An Engineer’s Guide to Specify the Right Thermoplastic

Steve Maki
Vice President Technology
• **Compounder** = We blend thermoplastic resins with fillers, additives, and modifiers

• **Specialty** = We create engineered formulations

• **Independent** = We are unbiased in our selection of raw materials
• Define Compounding
• Plastic Resin Selection Process
• Application Case Studies
• Compounding Performance
• Engineered Thermoplastic Compounds
Compounding Process
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Raw Materials → Blender → Extruder → Cooling → Pelletizer → Classifier → Finished Product
Compounding Objectives

- Mixing
  - Distributive
  - Dispersive
Compounding Extruders
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Single Screw  Twin Screw  Co-Kneader
• Conductive carbon black surface area = 130 m$^2$/gram
• 34 grams carbon black = surface area of football field (4460 m$^2$)
• Dispersing a 20% carbon black compound is similar to evenly coating a football field with 136 grams of plastic!
Resin Selection
The Dilemma

- 60 Thermoplastic Resins + 100 Additives = 1000’s of Potential Compounds
- Which 1 Do I Choose For My Application???
• Step 1 – Use Resin Morphology

• Step 2 – Use Thermal & Cost Requirements

• Step 3 – Fine Tune & Special Features
The form and structure the molecules of a polymer take upon solidification

Amorphous  Semi-Crystalline
Compare

- Molecular Packing (Shrinkage)
- Resistance to Molecular Disentanglement (Chemical/Abrasion Resistance)
- Light Refraction (Opacity)
- Melting Characteristics (Flow)
# Morphology Characteristics

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<tr>
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## Morphology Characteristics

**Amorphous** | **Semi-Crystalline**
---|---
Low Shrinkage | ✴
Low Warpage | ✴
Tight Tolerances | ✴
Transparency | ✴
Mold Flow Ease | ✴
Chemical Resistance | ✴
Wear Resistance | ✴

- Lens?
- Fuel Float?
- Lamp Housing?
- Tool Housing?
- Pulley?
- Precision Printer Chassis?
- Intake Manifold?
- Grease Fitting?
- Laptop Cover?
### Morphology Of Thermoplastics

**YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS**

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Plastic Selection Process

• Step 1 – Use Resin Morphology
• Step 2 – Use Thermal & Cost Requirements
• Step 3 – Fine Tune & Special Features
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Commodity (<$1.50) • Engineered ($1.50-$4.00) • High Performance (>=$4.00)
• Step 1 – Use Resin Morphology

• Step 2 – Use Thermal & Cost Requirements

• Step 3 – Fine Tune & Special Features
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Commodity (<$1.50) • Engineering ($1.50-$4.00)
Styrenic Features

- **Morphology Features** – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent (except HIPS & ABS), Poor Chemical & Abrasion
  - **PS** – Good Transparency @ Low Cost, Brittle
  - **HIPS** – Moderate Impact Resistance @ Low Cost
  - **SAN** – Good Transparency, Slightly Better Chemical Resistance, Brittle, Low Cost
  - **ABS** – Excellent Impact Resistance & Gloss, Slightly Better Chemical Resistance, Low-Moderate Cost
• **Morphology Features** – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Chemical & Abrasion
  
  – **PMMA** -- Optical Quality Transparency, Excellent UV Stability, Brittle, Low Cost
• **Morphology Features** – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Chemical & Abrasion
  
  – **PC** -- Optical Quality Transparency, High Impact Resistance, Moderate Cost
• **Morphology Features** – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections, Poor Dimensions
  
  – **PP** -- Low Density, Better Thermal Resistance Than PE, Living Hinge Capable, Brittle @ Low Temperatures, Low Cost
  
  – **HDPE** -- Good Low Temp Impact Performance (Tg = -77°C vs -9°C for PP), Low Cost
• **Morphology Features** – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections (Except Amorphous Nylon), Poor Dimensions
  
  – **Nylon 6** -- Strong/Stiff (But Humidity Dependent), Good Surface Finish Even When Reinforced, Moderate Cost
  
  – **Nylon 66** -- Strong/Stiff (But Humidity Dependent), Higher Thermal Than 6, Mod. Cost
  
  – **Nylon 6/12, 11, 12, etc.** – Less Sensitive to Humidity, High Cost
• **Morphology Features** – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Abrasion
  
  — *Amorphous Nylon* -- Good Chemical Resistance for Amorphous Morphology, Moderate-High Cost
**Polyester Features**

- **Morphology Features** – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections, Poor Dimensions
  
  - **PET** -- Difficult to Mold (Poor Nucleation & Hydrolysis), Good Electrical Resistance, Mod. Cost
  
  - **PBT** -- Easy to Mold, Good Electrical Resistance, Properties & Dimensions Do Not Fluctuate With Humidity (Same For PET), Moderate Cost
  
  - **PLA** – “Green” Polymer, Poor Impact, Poor Heat Resistance, Difficult to Mold (Poor Nucleation & Hydrolysis), Low Cost
• **Morphology Features** – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections, Poor Dimensions

  – **Acetal** – Low Friction & Wear, Excellent Resiliency & Fatigue Endurance, Moderate Cost
Putting It All Together

• Step 1 – Use Resin Morphology
• Step 2 – Use Thermal & Cost Requirements
• Step 3 – Fine Tune & Special Features

Test Your Knowledge With Application Examples
Case Study

- **CD Jewel Case**
  - Transparent
  - Flat & Dimensionally Stable
  - Low Cost

- **PS**
Case Study

- **Gas Tank**
  - Good Chemical Resistance
  - Good Low Temperature Impact
  - Low Cost

- **HDPE**
Case Study

- Auto Tail Lamp Cover
  - Transparent Colors
  - Dimensionally Stable
  - Excellent UV
  - Low Cost

- PMMA
Case Study

- Plastic Glass Tumblers
  - Transparent
  - Reasonable Thermal & Chemical Resistance (Dishwasher Cycles)
  - Low Cost

- SAN
Case Study

• Sump Pump Housing
  – Chemical Resistance
  – Reasonable Thermal Resistance
  – Low Cost

• PP + GF
Case Study

• Safety Glasses
  – Optical Transparency
  – High Impact
  – Moderate Cost OK

• PC
Case Study

• Truck Wheel Odometer Lens
  – Transparent
  – Good Chemical Resistance
  – Moderate-High Cost OK

• Amorphous Nylon
• Chemical Beakers
  – Excellent Chemical Resistance
  – Low Cost
  – Transparent

• ?????????
Case Study

• Nail Gun Housing
  – Good Chemical Resistance
  – Excellent Strength, Stiffness & Impact
  – Good Surface Finish When Reinforced
  – Moderate Cost OK

• Nylon 6 + GF
Case Study

• Automotive Intake Manifold
  – Chemical Resistance
  – Excellent Strength, Stiffness & Impact
  – Moderate Heat Resistance
  – Moderate Cost OK

• Nylon 66 + GF
Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

• Oil Pan
  – Chemical Resistance
  – Excellent Strength, Stiffness & Impact
  – Moderate Heat Resistance
  – Moderate Cost OK
  – Extremely Tight Dimensions & Flat

• ??????????
• Electrical Connectors
  – Good Flow in Thin Walls
  – Excellent Electrical Properties
  – Dimensionally Stable in Humidity
  – Moderate Cost OK

• PBT (PET) + GF + FR
Case Study

• **Conveyor Rollers**
  – Good Abrasion Resistance
  – Low Wear & Friction
  – Moderate Cost OK

• **Acetal**
• Printer Gears
  – Extremely Tight Dimensions
  – Moderate Cost OK
  – Good Abrasion Resistance
  – Low Wear & Friction

• ??????????
Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Lawn Tractor Hood**
  - Tight Dimensions & Low Warp
  - Moderate Cost OK
  - Chemical Resistance
  - Good Mold Flow
  - High Impact

- ???????????
Overcoming Morphology Deficiencies Via Compounding
### Morphology Deficiencies

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• Can We Reduce Shrink Rate & Improve Dimensional Stability of Semi-Crystalline Resins?
Fiber Reduces Shrink

Shrink Rate \( X \neq \) Shrink Rate \( Y \) → Warp
Warp Control

Shrink Rate X = Shrink Rate Y → Flat Part

But Low Strength!
Common Loading = 15% Glass Fiber & 25% Mineral or Beads
Case Study

• Oil Pan
  – Chemical Resistance
  – Excellent Strength, Stiffness & Impact
  – Good Heat Resistance
  – Moderate Cost OK
  – Extremely Tight Dimensions & Flat

• Nylon 66 + 15% GF + 25% Mineral
• Can We Make A Semi-Crystalline Resin Transparent?
Compounding nucleator into PP or PE controls crystal size to less than wavelength of light = Transparency

 Courtesy Milliken Chemical
• Chemical Beakers
  – Excellent Chemical Resistance
  – Low Cost
  – Transparent

• PP + Nucleator
• Can We Improve Chemical Resistance & Mold Flow of Amorphous Resins?
• **Alloy PC with ABS**
  – RTP 2500 A Series

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<tr>
<th>Property</th>
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<tr>
<td>Tensile Strength, psi</td>
<td>9000</td>
<td>8900</td>
</tr>
<tr>
<td>Flexural Mod, E6 psi</td>
<td>0.34</td>
<td>0.40</td>
</tr>
<tr>
<td>Izod Impact, ft lb/in</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>HDT @ 264 psi,°F</td>
<td>270</td>
<td>210</td>
</tr>
<tr>
<td>Fuel Resistance</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Melt Flow, gm/10 min</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Clarity</td>
<td>Transparent</td>
<td>Opaque</td>
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• **Alloy PC With Polyester (PBT or PET)**
  – RTP 2099 X 63578 B

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• Lawn Tractor Hood
  – Tight Dimensions & Low Warp
  – Moderate Cost OK
  – Chemical Resistance
  – Good Mold Flow
  – High Impact

• PC/PBT Alloy
Case Study

- GPS Housing
  - Tight Dimensions & Low Warp
  - Moderate Cost OK
  - Good Mold Flow
  - High Impact
- PC/ABS or PC/PBT Alloy
  - Want Sustainability
- PC/PLA Alloy (30% Bio)
  - Want More Sustainability
- Recycled (PCR) PC/PLA Alloy
  (30% Bio + 60% PCR = 90% Sustainable)
• Can We Make An Amorphous Resin Wear Resistant?
• Compound PTFE Into PC
  – RTP 300 TFE 15

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<th></th>
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<th>PC/15 PTFE</th>
<th>Acetal</th>
</tr>
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<tbody>
<tr>
<td>Wear Factor</td>
<td>560</td>
<td>130</td>
<td>90</td>
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<tr>
<td>Dynamic Coef. of Friction</td>
<td>0.60</td>
<td>0.33</td>
<td>0.40</td>
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Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Printer Gears
  - Extremely Tight Dimensions
  - Moderate Cost
  - Good Abrasion Resistance
  - Low Wear & Friction

- PC + PTFE
• Intro To Compounding
• The Dilemma
• Resin Selection Procedure
  – Resin Morphology
  – Resin Performance (including cost)
  – Unique Resin Features
• Application Case Studies
• Compounding in Performance
  – Overcoming Resin Deficiencies
Questions?

Steve Maki
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(507) 474-5371