Cluster R focuses on fabricating and characterizing polymer-based nanostructured materials, hybrid nanomaterials and templates on scaled, flexible substrates via roll-to-roll (R2R) process platforms. These process and materials technologies can be applied in the advanced coating and printed electronics industry to fabricate functional flexible materials and devices for high-value added products. Expertise includes synthesis of polymer and polymer-nanoparticle systems, self-assembly of complex nanostructures, process modeling, control, and characterization for high-throughput, flexible substrate processing platforms. Cluster R patterning technologies include UV-assisted R2R nanoimprint lithography (NIL) to generate substrate patterns with sub-100 nm features, nanotextured substrates, and continuous patterning of device-level features on a R2R platform. The cluster also studies additive-driven self-assembly involving well-ordered hybrid materials in which polymer templates guide the assembly of nanoparticles, nanotubes, fullerenes and other materials to produce functional device layers that can be applied via R2R coating techniques. These nanomanufacturing approaches combine to help cluster members develop large-area, low-cost synthesis and fabrication strategies for complex nanostructured materials on high-volume platforms. Advanced R2R products not only include electronic and energy devices such as solar cells, sensors, antennas, memory, displays, capacitors and batteries, but also many other functional components such as barrier layers, security films, transparent conductor layers, magnetic metamaterials, chem/bio shielding, water-repellent surfaces, filtration/separation membranes and other products incorporating nanomaterials-on-film. This cluster connects industry to translational research efforts within the Center for Hierarchical Manufacturing, an NSF-supported nanotechnology center, leveraging $4 million/year of federally-funded nanomanufacturing research.

**Cluster R Research Areas**

**Planarization:** Cost-effective and robust planarization layers are essential for many applications. UMass research involves the use of in-line planarization to achieve 1 nm RMS surfaces as a low-cost alternative to pre-planarized films. The approach can be adapted for introducing functionality into the layer.

**Imprint Embossing and Patterning:** UMass imprinting research aims to enable a wide variety of continuous process fabrication methods. Critical dimension sizes of imprinted features may vary widely depending upon the application but optimized to 50 nm for arbitrary patterns and 1-5 nm for large area nano-texturing for self-assembly. While production speeds of 25 m/min are attainable, speeds up to 1 m/min are envisioned for nanopattern transfer. Other parameters being studied and optimized include patterns aspect ratio (> 10:1), minimization of residual layer (< 5 nm), wet and dry etch, adhesion to substrate and release from mold, and substrate variation (PET, PEN, polylimide, paper).

**Alternative Conducting Layers:** There is a clear and immediate need for alternative conducting films for device applications especially in the area of transparent conductors. Work in this area explores development of polymer/nanoparticle and polymer/additive systems to achieve coatable films with excellent conductivity.

**Nanoporous Membranes:** Many applications require nanometer-scale porosity on a supported or unsupported film. Cluster R nanoporous membrane research explores the use of block copolymer additive systems in which the additive undergoes phase-selective chemistry or is used as a porogen that can be selectively removed to generate robust films with well-defined pores.

**Functional Hybrid Films:** Many applications require thin polymer films whose behavior is defined by additive packages. Research in this area explores the design and development of polymer/additive films with high loadings of a functional component such as a nanoparticle. Targets include high refractive index films, polymer-based films with high or low dielectric strength, and semiconducting films with improved carrier mobility.

**Coating of Viscoelastic Fluids:** Many applications require the production of films from coating fluid containing polymer and/or nanoparticle additives. The resulting fluids can become rheologically complex. Studies explore the effect that viscoelasticity has on gravure and slot coating systems so that they can be optimized for use with a wide spectrum of coating fluids.

**R2R Integration Issues:** This topic covers challenges for device integration on the web, with potential projects including selective area metallization by lift-off or etching through a NIL mask.

**Design for Manufacturability:** To lower development time and cost in R2R production of multifunctional devices, research focuses on design-process prototyping to establish design rules for simple devices that utilize heterogeneous nanostructured materials to combine electronic, magnetic and optical properties on a continuous line. Low-cost signal manipulation, sensing, power management, and communication are key issues.

**Roll-to-Roll Process Research Facility**

- NANOCoat 100 precision 6" R2R coater
- NANOemBOSS 6" modular UV-assisted roll-to-roll nanoimprint lithography (NIL) system
- Microgravure coater for block copolymer systems
- Full-time staff
- Access to facility tools for company/partner evaluation

**Contact**

Center for UMass / Industry Research on Polymers
University of Massachusetts Amherst
Silvio O. Conte Center for Polymer Research
120 Governors Drive
Amherst, MA 01003-4530
Telephone: 413-577-1243
Fax: 413-577-1517
Email: cumirp@mail.pse.umass.edu

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