Ultraviolet Curable Powder Coatings With Robotic Curing for Aerospace Applications
Report Documentation Page

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Outline

- Project Team
- UV-Cure Technology
- UV-Curable Powder Overview
- Current Status of ESTCP Project WP-0801
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UV Cure Technology
UV Cure Technology

Typical medium pressure mercury discharge lamp power distribution.

- Ultra-violet radiation:
  - 25 - 30%
  - 2.5 - 3.0 kW

- Visible light radiation:
  - 5 - 10%
  - 0.5 - 1.0 kW

- Infra-red radiation:
  - 60 - 65%
  - 6 - 6.5 kW

UV-Cure Technology

- Typical Ultraviolet Lamp Spectra:
UV Cure Technology

- Chemistry of UV-cure coatings
  - Can be virtually any polymer matrix used for organic coatings
  - The common denominator is the presence of a UV light reactive species on/in the polymer matrix
  - Commonly vinyl, acrylate or methacrylate groups

![Chemical structures of Vinyl, Acrylates, and Methacrylates]

UV Cure Technology

- Chemistry of UV-cure coatings
  - Typically, the most common UV curable powders are:
    - Polyurethanes
    - Polyesters
    - Epoxies
    - Hybrids and mixtures of the above
  - For the UVCPC project, we use a special composition of light activated polyurethanes and polyesters
UV Cure Technology

- Polyurethane diacrylate (typical) MW \(~2000 - 4000\)
UV Cure Technology

- Polyester diacrylates (typical) MW ~2000 - 4000

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H₂C=CH·C[O·R₁·O·C·R₂·C·O]ₙ·R₁·O·C·CH=CH₂
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UV Cure Technology

- UV Cure formulations require:
  - Light reactive polymer resins
  - Additives such as pigments and flow agents
  - Photoinitiators
UV-Curable Powder Overview
UV-Curable Powder Overview

- Previous ways of thinking about powder
  - Coating cure temperatures – typically above 220°C
  - Prohibitive for use on tempered metals (Al, Mg, Ti)
  - Prohibitive to use on composites
  - Powder coatings were designed as barrier protection
UV-Curable Powder Overview

- Modern powder coatings can be formulated to have:
  - Lower melt & flow temperatures (< 110°C)
  - UV or EB cure functionality can be added
  - Various advanced non-chrome corrosion inhibitors
Advantages of UV-cure powder coating:

- Elimination of volatile organics (VOC)
- Elimination of hazardous air pollutants (HAP)
- Reduction/elimination of hazardous waste
- Transfer efficiencies as high as 95% (w/reclaim)
- Decrease in thermal exposure.
- Large bulky parts that cannot fit into existing ovens can be coated and cured.
- UV-cure powder requires less energy because the energy is focused to a specific part only as long as needed.
UV Curable Powder Overview

- Powder is applied using electrostatic powder gun
- Applied powder is cured with IR and UV lights mounted on robotic curing system
UV Curable Powder Overview

- The UV cure powder process:

1. **IR heating**
   - Powder applied to substrate, heating starts

2. **IR heating**
   - Powder melts, flow starts

3. **Flow completed**

4. **UV irradiation**
   - Coating cures
**UV Curable Powder Overview**

- Crosslinking occurs during UV irradiation:

![Diagram](image)

- **unsaturated resin + photoinitiator**
- **photoinitiator breaks down to form free radicals**
- **resin crosslinks**

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ESTCP Project WP-0801
The Problem:

- DoD spends millions of dollars annually on solvent-based coatings
- Hexavalent chrome primer use still very widespread
- Contains or requires volatile solvent use
- Significant hazardous waste costs
- Hazardous materials pose risks to human health and environment
- Process times measured in hours to days
- Transfer rates are less than 60%
The WP-0801 Objectives are:

- Demonstrate a VOC/HAP-free, Ultraviolet cure powder coating (UVCPC) on DoD hardware
- Demonstrate state-of-the-art robotics for curing
Requirements of a UVCPC for military use:

- Must perform at least as well as MIL-PRF-23377 primer
- Must also perform as well as MIL-PRF-85285 topcoat
- Can be prepared in gloss, semi-gloss, and flat finishes
ESTCP Project WP-0801

- Robotic Curing System:
  - Robot carries the Infrared and Hg vapor UV lamps
UV Cure Powder:

- Currently utilizing one vendor
- Three colors, two gloss whites, one semi-gloss gray
- Current powder melts and flows at 115°C
- Has undergone a number of tests to validate performance
- The current powder has no Chromium, Molybdenum, Vanadium, Barium, or any rare earth inhibitors
- In fact, it has no corrosion inhibitors
 UV Cure Powder Performance Summary:

- Greater than 4400 hours scribed B117 salt spray
- 18 months on beach with shiny scribes
- Better than the control in 1000 hour filiform
- UVCPC is 38% more durable in falling sand testing
- Easily passed fluid immersion testing
- Strippability demonstrated
ESTCP Project WP-0801

- Salt Spray Panels
  - 12 months on beach
  - 4400 plus hours B117

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- Filiform corrosion resistance results
  - Testing performed by NAVAIR, Patuxent River
  - Panels removed after 1000 hours without failure
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- Reverse Impact Flexibility
  - >120 in-lb
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- Fluid Immersion Resistance
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- Strippability Tests

Initial stripper applied

UVCPC after 4 hours
## Summary of Validation Testing

### UVCPC Minimum Required Tests to Validate

<table>
<thead>
<tr>
<th>Test in Progress/Complete</th>
<th>Test in Progress/Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>B117 - 4130 steel (ZnPhos)</td>
<td>Outdoor beach exposure (months)</td>
</tr>
<tr>
<td>B117 - 4130 Steel S-W Wash Primer</td>
<td>Aluminum - scribed</td>
</tr>
<tr>
<td>B117 - Aluminum (Alodine 1600)</td>
<td>Aluminum - unscribed</td>
</tr>
<tr>
<td>B117 - S-W Wash Primer</td>
<td>Steel - scribed</td>
</tr>
<tr>
<td>Filiform Corrosion</td>
<td>Steel - unscribed</td>
</tr>
<tr>
<td>SO₂ Corrosion - steel (500 hr)</td>
<td>Gloss</td>
</tr>
<tr>
<td>SO₂ Corrosion - aluminum (500 hr)</td>
<td>Weatherability</td>
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<tr>
<td>Impact Flexibility</td>
<td>Color</td>
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<tr>
<td>Reverse impact flexibility</td>
<td>Gloss</td>
</tr>
<tr>
<td>-60F Low temperature flexibility</td>
<td>Cleanability</td>
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<tr>
<td>Wet tape adhesion</td>
<td>Heat Resistance</td>
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<tr>
<td>Dry tape adhesion</td>
<td>Fluid Resistance</td>
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<tr>
<td>Pencil hardness</td>
<td>Strippability</td>
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<tr>
<td>Appearance</td>
<td>Sand Erosion D968</td>
</tr>
<tr>
<td>Color</td>
<td>62 L/mil vs 55 L/mil</td>
</tr>
</tbody>
</table>

**NOTE:**
- Outdoor beach exposure (months) requires a minimum of 1882 hours, with 1000 hours noted as a requirement for UV exposure.
- Steel passivation into Ferrite at scribe is required.
- Cleanability is based on outdoor exposure testing with an ΔE = 1.84.
- 

**Case Number:**
88ABW-2012-2804, 9 May 2012.
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- Planned demonstration weapon systems:
  - EA-6B wheels, landing gear
  - HH-65 helicopter
  - P-3 wheels, landing gear, radomes
  - Mk-48 ADCAP torpedo
  - HC-130 main landing gear doors
  - Ammunition and storage cases
ESTCP Project WP-0801

■ Studies:
  ■ UVCPC aircraft wheels for PEWG
  ■ Successfully demonstrated capability to electrostatically powder coat otherwise non-conductive materials.
Questions?