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

An Engineer's Guide to Specify the Right Thermoplastic

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AGENDA

1. Define Compounding
2. Plastic Resin Selection Process
3. Application Case Studies
4. Compounding To Enhance Performance
5. New RTP Technologies

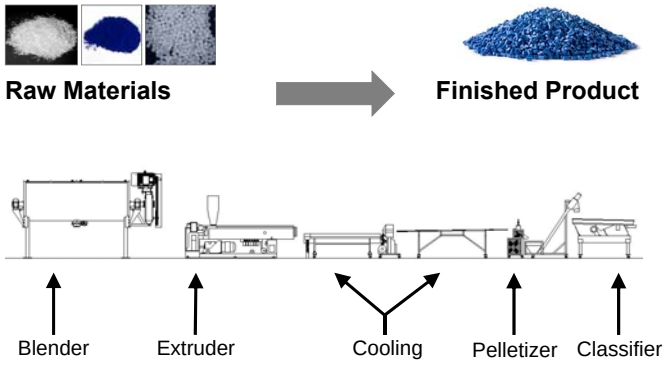
INDEPENDENT SPECIALTY COMPOUNDER

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

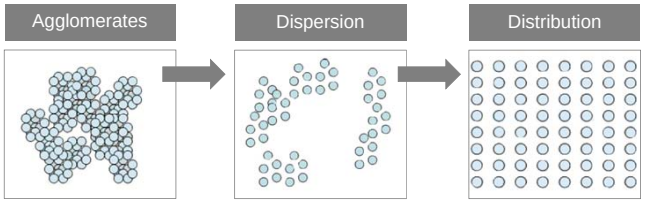
COMPOUNDING PROCESS



COMPOUNDING OBJECTIVES

Mixing

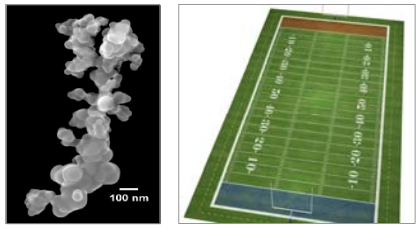
- Dispersive
- Distributive



COMPOUNDING EXTRUDERS

Single Screw Twin Screw Co-Kneader

PUTTING COMPOUNDING INTO PERSPECTIVE



- Conductive carbon black surface area = 130 m^2/gram
- 34 grams carbon black = surface area of football field (4460m^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 ONE Do I Choose For My Application???

PLASTIC SELECTION PROCESS

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

PLASTIC SELECTION PROCESS

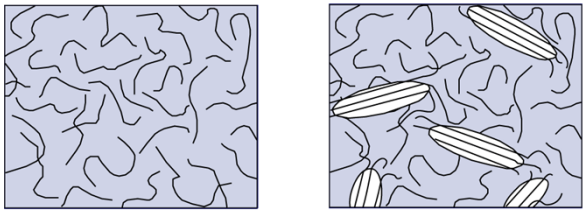
Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

MORPHOLOGY

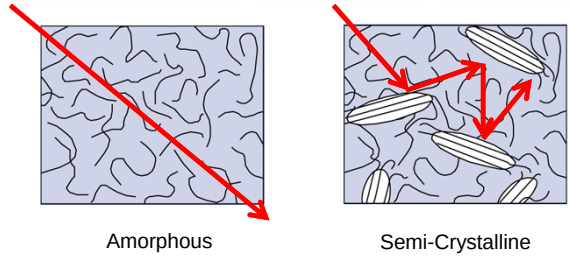
The form and structure the molecules of a polymer take upon solidification



Amorphous

Semi-Crystalline

MORPHOLOGY

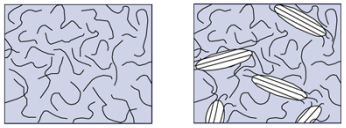


Amorphous | Semi-Crystalline

Compare

- Molecular packing (shrinkage)
- Resistance to molecular disentanglement (chemical/abrasion resistance)
- Melting characteristics (flow)
- Light refraction (opacity)

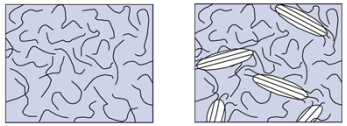
MORPHOLOGY CHARACTERISTICS



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

MORPHOLOGY CHARACTERISTICS

Lens?
Fuel Float?
Precision Printer Chassis?
Tool Housing?
Multiple Pin Connector?
Pulley?
Grease Fitting?
Laptop Cover?



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

MORPHOLOGY OF THERMOPLASTICS

Amorphous

Polyetherimide (PEI)
Polyethersulfone (PES)
Polysulfone (PSU)
Amorphous Nylon
Polycarbonate (PC)
Acrylic (PMMA)
Acrylonitrile Butadiene Styrene (ABS)
Styrene Acrylonitrile (SAN)
High Impact Polystyrene (HIPS)
Polystyrene (PS)

Semi-Crystalline

Polyetheretherketone (PEEK)
Polyphenylene Sulfide (PPS)
Polyphthalamide (PPA)
Polyamide (PA/Nylons)
Polybutylene Terephthalate (PBT)
Polyethylene Terephthalate (PET)
Acetal (POM)
Polylactic Acid (PLA)
Polypropylene (PP)
Polyethylene (HDPE, LDPE, LLDPE)

PLASTIC SELECTION PROCESS

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

MORPHOLOGY VS. THERMAL/COST

Amorphous

Semi-Crystalline

Amorphous	Semi-Crystalline
Polyetherimide (PEI)	Polyetheretherketone (PEEK)
Polyethersulfone (PES)	Polyphenylene Sulfide (PPS)
Polysulfone (PSU)	Polyphthalamide (PPA)
Amorphous Nylon	Polyamide (PA/Nylons)
Polycarbonate (PC)	Polybutylene Terephthalate (PBT)
Acrylic (PMMA)	Polyethylene Terephthalate (PET)
Acrylonitrile Butadiene Styrene (ABS)	Acetal (POM)
Styrene Acrylonitrile (SAN)	Polylactic Acid (PLA)
High Impact Polystyrene (HIPS)	Polypropylene (PP)
Polystyrene (PS)	Polyethylene (HDPE, LDPE, LLDPE)

Thermal & Cost Increases

Commodity (<$1.50) • Engineered ($1.50-$4.00) • High Performance (>$4.00)

PLASTIC SELECTION PROCESS

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

ENGINEERED & COMMODITY RESINS

Amorphous

Semi-Crystalline

Amorphous	Semi-Crystalline
Amorphous Nylon	Polyamide (PA/Nylons)
Polycarbonate (PC)	Polybutylene Terephthalate (PBT)
Acrylic (PMMA)	Polyethylene Terephthalate (PET)
Acrylonitrile Butadiene Styrene (ABS)	Acetal (POM)
Styrene Acrylonitrile (SAN)	Polylactic Acid (PLA)
High Impact Polystyrene (HIPS)	Polypropylene (PP)
Polystyrene (PS)	Polyethylene (HDPE, LDPE, LLDPE)

Commodity (<$1.50) • Engineering ($1.50-$4.00)

AMORPHOUS RESINS

Morphology Features -- Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent (except HIPS & ABS), Poor Chemical & Abrasion, Poor Flow in Thin Mold Sections

Amorphous	Special Features
Amorphous Nylon	Transparent/good chem. resistance
Polycarbonate (PC)	Optical transparency/high impact
Acrylic (PMMA)	Optical transparency/UV stable
Acrylonitrile Butadiene Styrene (ABS)	High impact/high gloss/opaque
Styrene Acrylonitrile (SAN)	Transparent/mod. chem. resistance
High Impact Polystyrene (HIPS)	Moderate impact/opaque
Polystyrene (PS)	Transparent/brittle

Commodity (<$1.50) • Engineering ($1.50-$4.00)

SEMI-CRYSTALLINE RESIN

Morphology Features -- Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections, Poor Dimensions, Opaque

Semi-Crystalline	Special Features
Nylon 6/12	Less Sensitive to humidity vs. 6&6/6
Nylon 6/6	Better thermal vs. 6/humidity Dep
Nylon 6	Hides GF/strong but humidity Dep
Polybutylene Terephthalate (PBT)	Good electricals/easier to mold
Polyethylene Terephthalate (PET)	Good electricals/difficult to mold
Acetal (POM)	Low wear & friction/high fatigue
Polylactic Acid (PLA)	Green/Low impact & thermal
Polypropylene (PP)	Poor low temp impact/mod thermal
Polyethylene (HDPE, LDPE, LLDPE)	Good low temp impact

Commodity (<$1.50) • Engineering ($1.50-$4.00)

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

Hub Odometer Lens

- Transparent
- Good Chemical Resistance
- Moderate-High Cost OK

Amorphous Nylon

CASE STUDY

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

Oil Pan

- Chemical resistance
- Excellent strength, stiffness & impact
- Moderate heat resistance
- Moderate cost OK
- Extremely tight dimensions & flat

?????????

CASE STUDY

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

CASE STUDY

Printer Gears

- Extremely tight dimensions
- Moderate cost OK
- Good abrasion resistance
- Low wear & friction

?????????

CASE STUDY

Lawn Tractor Hood

- Tight dimensions & low warp
- Moderate cost OK
- Chemical resistance
- Good mold flow

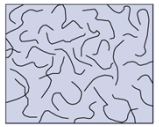
?????????

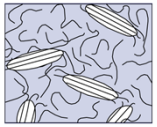
Overcoming Resin Deficiencies

Via Compounding

MORPHOLOGY DEFICIENCIES

	Amorphous	Semi-Crystalline
Low Shrinkage	✖	D
Low Warpage	✖	D
Tight Tolerances	✖	D
Transparency	✖	D
Mold Flow Ease	D	✖
Chemical Resistance	D	✖
Wear Resistance	D	✖

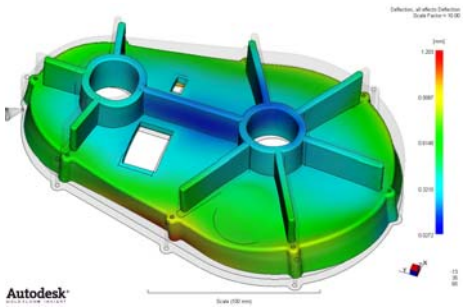




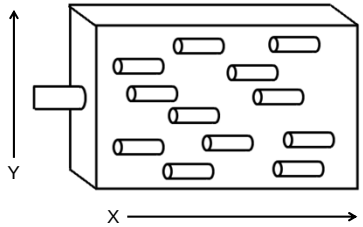
DIMENSIONAL STABILITY

Can We Reduce Shrink Rate & Improve

Dimensional Stability of Semi-Crystalline Resins?

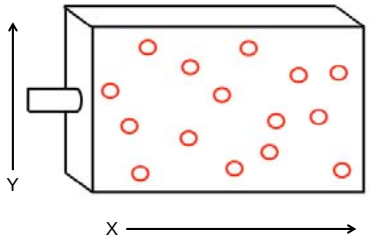


FIBER REDUCES SHRINK



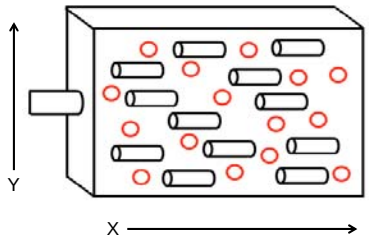
Shrink Rate X ≠ Shrink Rate Y ⟹ Warp

WARP CONTROL



Shrink Rate X = Shrink Rate Y ⟹ Flat Part
But Low Strength!

STRENGTH & WARP CONTROL



Common Loading = 15% Glass Fiber &
25% Mineral or Beads

CASE STUDY

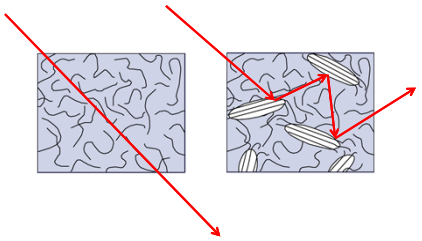
Oil Pan

- Chemical resistance
- Excellent strength, stiffness & impact
- Moderate heat resistance
- Moderate cost OK
- Extremely tight dimensions & flat

Nylon 66 + 15% GF + 25% Mineral

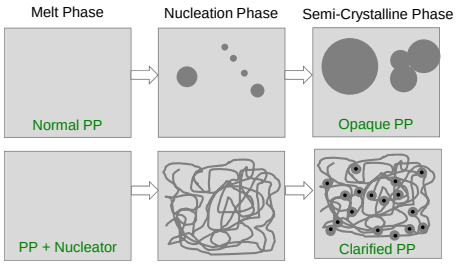
TRANSPARENCY

Can We Make A Semi-Crystalline Resin Transparent?



NUCLEATION/CLARIFICATION

Compounding nucleator into PP or PE
controls crystal size to less than wavelength of light
= Transparency



CASE STUDY

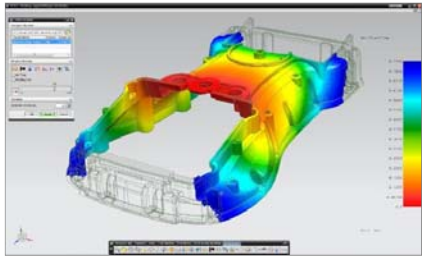
Chemical Beakers

- Excellent chemical resistance
- Low Cost
- Transparent

PP + Nucleator

CHEMICAL RESISTANCE/MOLD FLOW

Can We Improve Chemical Resistance & Mold Flow of Amorphous Resins?



ALLOYING

Alloy PC with ABS

RTP 2500 A Series

	PC	PC/ABS
Tensile Strength, psi	9000	8900
Flexural Mod, E6 psi	0.34	0.40
Izod Impact, ft lb/in	15	13
HDT @ 264 psi, ^{0}F	270	210
Fuel Resistance	Poor	Poor
Melt Flow, gm/10 min	10	15
Clarity	Transparent	Opaque

ALLOYING

Alloy PC With Polyester (PBT or PET)

RTP 2099 X 63578 B

	PC	PC/PBT
Tensile Strength, psi	9000	8700
Flexural Mod, E6 psi	0.34	0.35
Izod Impact, ft lb/in	15	15
HDT @ 264 psi, ^{0}F	270	250
Fuel Resistance	Poor	Fair
Melt Flow, gm/10 min	10	20
Clarity	Transparent	Opaque

CASE STUDY

Lawn Tractor Hood

Tight dimensions & low warp

Moderate cost OK

Chemical resistance

Good mold flow

PC/PBT Alloy

WEAR RESISTANCE

Can We Make An Amorphous Resin Wear Resistant?

PTFE LUBRICATED

Compound PTFE Into PC

RTP 300 TFE 15

	PC	PC/15 PTFE	Acetal
Wear Factor	560	130	90
Dynamic Coef. of Friction	0.60	0.33	0.40

CASE STUDY

Printer Gears

- Extremely tight dimensions
- Moderate cost OK
- Good abrasion resistance
- Low wear & friction

PC + PTFE

WHAT'S NEW?

New Technologies

NEW TECH (HEALTHCARE)

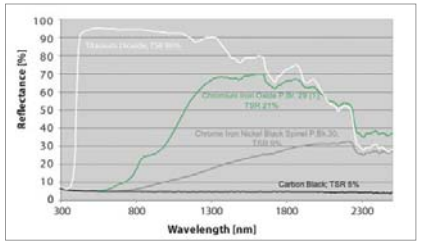
RTP 2000 HC Series

- Increased chemical resistance to healthcare cleaners vs PC, ABS, PC/ABS
- Good dimensional stability with shrinkage similar to above resins
- Flame retardant grade for electronic housings
  - RTP 2000 HC FR A

NEW TECHNOLOGIES (COLOR)

IR Reflecting Colors

Allows Dark Colored Plastics To Remain Cool When Exposed To Sunlight



- Patio Furniture
- Decking/Pavers
- Roofs/Siding
- Auto Interiors

NEW TECHNOLOGIES (FR)

FR Compounds for Plenum Applications (UL 2043)

Low Heat/Smoke Release Grades

- FR PP Grades (Glass Fiber, Mineral, Unfilled)
- FR Nylon (Glass Fiber)

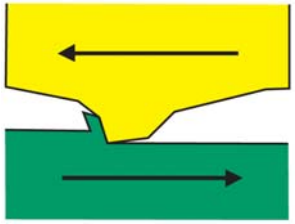
Opportunities

- Wireless Access Points
- Speaker Housings
- Vent Diffusers
- Cable Racks
- Light Housings

NEW TECHNOLOGIES (WEAR)

Abrasion Resistant Compounds

To Compete With UHMWPE (Not Moldable)

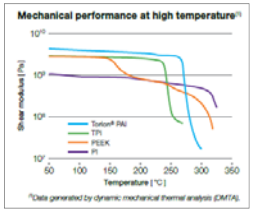


- Injection Moldable Polyolefin Alloy
- Similar Abrasion Resistance To UHMWPE
  - → Gears
  - → Cams
  - → Slides
  - → Wear Liners

NEW TECH (HIGH TEMPERATURE)

Specialty Torlon Compounds

RTP has a license agreement with Solvay Specialty Polymers to manufacture specialty compounds based on Torlon polyamide-imide



- Custom Fiber Reinforced
- Custom Wear Formulas
  - → Automotive
  - → Aerospace
  - → Industrial

REVIEW

Intro To Compounding

The Dilemma

Resin Selection Procedure
- Resin Morphology
- Resin Cost & Thermal Performance
- Unique Resin Features

Application Case Studies

Compounding in Performance
- Overcoming Resin Deficiencies

Introduction To New Technologies

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