Environmental Legislation; Drivers

- CAAA Clean Air Act Amendments
- Volatile Organic Compounds (VOC's)
- Ozone
- Benzene
- Hexavalent Chromium
- Green House Gases (GHG)
- Cadmium
- Nano Technology
- Formaldehyde
- Acid Rain
- Photochemical Reactivity
- Aquatic Toxicity
- Reduction in HAP's
- Particulate Matter
- Lead
- Odor
Advances in Coatings Discussed Today

- Trends / Drivers

- Pigments
  - Synthetic
  - Interference
  - Infrared Reflecting

- Integrated Processes

- Film Laminates
Trends & Drivers
<table>
<thead>
<tr>
<th>Year</th>
<th>Technology Introduced</th>
<th>Main Development Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>Lacquer</td>
<td>Weathering, Film Erosion</td>
</tr>
<tr>
<td>1960</td>
<td>Alkyd-, Nitrocombi-paint</td>
<td>Gloss, Non-Yellowing</td>
</tr>
<tr>
<td>1970</td>
<td>1K AC/ MF-paint</td>
<td>Cracking, Durability</td>
</tr>
<tr>
<td>1980</td>
<td>2K AC/ NCO-paint</td>
<td>Chemical Resistance</td>
</tr>
<tr>
<td>1990</td>
<td>Powder/ Powderslurry, WBBC</td>
<td>Lower Emission</td>
</tr>
<tr>
<td>2000</td>
<td>Carbamate, UV-Cure</td>
<td>Scratch, Mar, Etch, Resistance</td>
</tr>
<tr>
<td>2010</td>
<td>3-WET Integrated Systems</td>
<td>Stream Line Manufacturing</td>
</tr>
</tbody>
</table>
Technical Advancement in VOC Reduction

- Energy Minimization
  - Integrated systems (reduce carbon footprint)
  - Low energy cure systems
  - UV and electron beam
  - New chemical approaches
  - Application improvements
  - one & two coat bell application

- Renewable and Re-cyclable Resources
  - Bio-based material (renewable feed stock)
  - Bio-degradable
  - Use of microbes, bacteria, enzymes as catalysts
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Cool Cars are Timeless!
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All Markets are Connected by Color
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Automotive Color Popularity
North America
Integrated Processes
Benefits of Integrated Coating Systems

- Elimination of a Bake Oven
  - Total energy reduction
  - Lower emissions of CO₂

- Reduce the Paint Shop Footprint
  - Less materials for construction
  - Lower heating/cooling costs

- Elimination of Waste
  - Less material usage
  - Less paint sludge
Integrated Processes

Standard Process

Integrated Process 1 (WBBC)

Integrated Process 2 (WBBC)

Integrated Process SB (HSBC)

ED → Primer → Basecoat → Clearcoat

ED → ColorPro I → ColorPro II → Clearcoat

ED → ColorPro I / ColorPro II → Clearcoat

ED → ColorClassic I / II → Clearcoat
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Color & Appearance are More Difficult to Control
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Pigments
Synthetic
Interference
Infrared Reflecting
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The Market for Effect Pigments

- The total amount for all pigments produced in 2006: 7 million tons, dominated by titanium dioxide at $2/kg.
- Color pigments make up 25% of the above, totaling 1.8 million tons, with iron oxide as the major pigment at $3/kg.
- Color organic and special effect pigments make up 20% of the above, totaling 360 thousand tons, with organic colorants priced between $6 - $25/kg.
- Special effect pigments: 65 thousand tons, less than one percent of the total amount, with prices ranging from $3 - $1000+ /kg.
Anatomy of an Effect Pigment

Substrate (Core)
- Aluminum
- Natural and Synthetic Mica
- Glass Flakes
- Alumina
- Silica
- Varies smooth to rough
- Varies opaque to transparent

Coated platelets
- Increased chroma and luster
- Reflection + Interference
- Absorption
- Improved orientation
- Decreased opacity
- Appearance more critical
- Durability protection

Coating Layer: thickness determines the color
- High index of refraction: Absorption + Interference color
- Low index of refraction: Absorption color

Weather Treatment (optional): Outermost layer
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Target: Mimic Nature
Principle of Light Interference
Color Flop and Goniochromaticity

Reflection at the surface

Partial reflection/transmission: various reflection and transmission points

Interference effect generated

$n_1 >> n_0$
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Changing the Substrate

Mica
- Hiding power

Silica
- Color
- Travel

Alumina
- Sparkle
- Performance

Borosilicate
- Transparency
- Gloss

Diffraction
- Aluminum
- Holographic

Photos courtesy EMD Chemical
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Color Dependent on Coating Thickness

- **Interference:**
  - TiO₂ Coated

- **Absorption:**
  - Fe₂O₃ Coated

- **Combination:**
  - TiO₂ + Fe₂O₃ Coated
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Colorstream

Silica Flake coated with a layer of iron oxide

Photo courtesy EMD Chemical
BASF Coatings

Color Enhances Shape
Heat build up is caused by solar radiation
  - Major component for increase in temperature is IR region
  - “heat island” effect

Pigments can reduce the reflectivity of solar radiation

All pigments absorb, reflect, and transmit solar radiation to different degrees

Substrate plays a major effect on solar reflectance
  - Visual hiding versus solar hiding

BASF has excellent market success in “ULTRA-Cool” colors for building materials
“Cool” Pigments

- IR transparent
  - Organic Perylene Pigment Black 32

- Some IR reflective pigment chemistries
  - Inorganic Pigment Green 17 (FeCr)
  - Inorganic Brown 29 (FeCr)
  - Inorganic Yellow 164 (MnSbTi)

Many pigments, e.g. aluminum flake or titanium dioxide, are very efficient at reflecting infrared light.
**BASF Coatings**

**Spectral Radiation of Sunlight**

Infrared (IR) radiation is electromagnetic radiation of a wavelength longer than that of visible light, but shorter than that of radio waves. Infrared radiation spans three orders of magnitude and has wavelengths between approximately 750 nm and 1 mm.[1]
<table>
<thead>
<tr>
<th>Image exposure to visible spectral range</th>
<th>Image exposure to near-infrared spectral range, 700–1000 nm</th>
</tr>
</thead>
</table>

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Heat Reflecting Mechanisms:
- Pigment: Organic Black Pigment
  - Darker Black
  - Inorganic Black Pigment: Greenish Brown Black
- Primer-(white)
- Primer-(Gray)
- Electro-Coat
- Base-Coat
- Clear-Coat

Absorb visible and Infrared lights...
- Black color

Reduced Thermal Propagation
Understand the benefits of coating an automobile with solar reflective pigments
- Limitations of the color palette
- Heat Island Effect
- Impact on HVAC mass reduction
- Passenger comfort and convection cooling
- Contribution of the window glazing

Thorough studies needed to quantify the relative portion the coating makes on heat build up

Continue to work with CARB to ensure good approach to cool
BASF Coatings

It Can Get Complicated
Functional Pigments
Magnetic Imager Effect
Oriented Towards Color

- Magnetically oriented lamellar effect pigments
- Badging/branding, contour lines, etc
- Mass reduction
UV Film Benefits

✓ Class A finish on plastic surfaces
✓ Improved scratch and mar resistance
✓ No spray equipment required for application
  ✓ Less complex
  ✓ No VOC issues
  ✓ Less energy
  ✓ Smaller footprint for application
After applying laminate film, parts may be post-processed to enhance properties.

- Exterior part
- Backfill molding
- Radiant UV Energy
- Thermoforming
E7 Concept design intent

- Aluminum space frame
- All exterior body panels are composite
- Doors TPO with Kevlar mesh inserts – Bullet Proof
- Door structure – Rigid Composite
- Fenders & Quarter panels – TPO
- Hood, Roof and Deck – Reinforced TPO and other composites
- All exterior surfaces utilize advanced UV cure paint film
- Print on demand graphics for turn-key manufacturing
- Performance specifications: www.carbonmotors.com
BASF Coatings

Carbon Motors Corporation – E7 Police Interceptor
Still, Cool Cars are Timeless!
Acknowledgements

- Trace Evidence Symposium Organizers
- Lee Brun-Conti
- Everyone @ BASF