DOE – DoD Multi-topic
Ft worth, TX workshop
R2R Breakout Session
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OUTLINE

Institute elements
Challenges and Rational
Deposition/Printing Technologies
Equipment and Process Control (Integration)
Substrate Materials
Applications Technology Application Areas
(Electronics, Buildings, Membranes, Energy Specific)
Metrology
Development Path/Expectation
Summary
### Possible Institute Elements

- Establishments of the 2-D R2R platform as a foundational manufacturing technology for energy applications
- Embedded electronics to enable “smart” applications
- Enabling High-rate, industrial-scale manufacturing platforms for continuous large-area roll-to-roll processing.
- Equipment for small-scale (e.g., microelectronics) to medium-scale (windows and window films) to large-scale (membranes for biofuel and natural gas processing) applications
- Development of detailed “Roadmaps” introducing initial technologies at TRL/MRL 3 - 4 with production demonstrations in 2-3 years and enabling select sustaining products from Industry at 5 – 7 years.
Challenges/Needs/Metrics

- Meters-per-minute rates on plastic film, paper, fabric or foil achieving feature dimensions as small as ten nanometers encompassing billions of identical devices. (100k mm²/min.)
- Develop paths for the electronic manufacturing service to move from plate-to-plate standard lithography to continuous R2R processing or blend of the technologies.
- Large format “smart” process equipment including “feed-back” process control, metrology, quality control/assurance, and embedded sensing
- Cost/Area vs. Throughput (25%/5 years)
- Materials cost for substrates? (5%/year)
- Size Scale (Kerfless, mm to Sub-micron to nano)

Why Us, Why Now?

- High risks and costs for R2R technologies preclude investment by a single company, but can be addressed effectively using a public-private partnership
- An Institute will accelerate technology development to higher TRL/MRL with concurrent technology transfer to industry.
- Flexible electronics, which is well supported using R2R technology, is currently a DOD technology development priority and has been discussed for inter-agency collaboration to enable leveraging of mutual assets.
Deposition Technologies (Thick vs Mid vs Thin Film Methods)

40 nm features on 50µm polyimide film at 5 m/minute
Process Equipment/Sensor-Control Integration

- R&D → Pilot → Volume Production

- Thick-film deposition (Screen-Print and Casting)
- CIGS continuous deposition Chamber
- Electrochromic deposition
- Additive/Subtractive micro-electronic printing on Flex-Glass

Parallel Detecting, Spectroscopic Ellipsometer (PDSE)
- IR/visible material characterization (bandgap, conductivity, surface properties, etc.)

X-Ray Florescence (XRF)
- Composition control and system behavior

Atomic Absorption Spectroscopy (AAS)
- Elemental flux measurement
Materials - Substrates

U.S. Department of ENERGY

MCC, YSZ, Spinel

Quality control
Model of Thermal Processing
Optimized PTP

Optimized atmosphere

Single layer graphene
Multi-layer graphene

Transfer to plastic, glass substrate

OPV, OLED devices

Roll to Roll Graphene

Other polymer materials: Polyester (Mylar™), Polyethylene (PE), Polyethylene Naphthalate (PEN), Polyethylene Terephthalate (PET), Polycarbonate (PC), Vinlys, Insulated Metal (IMS), Thermal Conductive (TAC)
Technology Areas

- Membranes (Fossil and Separation)
- Flexible Electronics and Interconnects (active and passive, etc.)
- Battery Technology
- PEM and SOFC Fuel Cells
- Flexible - Photovoltaics
- Formatted, Higher Quality Depositions
- Photonics, Magnetics, Conductors/superconductors, electrochromics, Transducers/MEMs, TFTs
- Structural Electronics/Infrastructure Health Monitoring/sensors
Manufacturing Issues
- Reproducible Scalable Solutions
- Metrology and In-Process Control
- Quality Control and systems
- Cost-Competitive, Economic Solutions
- Process Equipment and Materials

Metals Processing

Size Specific Crystalline/Semi-crystalline Polymer Membrane Stretch preparation

R2R processing of high-temperature YBC Superconductor on Ni at AMSC

Pilot Processing Equipment Supporting MEA Membrane Fabrication for Proton OnSite
Daylight Redirecting Films (3M)

Electrochromic Windows (Sage, View)

Low-e Window Films (Solutia)

Manufacturing Challenges/Barriers

- Large/Customized area
- Process automation and integration
- Low defect tolerance, Clarity Improved yields (dynamic products)

Payback < 1 year
Market Ready in < 5 years

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<th>Metric</th>
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<tr>
<td>R-value</td>
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<tr>
<td>Cost</td>
<td>&lt;$1/ft²</td>
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Facility/Infrastructure Automation

Temperature Sensing
- CO₂
- Optional Humidity, Motion, and CO₂ Sensing

Inputs for Other Sensors or Contacts
- 24 Volts AC Power

Applications
- AHU
- FCU
- HPU
- RTU

Optional Humidity and Motion Sensing
- Application

Temperature Sensing
- Inputs for Other Sensors or Contacts
- Outputs (Analog and/or Relays)
- 24 Volts AC Power
- Quick (Temporary) Network/Programming Access

Applications
- AHU
- FCU
- HPU
- RTU

Building Zone 1 (with BAC-5831 and NetSensor)

Building Zone 2 (with FlexStat)

Passive Energy Generation

Building integrated photovoltaics (BIPV)

Manufacturing

Challenges/Barriers
- Quality Substrates
- Resolution (sensors), patterning
- Process tolerance, temperature
- Inspection Tools, Metrology, Standards
- Defect density and repair
- Capacity, Yield and Size scale
- Materials/Equipment-availability and cost

OLEDs

Advanced Manufacturing Office (AMO)
PV Metrology – R&D Effort Examples

Optical Reflectometry
- Spectral (Reflection, Transmission, or Absorption)
- Very rapid data-acquisition (msec)
- Areal thickness measurement
- Identification of defects (10-100µm)
- Multi-layer, multi-component, etc.

Active Infrared Thermography
- Apply voltage across electrode layer
- Resulting current causes resistive heating
- Rapid data-acquisition (~sec)
- Areal measurement of resistive uniformity
- Pilot Tested at 10-60 ft/min.

Reactive gas excitation
- Impinge reactive, non-flammable but reactive gas mixture onto electrode
- Detect uniformity of thermal response
- Demonstrated with moving sheets
- Evaluate at Δ Defect Loading
Range of Scale

**Bench-top**

- Technique development
- Material validation

**Prototype**

- Parametric studies
- Process validation

**Full-scale**

- In-line validation
- Industry roll goods
Technical/Scale Up Challenges: The challenges for R2R manufacturing are primarily in providing a low cost, high yield, materially-consistent and homogeneous, R2R-manufactured products that can scale up to high-speed production rates processed on proven technology “SMART” equipment meeting current and to-be established Quality Standards that are consistent with environmental, industry and commercial needs by overcoming issues with substrates, control drift, web drift, size scale, metrology, and alignment/registration, etc.
What’s Next Today

• Hear from across DOE and DoD community

• Hear from across AMNPO & across Government, such as DOC’s AMTECH Investments

• Hear from You: Industry and Research Community

Thank You

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