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Science & Technology

Flexible glass substrates for continuous manufacturing

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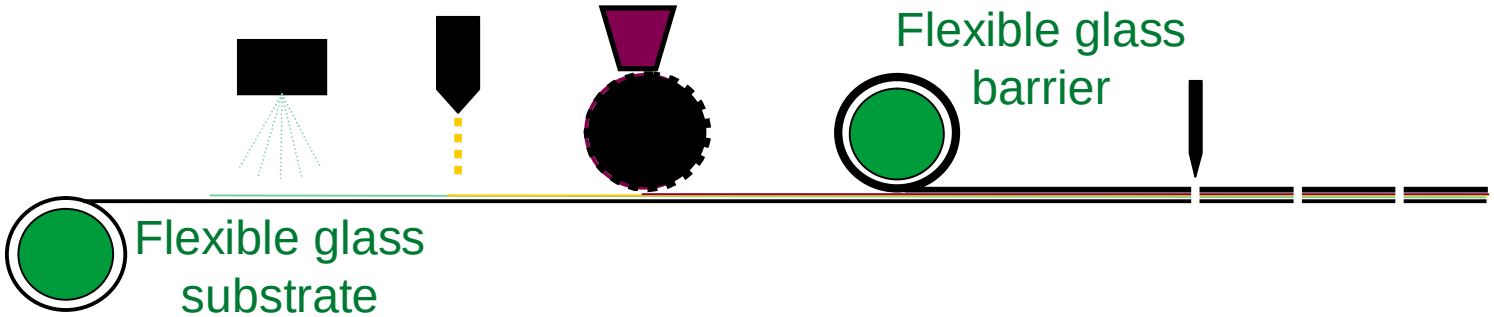
Outline

- Flexible glass for electronic devices
- Flexible glass mechanical reliability
  - Strength
  - Coatings
  - Stress
- Roll-to-roll photolithography
- Summary

Flexible Glass Enables High-Quality Electronics

Substrate choice critical for device fabrication & performance

- Substrate integrates designs, materials, & processes
  - Essential for overall optimization
  - Glass enables improved resolution, registration, performance & lifetime



Flexible Glass
- Thermal stability
- Dimensional stability
- Hermeticity
- Optical transmission
- Surface roughness

Capabilities →

← Requirements

Device Designs
E-paper, touch sensor, PV, OLED

Materials
Conductor, semiconductor, dielectric

Continuous Processes
- Patterning (gravure, ink jet, photolithography)
- Etching (wet, plasma)
- Coating (lamination, slot die, vacuum)

Glass Surface & Bulk Properties Optimize Devices

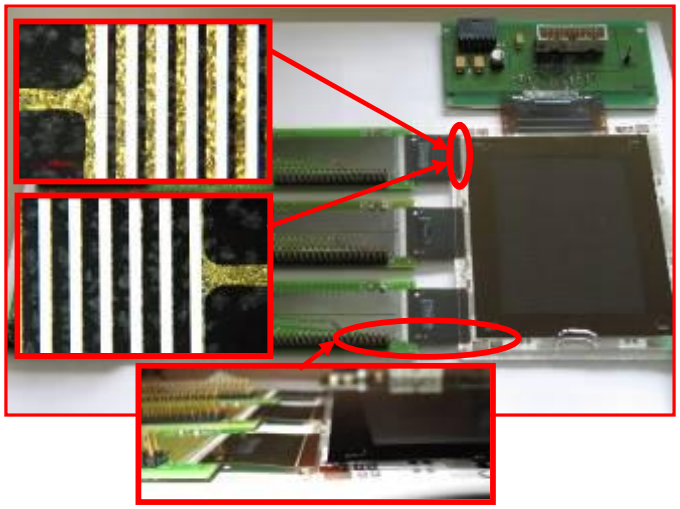
Flexible glass device capability demonstrated in <170µm LCD

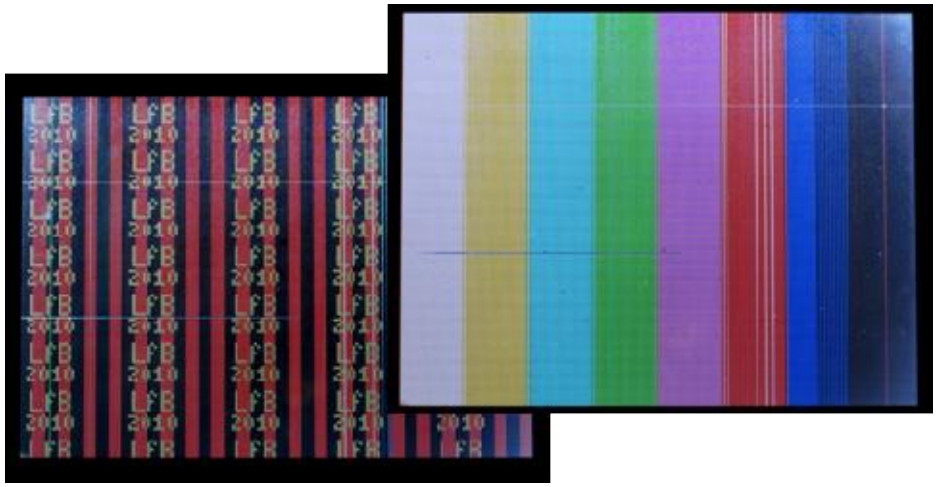
- Twisted nematic LCD
- qVGA (320 x RGB x 240)
- 4” diagonal (80mm x 60mm)
- Pixel size 83µm x 250µm
- Aperture 52%

- a-Si:H active matrix backplane
- TFT channel L=10µm, W=50µm

- Polymeric substrates not compatible
  - 300°C backplane fabrication
  - 210°C frontplane fabrication

- 75µm flexible glass thickness
  - LC cell <170µm



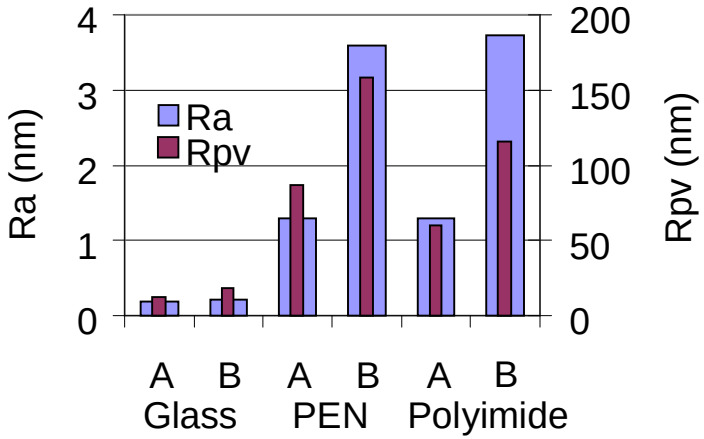


S. Hoehla, et al., “Full Color AM-LCDs on Flexible Glass Substrates”, IDW 2010, p.1689-1692.

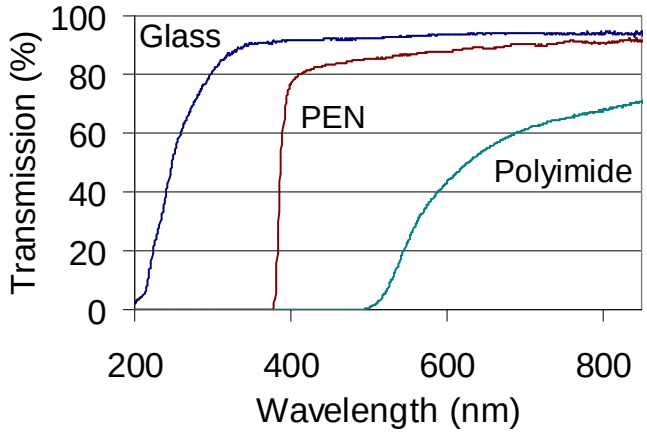
Glass Enables Performance & Process Optimization

Flexible glass offers dimensional stability for R2R fabrication

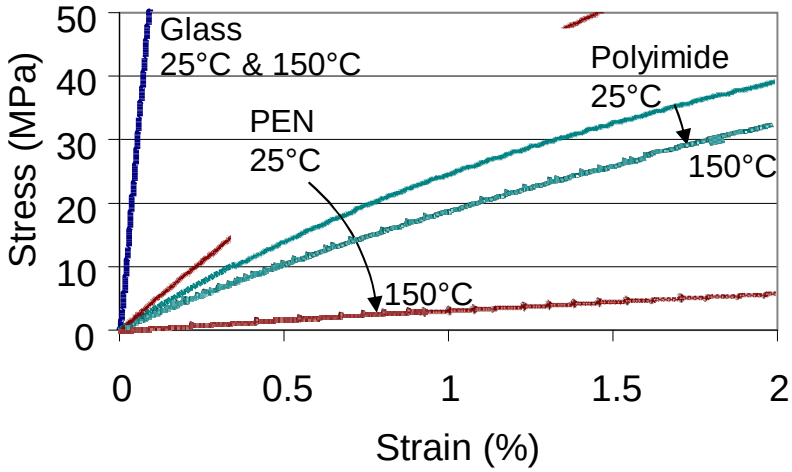
Surface Roughness



Optical Transmission



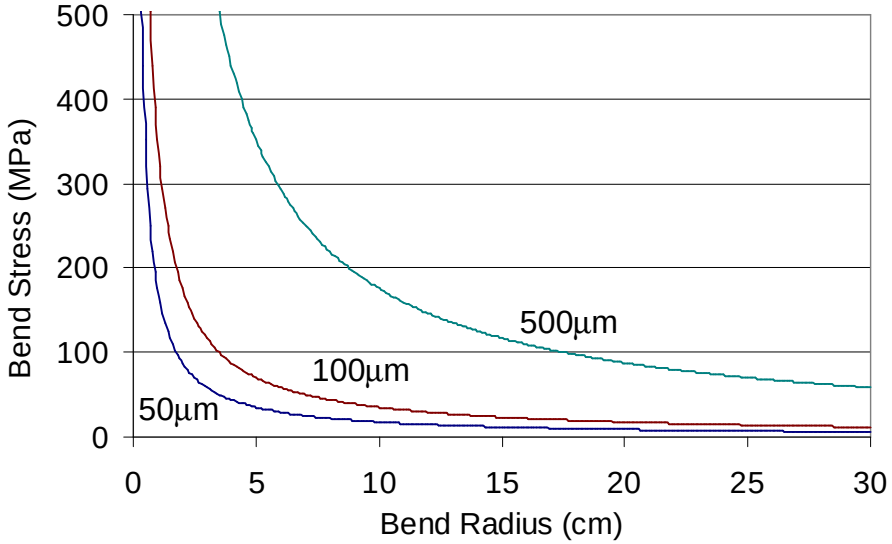
Dimensional Stability

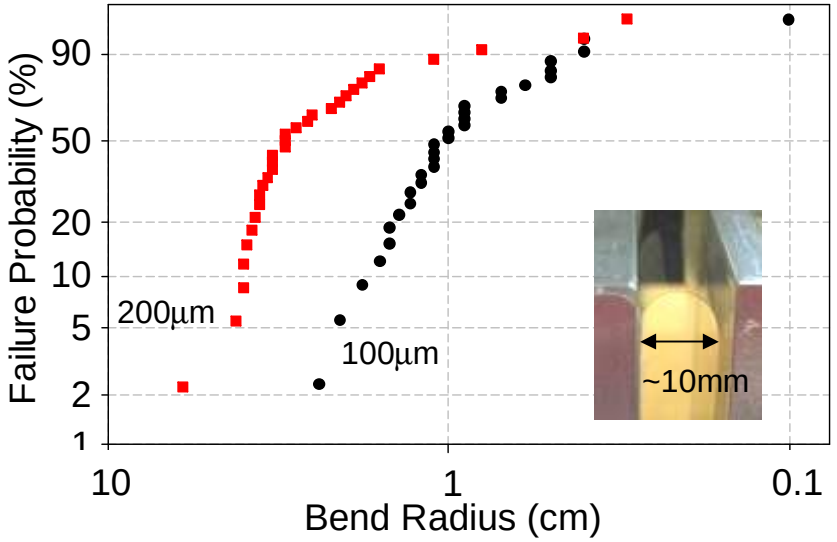


Mechanical Reliability of Flexible Glass

Substrate solutions optimized for continuous processing

- Mechanical reliability of glass understood
  - Failure due to distributions of defects & applied stresses
  - Bend strength independent of thickness
- Mechanical reliability requires controlling defects & applied stress
  - High strength glass forming including surfaces & edges
  - Protecting substrate from damage
  - Managing stresses during conveyance, handling & application



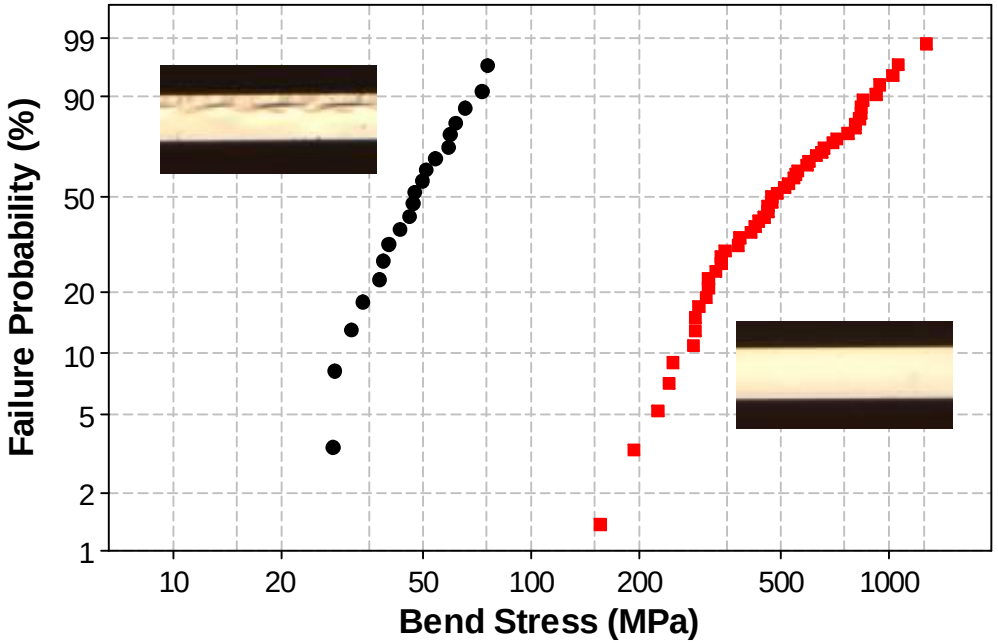


Glass After Forming is Inherently Strong

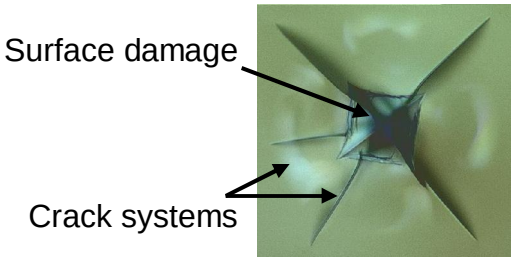
Managing defect size & distribution enables reliability

- Pristine glass surfaces are extremely strong
  - Bend strengths >6GPa measured in substrate compositions
  - Subsequent handling & environment can reduce strength ~100x
- Glass strength depends on glass history
  - Quality of surfaces & edges critical

Edge quality affects bend strength



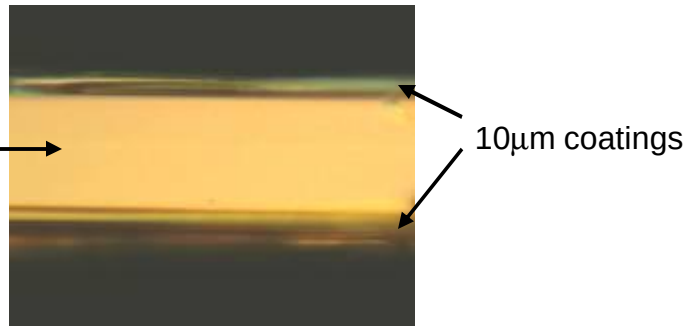
Surface quality affects bend strength



Protective Coatings Preserve Glass Strength
Coating selection specific to application

- Crack systems form when flaw size & stress reach threshold
- Coatings minimize contact damage induced during:
  - Handling, packaging, shipping
  - Device manufacturing
  - In-service use
- Coating optimized for specific device & fabrication processes
  - Material & thickness selected for anticipated conditions
  - Full-width and partial-width coatings enable different device designs
  - Mechanical properties dominated by glass

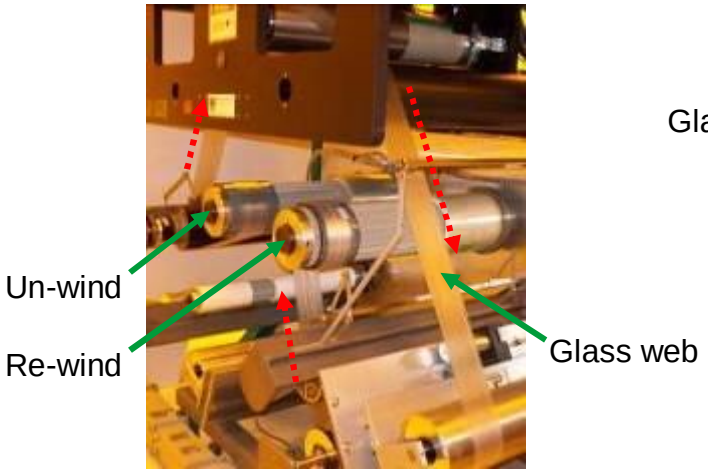
Coated Substrate Cross-Section



Convey Flexible Glass with Roller Systems
Requires managing bend stress during device fabrication

- Flexible glass is flexible – Do not handle as rigid substrate
  - Stiffness of 50µm glass ≈ 120µm PEN
  - Control stresses through roller handling system
  - Approach compatible with sheet-fed or roll-to-roll systems

Conveyance in CAMM ECD Tool



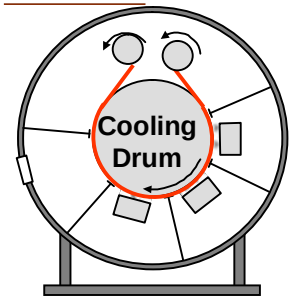
Al Sputtering in CAMM General Vac System

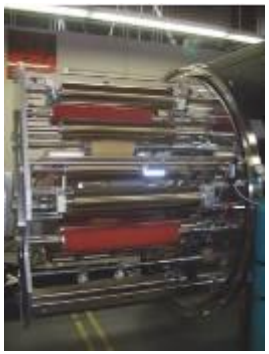
Flexible Glass is Compatible with R2R Processing

Demonstrated continuous ITO patterning

ITO Deposition

CAMM





Slot Die Coating

Exposure

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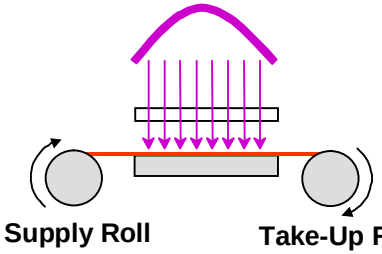

Development & Etch

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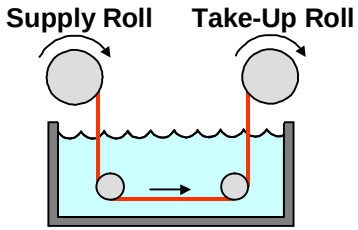
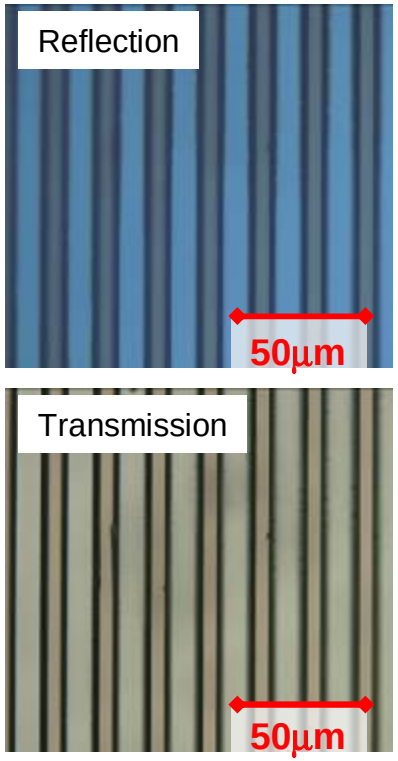


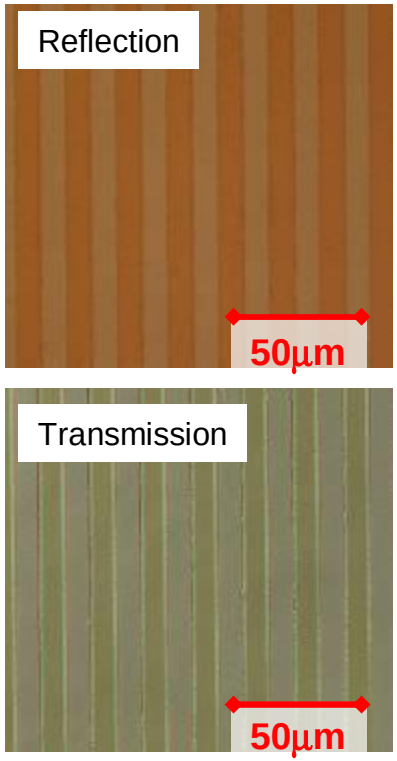
Roll-to-Roll Patterning of 10µm ITO Lines
Deposition, slot coat, repeated exposure, develop & etch

- Spooled glass with partial width coating
- 10µm ITO lines with 30 Ω/□ resistivity

Patterned Photoresist



Patterned ITO



Summary

- Flexible glass offers advantages for device designs, materials & processes
  - Includes dimensional & thermal stability and hermeticity
  - Enables high performance active devices
- Glass mechanical reliability understood
  - Form high initial strength & minimize defects
  - Manage stresses with appropriate conveyance
  - Optimized solutions are application specific
- Flexible glass is compatible with continuous processing
  - Demonstrated patterning of 10μm ITO lines
  - Process optimizations possible to take advantage of glass capabilities

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  - Scott Glaesemann
  - Don Clark
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