Bringing Color to your designs with Masterbatch Advanced Solutions

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Agenda

1. Introduction
2. Color Science
3. Masterbatch
4. Color Effects
5. Coloring of Recyclates
6. Design for Circularity
Advanced Polymer Solutions

Our diverse portfolio is used to create customizable products including:

- Reduced GHG emissions & improved fuel economy
- Delivering potable water
- Quality healthcare
- Agricultural efficiency
- Food safety & access
- Sustainable & modern living

- Catalloy
- Polybutene-1
- Specialty Powders
- Polypropylene Compounds
- Engineered Composites
- Engineered Polymers
- Color Concentrates
- Masterbatches

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Global Masterbatch Asset Footprint

- Global production network with 20 masterbatch manufacturing sites
- Masterbatch technology centers in each region
- Local color development centers with application specialty
- Standardized manufacturing and laboratory process providing flexible and consistent service
- Extensive materials expertise, analytical laboratories and pilot process capability to support customer developments and innovation
- Certified quality standards; supporting global regulatory requirements
Masterbatch & Color Concentrates

Application Areas

Packaging
Building & Construction
Transportation
Agriculture
Consumer Goods
Appliances

Key Properties

<table>
<thead>
<tr>
<th>Processing Additives</th>
<th>Functional Properties</th>
<th>Optical Appearance &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Anti-oxidant</td>
<td>▪ Slip, Anti-blocking, De-nesting, Release agent</td>
<td>▪ White, Black</td>
</tr>
<tr>
<td>▪ Processing aid, Lubricant</td>
<td>▪ Anti-static, Anti-fog</td>
<td>▪ Matt, Synthetic paper, Soft-touch</td>
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Core portfolio:
Our Masterbatch portfolio addresses modern customer needs

- Polybatch Color Concentrates: Standard Colors, Custom Colors, Special Effects
- Polyblak Black
- Polywhite White
- Polybatch Additives

Advanced Solutions addressing:
Plastic Waste / Climate Change / Thriving Society

- Circulen
  - CirculenRecover
  - CirculenRevive
  - CirculenRenew

Carriers – A variety of different carriers are available

- PP, PE, EVA, Styrenics, PET, PETG, PA, Bio-resins, Technical polymers
- Sustainable Polymers + Sustainable Ingredients
- PCR, PIR, r-PET, Bio-renewable feedstock, Advanced recycling
Color Science

- Color exists only in our mind and is seen when light waves reflected off an object meet the eye.
- An object appears colored because it absorbs some light wavelengths and reflects back others.
The human eye can see more than 1,000,000 different colours and we all experience them differently!

- No physical scale
- Subjective color perception
- We describe colors in different ways, e.g. ‘Blue Ocean’, ‘Crimson Red’
Color perception is complex and involves the interaction of several factors:

- **Light source** – color can appear differently depending on type of light
  - Daylight – sunlight intensity, time of day
  - Artificial Light – Incandescent, Fluorescent, Halogen, LED
  - Metamerism

- **Object**
  - Size and shape
  - Material – reflection, absorbance, diffraction

- **Observer**
  - Human – different people see colors differently
  - Digital – type of device

- **Angle of viewing**
  - Amount of reflection and transmission of light

- **Background effect**
  - Light or dark background changes color perception
Color science

Credit: Barton L. Anderson & Jonathan Winawer
For color design it is important how we communicate color:

- **Define the color master**
  - Including material and texture
  - Master chip with L*a*b* coordinates or RAL, Pantone ….

- **Define measurement conditions**
  - Measuring equipment
  - Light Source e.g. D65, TL84, A
  - Measurement angle
  - Color calculation model – e.g. CIELAB 1976, dE2000, CMC

- **Specification and tolerances**
  - Prototype scale up to production
  - Batch to batch consistency
    - Use master chip with L*a*b* coordinates

- **Consistency of color across different materials**
  - Same color in different polymer or materials
Masterbatch Composition

- **Masterbatch is a combination of pigments and additives encapsulated in a polymer matrix.**
  - Pigments + Additives are blended and extrusion compounded to provide optimum dispersion of the ingredients in the polymer matrix.
  - Recipe is designed to be diluted into the converters polymer to provide the required color and properties when used at the specified dosage (usually between 1% to 5%).

- **Benefits of Masterbatch:**
  - Controlled and clean dosing compared to dry pigments
  - Customised to provide required color and additive properties
  - Economical and flexible
Masterbatch Composition

Masterbatch developer needs to consider many factors for the optimum combination of materials:

- **Polymer**
  - Compatibility of colorant & carrier for end application
  - Optimum dispersion & dilution of colorant

- **Application**
  - Color – opaque, transparent, special effect?
  - Type of article – e.g. rigid or flexible?
  - Processing method – temperature and shear sensitivity
  - Service Life - how many years does the part need to last & where?
  - Additional functionality – does the part need to be UV stabilised, Antistatic ….
  - Interaction of Pigment and Additives to avoid affecting performance or color

- **Regulatory and Sustainability**
  - Product Safety and Regulations – e.g. RoHS, VOC, Food Contact …
  - Recyclablility – NIR detection
  - Sustainability
Pigments are typically classified as Inorganic, Organic or Dyes
Choice of pigment needs to consider the application, polymer and color requirements
Soluble Dyes are used in specific polymers, e.g. Styrenics, PET, PA, PC and PMMA

<table>
<thead>
<tr>
<th>Pigment Selection</th>
<th>Inorganic</th>
<th>Organic</th>
<th>Dye</th>
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<tbody>
<tr>
<td>Color Shade</td>
<td>Dull</td>
<td>Medium → Bright</td>
<td>Bright</td>
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<tr>
<td>Tint Strength</td>
<td>Low</td>
<td>Medium → High</td>
<td>High</td>
</tr>
<tr>
<td>Opacity</td>
<td>Opaque</td>
<td>Semi-opaque → Transparent</td>
<td>Transparent</td>
</tr>
<tr>
<td>Light Fastness</td>
<td>Good → Very Good</td>
<td>Poor → Very Good</td>
<td>Poor → Good</td>
</tr>
<tr>
<td>Heat Stability</td>
<td>Good → Very Good</td>
<td>Poor → Very Good</td>
<td>Poor → Very Good</td>
</tr>
<tr>
<td>Chemical Stability</td>
<td>Good → Very Good</td>
<td>Poor → Good</td>
<td>Poor → Good</td>
</tr>
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Pigment Selection

- Selection of pigments dependent on polymer and application
- Available pigment palette for the developer reduces as application demands increase

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<tr>
<th>Pigments for Plastics</th>
<th>+ Food Contact</th>
<th>+ Outdoor Application</th>
<th>+ Engineering Polymers</th>
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Color Effects

- Metallic
- Pearlescent
- Marble
- Glitter
Color Effects

■ Fibre
  ▪ Different fibre material types, color, length and diameter

■ Fluorescent
  ▪ Bright colors
  ▪ High fluorescence under UV light

■ Phosphorescent
  ▪ ‘Glow in the dark’

■ Thermochromic
  ▪ Color change with temperature
Surface Effects

Surface effects can be created by selection of materials or mold design, changing the reflective properties.

- **Material**
  - Selection of polymers with high gloss or matt appearance
  - ‘Soft touch’ design with *Catalloy* polymer

- **Mold Design**
  - Mold surface can be polished, matt or engraved to create different textures
Pre-consumer or post-consumer recyclate can come in many different colors.
- Ivory to Dark Grey color range
- Color masterbatch needs to be matched depending on the recyclate source
- Color shade can be limited by color of the recyclate
Masterbatch solutions for recyclate resins

- Color travel with increasing content of recyclate
- Same masterbatch can give different color with different quality of recyclate
  - Color design always needs to consider the recyclate material being used

RAL 5012 with PCR Ivory
100% - 75% - 50% recyclate

RAL 5012 with PCR Grey
100% - 75% - 50% recyclate

RAL 5012 with PCR Ivory (L) and Grey (R)
100% recyclate
Masterbatch solutions for recyclate resins

- Metallic and Pearlescent special effects are still possible with recyclate resins
  - Color and quality of recyclate needs to be good to avoid losing impact of special effects

RAL 4011 with PCR Ivory
100% - 75% - 50% recyclate

RAL 7048 with PCR Ivory
100% - 75% - 50% recyclate
- Parts need to be designed to enable sorting by polymer type using NIR spectroscopy in material recycling centres
- Certain pigments, especially carbon black, can prevent NIR detection and polymer sorting
- Black and dark colors can be designed using alternative NIR detectable pigments
- NIR spectroscopy can be used during masterbatch design
Design for Circularity: Material solutions to address the challenge of designing functional and aesthetic packaging which can be more easily sorted and mechanically recycled.

Mono-material packaging

- Re-design complex and difficult to recycle multi-material packaging to mono-material alternatives while maintaining desired properties and performance.
- *Polybatch* additives for processing of orientated PE films used in food packaging.

Near-infrared (NIR) sortable packaging

- NIR detectable masterbatches for a range of polymers to enable sorting of black and dark colored plastic articles in post-consumer waste streams.
- *Polybatch* 73641 NIR with COTREP certification

Masterbatches for Recyclates

- Masterbatch additives for recyclers and converters to improve processing and quality of recycled material.
- Enables recyclates for multiple recycling loops.
Leading global supplier of high-performance plastic compounds, masterbatches and resins

Providing innovative solutions to exactly meet customer application requirements

One-Stop shop for color and additive masterbatches

Raw materials harmonization to ensure consistent quality and supply, worldwide

Specialized color competence and masterbatch technology centers

Sustainability is a core value and a driver
Thank you

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