Presentation Outline

- **SMART, FUNCTIONAL, AND PROTECTIVE COATINGS**
  - History of Coatings
  - Definitions

- **WHAT CAN THEY DO?**
  - Current status
  - Examples

- **HOW DO THEY DO IT?**
  - Mechanisms
  - Examples

- **UV CURABLES TODAY**

- **WHAT DOES THE FUTURE HOLD?**
History of Coatings

**PAINT**
- Pigments & paint grinding equipment in South Africa (~350-400,000 years ago)
- Cave paintings in Southern France (30,000 years ago)
- Colored walls in Egypt (2,000 years ago)
- Painted ceilings in Ardea, an ancient Roman town
History of Coatings

- **Ancient Egypt (3,000 BC):** waterproofing for boats with pitch/balsam
- **China (1,200 BC):** coffin lacquers from tree sap
- **1754:** Devoe Paint (1st US paint brand)
- **1850:** internal can lacquer
- **1935:** first beer can
Definitions

- **PAINT**
  - Provides decorative or aesthetic properties

- **COATING**
  - Defined by its protective, rather than aesthetic properties, although it can provide both

- **SMART COATING**
  - Provides protective properties, and is capable of actively responding to its environment in a functional and predictable manner
  - May be permanent or reversible change
Smart/Functional Coatings: What Can They Do?

- MODIFY OPTICAL PROPERTIES
  - Anti-reflective
  - High reflection
  - Selective reflection
Smart/Functional Coatings: What Can They Do?

- **SENSE ENVIRONMENTAL CHANGES**
  - Electrochromic
  - Thermochromic
  - Color shifting
  - pH sensing
  - Oxygen sensing
  - Pressure sensing
Smart/Functional Coatings: What Can They Do?

- MODIFY ELECTROMAGNETIC PROPERTIES
  - Conductive
  - Insulative
  - Radio frequency sensor
  - Stealth coatings
Smart/Functional Coatings: What Can They Do?

- CLEAN/PROTECT THEMSELVES
  - Self cleaning
  - Easy to clean
  - Anti-fingerprint
  - Anti-graffiti
    (stain resistant)
Smart/Functional Coatings: What Can They Do?

- CLEAN/PROTECT THEMSELVES
  - Anti-microbial
  - Anti-inflammatory
  - Fire retardant/resistant

Harvard University
Smart/Functional Coatings: What Can They Do?

- **CLEAN/PROTECT THEMSELVES**
  - Ice prevention
  - Ice shedding
**Smart/Functional Coatings: What Can They Do?**

- **CLEAN/PROTECT THEMSELVES**
  - Fog prevention
  - Self healing

Samadzadeh, et.al.; *Progress in Organic Coatings*
Smart/Functional Coatings: What Can They Do?

- **DESTROY THEMSELVES**
  - Self erasing inks
  - Self destructing coatings
  - Peelable coatings

Images and logos from Northwestern University, AkzoNobel, and Nova Vision.
Smart/Functional Coatings: What Can They Do?

• PROVIDE MULTIPLE FUNCTIONALITIES IN A SINGLE COATING
  – Substrate adhesion
  – Corrosion protection
  – Color
  – Surface functionality/activity

  – Saves time and money
  – Intercoat adhesion no longer an issue
Smart/Functional Coatings: How Do They Do It?

- **CONTROL**
  - Coating composition on molecular level and/or
  - Coating morphology at nanometer scale

- **SOLUTIONS OBTAINED FROM**
  - Additives
  - Polymers
  - Coating systems

- **BIOMEMETICS OR BIOMIMICRY**
  - Structured surfaces

Min, et.al; *Advanced Materials*
Smart/Functional Coatings: How Do They Do It?

• **RESPOND TO**
  – pH
  – Ionic strength
  – Temperature
  – Pressure
  – Surface tension
  – Electrical or magnetic fields
  – Light
  – Acoustics
  – Mechanical forces

• **RESULTING IN**
  – Acid-base reactions
  – Complexation
  – Bond formation/breakage
  – Electrochemical reactions
  – Photochemical reactions

Kartsonakis, et.al., *Corrosion Science*
Smart/Functional Coatings: How Do They Do It?

- REVERSIBLE CHANGES (SWITCHES)
  - Protonation/deprotonation
  - UV induced isomerization, rearrangement, dissociation
  - Redox reactions
  - Temperature induced ring openings
**Smart/Functional Coatings: How Do They Do It?**

- **SELF STRATIFYING**
  - Two, three, or more coatings from one coating application
  - Incompatible polymers, solvents, kinetics
  - Surface tension gradients
  - Pigment treatment
  - Solventborne, waterborne, and UV coatings

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**Diagram:**

Verkholantsev; *Pigment & Resin Technology*
Smart/Functional Coatings: How Do They Do It?

- SELF HEALING VIA CLICK POLYMERIZATION

Wei, et.al.; Scientific Reports
• **SELF HEALING VIA ENCAPSULATION**
  – Advancing crack breaks capsule (temperature, humidity, UV exposure, osmotic pressure)
  – Corrosion inhibitors
  – Reactive components (A + B)

• **SELF HEALING VIA THERMOPLASTIC POLYMERS**
  – Low surface tension
  – Moves to surface over time, and fills cracks

• **SELF HEALING VIA VOLUME EXPANSION**
  – Clays
  – Polymers must be hydrophilic and have Tm
  – Moist heat needed to heal
Smart/Functional Coatings: How Do They Do It?

- **SELF HEALING VIA UV EXPOSURE**
  - Coating composition: chitosan, oxetane, PU polymer
  - Heals in 30 minutes

IR and Optical Images

Marek Urban, *Science*
Smart/Functional Coatings: How Do They Do It?

- **SELF ASSEMBLY: LAYER BY LAYER (LBL)**
  - Superhydrophobic Coatings

Lin, et.al.; *Langmuir*
Smart/Functional Coatings: How Do They Do It?

• **SELF ASSEMBLY**
  – Polymer brushes plus fibronectin
  – Titanium implants with improved adhesion to bone

Georgia Institute of Technology
- SELF CLEANING VIA SELF ASSEMBLY

Naphthalene diimide core with two guanidinocarbonyl pyrrole “arms” can form highly ordered self-assembled microarrays with solvent dependent morphologies.
Smart/Functional Coatings: How Do They Do It?

- **SELF ASSEMBLY**
  - Structured coatings

[Diagram of self-assembly process]

*Silicate or organosilicate patterns generated by self-assembly using ionic surfactants or block copolymers*

*Baer, et.al.; Progress in Organic Coatings*

*Ro and Soles, *Materials Today*
Smart/Functional Coatings: How Do They Do It?

- **ANTI-MICROBIALS**
  - Resist bacterial attachment
  - Kill bacteria on contact
  - Release biocides to kill bacteria
  - Additives or polymer modification
  - Ag, alkyl ammonium salts, N-haloamines, TiO$_2$

**APPLICATIONS**
- Biomedical devices
- Filters
- Paints
- Coatings
- Textiles
Smart/Functional Coatings: UV Curables Today

• APPLICATIONS
  – Optical
  – Photochromic
  – Self-cleaning/anti-graffiti
  – Conductive
  – RFI
  – Anti-microbial
  – Fire retardant
  – Anti-icing
  – Anti-fog
  – Others

Anti-Glare Coating; Peerless
Smart/Functional Coatings: UV Curables Today

- **EASY TO CLEAN PRODUCTS**
  - Two offerings from Cytec
    - (PRODUCT A >60% and PRODUCT B 25% incorporation levels)
    - Easy fingerprint removal without smudging
    - Oil and water repellant
    - Anti-graffiti (excellent chemical and stain resistance)
    - Excellent surface hardness (resists mechanical wear)
    - Outstanding slide angle

- **Targeted Applications**
  - Consumer Electronics (casing & display)
  - Optical Film
  - Display Partitions & Color Resist
  - High Gloss & Metallic Finishes
  - Luxury Packaging
UV Curables Today: Easy to Clean

- SOLVENT BASED MARKER TEST

Uncoated (control sample)  Coated with PRODUCT A  Coated with PRODUCT A (after dry wipe)
### DURABLE PERFORMANCE; LONG LASTING EFFECT

<table>
<thead>
<tr>
<th>Percent PRODUCT A</th>
<th>Average # of wipes to remove fingerprint</th>
<th>Average # of wipes after 200 Steel wool (0000) rubs, 1kg</th>
<th>Average # of wipes after 100 MEK rubs, 1kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>90</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>70</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Surface cleaned with dry wipes

Substrate = PC
Coating dry thickness = 12 microns
## UV Curables Today: Easy to Clean

### ROBUSTNESS OF E2C PROPERTY & BENCHMARKING

**PRODUCT B** provides unique superior & long lasting E2C performance when compared to competitive products.

<table>
<thead>
<tr>
<th>Property</th>
<th>E2C formulation 25% PRODUCT B</th>
<th>COMP1 UV additive based coating</th>
<th>COMP2</th>
<th>COMP3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of dry wipes to remove fingerprint</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Pencil Hardness</td>
<td>3H</td>
<td>2H</td>
<td>3H</td>
<td>3H</td>
</tr>
<tr>
<td>Permanent marker resistance (dry wipes)</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>Steel wool scratch resistance, 200 rubs, 1kg load</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Permanent marker Resistance after 200 steel wool rubs, 1kg</td>
<td>Excellent</td>
<td>Poor</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>Smearing during wipe</td>
<td>slight</td>
<td>moderate</td>
<td>moderate</td>
<td>slight</td>
</tr>
<tr>
<td>Smearing during cleaning after 200 steel rubs, 1kg load</td>
<td>slight</td>
<td>severe</td>
<td>moderate to severe</td>
<td>severe</td>
</tr>
</tbody>
</table>
Smart/Functional Coatings: Future

• WHAT
  – Microelectronics with no moving parts
  – Coatings with very long lifetimes
  – Replacement of mechanical sensors
  – On-demand control of functionality

• APPLICATIONS
  – Medical fields
  – Military applications
  – IT technologies
  – Aerospace
  – Food & Packaging
  – Agriculture
  – Automotive
  – Architectural
  – Industrial
  – Household
  – Cosmetics & Personal Care
  – Apparel
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