Color – More than meets the Eye

Anna Kreofsky
Color R&D Engineer

TOPICS

Brief introduction to RTP Company Color Division

Color Fundamentals
- Three Sciences of Color
- Colorant Types & Limitations
- Evaluation & Control
- Effective Color Communication

Beyond Visible Light
- Near Infrared Attenuation
- Laser Welding
- Laser Marking

Questions

RTP COMPANY COLOR DIVISION

Color virtually all resins
- Engineering resins
- Styrenic resins
- Polyolefin resins

Color in multiple formats
- Masterbatches
- Precolored resins
- Cube blends

Advanced Color Development
- Custom colors
- Multiple light sources
- Regulatory knowledge
  - UL, FDA, USP, RoHS, etc.

GLOBAL COLOR CONSISTENCY

8 Color Labs
- USA, France, China, Singapore, Mexico

Color Control
- Consistent raw materials
- Consistent hardware
- Consistent software
- Global database

Speed
- Fast color matching service
- Transfers across regions
- Global color palette
**COLORING OPTIONS**

Masterbatches
- Concentrated formulation of colorants and/or additives dispersed in a polymer carrier
- Usage defined by let-down ratio or percentage
- Most widely used form to color commodity resins

Precolor
- Colorants are added to the polymer and extruded
- Ready to use as-is

Cube blend
- Masterbatch is blended with resin (two or more pellet solution)

**PRODUCT FAMILIES**

Compounds formulated to meet performance requirements, from one property to multiple technologies

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**COLOR SCIENCE**

**Biology**
- Color perception

**Physics**
- Light interactions

**Chemistry**
- Colorants
BIOLOGY

How do we see color?

Light Source → Object → Observer

Two types of Photoreceptors - Detector

- Rods: Vision at low light levels
- Cones: Sensitive to three colors

Optical nerve sends signal to brain for decoding

PHYSICS

Increasing energy → Increasing wavelength

Gamma rays, X-rays, Ultraviolet, Infrared, Radio waves, Rotor, TV, FM, AM

Visible light: 400 nm, 500 nm, 600 nm, 700 nm

ART OF COLOR

Light behaves like a wave

Color—More than Meets the Eye - Anna Kreofsky
PHYSICS

White light is made up of all wavelengths of visible light. It is separated into individual colors when light passes through a glass prism.

Appears blue
Blue object

Appears black
Black object

SPECTRAL REFLECTANCE

- Spectral reflectance curves produced by spectrophotometer
- Graph shows light reflected from an object at each wavelength
- Each color has a unique spectral curve

CHEMISTRY - COLORANT TYPES

Inorganic Pigments:
- Pigments from various metals or other substances from nature

Organic Pigments:
- Pigments made synthetically

Dyes:
- Synthetic substances that are soluble

ORGANIC VS. INORGANIC

Organic Pigments:
- Small particle size
- Difficult to disperse
- Limited heat stability (300 °C max)
- High color strength
- Light fastness
  - Evaluated on individual basis

Inorganic Pigments:
- Large particle size
- Easy to disperse
- Heat stable
- Weak color strength
- Improved light fastness
DYES

Soluble
  • Migration concerns

High color strength

Transparent

Commonly used in:
  • Styrenic Resins
  • Engineering Resins

COLOR EVALUATION & CONTROL

Visual Color Evaluation
  • Confirmed color vision
  • Color standards for reference
  • Controlled light
  • Agreed upon color space

Instrumental Color Evaluation
  • Calibrated instruments
  • Color standards for reference
  • Controlled temperature
  • Agreed upon color space

ENVIRONMENTAL FACTORS

Observer
  • Each person sees color uniquely

Light Source
  • Different spectral distributions (D65, CWF, Incandescent)

Background
  • Contrast difference makes colors appear different

Viewing Angle
  • Most common 45°
  
  Keep viewing conditions CONSTANT

SPECIFICATION & TOLERANCES

Numeric Color Modeling

Numeric model provides
  • 3 dimensional color space
  • Quantify colors numerically
  • Can be used for specification, identification, comparison

Several Color Spaces
  • CIE 1931 Yxy
  • CIE L*a*b* 1976
  • CIE LCh
  • CMC l:c 1984
### COMMON COLOR TERMS

**Hue**
- Color perceived

**Chroma (Saturation)**
- Vividness of a color

**Lightness**
- Measure of brightness
  (think about gray scale)

**Tint:** Hue has been lightened
- Pink is a tint of red

**Shade:** Hue has been darkened
- Maroon is shade of red

### COLOR SPACE

#### CIE 1931 Yxy
- Uses numeric values Yxy
  - Y - Luminance
  - x, y - Chromaticity values
- Only x, y chromaticity values shown
- Hue changes around color gamut
- Chroma increases from center towards edge

#### CIE L*a*b* Model (Traditional X-Y-Z coordinate system)
- Developed in 1976
- Most popular color space
- Uniform color space
- Identified by numeric values
  - \( L^* \) = lightness to darkness (0-100)
  - \( a^* \) = redness to greenness
  - \( b^* \) = yellowness to blueness
  - \( \Delta E^* \) = total color shift (dimensionless)

### COLOR SPACE

#### LCh Model (cylindrical coordinates r, \( \Phi \), z)

\[
L = L \\
C = \sqrt{a^* + b^*} \\
h^* = \tan^{-1} \left( \frac{b^*}{a^*} \right)
\]
COLOR SPACE

CMC l:c (1984)
- Used for tolerancing
- l:c (lightness:chromaticity) values are typically 2:1
- Provides better agreement between visual and instrumental assessment
- Allows user to vary ellipse tolerance per application

\[ \frac{l}{c} = 2:1 \quad \frac{l}{c} = 1.5:1 \]

TOLERANCES

- Tolerances developed around variation in raw materials, processing, customer goals for visual appearance

* Asymmetrical color tolerances are perfectly acceptable to use

COLOR COMMUNICATION

It’s important to specify all targets through color communication

APPLICATION REQUIREMENTS/TARGET

Application Requirements:
- Resin/Compound
- Regulatory Restrictions
- Processing Method
- Secondary Operations

Color Target:
- Grass Green Pantone: 347
- \[ L^* = 43 \]
- \[ a^* = -22.9 \]
- \[ b^* = 26.21 \]
SATISFYING EXPECTATIONS

Color nomenclature:
- Identifies both regulatory and formulation commitment

Lot control:
- Ingredient traceability

Process control:
- Defined manufacturing specifications
- Engineering review during development and continuous improvement
- Contributes to consistency

Color quality control:
- Color meets defined requirements
- Physical properties
- Composition consistency

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BEYOND VISIBLE LIGHT - IR/NIR

Active 700 – 2500 nm range
Combination of light controlling attributes
Transparent or opaque at specific wavelengths

Commonly used in:
- Fiber optics
- Transmitters/receivers

TRANSMITTANCE

Visible
Infrared

<table>
<thead>
<tr>
<th>Sample Thickness</th>
<th>% Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 mm</td>
<td>Unfilled Polycarbonate</td>
</tr>
<tr>
<td></td>
<td>RTP 0399 SC-803660 IR BLACK</td>
</tr>
<tr>
<td></td>
<td>RTP 0399 SC-803660 BLACK</td>
</tr>
<tr>
<td></td>
<td>RTP 0399 SC-803660 IR ABSORBER</td>
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Wavelength (nm)
**Method for joining thermoplastic parts by using the power of the laser to bond materials**

**LASER WELDING MECHANISM**

A: Light transmits through upper material and is absorbed by lower material

B: Melting pool is created

C: Heats upper layer

D: Melting pool solidifies under external pressure

**ADVANTAGES OF LASER WELDING**

- Weld complex parts
- No flash is produced
- High-precision joints can be produced (Hermetic seals)
- Resins of different compositions can be joined
- No consumables (adhesives, fasteners, etc.)

**ORGANIC VS. INORGANIC**

- **IR Transparent Resin:**
  - Amorphous Resins
    - Require the least amount of energy
  - Semi-Crystalline
    - Require more energy due to scattering
  - Welding challenges
    - PEEK, LCP, PPS, etc.
  - Highly crystalline materials have significant scatter

- **IR Absorbing Resin:**
  - All resins...
    - Amorphous
      - Semi-Crystalline
      - ...need IR Absorbing colorants
**ORGANIC VS. INORGANIC**

**IR Reducing:**
Glass fibers, glass beads, colorants
Various additives
- UV stabilizers, heat stabilizers, etc.

**IR Blocking:**
Carbon fiber, minerals, metals, etc.

**ONE LIGHT – TWO MARKS**

<table>
<thead>
<tr>
<th>Laser energy absorbed causing a reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Charring (dark mark)</td>
</tr>
<tr>
<td>• Foaming (light mark)</td>
</tr>
<tr>
<td>• Ablation (removal of layer, ex. Paint)</td>
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</tbody>
</table>

**Degree of Complexity**

- RTP Company has experience with pigment/filler combinations, and loading levels, to support successful welding using both Diode and Nd:YAG lasers
- Color combinations influence complexity of formulation

**Basic mechanism**

- Charring produces (dark marks)
- Foaming produces (light marks)

**No Universal Additives**
- Can be combined with other additive technologies
- Unique colors achievable

**Marks vary with resin, additive, and color package**
Black resin color with light marks:

- PP (Olefins)
- Nylon
- ABS (Specific Grades)
- POM
- PMMA
- Possibly more

Different lasers can be used, Nd:YAG (Neodymium doped Yttrium Aluminum Garnet) is the best compromise of...

- Speed
- Flexibility
- Marking quality

Laser and marking parameters will influence quality of mark

SUMMARY

- RTP Company supplies innovative colors and functional additives
- Color communication is crucial to color matching and tolerancing
- Light attenuation is the selective control of transmission, either by wavelength, intensity, or both
- Three main factors for successful welds: material selection, laser source, joint configuration
- Dark and light marks can be achieved using same laser source with overall goal of a high contrasting mark

QUESTIONS

Any Questions???
Thank You!

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