COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

# Color – More than meets the Eye

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## 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

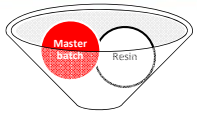
Color Control
- Consistent raw materials
- Consistent hardware
- Consistent software
- Global database

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

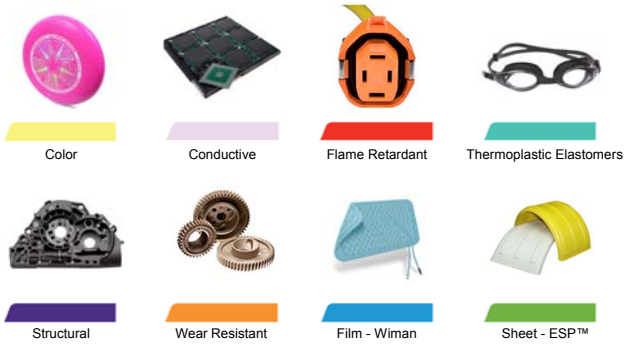
Cube blend

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

*Your Color – Your Way*

## PRODUCT FAMILIES

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

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## COLOR SCIENCE

Biology

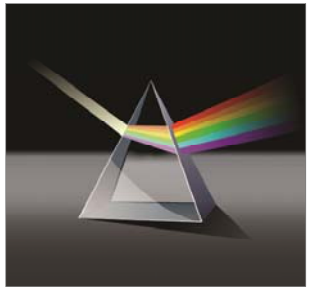
- Color perception

Physics

- Light interactions

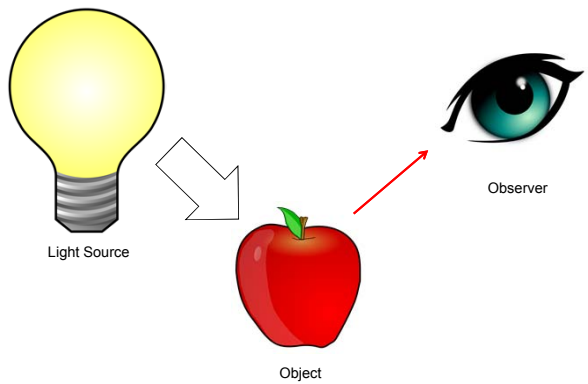
Chemistry

- Colorants



## BIOLOGY

### How do we see color?




## BIOLOGY

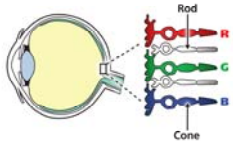
### Two types of Photoreceptors - Detector

Rods

- Vision at low lights levels

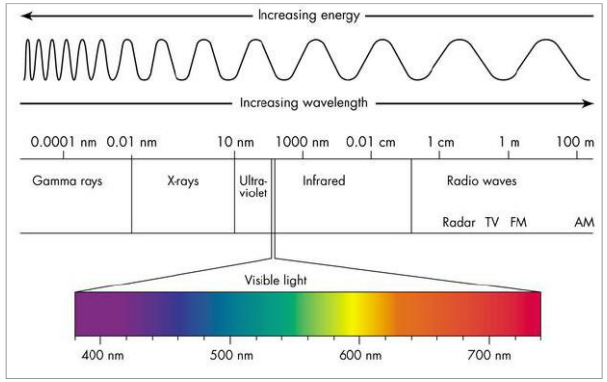
Cones

- Sensitive to three colors



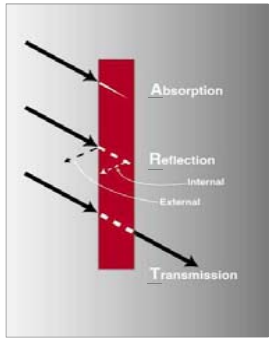

Optical nerve sends signal to brain for decoding

## PHYSICS




## ART OF COLOR

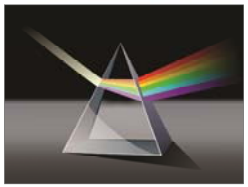
Light behaves like a wave

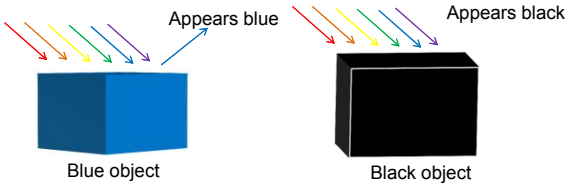


## PHYSICS

White light is made up of all wavelengths of visible light.

It is separated into individual colors when light passes through a glass prism.






## 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

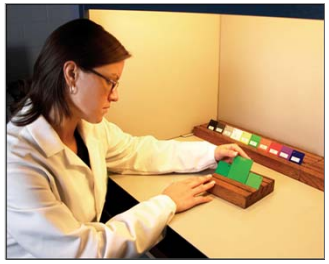
Soluble
- Migration concerns

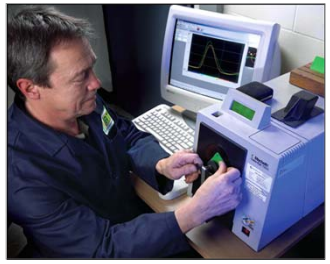
High color strength

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 45º

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

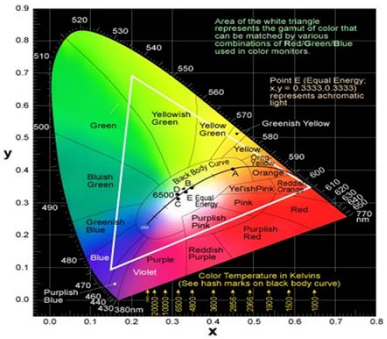
Lightness
- Measure of brightness (think about gray scale)

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

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

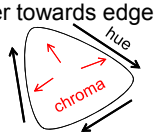

## COLOR SPACE

**CIE 1931 Yxy**



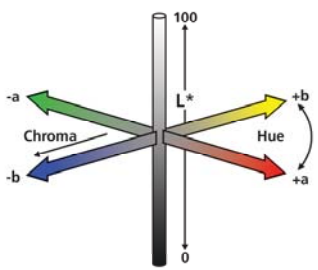

Non-Uniform Color Scale

- 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




## COLOR SPACE

**CIE L*a*b* Model** (Traditional X-Y-Z coordinate system)



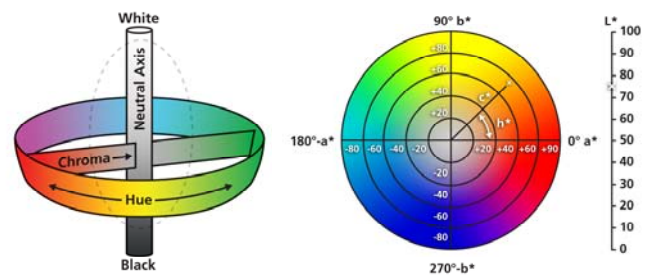

$(L_1^*, a_1^*, b_1^*)$ *and* $(L_2^*, a_2^*, b_2^*)$

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

- 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
  - ΔE* = total color shift (dimensionless)

## COLOR SPACE

LCh Model (cylindrical coordinates r, Φ, z)

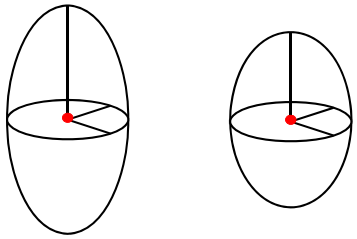



$L = L$ $\quad C = \sqrt{a^2 + b^2}$ $\quad h° = tan^{-1}(\frac{b}{a})$

## 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



l:c = 2:1 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:

Physical Color

**Grass Green**
Pantone: 347

Color Reference

L* = 43
a* = -22.9
b* = 26.21

Color Space Values

## 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

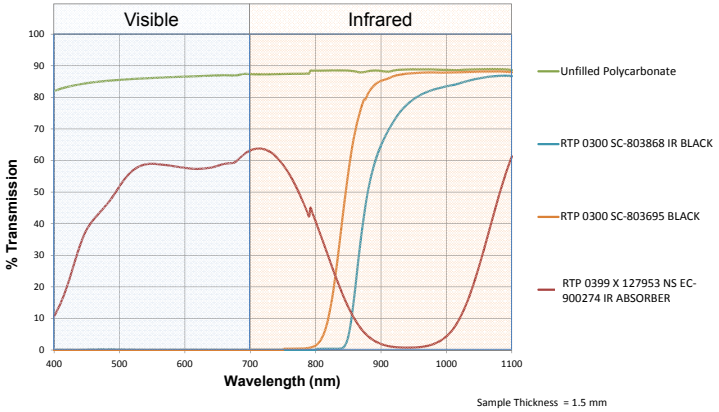
Combination of light controlling attributes

Transparent or opaque at specific wavelengths

Commonly used in:

- Fiber optics
- Transmitters/receivers

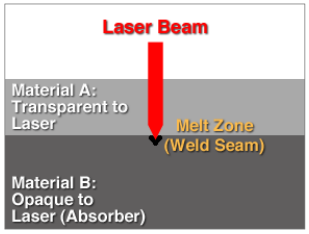
## TRANSMITTANCE



## 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



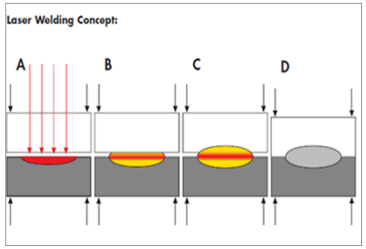

## LASER WELDING MECHANISM

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.)

## 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.

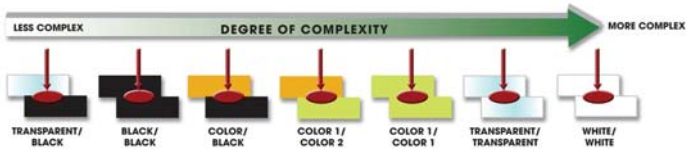
**IR Blocking:**

Carbon fiber, minerals, metals, etc.

**Part thickness and laser frequency also determine material transmissivity**

## 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

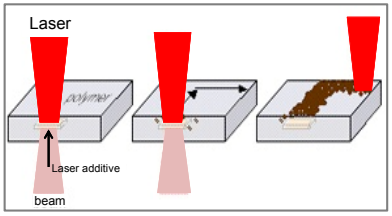



## LASER MARKING

Basic mechanism

Laser energy absorbed causing a reaction

- Charring (dark mark)
- Foaming (light mark)
- Ablation (removal of layer, ex. Paint)




## ONE LIGHT – TWO MARKS

One Light Source

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

## HIGH CONTRASTING MARKS

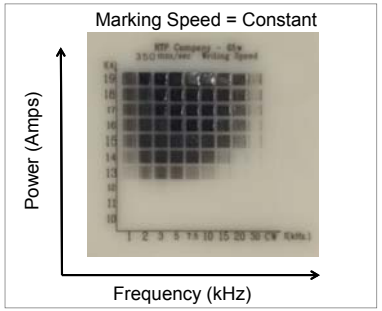
Black resin color with light marks:

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

## LASER PARAMETERS

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???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