Brief introduction to RTP Company Color Division

Color Fundamentals
- Three sciences of color
- Evaluation & control
- Effective color communication

Laser Welding
- IR transparent materials
- IR absorbing materials
- Basic laser welding process

Light Control
- Basic technologies
- Optical data offered
- Development process
**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**

7 Color Labs
- USA - Winona, MN; Fort Worth, TX
- Monterrey, Mexico
- Beaune, France
- Shenzhen and Suzhou, China
- Singapore

Color Control
- Consistent raw materials
- Identical hardware and software
- Global color 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/compound and extruded
- Ready to use as-is

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

Your Color – Your Way

PRODUCT FAMILIES

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

- Color
- Conductive
- Flame Retardant
- Thermoplastic Elastomers
- Structural
- Wear Resistant
- Film - Wiman
- Sheet - ESP™
TOPICS

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COLOR SCIENCE

Biology
- Color perception

Physics
- Light interactions

Chemistry
- Colorants
How do we see color?

Light Source → Object → Observer

Rods
- Vision at low light levels

Cones
- Sensitive to three colors

Optical nerve sends signal to brain for decoding

Two types of Photoreceptors - Detector
Light behaves like a wave
White light is made up of all wavelengths of visible light. It is separated into individual colors when light passes through a glass prism.

- Blue object appears blue
- Black object appears black

**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** - Measures the transmissivity and chromaticity

- Uses numeric values Yxy
  - Y - Luminance
  - x,y - Chromaticity values

- Only chromaticity values shown on graph
- Hue changes around color gamut
- Chroma increases from center towards edge
COLOR SPACE

CIE L*a*b* Model – Measures Reflected Color

- Developed in 1976
- Most popular color space
- Uniform color space
- Uses traditional x,y,z coordinate system
- Identified by numeric values
  - $L^*$ = lightness to darkness (0-100)
  - $a^*$ = redness to greenness
  - $b^*$ = yellowness to blueness
  - $\Delta E^*$ = total color shift (dimensionless)

\[ \Delta E^* = \sqrt{(L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2} \]

COLOR SPACE

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

- Lightness
  \[ L = L \]
- Chromaticity
  \[ C = \sqrt{a^2 + b^2} \]
- Hue
  \[ h^\circ = \tan^{-1} \left( \frac{b^*}{a^*} \right) \]
COLOR SPACE

CMC l:c (1984)

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

![CMC l:c (1984) diagram]

TOLERANCES

- Tolerances developed around variation in raw materials, processing, customer goals for visual appearance
- Asymmetrical tolerances are perfectly acceptable

![Tolerance diagram]
**APPLICATION REQUIREMENTS/TARGET**

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

**Color Target:**
- Physical Color
- Grass Green Pantone: 347
- Color Reference
- Color Space Values
  - $L^* = 43$
  - $a^* = -22.9$
  - $b^* = 26.21$

**TOPICS**

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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
- Laser welding applications

**LASER WELDING**

Requires two types of materials with different behavior in the NIR

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.)
• Repeatable and reliable welds
TRANSMITTANCE

Visible Infrared

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<th>Wavelength (nm)</th>
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Polycarbonate IR Absorbing IR Black

Sample Thickness = 1.5 mm

IR TRANSPARENT MATERIALS

Naked Eye:

IR Camera:
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 Transparent Resin:

IR Absorbing Resin:
- All resins...
  - Amorphous
  - Semi-Crystalline

...need IR absorbing additive

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

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

Part thickness and laser wavelength also influence material transmissivity
• 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

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Our light diffusion product line and customer application base has grown significantly over the years. The photo below still emphasizes the majority of requests we received. How to hide the ‘hot spots’.

However, our product line includes all optical demands from transparent to highly opaque and the infinite levels of translucent performance in between.

**THE BASIC TECHNOLOGIES**

- Brilliant
- Emergence & Chromergence
- Veil & Eclipse
- Pure
**THE BASIC TECHNOLOGIES**

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**BRILLIANT**

Opaque, highly reflective white surfaces

**Common Uses**

- LED Reflectors
- Light boxes for LCD backlighting
- Illuminated pushbutton actuators
- Reflective light guides
- Light isolators

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**EMERGENCE & CHROMERGENCE**

Often used for buttons! Highly reflective, but transmits some light. Daytime white is most common. Nighttime blue, green, red, etc.

**Common Uses**

- Multi-shot graphics
- Illuminated Indicators
- Graphics with LED color correction
- Paint and laser etched graphics in white and colors
THE BASIC TECHNOLOGIES

VEIL & ECLIPSE

Features
• Wide or narrow angle diffuser
• High transmission and efficiency
• Neutral transmission, density or color
• Laser etch-able, printable, paintable

Common Uses
• LED hotspot elimination
• Hidden-until-lit graphics in color
• LED color tuning diffusers
• Substrate for surface decorated illuminated graphics

PURE

Features
• Very high light transmission
• Color tunable
• Available in wide variety of scatter angles from very narrow to wide angles

Common Uses
• Long light path light pipes
• LED color correcting lenses and guides
• Point source softening elements
• Complex light distribution covers
Characterization of optical properties for light diffusion material:
(all measurements are thickness dependent)

- Color Measurements
  - Reflected Color / Nighttime color
- Transmission
- Haze
- Half Angle
- Scatter Angle plot

### TRANSMISSION CURVE AND VALUES

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### S-900173 Transmission

- % Transmission
- Wavelength, nm

Measured at 3 mm (0.117") using ISO 11664-4:2008 (IEC 60144-4/E:2007) and ASTM E308-15
WHAT IS HALF ANGLE?

- Scatter angle plot shows the intensity of light at different viewing angles
- Half angle is the value at which the light intensity is half of the initial intensity at 0°
- Plot and half angle measurement provide better data than a standard haze measurement alone

HALF ANGLE MEASUREMENTS
### WHAT IS HALF ANGLE?

#### Remember “PURE”?

It means the product is very clear and transparent. Very little ‘haze’ or light scattering, which produces a very narrow or small half angle plot.

#### Remember “VEIL”?

It means the product scatters a large amount of light. It has very high ‘haze’ or light scattering, which produces a very wide or large half angle plot. Notice the half angle alone doesn’t fully define the optical characteristics. The shape or light distribution is important to maximize the desired performance in the final application.
NEW APPLICATION DEVELOPMENT

Defining the parameters for the color development process

What information does RTP need to get started?

- LED data or light source for the application
- Drawing with dimensions included
- Your color and chromaticity specification
- Molded parts and data from any previous work
- How will our material be evaluated
- What parameters do we need to measure/report

NEW TOOLS
SUMMARY

• RTP Company supplies innovative and functional colors
• Color communication is crucial to color matching and tolerancing
• A large factor for successful laser welding depends on material choice and color
• Light attenuation is the selective control of transmission, either by wavelength, intensity, or both resulting in countless clear and opaque options

Questions?
Thank You!

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