Water-based PVDF Coatings for Cool White Roof Applications

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&
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Outline of talk

- PVDF Introduction
- Cool white roof introduction
- New PVDF-acrylic hybrids for cool roofs
- Stay clean properties
- Solar reflectance properties
- Conclusions
The importance of cool roof technology

- Solar-reflective “cool roofs” are becoming an important component of many national energy policies, due to their proven ability to reduce electrical demand, particularly during peak summer energy periods.

- Cool roofs have the potential to
  - Mitigate urban heat islands
  - Slow global warming
  - Savings on electricity
Extending the “cool roof” color space using a basecoat/topcoat approach

Durable topcoat with “cool pigment” (Minimal pigment for visual hiding)

High solar reflectance, opaque basecoat

Roof Substrate

But to make this work: The topcoat must retain its decorative properties, over the multi-year service life of the object!
PVDF among Fluoropolymers

- Polyvinyl fluoride (PVF)
- Polyvinylidene fluoride (PVDF)
- Polychloro-fluoride trifluoroethylene (PCTFE)
- Polytetrafluoroethylene (PTFE)
- Tetrafluoroethylene + hexafluoropropene (FEP)
- Tetrafluoroethylene + perfluoropropylether (PFA)
- Tetrafluoroethylene + ethylene (ETFE)
- Chlorotrifluoroethylene + ethylene (E-CTFE)
Polyvinylidene Fluoride (PVDF) Properties

- Resistant to UV degradation
- Chemically resistant
- Low surface energy; Non supportive of fungus or bacteria
- High mechanical strength
- Cold weather impact strength
- High thermal stability
- Abrasion resistant
- Creep resistant
- Semi-crystalline
- Easily melt processable and weldable
- Soluble in polar solvents
- Miscible with other polymers
- Low permeation to most gasses and liquids
- Low flame and smoke characteristics
- High purity
General properties of fluorine-containing materials

- C-F bond is very strong—resistant to chemical attack and also photochemically stable
- C-F bond is highly dipolar, can dominate interactions in cases where there is local asymmetry
- Highly fluorinated materials are very hydrophobic

The basis for weathering properties

- Resistance to Dirt Pick-up
- Resistance to Film Erosion
- Resistance to Mildew & Fungi
- Resistance to Rain and Chemicals
- Retention of Color and Gloss

C-F Bond
PVDF licensed finishes are typically 70% PVDF / 30% acrylic, solvent-based, baked on metal substrates
Coating properties – color retention

<table>
<thead>
<tr>
<th>Unexposed</th>
<th>Exposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0173 1081</td>
<td>1067 432</td>
</tr>
<tr>
<td>0769 545</td>
<td>1067 432</td>
</tr>
<tr>
<td>0173 1107</td>
<td>1067 432</td>
</tr>
<tr>
<td>0173 1101</td>
<td>Continuous exposure since October 1967</td>
</tr>
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</table>
Coating color fade and chalk

Commercially coil coated samples after 17 years of Florida exposure.
Waterborne PVDF hybrid dispersions open up new possibilities for “green” coatings

- Environmentally friendly due to:
  - Low VOC coatings
  - APEO-free
  - Fluorosurfactant-free
  - Very long service life at low film thickness, reducing the use of consumption of materials
New platform for waterborne PVDF hybrid coatings

- **Stage 1: Fluoropolymer Emulsion Polymerization**
  - PVDF Copolymer
  - Lower crystallinity than PVDF homopolymer used in baked solvent coatings
  - Slightly higher fluorine level than homopolymer

- **Stage 2: Seeded Acrylic Emulsion Polymerization**
  - Acrylic monomers added and polymerized
  - Variable PVDF/acrylic ratio
  - Intimately mixed phases
  - Formulates like acrylic latex
  - Air-dry or low temp. bake coatings
## Water-based PVDF product range

<table>
<thead>
<tr>
<th>Type</th>
<th>High PVDF level, thermoplastic</th>
<th>Moderate PVDF level, thermoplastic</th>
<th>2-k Crosslinkable Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVDF : Acrylic Weight Ratio</td>
<td>70:30</td>
<td>50:50</td>
<td>70:30</td>
</tr>
<tr>
<td>Functional group level</td>
<td>Thermoplastic</td>
<td>Thermoplastic</td>
<td>OH# = 18 on total solids</td>
</tr>
<tr>
<td>MFFT</td>
<td>26-28°C</td>
<td>12-14°C</td>
<td>15°C</td>
</tr>
<tr>
<td>Target Applications</td>
<td>Highly weatherable OEM</td>
<td>Low VOC field applied / cool white roof coatings</td>
<td>Enhanced hardness, solvent and abrasion resistance</td>
</tr>
</tbody>
</table>
Validation of weatherability, water-based PVDF paints

Water-based PVDF masstone series, 10 years Florida, with proven metal oxide pigments, 70% PVDF resin / 30% acrylic—minimal color fade

PVDF: acrylic ratio ladder with cobalt blue pigment:
Max test of weatherability.
At 7 years FLA S45.
Latex paints, left to right:
70% PVDF resin, 50% PVDF resin, acrylic I, acrylic II, 70% KYNAR resin
Color fade vs. PVDF level (inorganic pigments)

Waterborne coatings, 12 PVC Appearance after 7.5 years South 45º Florida exposure

- Cobalt blue pigment allows some penetration of UV into the binder
- Color fade comes only from binder degradation and chalking effects
- Color fade rate scales roughly with total acrylic content
- No chalking or cracking for systems with 50% or higher PVDF
10-Year Florida exposure

Water-based PVDF vs. Solvent-based PVDF
Meets AAMA 2605, 615, & 625

Water-based PVDF

Solvent-based PVDF

[Image of chart comparing water-based PVDF and solvent-based PVDF, showing results that meet AAMA 2605, 615, & 625 standards.]
Why PVDF/acrylic blends with high PVDF resin levels have reduced chalking and improved color retention

Acrylic at surface weathers away but the PVDF resin keeps the pigments encapsulated—no chalking!!!
Dirt pick-up resistance

- **Carbon Black (Water Wash Off)**
- **Original Color**
- **Water-based PVDF**
- **Elastomeric Acrylic**
- **Iron oxide slurry**
Mildew and fungus resistance

- After 8 months exposure in Florida at 5 degree south exposure
- Test paints formulated without mildewcide
Dirt & stain resistance properties of PVDF-based coatings

Paints applied on SBS asphalt substrate; air-dried then baked at 60°C for one week

Acrylic basecoat - 10 mils dry-film thickness and Fluoropolymer topcoat - 2 mils dry-film thickness

Commercial elastomeric acrylic paint - 10 mils dry-film thickness

Single coat, paint based on Fluoropolymer 2 mils dry-film thickness

Original paint colors
Extreme low water pickup of PVDF-based coatings

After 7 day air-dry

- Acrylic
- Fluoropolymer

% wt gain vs. immersion time (hr)
Water-based fluoropolymer coatings can be applied:

- Over aged coatings for color restoration & to multiple surfaces
  - EPDM, PVC, and TPO roofing membranes.
  - Concrete, synthetic, bitumen and asphalt tiles and shingles.
  - PVC, polyester pultrusion, aluminum window and door frames.
  - Previously coated metal substrates including roofing and siding.

![Image of buildings and coatings]
Water-based PVDF cool roof coating application

**TOPCOAT**
PVDF Latex
- 2-3 mils
- ½ gallon/square

**BASECOAT**
Elastomeric Acrylic
- 10-15 mils
- 1 ½ gallon/square
Water-based PVDF vs acrylic based coatings
PVDF Latex Based Cool White Coating versus Elastomeric Acrylic

PVDF Latex

3 Year TSR
80

Initial TSR 0.87

Elastomeric Acrylic

3 Year TSR
55

Initial TSR 0.85
Fluoropolymer test on PVC membrane
1 year of exposure in southern Georgia

PVC Membrane on Peanut Dome

Water-based PVDF Coating
9 years Florida PVDF vs. PVC membrane

PVDF based painted metal roof with 0.80 Solar Reflectance

PVC membrane with ~ 0.50 Solar Reflectance

Source: Florida Solar Energy Research Institute
Annual Cooling Energy Savings of a Cool White Roof Coating versus a Non-Cool Roof at 0.20 TSR

- Arizona
- California
- Florida
- Texas

Elastomeric Acrylic
TSR: 0.55

Fluoropolymer Latex
TSR: 0.77

>60%
PVDF latex based white coatings exposed in South Florida

Unexposed

Exposed Unwashed

Exposed Washed

<table>
<thead>
<tr>
<th>Total Solar Reflectance</th>
<th>Initial</th>
<th>5 Years</th>
<th>10 Years</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0.82</td>
<td>0.81</td>
<td>0.78</td>
</tr>
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</table>
Wells Fargo Bank in Pensacola, FL

0.15 TSR

25% Savings on Electricity

0.85 TSR

Electrical Demand, kWh

Prior 3-yr April Ave

Apr-11
20-year life cycle advantages with water-based PVDF compared to acrylic based coatings

- Double the life
- Equivalent initial application cost
- Lower life cycle cost
- 1/3 less V.O.C. releases
- Reduction in CO2 emissions
- Superior dirt shedding properties
- Superior mildew resistance
- Superior asphalt stain bleeding properties
- Superior moisture absorption resistance
- Significant film erosion resistance
In conclusion, coatings based on PVDF offer:

• Abrasion resistance
• Chemical resistance
• High thermal stability
• High mechanical strength
• Excellent solar reflectance
• Miscible with other polymers
• Resistance to UV degradation
• Improved dirt pick-up resistance
• Improved algae, mildew and fungal resistance
Color retention, solvent and waterborne PVDF paints

9 Years South Florida Exposure

Panel photos taken December 17, 2009

Color retention of 70% PVDF paints (25 microns thickness) is quite comparable, for waterborne hybrid and baked solvent paints
Questions?

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