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Intellivation: The Experts for Innovative Vacuum Thin Film Web Systems

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As multi-pass, multilayer flexible coated devices grow in complexity, the need for modulatory and versatility in a vacuum R2R system is essential. The ability to incorporate a wide range for PVD source technologies and monitoring across multiple wavelengths while still maintaining precision controls and substrate handling, including particle management, substrate interleaves, thermal control in a single pass or throughout hundreds of passes is required. Delivering state of the art R2R Vacuum deposition systems for precision layers can also be enhanced by leveraging laser technology for annealing or surface modification for individual device performance.

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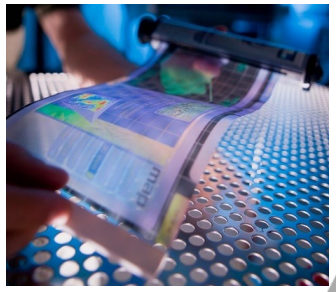
INTELLIVATION
ENGINEERED SOLUTIONS

Intellivation: The Experts for Innovative Vacuum Thin Film Web Systems

INTELLIVATION:
THE EXPERTS IN VACUUM THIN FILM WEB COATERS

Intellivation manufactures innovative & state-of-the art vacuum thin film coating equipment and components.

- R2R Series web coating systems have a compact and ergonomic design for coating flexible substrates and metal foils with a wide range of thin film materials.
- Development services with an applications laboratory featuring our R2R600 & R2R330 web coating systems and a full materials characterization laboratory.
- Unique planar sputter and rotary magnetrons offer industry-leading magnetic, thermal and mechanical design and expertise.



"Access to a robust R2R vacuum web coating tool platform and onsite characterization equipment is truly unique and beneficial, enabling process and product development which accelerates their time to market. "

COMPANY

INTELLIVATION
ENGINEERED SOLUTIONS

Engineering & Process Centric Equipment Company

- Founded in 2009, Celebrated 15 years.
- Innovation Center
- Located in Loveland, Colorado, USA

Production Roll to Roll Coating Equipment

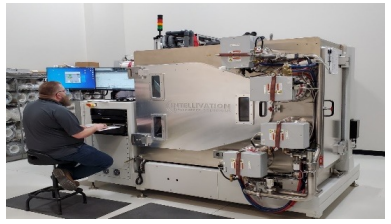
- Innovative R2R Systems up to 2 Meters Wide
- Advanced Process Technology & Monitoring Technologies
  - Reactive Sputtering Control
  - Magnetrons & Magnetics
  - Substrate Pre-Treatment
  - In-Situ Monitoring

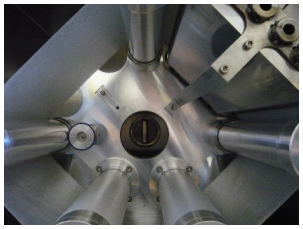
Vertically Integrated

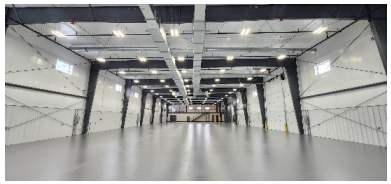
- >50,000 ft^2 Purpose-Built Facility
- Engineering, Machining, Fabrication, Assembly and Testing

In-House Application & Development Lab

- Process & Product Development
- Technology, Component & Process Demonstration







Roll To Roll Vacuum Coating Systems

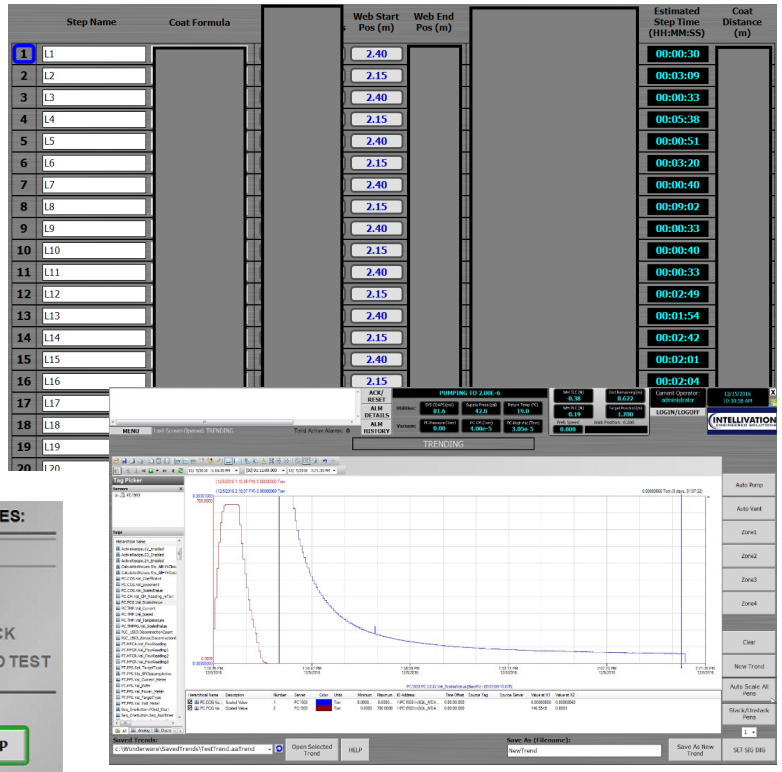
INTELLIVATION ENGINEERED SOLUTIONS

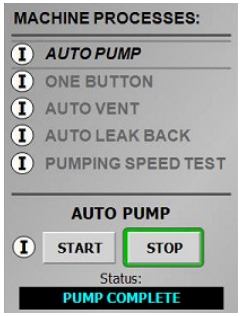
Innovative & Unique Design

- **Compact Footprint**
- **Ease of Access**
- **Smart Controls for Product and System**
- **Modular Deposition Sources**
- **Fully Reversing Web Drive System**
- **Up to 2 m Wide**
- **Clean Room Compatible**
- **Wide Range of Web Handling Capabilities**
  (polymer, fabric, glass, metal)

The New Frontier of Vacuum Coatings: Multiple Deposition Technologies & Sources

ROLL TO ROLL VACUUM COATING SYSTEMS





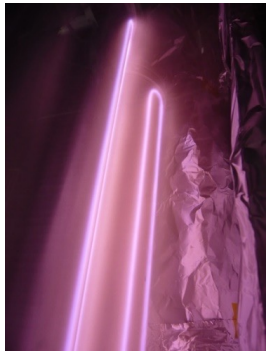
Data logging trend window

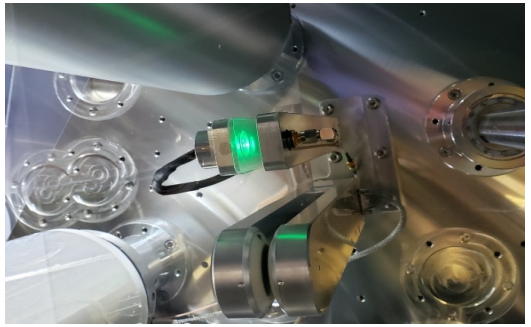
Industry – Leading Automation

- Intuitive HMI
- Automated Pump, Vent, Process, and Diagnostic Modes
- Recipe-Based Processing With Unlimited Layer Count
- Automated Reporting, Alerts, Alarms, Shutdown
- Data Logging
- MRP System Integration

ROLL TO ROLL VACUUM COATING SYSTEMS

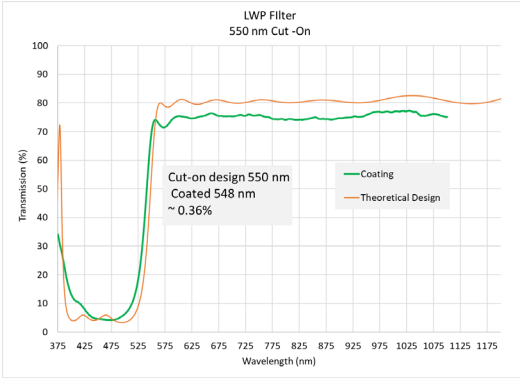
Process Control & In-Situ Monitoring

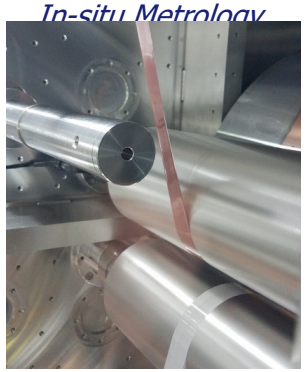




In-situ Metrology

- **Precision Winding & Material Handling**
- **Reactive Sputter Control**
  - PEM and Volt modes
  - Consistent reactive process
  - High deposition rate
  - Oxides, Nitrides, Oxynitride
- **Stationary or Crossweb Scanning In-situ Monitoring**
  - Optical Monitoring
    - Reflectance, Transmission
    - Spectral or fixed wavelength
    - UV, Visible, IR
    - Optical Density
  - Sheet Resistance / Conductivity



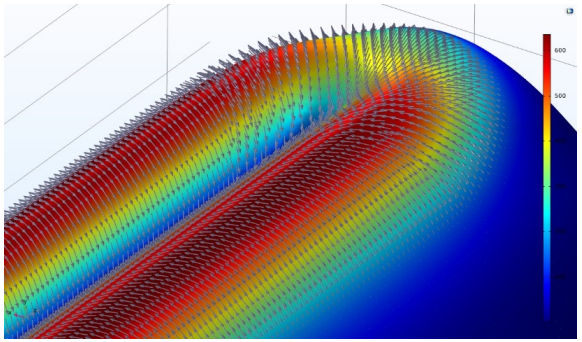


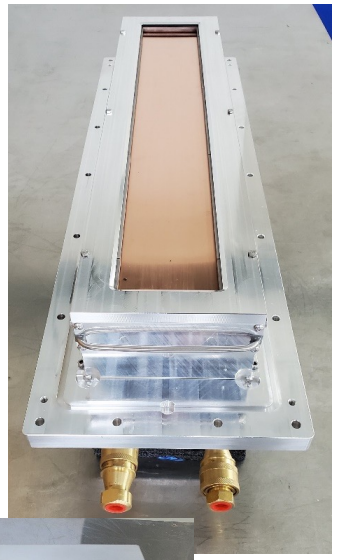
20 micron thick ceramic being coated with copper

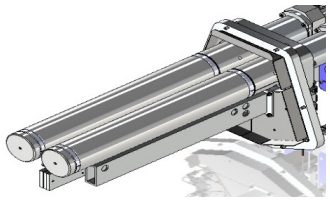
SPUTTER CATHODES

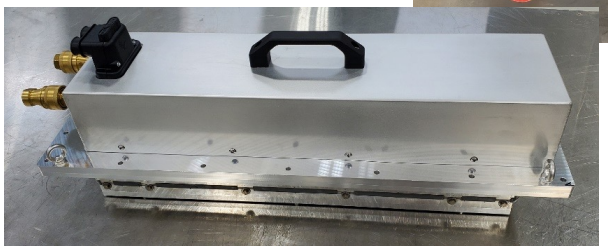
PHIMAG™ Magnetrons

- **Rotary Magnetrons**
- **Planar Magnetrons**
- **Magnetic Target Material Sputtering**
  - 80% target utilization for magnetic rotary targets
  - Patent-pending innovations
- **Power Supplies: BiPolar Pulsed DC, DC, RF, HIPIMS**
- **3D Simulation of Magnetics**





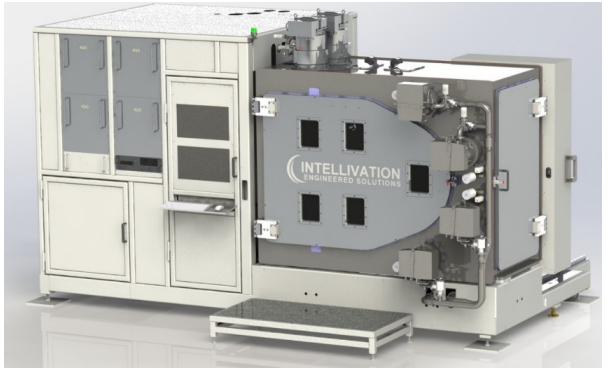


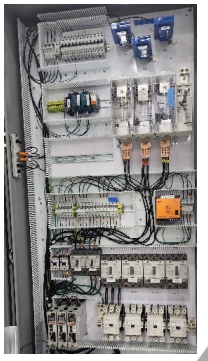


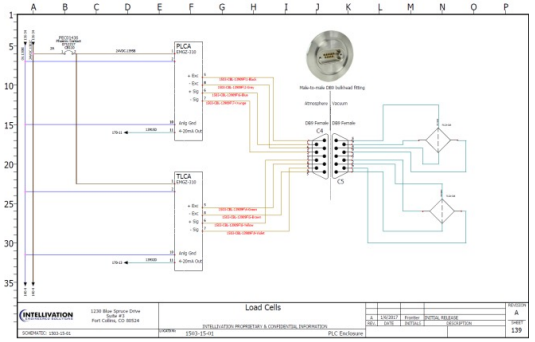
IN-HOUSE ENGINEERING

In-House Engineering & Analysis

- **SolidWorks 3D CAD and Simulation Software**
  - Including structural and thermal FEA
- **COMSOL Multiphysics FEA**
- **SolidWorks Electrical Schematic Software**
- **PLC Programming**
- **HMI Programming with Data Logging**
- **Thin Film Optical Modeling Software**
- **Licensed Professional Engineer (PE)**





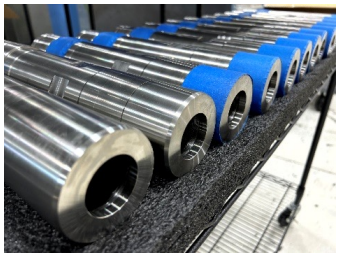


VERTICAL INTEGRATION

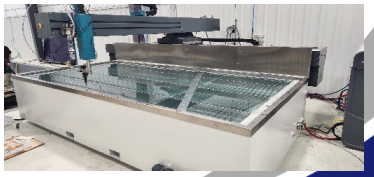
INTELLIVATION
ENGINEERED SOLUTIONS

Manufacturing, Assembly and Testing

- **Skilled technicians, machinists, and welders**
- **Machining**
  - Comprehensive Suite of CNC & Manual Machine Tools
  - Water Jet
  - Horizontal Boring Mill (50,000 lb. capacity, final chamber machining)
  - CNC Machine Travels up to 144” x 102” x 140”
- **Welding & fabrication**
  - Vacuum chambers
  - Machine frames
- **25T overhead crane**
- **Precision vacuum and assembly testing**
- **Electrical power and process cooling water for multiple systems**
- **Full commissioning and demonstration of systems before shipment**

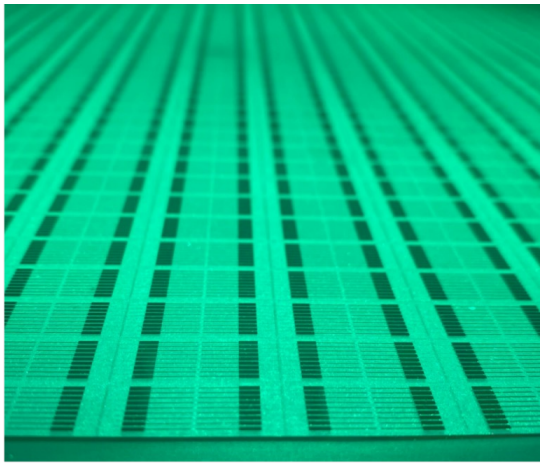


All Parts required for R2R systems including chamber are manufactured in-house.



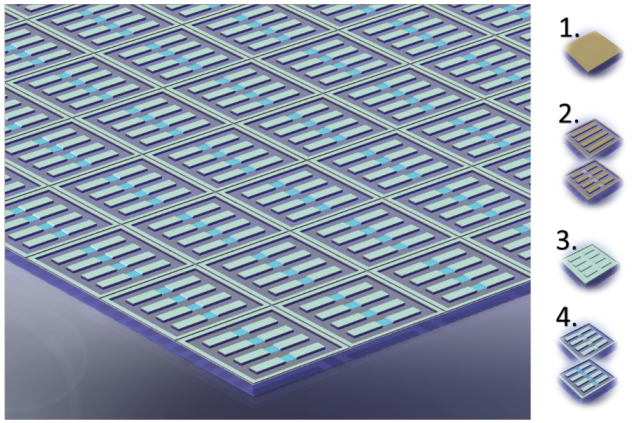
LASER TECHNOLOGY

Laser Patterning of Sputtered Coatings



Large area coated and patterned material for sensor applications.

- High Precision
- Scalability
- Repeatability
- Flexibility in Design
  - Material development
  - Performance optimization
- Reduced Waste
- Speed & Efficiency
- Cost Savings (Development & Manufacturing)

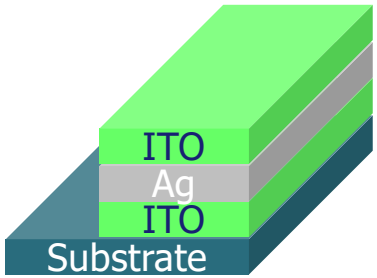


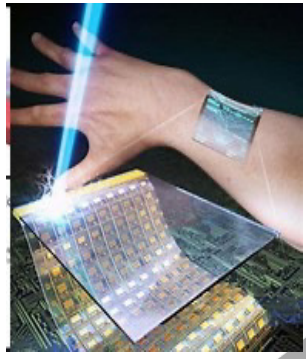
Process overview of coating and laser processing of subsequent layers for sensor for molecule detection.

THIN FILM COATING DEVELOPMENT

Intellivation R2R600 Application Lab

- **Process Demonstration and Development**
  - Complex multi-layer coatings and single layers
  - Metals, oxides, nitrides, oxynitrides
- **Interchangeable Deposition Modules**
  - Single or Dual Rotatable & Planar Magnetrons
  - Power Supplies: Bipolar Pulsed DC, DC, RF, HIPIMS,
- **In-Situ Monitoring Suite**
  - Crossweb Scanning UV/Vis Reflectance and others
- **Many Target Materials Available On Site**
- **Rapid Coating Development**
- **Intellivation Process Know-how and Support**
- **Modeling and Design of Multi-Layer Coatings**
- **In-house Characterization Lab**



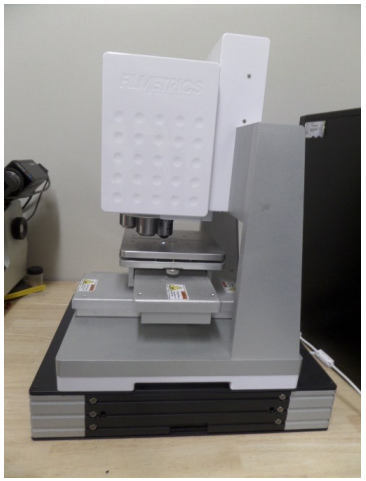


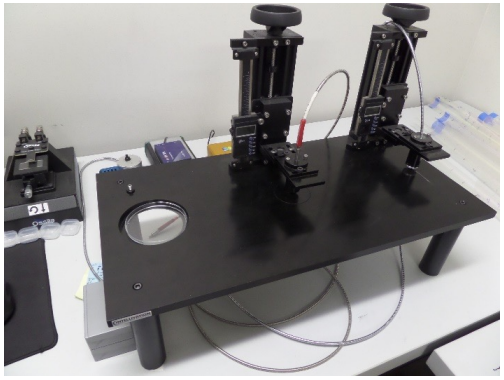
CHARACTERIZATION LAB

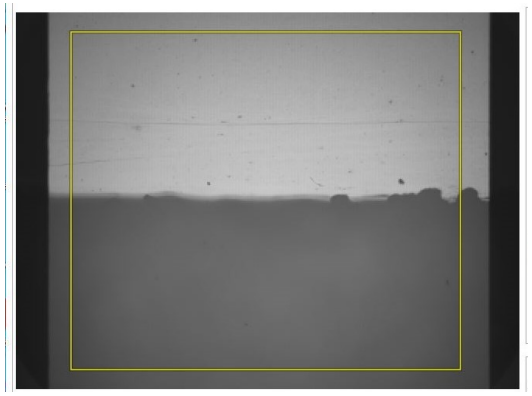
INTELLIVATION ENGINEERED SOLUTIONS

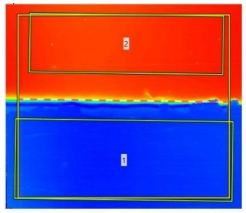
Intellivation Characterization Lab

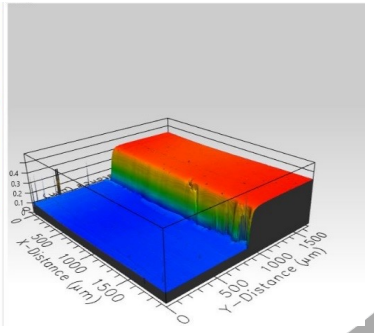
- **Optical & Dektak Stylus Profilometers**
- **Optical Spectrometer for Reflectance and Transmission (200-1100 nm) & Integrating Sphere**
- **4 Point Probe Sheet Resistance**
- **Optical Microscope**
- **Outside Sources with Additional Capabilities**
  - SEM, TEM, RAMAN & IR Spectroscopy, Others







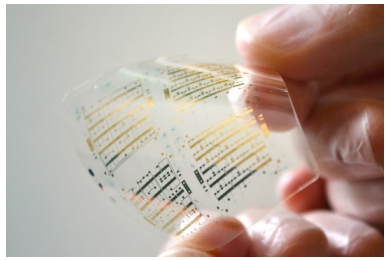




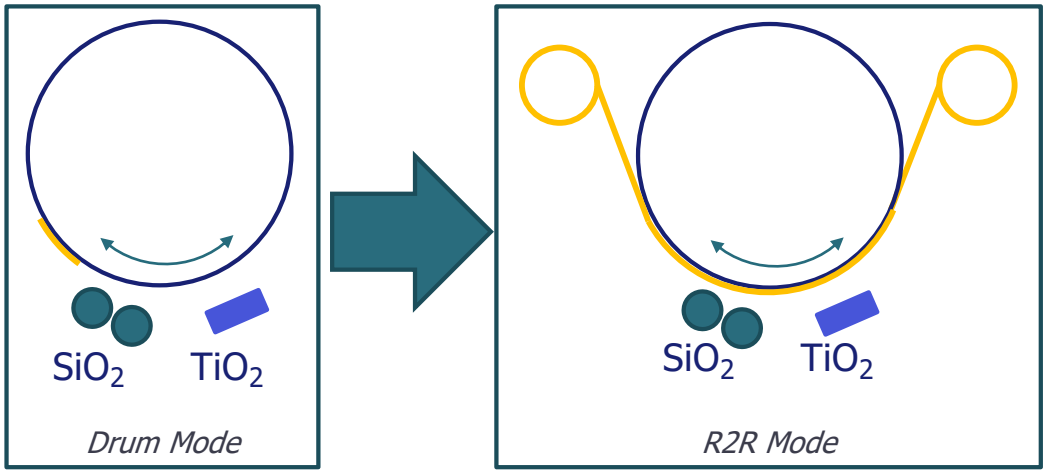
ROLL TO ROLL VACUUM COATING SYSTEMS

Rapid Coating Development

- **Drum Mode**
- **In-Situ Monitoring**
- **Automated Recipe-Based Processing**
- **Explore Huge DOE Spaces Efficiently**



Patterned Flex Circuit



A process can be developed in Drum Mode and transferred seamlessly into R2R Mode

RAPID COATING DEVELOPMENT

Advanced Process Automation

Program coating stack in HMI

- Recipe data
  - Coating Design (Layer Thickness)
  - Layers
- Input Position on the drum or Length of web to coat
- Process Parameters
  - Sputter Power, Frequency, etc..
  - Gas Flows
  - Drum Temperature

Start the coating => Runs to Completion

- No Operator Required
- Complete Automation
- Smart Controls

Intellivation Process Automation HMI Screen

R2R Coatings Applications & Requirements

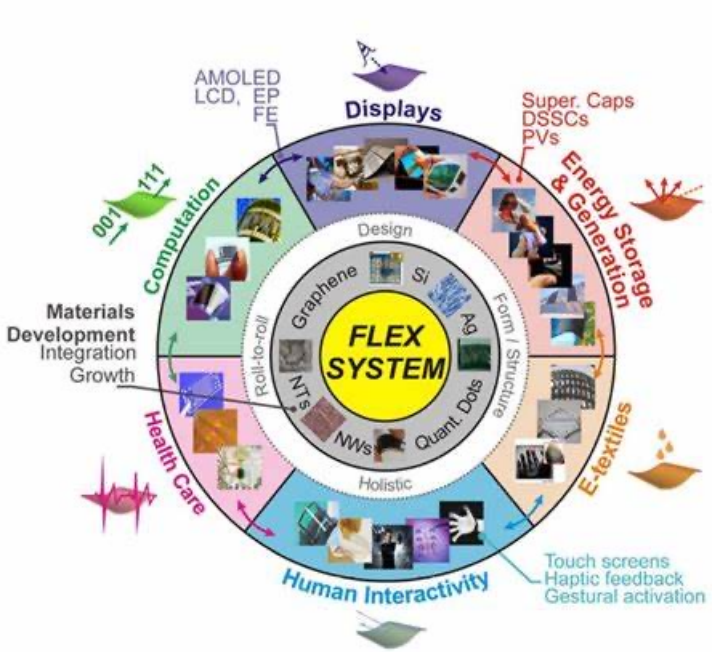
INTELLIVATION ENGINEERED SOLUTIONS

Applications

Electronics
- OLED
- Printed Electronics
- Photovoltaic
- Electrochromic

Energy
- Storage
- Solar Control
- Concentrator
- Battery

Other
- Security / Hologram / Anti-Counterfeit
- Military
- Barrier
- Specialty/Functional



Requirements

- Flexibility
- Advanced automation
- In-situ metrology
- Multiple and changing deposition techniques
  - Sputtering
  - Evaporation
  - Sublimation
  - CVD
  - i-CVD
  - HIPMS
- Multi-layer coatings with numerous passes
- Particle management
- Precise control of layer thickness
- Interleaves
- Application-tailored substrate pre-treatment

Roll to Roll
Multi-pass Thin Film Coatings

INTELLIVATION
ENGINEERED SOLUTIONS

Development Versatility for Coatings on R2R Platform

Multi-Pass Coatings

- Multiple Passes to Manage Substrate Heat Load for Thick Single Layers
- Reversible winding for Single Pump Down

Multi-Layer Coatings

- Complex Layer Designs
- Multi-layer Coatings Manufactured via R2R Sputtering

  Metals, Oxides, Metal Oxides, Nitrides, Mixed Oxides, Reactive Materials….

Efficient Process Transfer From S2S or Single Wafer to Large Volume R2R Format

MULTIPLE DOE CELLS IN SINGLE PUMP DOWN

(EXAMPLE 1)

INTELLIVATION ENGINEERED SOLUTIONS

Multiple DOE Cells Setup

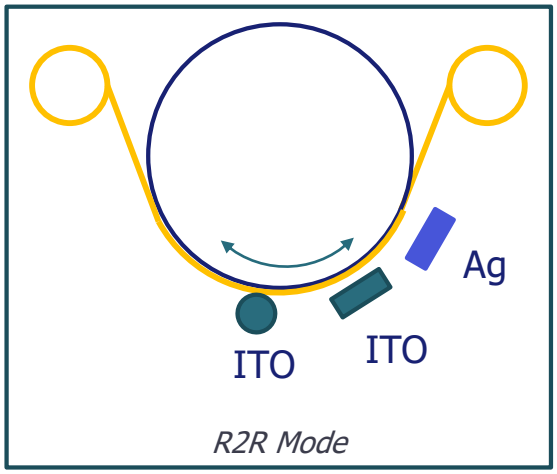
Define Length of Coated Substrate

- 0.5 - 1 meters coated for each design cell
  - Dynamic Deposition Rate (DDR) for Coat Zone
  - Heat Load to Substrate (Time @ Power in Coat Zone)

ITO Layer Calculation (Example)

35 nm Layer Thickness

- DDR 1st ITO Zone =31.9 nm-m/min
- DDR 2nd ITO Zone = 30.5 nm-m/min
  = 1st pass ~ 1.78 m/min



Configuration for IMI Process Development

Intellivation R2R Series equipment coats in **both** Directions

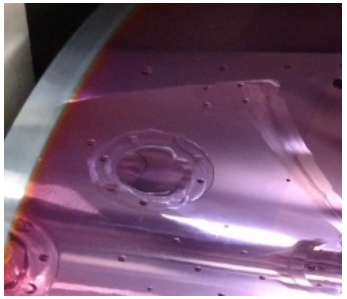
1st pass coats ITO layer
2nd pass coats Ag and ITO

RAPID COATING DEVELOPMENT

LARGE DOE: RAPID DEVELOPMENT (EXAMPLE 1)

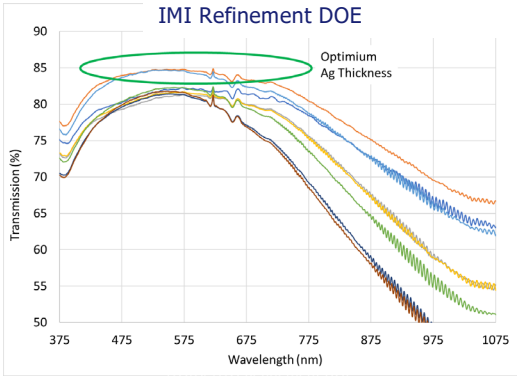
Rollable Polymer Material

- Low Thermal Load to retain substrate integrity
- Single layer Low Rsh typically achieved at Temperatures > 300 °C
- IMI metal dielectric stack is an alternative for low temp applications (< 80°C)

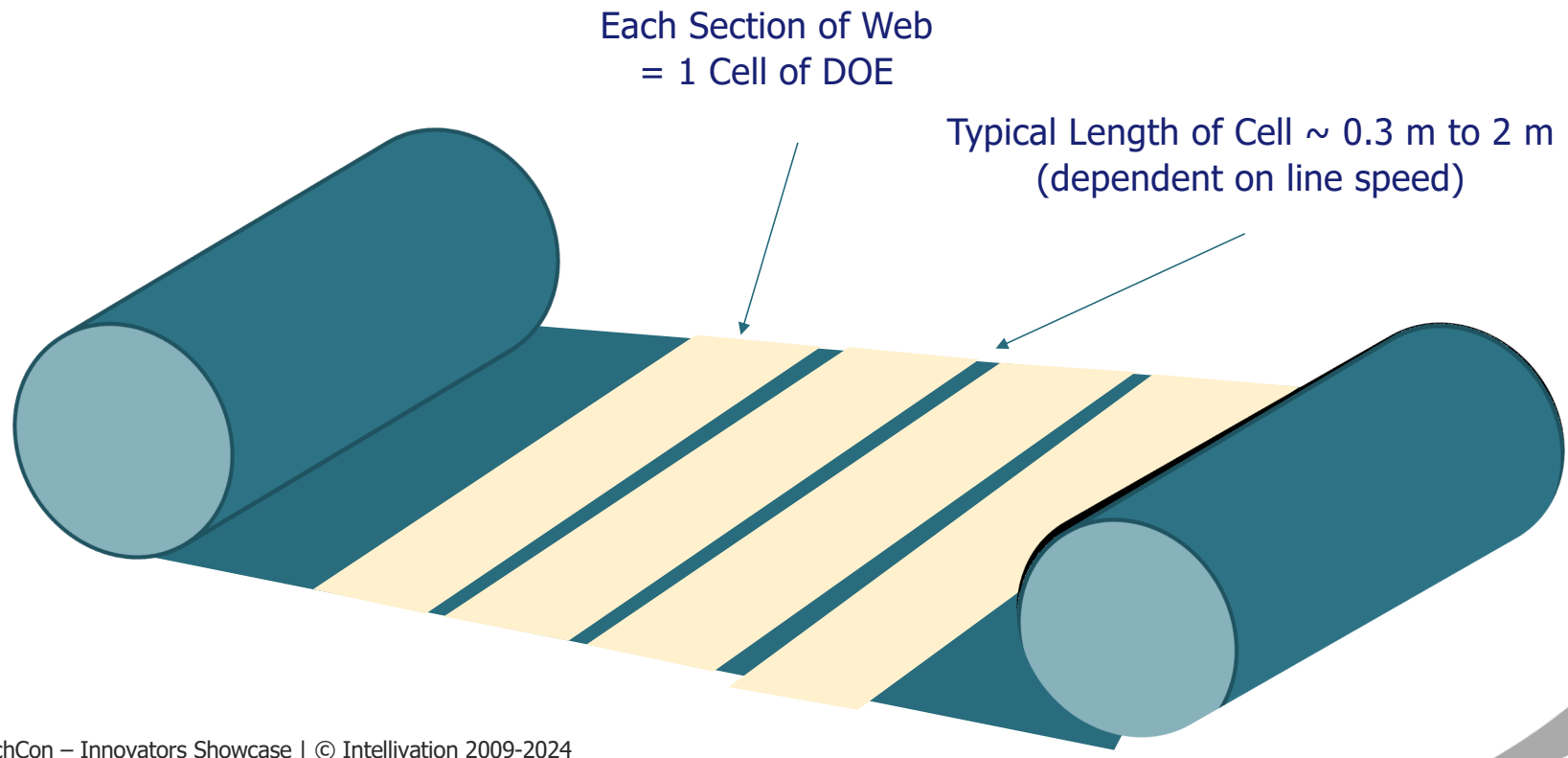


Rapid Development with Intellivation R2R Control System

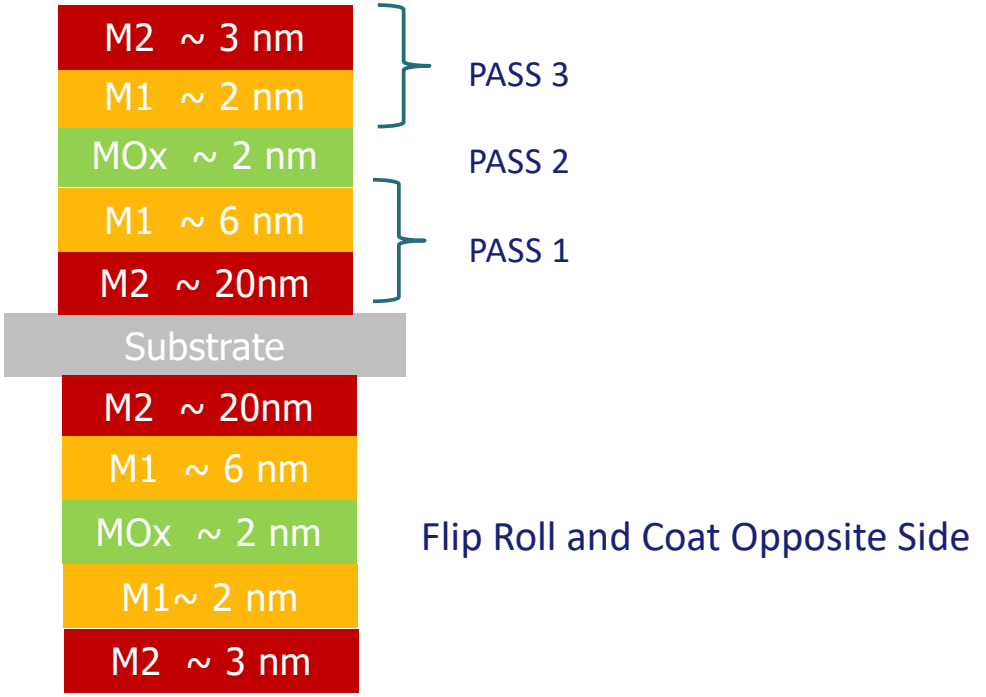
- Unlimited number of DOE Cells (Limitation is length of substrate) > 300 parameters
- Precise control of thin film properties and thicknesses
- Easily transferable process condition to Manufacturing



Layout of DOE Cells (Example 1)

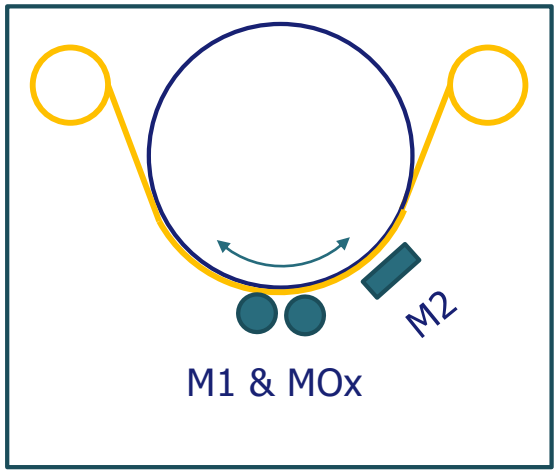


Thin Film Layer Stack & Machine Configuration (Example 2)

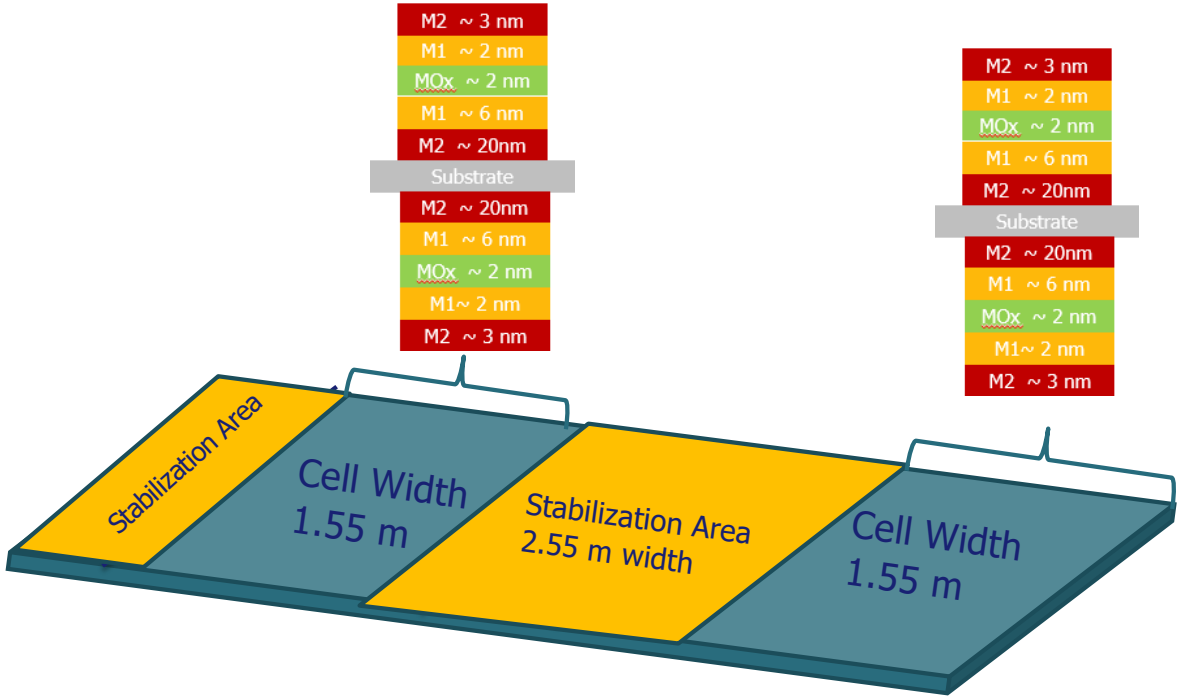


Flip Roll and Coat Opposite Side

Precision deposition and Controls of Multi-Layer Stack on Both sides of Substrate



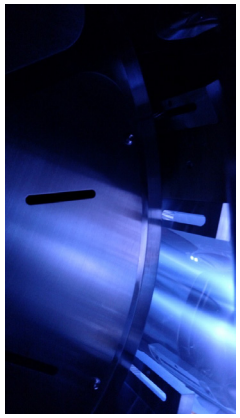
Cell Layout on Substrate (Example 2)



- Line Speed ~ 2.5 m/min
- Metal Oxide Process Stabilization ~ 1 minute
- DOE Cells Front and Back
- Several of the DOE Cells Match Yield of Single Wafer Tool

Throughput for R2R Significant Improvement over Single Wafer Tool for Complex Thin Film Catalyst

SUMMARY



Versatile & Modular Pilot Web Coater for Developmental & Industrial Applications

Unique Design & Source Options with Wide Range of Process Capabilities

Demonstrated Deposition of Complex Multi-Layer Coatings Capabilities

- Multi-Pass Capability Provides Layer Thickness Repeatability < 1%
- Coating Performance < +/-2% Layer Accuracy
- Complex layer optimization in Large DOE
- Rapid DOE results for Development and Transfer to Production

Modular R2R Series coating platform meets the changing needs of cutting-edge applications and streamlines product and process development

Intellivation application lab is available to provide support and assist customers in developing next-generation products

Smart controls for full process & manufacturing control

THANK YOU FOR YOUR ATTENTION

Intellivation is your flexible vacuum coating system solution provider. Our innovation, commitment to quality, engineering expertise and high level of personal service truly sets us apart.

"The New Frontier for Functional Vacuum Coatings"

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