Designed Surfaces
by
Plasma Nanoscale Coatings

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Micromorphological characteristics of water-repellent leaf surfaces:
(A) Hypericum aegypticum
(B) Marsilea mutica
(C) Nelumbo nucifera
(D) Lupinus polyphyllus.
(E) Gladiolus watsonioides
(F) Sinarundinaria nitida,
(G) Tropaeolum majus
(H) Melaleuca hypericifolia

Nature Inspired
Conformal Barrier Coatings

• Fuel and Hydrocarbon Barrier
  – Must protect from Hydrocarbons and Bio-Based Fuels

• Fuel Tanks for Small Engines
  – US annual volume: 19-20,000,000 units
  – Cost Sensitive

• Thermoplastic Polymer Substrates Made by Blow Molding usually Polyethylene

• Evolving Standards from California Air Resources Board and EPA [1g/m²/day]

• Moisture and Weather Barriers
  – Protect from Moisture, Environmental Polutants
  – May require UV Stability
  – Variations in Temperature Performance
  – May require reduced O₂ Permeability

• Applications
  – Packaging
  – Electronic Components
  – Displays, Signs and Signals

• Functional Barriers
  – Tie Coats and Subcoats
  – Designed Surface Chemistry
Nano-Texture + Layers: Multi Stage Plasma Based Conformal Coatings

Plasma Based Conformal Coatings Platform

StormRider Technologies Process, Patent Pending
Examples of TEOS [SiO$_x$] Coatings on EVA Foam Substrate

Fig. 2. Transmittance plot of surface ATR–FTIR signal through TEOS-coated PE-EVA foam substrate as a function of coating time.

Fig. 5. Hardness as a function of PECVD-TEOS coating time.

TEOS on EVA Foam Continued

![Graph showing elastic modulus as a function of PECVD-TEOS coating time.]

Fig. 6. Elastic modulus as a function of PECVD-TEOS coating time.

SiOx on Polycarbonate Edge Mask

101 nm SiOx on PolyCarbonate
SiOx on Glass Substrate 150nm
60 nm Polyolefin on Glass
Broad Technology Platform

- Wide Range of Substrates
  - Polyolefins
  - Polyolefin Foams
  - Polycarbonates
  - Carbon Fiber Composites
  - Rubber
  - Latex Films
  - Filled and Complex Formulations
- Dry-in, Dry-out
- Formed and Irregular Shapes
- Straightforward Scale-Up

- Organic Monomers:
  - Allyl Alcohol
  - Allyl Amine
  - Vinyl Acetate
  - Acrylic Acid
  - 2-Hydroxyethylmethacrylate
  - N-Vinylpyrrolidinone
  - Olefins
  - Fluorocarbons

- Inorganic/Ceramic Monomers
  - SiOx Precursors
  - TiOx Precursors

Surface-R -> Surface-R*
Surface-R* + Monomer -> Surface-R-Graft
Key Issues in Emerging Sectors

- Non Corrosive and Green Processes
- Conformal Coating Throughput [Mass Market Applications >300K Pieces/yr]
  - Chamber sizes are mass flow limited
  - Number of coating cycles/day/chamber
    - Parylene: 1-2 /day
    - Plasma: 10-20 /day
- Conformal Coating Cost
  - Cost per piece
  - Capital costs per coating applicator
  - Complex cyclophane monomer cost
- Coating Chemical/Physical Properties Flexibility
  - Temperature performance
  - Moisture resistance
  - Solvent resistance
  - Adhesion
  - Abrasion resistance
Applications Specificity: Defined by the End Use Market

- Wet Lubricious
- Dry Lubricious
- Reactive Functional Group
- Barrier Coatings
  - Moisture Barrier
  - Hydrocarbon Barrier
Some Potential Killer Applications Space

• Biomaterials
  • Tissue engineering
  • Regenerative medicine
  • Drug delivery
  • Proteins and peptides at interfaces
  • Lipid and biomimetic membranes

• Responsive colloids and materials
  • Biosensors
  • Surfaces and colloids in imaging and diagnostics
  • Radiation Detection

• Reactive Surfaces
  • Adsorption
  • Catalysis
  • Electrochemistry

• Materials for Advanced Electronics
  • Storage
  • Memory
  • Optical communications
  • Materials to enable novel device architectures

• Novel phenomena and techniques
  • Interfacial processes,
  • Capillarity and wetting in biological systems
Barrier Coatings
Solvent and Moisture Barrier Films

Solvent Barrier
- Applications
  - Fuel Tanks
  - Circuit Boards
  - LED Lighting
  - Chip Level Packages
- Coatings
  - SiOx Ceramic
  - Fluorocarbon

Moisture Barrier
- Applications
  - Circuit Boards
  - LED Lighting
- Coatings
  - SiOx Ceramic
  - Fluorocarbon
  - Polyolefin
  - TiOx Ceramic
    - [Photoactive-Self Cleaning]
  - Fluorosilicate
Ceramic Nano Coatings over Thermoplastics

- Glasses have low water and hydrocarbon permeability
- TiO$_x$ coatings have potential to be photo reactive and self cleaning.
- SiO$_x$ and TiO$_x$ coatings can be applied to thermoplastic parts at the nano scale via StormRider patented Plasma method.
- Commercial low cost monomers. Scalable process.
- Process is rapid: less than 1 hr/cycle
- Large scale plasma deposition machines available 42”x42”x54”.
- Dry-in dry-out process.
- Applications in Automotive, Consumer Electronics, Lighting, Medical Devices, Aerospace and Packaging.
Industrial Applications

• Abrasion Resistance
  – Instrument Panels
  – Displays
  – Solder Masks

• Circuit Board Level Barrier Coatings
  – Automotive
  – Consumer Electronics
Nature Inspired Passivation Films Afford Enhanced Protecting for Implantable Electronic Circuitry

Adapted from http://groups.csail.mit.edu/netmit/IMDShield/
Automotive Circuit Board Example. Hydrocarbon and Moisture Barrier

Automotive Control System Circuit Board

- Chasis-Underhood Environment
- SiOx Plasma Based Conformal Coating
  - 500K Units/yr
  - Temperature Tolerant to 140ºC Board Components
- Cycle Time: 25-50 min.
- Dry-in, Dry-out
- Economics [est.]:
  - Capital Hardware: $350K installed, 36”x36”x48” chamber
  - Throughput: 250/hr
  - Monomer Cost: $20K/yr
  - Low Emissions
Nature Inspired Passivation Films Afford Enhanced SORE Compliance with Permeation Regulations

CARB (California Air Resource Board) and the EPA’s (U.S. Environmental Protection Agency)
Blow Molded Fuel Tank Process Example. Hydrocarbon Barrier

- Blow Molded PE Small Engine Fuel Tank
- SiOx Plasma Based Conformal Coating
- Cycle Time: 25-50 min.
- Dry-in, Dry-out
- Economics [est.]:
  - Capital Hardware: $350K installed, 36”x36”x48” chamber
  - Throughput: 120/hr
  - Monomer Cost: $20K/yr
  - Low Emissions
Pilot Plasma Coating Unit
Production Plasma Coating Units

Production Plasma Coating Unit
36”X36”X48” Chamber
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