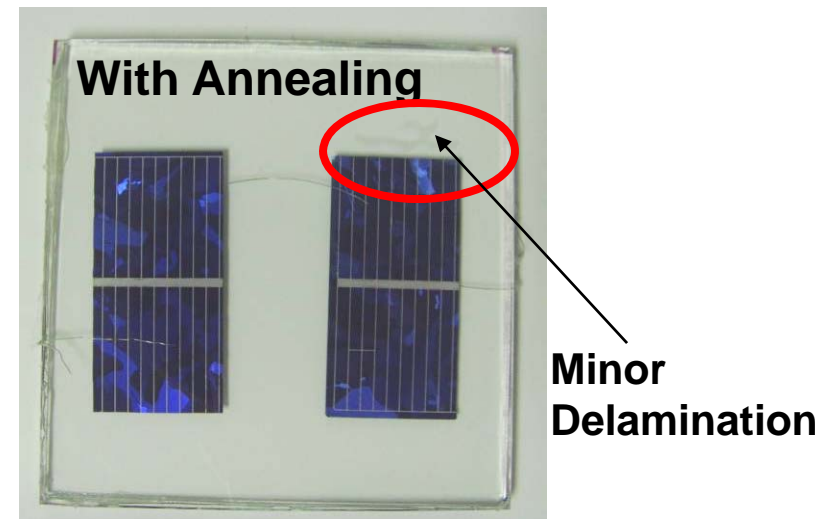
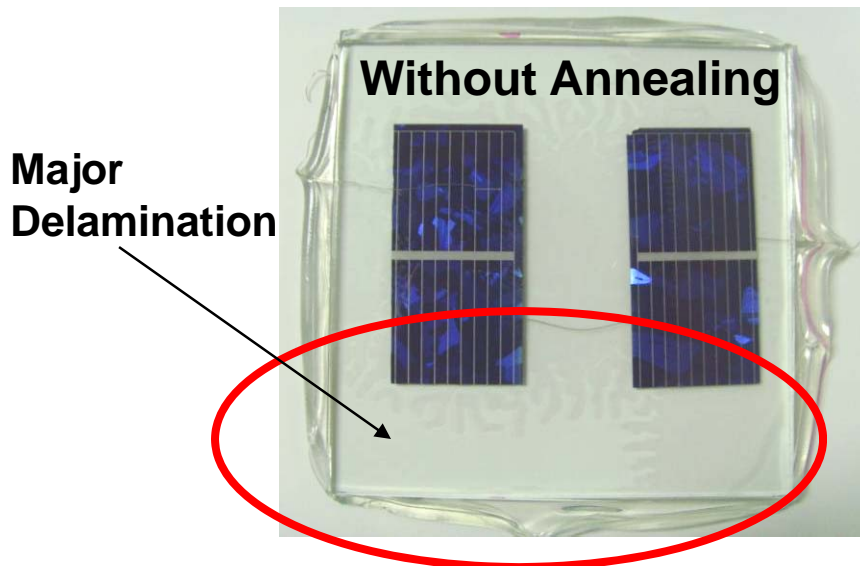
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# Solar Cells – Partial Panels

- Partial coverage induces stress in vinyl
- Delamination occurs after the vinyl cools due to residual stresses
- 20 minute, 80-100 °C anneal alleviates residual stress in the vinyl
- No anneal required for full coverage cells

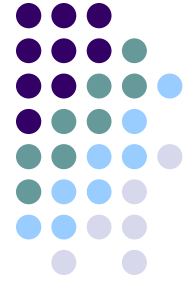


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**For Partial Coverage Structures in EVA  
Lay-up → Press → Anneal**





# Embedded electronics

- Light emitting diodes (LEDs)
- Sensors
- Co-laminate power supply & device



3-color LED after press  
Blue-Green-White (top to bottom)  
9" square glass with PVB



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# Durability

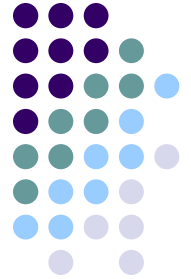
RF laminated glass was subjected to EU tests from EN ISO 12543-4:

Boil, 100 °C, 2 h  
Bake, 130 °C, 2 h

- Sekisui S-LEC EN **Passed**
- Bridgestone EVASAFE **Passed**
- **Deerfield A4700 TPU Passed**

ASTM C1172 visual inspection **Passed before and after**

- PVB bubbling in bake test → investigating pre-lamination steps



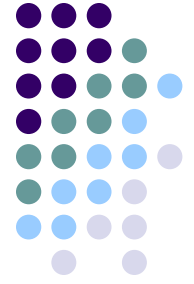
Boil Testing RF Laminated TPU



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# New Opportunities for RF Lamination

- Larger silicon solar panel demonstration underway
- Evaluation of other PV technologies
- PVB environmental stability progress
- Non-destructive evaluation of adhesion strength (with Dr. H. Reis, U. of Ill. Urbana-Champaign)

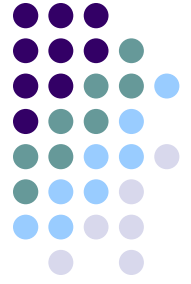


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# Rapid Manufacturing and Prototyping



- US Department of Energy sponsored for significant energy savings
- Method offers significant time savings →  
**Rapid Prototyping & Manufacturing**
- RF lamination proven successful for variety of materials
- Single piece workflow
  - QC & flexibility
- Ceralink offers feasibility testing
  - Equipment through strategic partner
  - Licensing and/or partnering to commercialize specific applications



**700-ton RF Press**

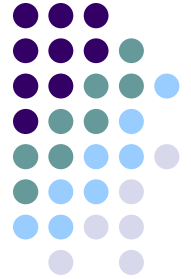


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# Acknowledgements



**Visit Thermex Thermatron and Ceralink at Booth 538  
at the Expo to see RF Laminated samples**

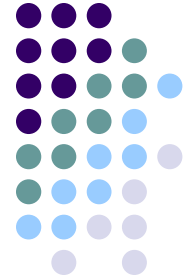


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# Thank you! Questions?

Ceralink Inc. develops advanced materials,  
green processes, and new products for industry.



**Contact: Shawn Allan**  
Sr. Materials Engineer  
(518) 283-7733  
shawn@ceralink.com



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**2007 U.S. patent applied for  
RF Press Lamination Technology**

