UV & EB Curing of Coatings – The Power of Light

Chicago Society for Coatings Technology
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Energy Curable Industrial Coatings
Energy Curable Graphic Arts Applications
What is UV/EB Curing?

- Using UV energy, visible light, or high energy electrons as opposed to thermal, evaporative, or oxidative (air-dry) cure to form a coating, film or ink

- Types of energy used for energy curing:
  - Ultra Violet (UV): 200 – 400 nm
  - Visible light: typically 380 - 450 nm
  - Electron beam: high energy electrons

While I will frequently use the term “UV/EB curable”, please note that the terms “radiation curable or “energy curable” may be used interchangeably.
What is the UV Curing Process?

Conventional Cure
- Wet Application
- Drying Stage
  - Solvent Removal
  - Coalescence
  - Heat/ Forced Air
- Dry Film
  - Dry Time in Seconds or Minutes
  - Property Development over Time

UV Curing
- Wet Application
- Instantaneous Cure milliseconds
  - Immediate Property Development
  - High Cross Link Density
  - Retains Shape
- Dry Film
Why Use Energy Curing?

- Productivity, Productivity, Productivity
  - Seconds to cure vs. minutes or hours

- Lower Overall Cost (per cured part)
  - 100% solids, cure speed, recycling of coating, etc

- Single component formulas
  - Eliminates mixing errors found in 2 component systems

- Regulatory Concerns (VOC emission)
  - Avoid solvent use in most cases

- Smaller equipment footprint
  - Less floor space needed

- Energy costs (esp. now with high oil prices)

- Did I mention Productivity?
Property Strengths

- UV/EB Curing can generate a high crosslink density network
  - High gloss
  - High hardness
  - Scratch and stain resistance
  - Fast cure
- Works best with flat substrates
Areas for Improvement

- Adhesion to metal, esp. during post-forming
- Adhesion to some plastics
- Tear resistance
- Low gloss in 100% solid systems
- Low film weight for 100% solids
- Overall cure of 3-D parts

EC coatings can have high shrinkage, which adversely affects adhesion to non-porous substrates. Lack of solvent coupled with a fast cure reduces the formulator’s ability to meet low gloss, low film build requirements. Additional lamps are needed to cure 3D parts since EC is a line of sight cure method.
UV Curing

- Acrylated Resin(s)  
  basic coating properties
- Monofunctional Monomer(s)  
  viscosity reduction, flexibility
- Multifunctional Monomer(s)  
  viscosity reduction, crosslinking
- Additives  
  performance fine tuning
- Photoinitiator Package  
  free radical generation
EB Curing

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Everything You Always Wanted to Know About UV Formulating

Selection of wavelength

Selection of photo initiators

Ratio of photo initiators

Selection of photo synergists

Exposure time

Selection of type of pigment (and extender)

Level of pigment (and extender)

Film thickness

Selection and level of monomer(s)

Selection and level of oligomers

Selection and level of additives

Idealised Reaction Route

U.V. Light

Photo Initiator

Singlet to triplet intersystem crossing

π → π⁺

250nm π → π⁺ 330nm

Free Radical

either homolytic fragmentation

A⁺ + B → AB

or

Hydrogen abstraction

A⁺ + R → *A + H

Chain Propagation

A⁺ + M → AM⁺ + M

AM⁺ + M → AM⁺ + M

AM⁺ + M → AM(1,1)M⁺

Chain Termination

producing desired film

AM(1,1)M⁺ + AM(1,1)M⁺ → AM(1,1,1)M⁴⁺

Absorption by monomers and oligomers

Absorption by pigments and extenders etc.

Reflection by pigments etc.

Transmission by pigments etc.

Phosphorescence

Quenching

Effect of substrate

Chain transfer

Recombination

A⁺ + B⁺ → AB

Absorption by pigments/extenders etc.

Side reactions

Degradation

Rearrangements

Odour generation

Oxygen inhibition

Branching

A⁺ + M → A⁺M⁺ + M

Chain termination

A⁺M⁺ + A⁺M⁺ → MA

Too low molecular weight

Too low crosslink density

Too high molecular weight

Too high crosslink density

Inadequate cure

Courtesy of Jim Hobbs, University of Leeds, Leeds, England
All three aspects are interrelated
Formulating a UV Curable System

- Photoinitiators
- Additives
- Monomers
- Oligomer
Formulating a UV Curable System

- **Photoinitiators**
- **Monomers**
- **Oligomer**
- **Additives**
Applications of UV/EB Curable Coatings

Industrial coatings and graphic arts market segments:

- Coatings for wood furniture and flooring
- Coatings for plastic, metal and paper
- Fiber optic coatings
- Coatings for electronic components
- Coatings used on automotive components
- Overprint varnishes
- Flexographic inks
- Screen Print inks
- Lithographic inks
- Laminating and pressure sensitive adhesives
Formulating for Properties

Some desirable properties for coatings that can be achieved through UV or EB cured coatings:

- Adhesion
- Cure speed
- SARC (scratch & abrasion resistant coatings)
- Weatherability
- Pigmented systems
Applications
Energy Curable Coatings for Wood

- Fillers for plywood, MDF, particle board
- Top coats on furniture
- Kitchen cabinets
- Coatings on hardwood or parquet flooring
- Wood molding
- Ready to assemble (RTA) furniture
Plastics Market

- Plastics: Very large and varied market, but two main sub-segments for UV/EB
- Automotive:
  - Headlamp lenses – hardcoats
  - Basecoats for Reflectors
  - Interior “soft touch” coatings
  - Interior hardcoats
  - Exterior side panels – hardcoats, sealers for SMC
- Non-Automotive: (rigid and flexible)
  - Rigid:
    - CD-DVD
    - Flooring – PVC
    - Containers
    - Hardcoats on plastics (e.g. cellphones)
  - Flexible:
    - Films (e.g. window films)
Some Typical Application Methods

- Automotive:
  Spray: usually out of solvent, some 100% solids
  Air-assisted atomization
  Airless hydraulic atomization
  Rotary atomization (best for 100% solids)
  Dip coating
  Spin coating

- Window Films
  Roll coater
  Gravure
  Reverse Gravure

- CD/DVD
  Spin coater

- Vinyl Flooring
  Roll coater
  Slot die
Challenges with UV/EB on Plastics

- Adhesion to Plastics
  - Getting “bite” in 100% solids system
  - High shrinkage with free radical cure – related to functionality
  - See recommendations
- 3-D curing, shadow cure (some plastic parts are intricate)
- Use of pigments (issue on any type of substrate)
  - Block some UV light
  - Need to use right PI combinations
  - Thick pigmented coatings difficult
- Getting low enough application viscosity
  - Increase diluent concentration
  - Lower viscosity oligomers
- Matting Agents – the right diluents
- Costs – need to look at the whole process benefits, and the overall performance benefits
Metal Market Segments Using UV/EB

- Pipe, tube and conduit
  - Clear and colored on tube

- Specialty coil
  - Fasteners

- Metal Deco
  - Inks and coatings on can bodies
  - Coatings on can ends
  - Inks and coatings caps & closures
Tube Coating

FLO-COAT® Process

Conversion Coating

Clear Organic Coating

Hot-Dipped Uniform Zinc Galvanized After Fabrication

UV clear coating on galvanized tub
UV/EB Coatings for Metal

Challenges

- Adhesion to difficult substrates
- Spray application for coating post-formed items
- Corrosion (salt spray) resistance
- Pigmentation (UV at higher coating thickness)

Advantages

- Low/no VOC
- Reduced energy costs
- Shorter cure time
- Space savings
- Hardness, scratch resistance, chemical resistance
**Why UV/EB?**

- **Open pot life**
  - consistent printing and color
  - reduced time for clean-up & fewer wash-up
  - low make-ready waste

- **Instant drying**
  - reduced floor space needed for drying
  - ability to “convert” in-line

- **Improved properties for inks and coatings**
  - improved film weight control (100% solids)
  - higher gloss
  - reduced dot gain
  - better solvent resistance
  - improved adhesion

- **Environmentally friendly**
  - very low volatiles e.g. VOC -- safer work environment
Why Not UV/EB?

• Additional capital cost
  – retrofitting can sometimes be difficult
  – EB is expensive, but is becoming more cost competitive

• Inks and coatings are can be more expensive
  – but offset by improvements in productivity, superior appearance

• Re-training of operators
  – UV/EB inks perform differently compared to conventional inks & coatings
RadTech International NA

- RadTech is a non-profit trade association
- Over 700 Members
- Just celebrated our 25th Anniversary
- Our members are across the supply change
- Members support over 20 application areas for UV and EB
- Coatings community is the strength of our group
RadTech 2012

- Our Biennial Conference and Exhibition
- Over 80 exhibitors and 100 papers—all UV and EB
- Sessions include: Sustainability, Field Applied UV, UV Curing for 3-D, Graphic Arts, Barrier Coatings & Conductive Films for Flexible Electronics, Harsh environments--corrosion, weathering & exterior, Nanomaterials, Photovoltaics, LEDs
- Special short courses if you are new to UV/EB
- As a member of CSCT—RadTech offers you our special member rate to attend

www.radtech2012.com
Thank You!