
*Effect Pigments
An Overview:
Composition, Optics and Uses*

Frank Mazzella

In Cosmetics 2007 - Paris

Overview

- Choosing a substrate
- The chemistry of Titanium Dioxide and other metal oxides.
- The theory of optics as a wave
- Manufacturing processes for assembling a metal oxide stack.
- The use of optical spacers to produce a dielectrics or optically variable pigment.

What is Light?

- Light is a form of radiant energy, having for normal human vision wavelengths ranging from about 380 to 770nm, and traveling at a speed of about 186,300 miles per second.

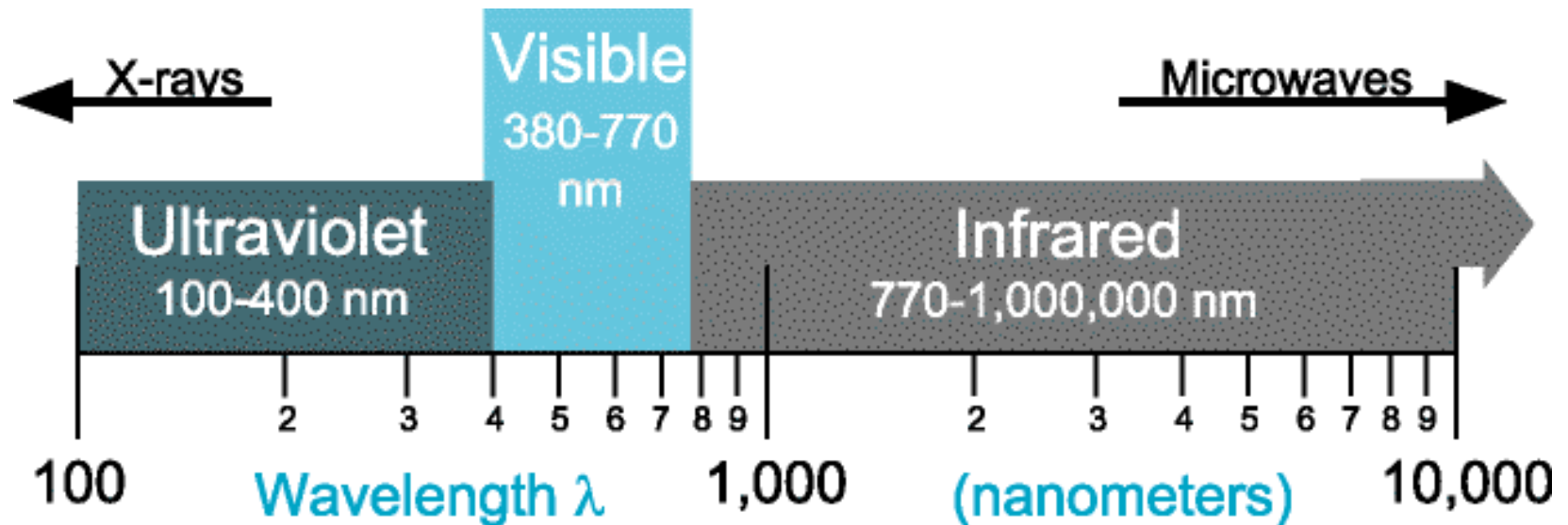
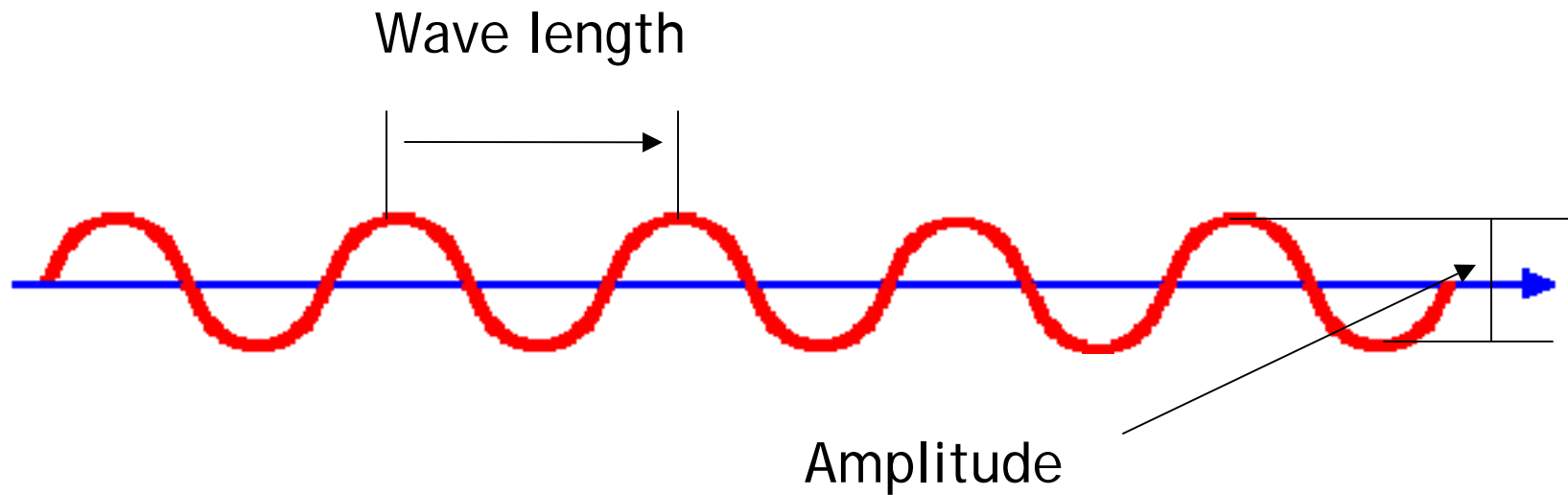


Fig. 1.1 The optical portion of the electromagnetic spectrum

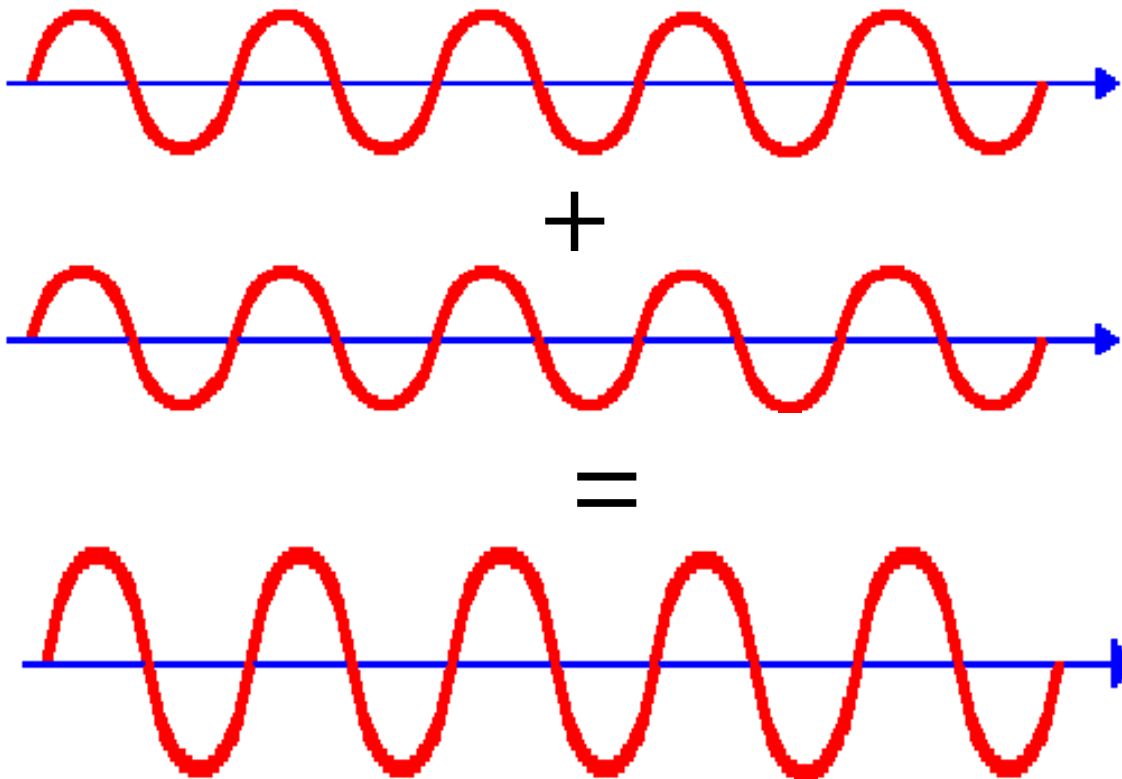
Light As a Wave



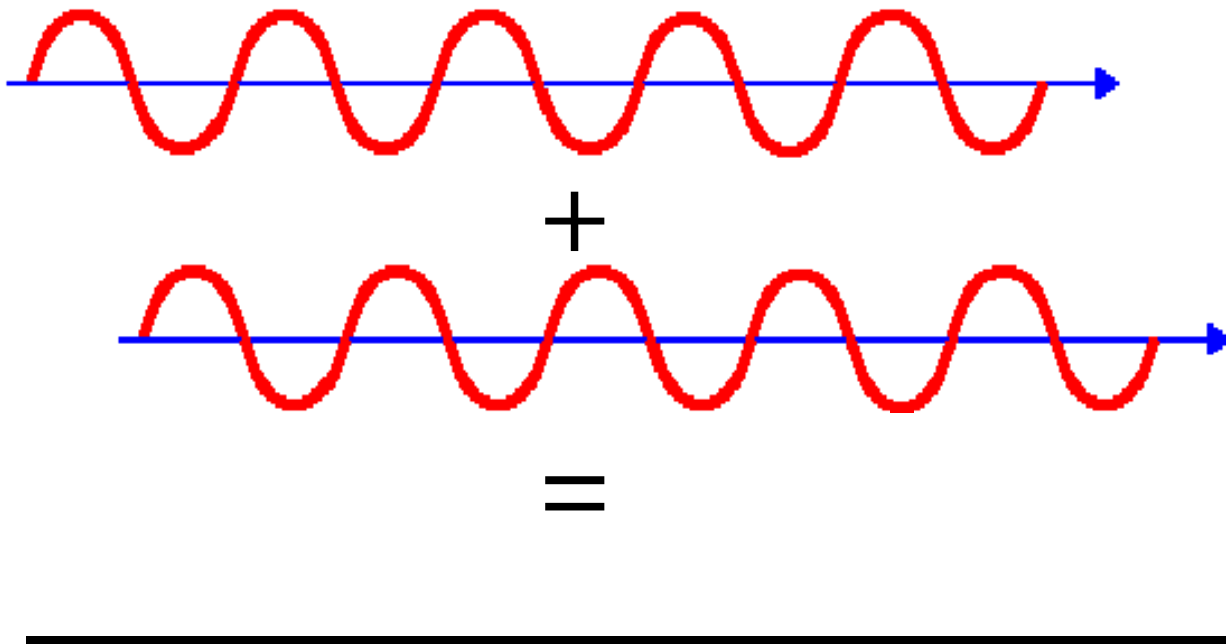
Wave length: the distance between crests.

Amplitude: the distance between the crest and trough.

Light Waves: Constructive Interference

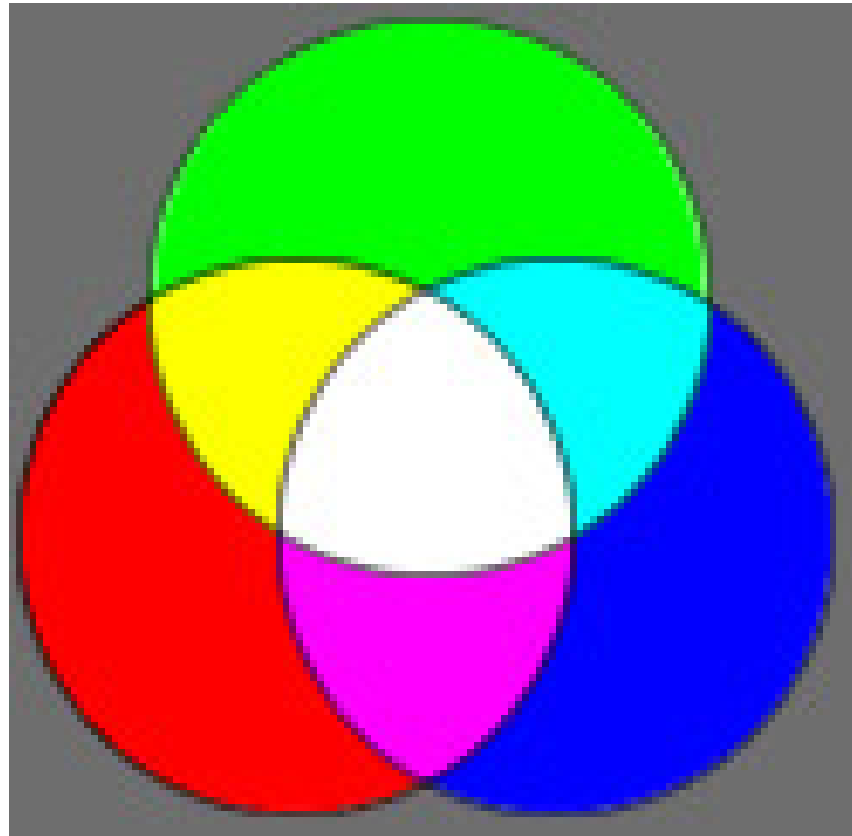


Light Waves: Destructive Interference



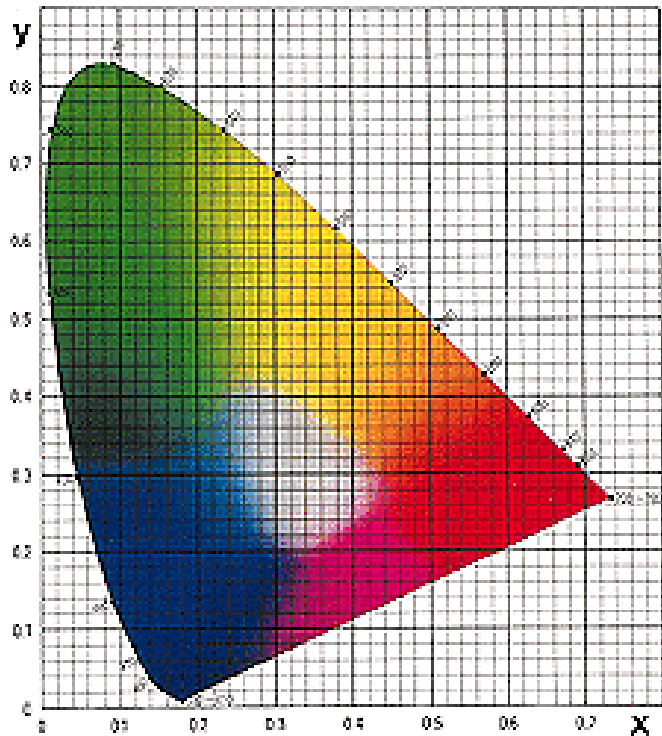
Color: Additive Properties of Color

- Prime Colors of Light: Red, Blue and Green
- Red + Green=Yellow
- Red + Blue = Violet
- Green + Blue = Cyan
- Red + Blue+ Green = White

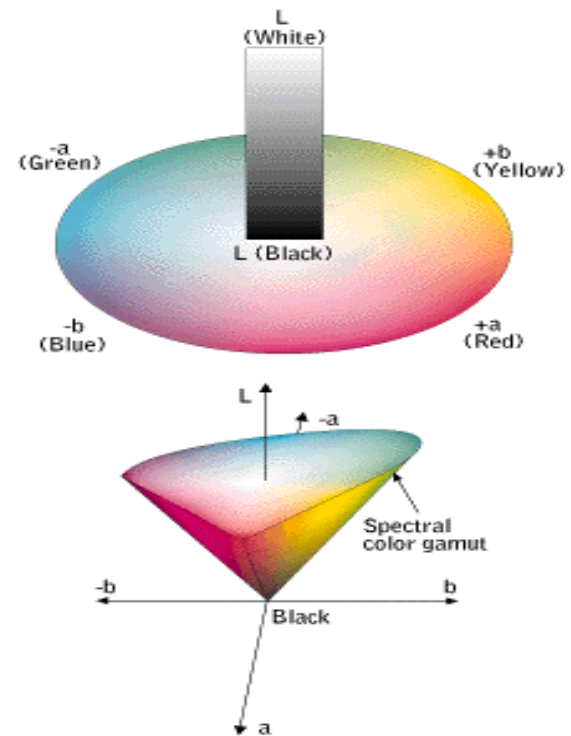


Measuring Color

XY Plot



CIE LAB

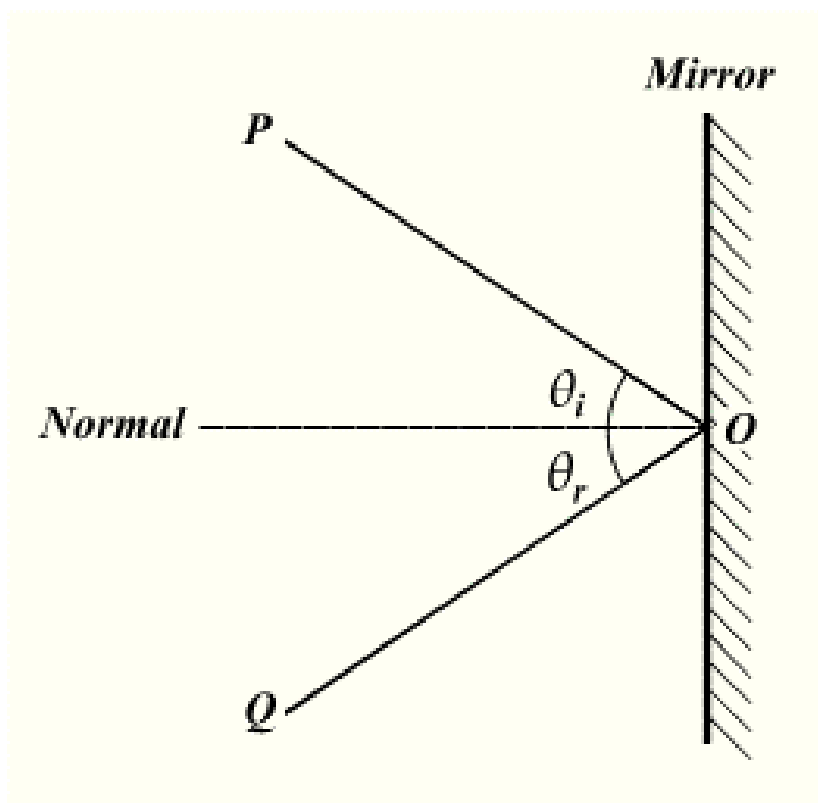


CIE LAB Color Space

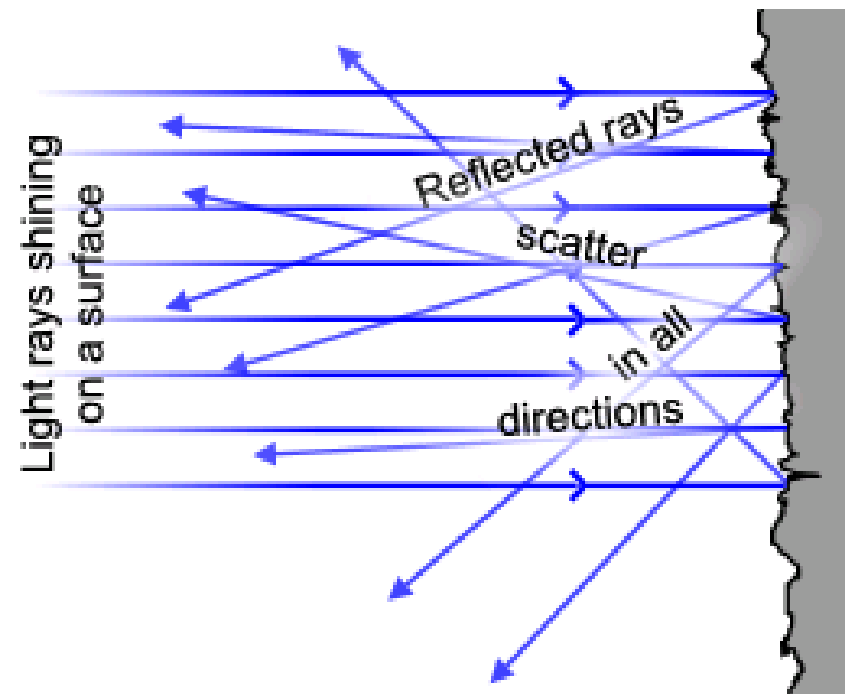
- L Value:
 - This can be defined as your shades of gray L=100 is white, L= 0 is black.
- a Value:
 - This is the Red-Green scale, where +a is red.
- b Value:
 - This is the Blue-Yellow scale where +b is yellow.

Reflection of Light

Specular Reflection

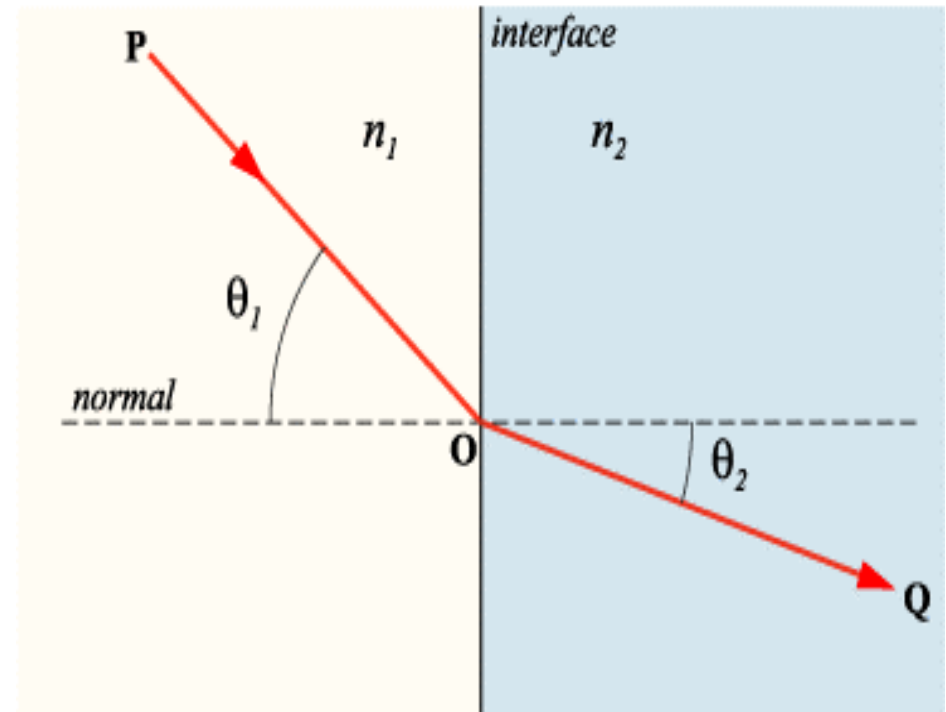


Diffuse Reflection

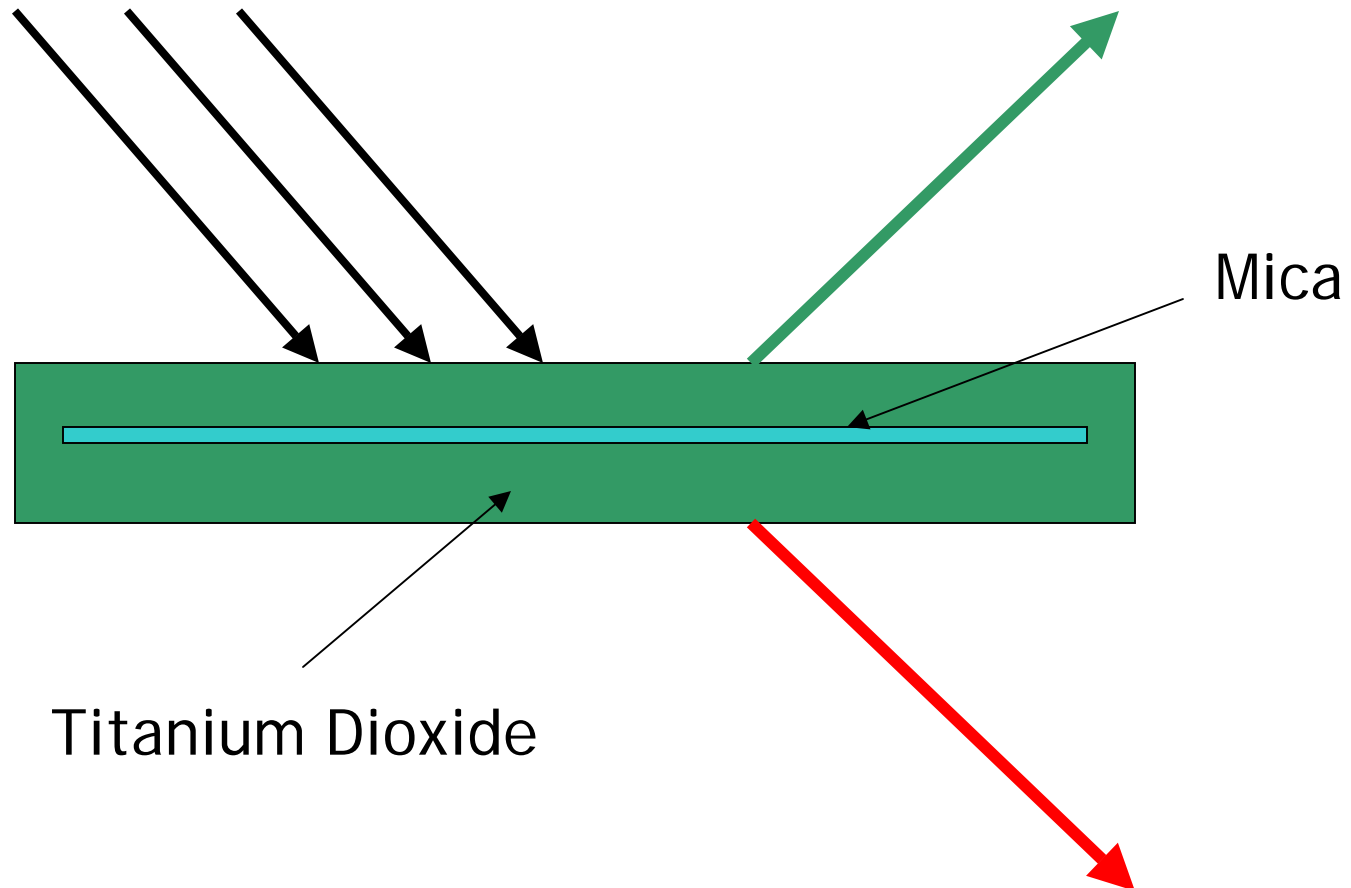


Snell's Law

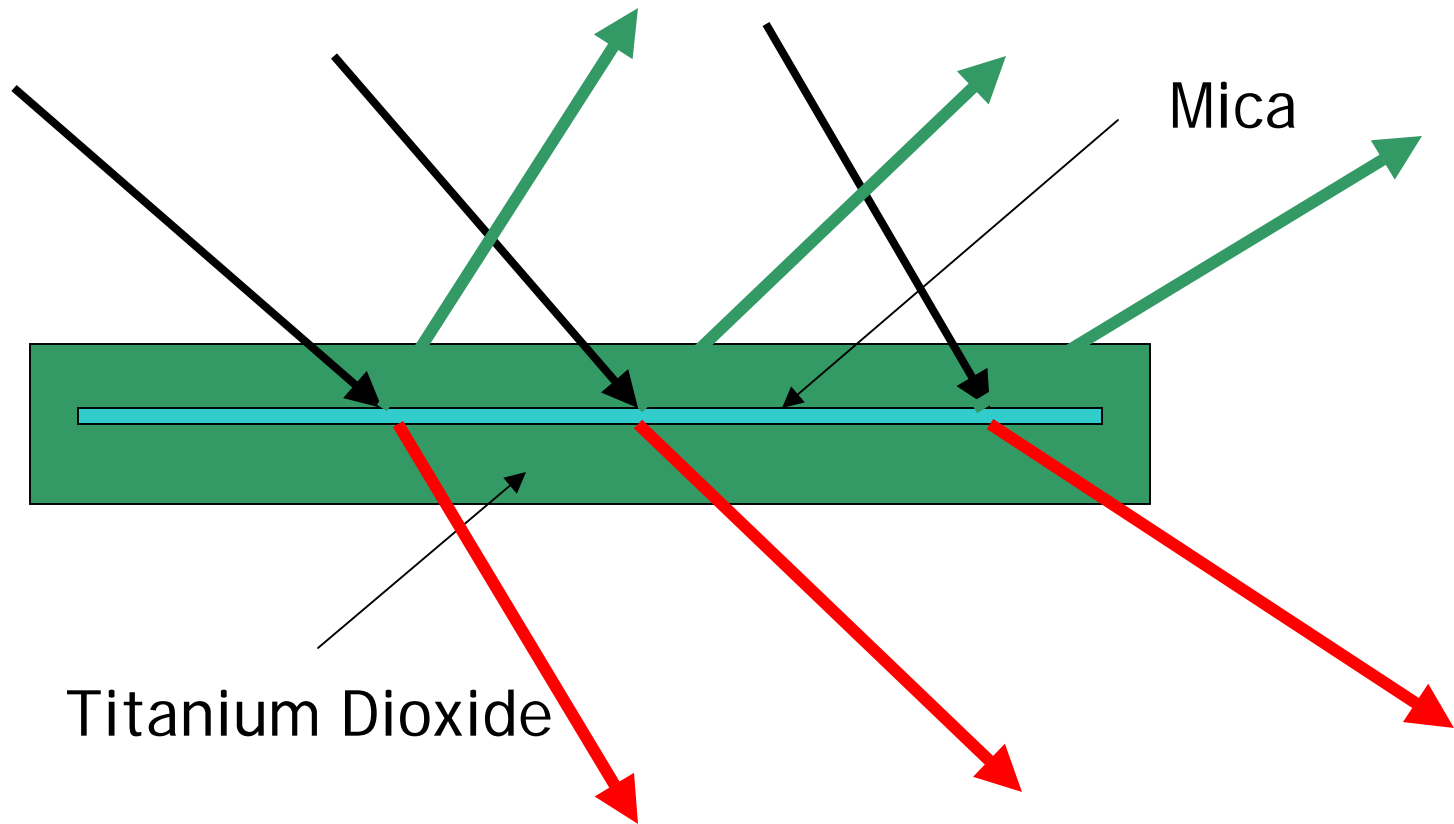
- When light travels through one medium into another, the light may change its angle of travel.
- The refracted angle relative to the incident angle in air is call the Index of refraction.



Green Pearl



Green Pearl: Color Travel



Effect Pigments

- US Patent #3,087,828 April of 1963, Linton, is the the document that gave birth to synthetic Pearl Pigment.
- An effect pigment can:
 - Display color travel.
 - Reflect or refract light.
 - Act as a mirror, (metal Flake).
 - Give multiple color effect, (iridescence)
- Pearlescent Pigments are In the group of Effect Pigments.

Effect Pigments

- Types of Effect Pigment:
 - Coated substrates:
 - Pearls
 - Polymer Stacks
 - Iridescent Film
 - Helicones
 - Mirrors:
 - Metallic Flakes
 - BiOCl
 - Metal Salt Stacks
 - OVP's

Coated substrates

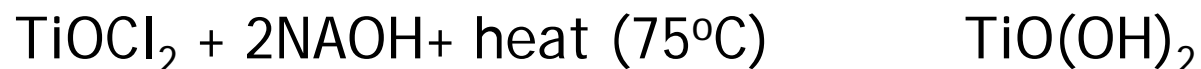
- Effect Pigment Substrates:
 - They are laminar: There must be a flat surface.
 - Can be synthetic or natural.
 - Can be removed after the effect pigment is created to make another effect pigment.
 - They must be transparent.

Substrates

- Mica, and Kaolin:
 - Laminar, plentiful and easy to process.
 - GRAS (Generally Regarded As Safe).
 - Wide range of particle size.
 - Synthetic mica is a possibility.
- Glass Flake and Fluorophlogopite:
 - Synthetic, and usually very uniform.
 - Better Particle Size control.
 - More uniform Aspect ratio.
 - Fewer Impurities.

The Chemistry of Titanium Dioxide

- Synthetic Titanium Dioxide is commercially produced by either the Chloride Process or the Sulfate Process.
- The Chloride Process.



- The Sulfate Process.



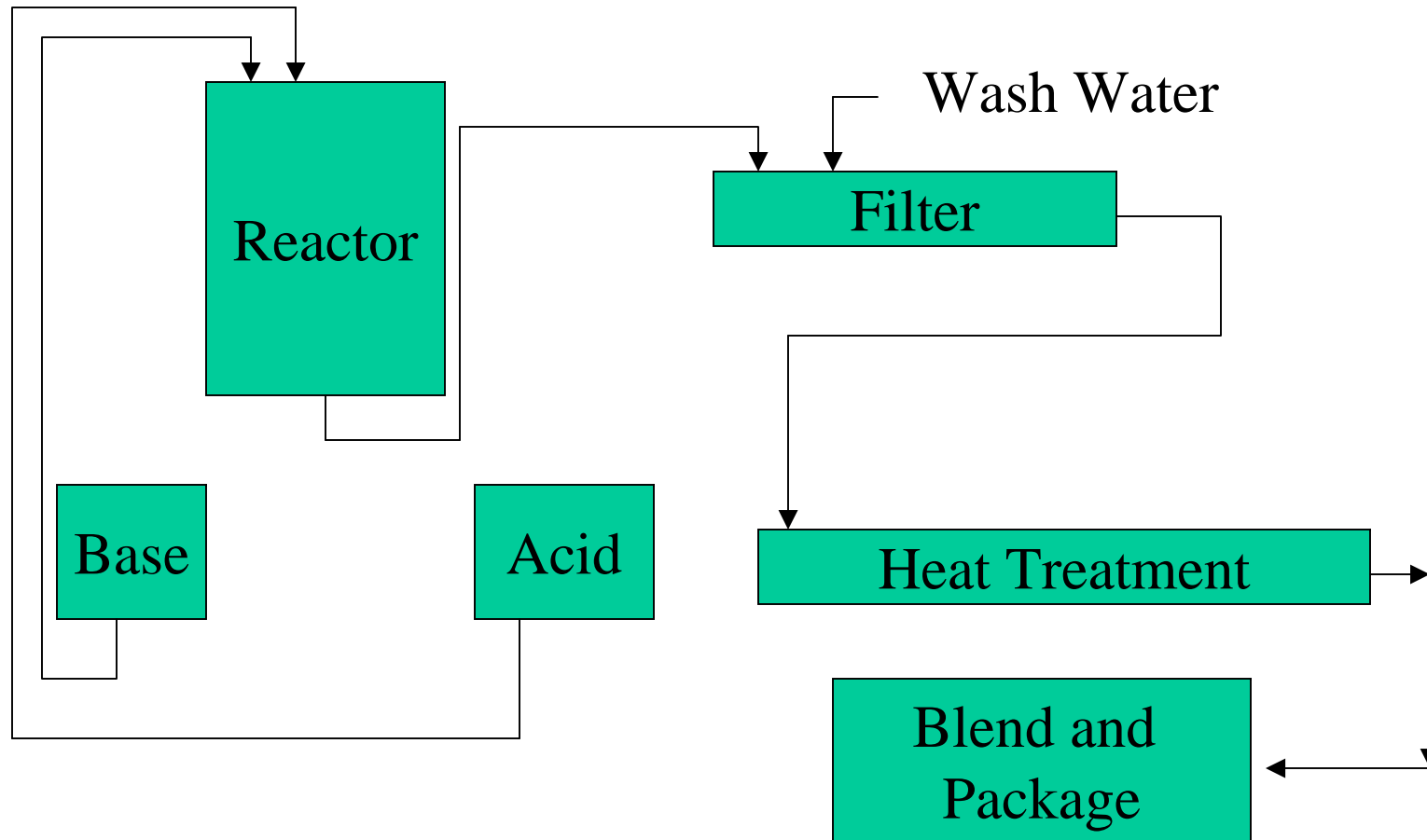
The Chemistry of Titanium Dioxide

- The Sulfate Process is seldom used to pearl pigments anymore.
 - A simple batch process, but color are close to impossible.
 - By-product of H_2SO_4 raises environmental issues.
 - Does not coat fine mica well, but it works well on large mica.
 - Reaction is only 85 - 95% complete.
 - Aluminum from the mica can dissolve.
 - Produces a very white TiO_2 as the H_2SO_4 will keep most impurities soluble.

The Chemistry of Titanium Dioxide

- The Chloride Process is used to produce all the colored pearls.
 - Cost effective and somewhat environmentally friendly.
 - Same process is used for Iron, Chromium, Zirconium and Aluminum.
 - Does not coat large particle size mica well.
 - Reaction is 100% complete and the Mica remains intact, except for iron. The TiO_2 is off white as the dissolved iron will precipitate as Fe_2O_3 .
 - A long control continuous neutralization.

Flow Diagram of Pearl Manufacture



Pearl Pigments

- Pearl Pigments are a pigment manufactured by coating a metal oxide on to a laminar substrate. The resulting pigment is semi-transparent, and has some unique optical properties. This coating process is usually a Sol-gel process, meaning salt solutions are used for the precipitation.
- Pearl Pigments can be broken down into two categories:
 - Natural Substrates: Mica, Kaolin, or Phlogopite
 - Synthetic Substrates: Alumina, Silica, Borosilicate or Synthetic Mica.
- When coating Alumina or Silicates with TiO_2 , the TiO_2 will always be anatase unless a rutile modifier is used. Examples are; Antimony, Tin, Iron, or Chromium.

Metal Oxides

- Metal oxides can be coated on to mica to produce interference color.
- The most common are: Titanium Dioxide, Iron Oxide, Chromium Oxide Green, Zirconium Oxide, and Silicon Dioxide.
- The valence of the cation must be +3, +4 or +5.
- Divalent cations will not coat.

Metal Oxide: Index of Refraction

- High Index
 - Hematite (Fe_2O_3)
 - Rutile
 - Anatase
 - Chromium Oxide
 - Zirconium Oxide
- Low Index
 - Zirconium Oxide
 - Brookite
 - Tin Oxide
 - Silicon Dioxide

Metal Oxide Coatings

- The index of refraction of the metal oxide will be a factor in the type and quality of the pearl.
- Varying the metal oxide layers with I of R > 0.2 can produce an OVP or a Dielectric:



- The quarter-wave stack: An optical thickness must equal to a whole number multiple of one-quarter of the wave-length at which interference is expected. Such construction of the so-called quarter-wave stack is a widely accepted and implemented condition.
- Because of this limitation, a unique layer thickness combination is essential in order to create each individual one of the interference colors of the visible spectrum.

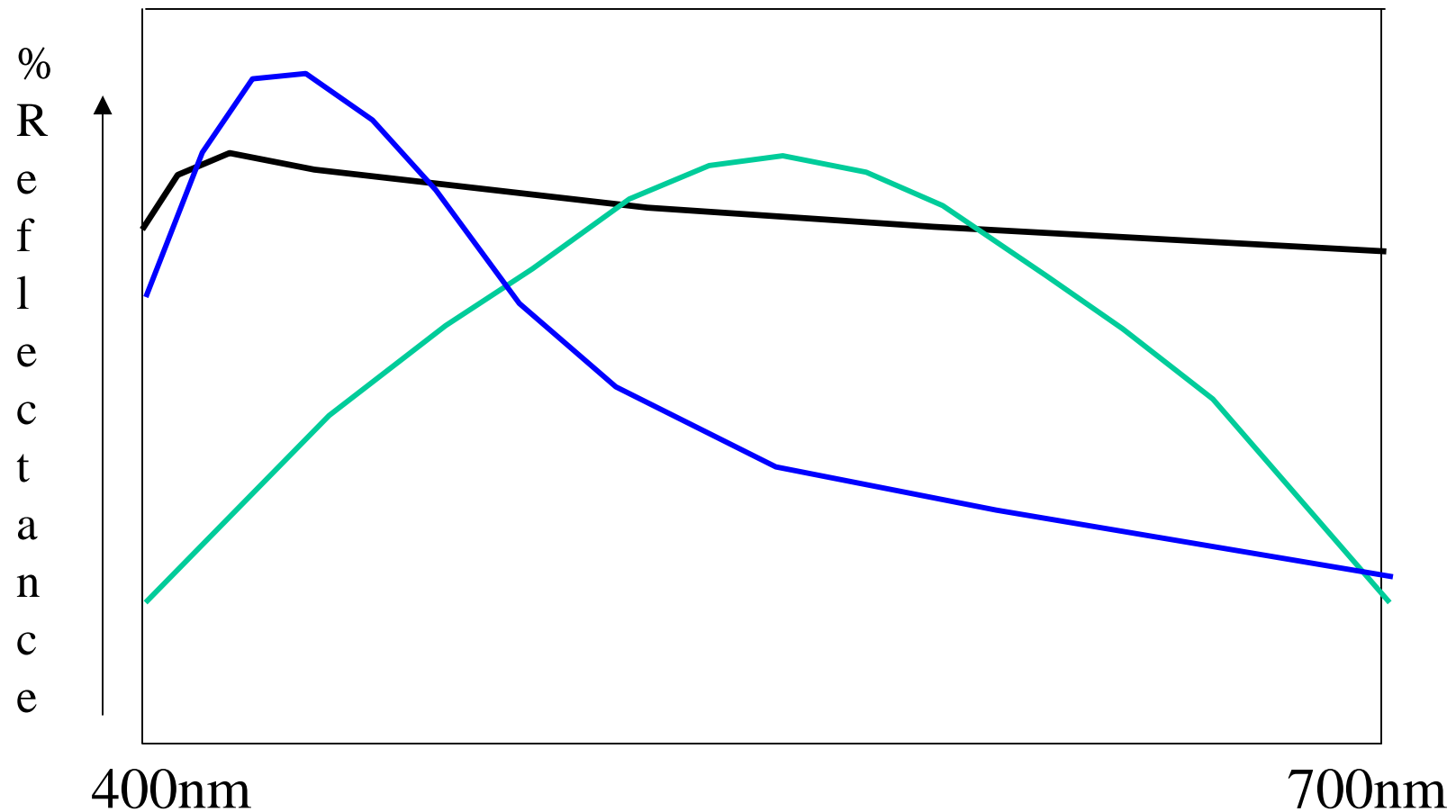
Titanium Dioxide Pearls

- TiO_2 coatings produce a white powder that:
 - Will reflect a specific color depending upon the thickness of the Titanium Dioxide thickness.
 - Have a transmission color that is the opposite of the reflected color.
 - Produce an anatase Titanium Dioxide unless modified for rutile.

Iron Oxide Pearls

- Fe_2O_3 coatings produce a gold, orange, or red absorption color.
- Reflect a specific color depending upon the thickness of the iron oxide thickness.
- Has a transmission color, but it is usually hidden by the absorption color.
- Index of refraction of 3.1.

Reflection color of Pearls



TiO₂ Coating on Mica

Color progression as the thickness of TiO₂ increases:



Guidelines for Using Pearl Pigments

- Do not try to get complete hiding using a pearl. If you want hiding use a smaller particle size pearl.
- Never mix colors: Red + Blue = White not Violet. If you need a Violet use a Violet.
- Ignore the rule above if the particle size is > than 300um.
- They photo darken especially the blue pearls, but this is reversible.
- They are not compatible with certain chemicals like Avobenzone.
- Be aware of the particle size restrictions on Mica.
- New: Coloring Drugs 21CFR73.1128 (7/13/206)