How Masterbatches & Compounds Enable Processing Biopolymers

PolyOne Sustainable Solutions™

23 April 2009

Agenda

- **PolyOne in snapshot**
- **PolyOne Sustainable Solutions**
- **PolyOne Color & Additive BIO Solutions**
  - **OnCap™Bio Additive Masterbatches**
- **PolyOne Engineered Material BIO Solutions**
  - **PHBV compound for bathroom accessories**
  - **Heat Resistant PLA compound**

PolyOne Sustainable Solutions

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- **PolyOne in a snapshot**
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  - OnColor™Bio Color Concentrates
- PolyOne Engineered Material BIO Solutions
  - PHBV compound for bathroom accessories
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PolyOne Sustainable Solutions

PolyOne is …

The World's premier provider of specialized polymer materials, services and solutions.

- $2.7 billion international polymer services company
- More than 35,000 specialty and commodity products
- 51 manufacturing facilities & 13 warehouses in 20 countries
- More than 10,000 customers in 35 countries
- 4700 Employees

Capabilities Overview

PolyOne Provides

Services to polymer producers, end-users, designers and processors in all markets

PolyOne's Advantages:

- **Global reach:** local supply from international operations and JV
- **Fully integrated IT network**
- **Broad market reach and knowledge**
- **Wide range of masterbatches and compounds with:**
  - Unbiased material selection
  - Customised grades
  - Consistent quality
  - Fast flexible delivery

Industries PolyOne Serves

Appliance

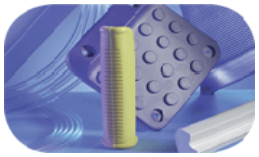
Automotive

Building & Construction

Electrical & Electronic

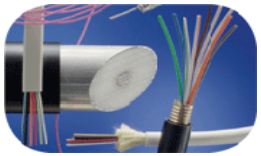
Consumer

Healthcare & Medical



Industrial

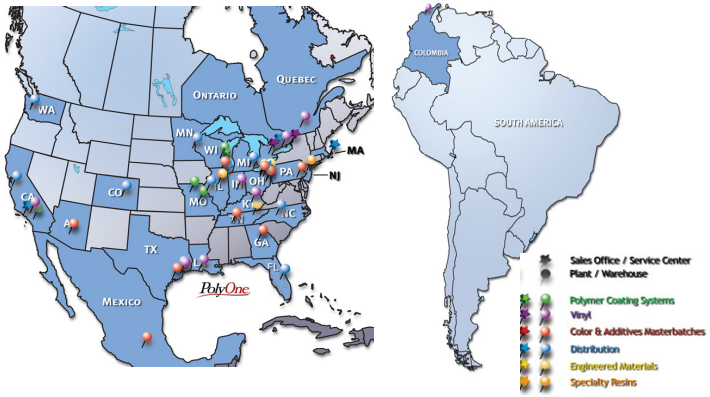
Packaging

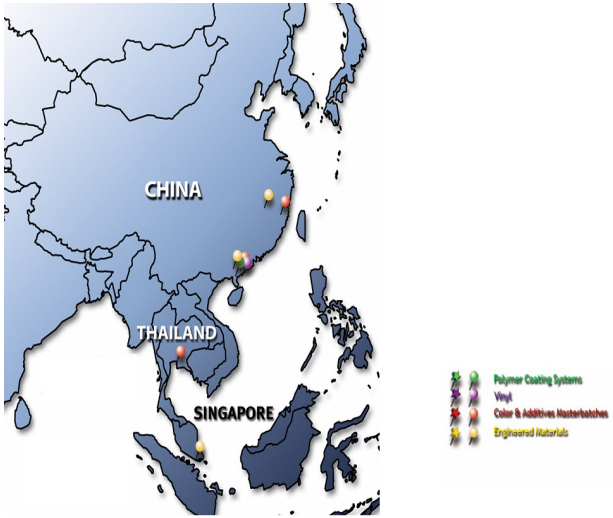


Wire & Cable

Textiles

PolyOne around the globe





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PolyOne Sustainable Solutions

PolyOne Sustainable Solutions

- PolyOne Certification on defined standard for sustainability
  - **Renewable**:
    - whole or in part on renewable resources
  - **Reusable**:
    - Packaging and other logistics-related systems which are easily returned or reused
  - **Recyclable**:
    - post-consumer or post-industrial recycle content
    - design for recycling such as PlanetPak™ packaging system
  - **Eco-friendly composition:**
    - lead, bisphenol-A (BPA), phthalates, or halogens replacement
  - **Resource efficient:**
    - reduce part weight or material consumption,
    - enable faster cycle times or
    - lower energy consumption

PolyOne

PolyOne
Sustainable
Solutions

PolyOne

The PolyOne Sustainability Promise

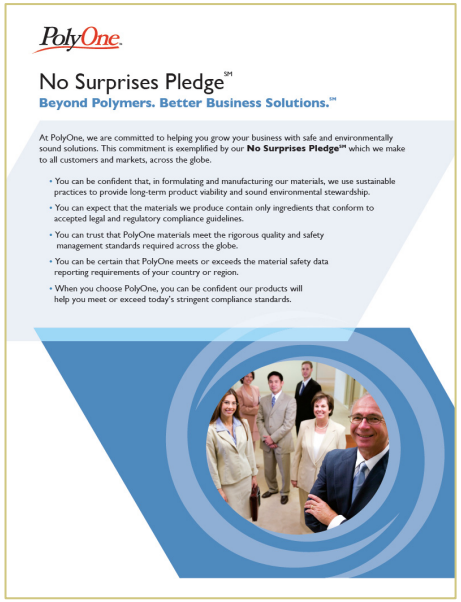
As the world's premier provider of specialized polymer materials, services and solutions, PolyOne is committed to meeting the needs of the present without compromising future generations' ability to meet their needs. We are committed to creating value for our customers, employees, communities and shareholders through our dedication to ethical, sustainable and fiscally responsible principles.

- We will put our **Customer First** by helping them grow their businesses with innovative, safe and environmentally sound solutions following the principles of trust and environmental stewardship established in our groundbreaking **No Surprises Pledge**.℠
- We will strive to minimize our environmental impact and maximize our conservation of the earth's resources by using energy-efficient technologies, recycling more, reducing waste, continuously improving operating efficiencies and driving operational excellence.
- We will provide a safe workplace for our employees and will protect our communities by continuously improving our world-class environmental, health and safety performance.
- We will create opportunity for our employees by growing our business, building a more diverse workforce, investing in world-class training and development, and making PolyOne the employer of choice.
- We will be involved in the communities in which we operate by building closer relationships with charitable and public service organizations and encouraging our people's engagement in local sustainability initiatives.
- We will work collaboratively with our suppliers to lessen the environmental impact of logistics across our global supply chain.
- We will build strong relationships with providers of leading-edge sustainable technologies.

PolyOne has established the "PolyOne Sustainable Solutions" certification to denote those products or services that meet defined standards for sustainability in areas such as renew-ability, recycle-ability, reusability, eco-friendly composition, or resource efficiency.

For more information go to www.polyone.com/sustain

PolyOne Sustainable Solutions - Literature



PolyOne

No Surprises Pledge℠

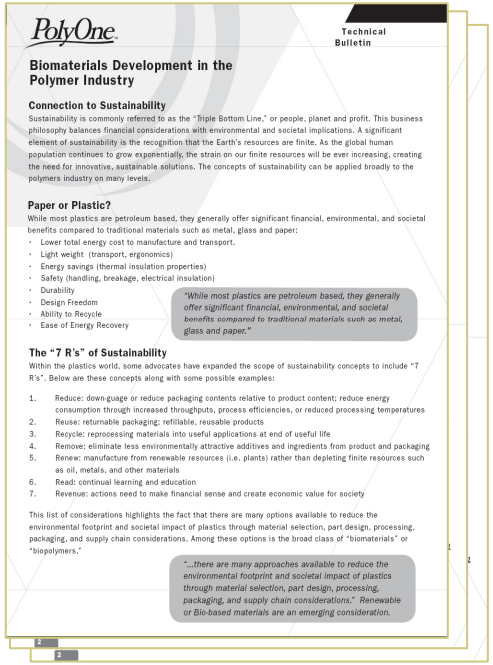
Beyond Polymers. Better Business Solutions.℠

At PolyOne, we are committed to helping you grow your business with safe and environmentally sound solutions. This commitment is exemplified by our **No Surprises Pledge℠** which we make to all customers and markets, across the globe.

- You can be confident that, in formulating and manufacturing our materials, we use sustainable practices to provide long-term product viability and sound environmental stewardship.
- You can expect that the materials we produce contain only ingredients that conform to accepted legal and regulatory compliance guidelines.
- You can trust that PolyOne materials meet the rigorous quality and safety management standards required across the globe.
- You can be certain that PolyOne meets or exceeds the material safety data reporting requirements of your country or region.
- When you choose PolyOne, you can be confident our products will help you meet or exceed today's stringent compliance standards.

No Surprise Pledge

Biopolymers Development in the Polymer Industry



PolyOne

Technical Bulletin

Biomaterials Development in the Polymer Industry

Connection to Sustainability

Sustainability is commonly referred to as the "Triple Bottom Line," or people, planet and profit. This business philosophy balances financial considerations with environmental and societal implications. A significant element of sustainability is the recognition that the Earth's resources are finite. As the global human population continues to grow exponentially, the strain on our finite resources will be ever increasing, creating the need for innovative, sustainable solutions. The concepts of sustainability can be applied broadly to the polymers industry on many levels.

Paper or Plastic?

While most plastics are petroleum based, they generally offer significant financial, environmental, and societal benefits compared to traditional materials such as metal, glass and paper:

- Lower total energy cost to manufacture and transport.
- Light weight (transport, ergonomics)
- Energy savings (thermal insulation properties)
- Safety (handling, breakage, electrical insulation)
- Durability
- Design Freedom
- Ability to Recycle
- Ease of Energy Recovery

"While most plastics are petroleum based, they generally offer significant financial, environmental, and societal benefits compared to traditional materials such as metal, glass and paper."

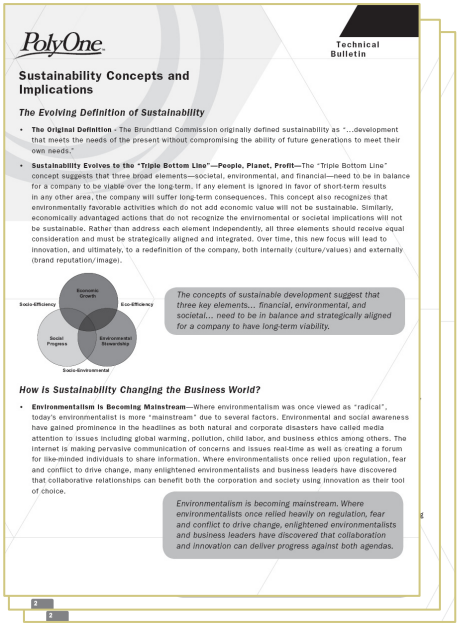
The "7 R's" of Sustainability

Within the plastics world, some advocates have expanded the scope of sustainability concepts to include "7 R's". Below are these concepts along with some possible examples:

1. Reduce: down-guage or reduce packaging contents relative to product content; reduce energy consumption through increased throughputs, process efficiencies, or reduced processing temperatures
2. Reuse: returnable packaging; refillable, reusable products
3. Recycle: reprocessing materials into useful applications at end of useful life
4. Remove: eliminate less environmentally attractive additives and ingredients from product and packaging
5. Renew: manufacture from renewable resources (i.e. plants) rather than depleting finite resources such as oil, metals, and other materials
6. Read: continual learning and education
7. Revenue: actions need to make financial sense and create economic value for society

This list of considerations highlights the fact that there are many options available to reduce the environmental footprint and societal impact of plastics through material selection, part design, processing, packaging, and supply chain considerations. Among these options is the broad class of "biomaterials" or "biopolymers."

"...there are many approaches available to reduce the environmental footprint and societal impact of plastics through material selection, part design, processing, packaging, and supply chain considerations." Renewable or Bio-based materials are an emerging consideration.



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Technical Bulletin

Sustainability Concepts and Implications

The Evolving Definition of Sustainability

- **The Original Definition** - The Brundtland Commission originally defined sustainability as "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
- **Sustainability Evolves to the "Triple Bottom Line"—People, Planet, Profit—**The "Triple Bottom Line" concept suggests that three broad elements—societal, environmental, and financial—need to be in balance for a company to be viable over the long-term. If any element is ignored in favor of short-term results in any other area, the company will suffer long-term consequences. This concept also recognizes that environmentally favorable activities which do not add economic value will not be sustainable. Similarly, economically advantaged actions that do not recognize the environmental or societal implications will not be sustainable. Rather than address each element independently, all three elements should receive equal consideration and must be strategically aligned and integrated. Over time, this new focus will lead to innovation, and ultimately, to a redefinition of the company, both internally (culture/values) and externally (brand reputation/image).

The concepts of sustainable development suggest that three key elements... financial, environmental, and societal... need to be in balance and strategically aligned for a company to have long-term viability.

How is Sustainability Changing the Business World?

- **Environmentalism is Becoming Mainstream**—Where environmentalism was once viewed as "radical", today's environmentalist is more "mainstream" due to several factors. Environmental and social awareness have gained prominence in the headlines as both natural and corporate disasters have called media attention to issues including global warming, pollution, child labor, and business ethics among others. The internet is making pervasive communication of concerns and issues real-time as well as creating a forum for like-minded individuals to share information. Where environmentalists once relied upon regulation, fear and conflict to drive change, many enlightened environmentalists and business leaders have discovered that collaborative relationships can benefit both the corporation and society using innovation as their tool of choice.

Environmentalism is becoming mainstream. Where environmentalists once relied heavily on regulation, fear and conflict to drive change, enlightened environmentalists and business leaders have discovered that collaboration and innovation can deliver progress against both agendas.

Sustainability Concepts & Implications

PolyOne Sustainable Solutions - Products

- OnCap™ BIO & OnColor™ BIO
  - *Performance enhancement additives and colorants for bio-derived polymers*
  - *Non-phthalate colorant masterbatches*
- OnFlex™ BIO
  - *Partly Renewable bases TPE's*
- Gravi-Tech™ & Trilliant™ PbF
  - *Lead replacement, high specific gravity compounds*
- BPA-free engineered material alternatives
- Geon™ Vinyl non-phthalate compounds and plastisols
- Geon™ Vinyl non-lead wire & cable systems
- Wilflex™ Oasis & Wilflex™ Quantum One
  - *Non-vinyl, non-phthalate, and water-based printing inks*
- ECCOH™
  - *Bromine-free & halogen-free solutions*
- PlanetPak™ Packaging System

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  - Heat Resistant PLA compound

PolyOne Sustainable Solutions

Creating a new value chain

Oil & Gas Pumping → Refining & Cracking → Polymer-ization

PolyOne Compounding & Distribution → OEM's → Processors & Assemblers → Retail

Farming & Milling → Bio-Transfor-mation → Polymer-ization

Biomass & Feedstocks | Monomer | Polymer

PolyOne connects raw material suppliers to market needs

Color & Additive Masterbatches for BioPolymers

- **PolyOne's Family of Biopolymer Masterbatch Technologies**
  - **OnColor™ Bio:** Color masterbatches
  - **OnCap™ Bio:** Additive masterbatches
  - **SmartBatch™ Bio:** Color & additive masterbatches combined
- **Optimized for Specific Biopolymers**
  - PLA
  - Starch and Starch Blends
  - BioPolyesters
  - PHA, PHB, PHBV
- **Over 9 Years of Experience in Biopolymer Additives Development**

Color & Additive Masterbatches for BioPolymers

- **PolyOne's Color and Additive Masterbatch technologies help facilitate biomaterials growth by:**
  - **Biopolymers have limitations in performance attributes**
  - **Improving performance properties**
  - **Expanding the application base**
  - **Enhancing the processability of these emerging technologies across a range of polymer processing equipment**

compostable

OK compost

AIB VINÇOTTE

FROST & SULLIVAN

2008 BEST PRACTICES AWARD

COLORANTS & MASTERBATCHES
GREEN EXCELLENCE OF THE YEAR AWARD

BioPolymers – Performance

Limit number of proven product-market combinations e.g.

- Mulch film
- Organic waste bags
- Festival service-ware

Narrow defined value proposition around biodegradation

Key Challenges

- Processing issues
- Low Heat Distortion Temperature
- Brittle (=/< Polystyrene)
- Moisture Sensitivity
- High Specific Gravity
- Properties Change upon Aging
- Flammability for Durable Applications
- Thermal Stability
- Rheology
- High Cycle Times

Broad defined value proposition around bio-based

OnCap™ BIO

Processing Improvement
· Slip · Antiblock · Antistat · Mould Release · Melt Flow Improver

Application Performance Improvement
· Optical Brightness · Denasting · Anti-Fog · UV barrier · Laser Marking · Impact Improvement · Transparent Impact Improvement · Antistat

Processing in Development
· Non-Reactive Melt Strength Enhancer · Reactive Melt Strength Enhancer

Performance in Development
· Foaming Agent · Hydrolytic stabiliser · Plasticiser

OnCap™ BIO L

OnCap™ BIO Additives Selection Guide

Function	Name	Reference	LDR %	Carrier	Transparent	Food Contact Approved	% Renewable Content	Max % to pass EN13432	Cast Extrusion / Thermoforming	Blown Film	BOPLA	Injection Moulding	Blow Moulding	Fibers / Filaments	Extrusion Coating
Antifog (concentrated)	AF BIO L 8463	CC10108463BG	8%	PLA	x	x	100%	1,67%	x						
Antifog (diluted)	AF BIO L 9526	CC10099526BG	30-33%	PLA	x	x	100%	6,67%	x						
Antistatic	AS BIO L 8712	CC10078712BG	10-15%	PLA	x	x	100%	6,67%	x	x	x	x	x		
Antistatic + Antibloc	ABAS BIO L 3494	CC10053494BG	5-10%	PLA	x	x	83%	Cert	x	x	x				
Denesting agent	ABAS BIO L 3494	CC10053494BG	5-10%	PLA	x	x	83%	Cert	x						
CaC03 concentrate	PL BIO L 8540	CC10108540BG	0-60%	PLA		x	40%	81,67%						x	
Chain Extender - viscosity booster	VB BIO L 9637	CC10099637BG	0,5-3%	PLA	x	x	70%	2,50%	x	x	x			x	x
Impact modifier	IM BIO L 2585	CC10112585BG	2.5-10%	PLA		x	60%	2,50%	x			x	x		
Impact modifier (transparent)	IM BIO L 2127	CC10112127BG	2.5-10%	PLA	x	x	60%	2,50%	x			x	x		
Laser	LM BIO L 6617	CC10036617BG	2-4%	PLA		x	80%	5,00%	x			x	x		
Melt flow improver	MF BIO L 5711	CC10115711BG		PLA	x	x	90%	100,00%				x	x	x	
Mould Release	SL BIO L 8711	CC10078711BG	5-7%	PLA	x	x	100%	6,67%	x	x					
Optical brighener (concentrated)	OB BIO L 0234	CC10080234BG	1-2%	PLA	x	x	100%	100,00%	x	x	x	x	x		
Optical brighener (diluted)	OB BIO L 8769	CC10048769BG	2-2.5%	PLA	x	x	100%	Cert	x	x	x				
Plasticizer	PZ BIO L 4752	CC10114752BG	5-20%	PLA	x	x	100%	5,00%	x	x	x	x	x		
Slip + Antiblock	ABSL BIO L 8713	CC10078713BG	5-7%	PLA		x	94%	6,67%	x	x	x				
Antiblock + Slip	ABSL BIO L 8713	CC10078713BG	5-7%	PLA	x	x	94%	6,67%	x	x	x				
UV Barrier - film	UVF BIO L 5309	CC10115309BG		PLA	x	x	80%	5,00%		x	x				
UV Barrier - sheet (200 -390 nm)	UVF BIO L 4627	CC10074627BG	3-5%	PLA	x	x	90%	10,00%	x			x		x	
UV Barrier - sheet (200 -390 nm)	UVF BIO L 4626	CC10074626BG	3-5 %	PLA	x	x	90%	10,00%	x			x		x	
Melt Strenght Enhancer (peroxide)	VB BIO L 0368	CC10110368BG	0,6-1,2	PLA	x	x	60%	2,50%	x	x	x		x	x	x
Viscosity booster (peroxide)	VB BIO L 0368	CC10110368BG	0,6-1,2	PLA	x	x	60%	2,50%	x	x	x			x	x
Antiblock	AB BIO E 9528	CC10099528BG	1-3%	Ecoflex		x	0%	100,00%		x					
Antistatic	AS BIO E 4960	CC10114960BG	0,05	Ecoflex		x	0%	100,00%		x					
Slip	SL BIO E 4602	CC10074602BG	5-10%	Ecoflex		x	0%	10,00%		x					
Slip + Antiblock	ABSL BIO E 7520	CC10117520BG	1 - 2%	Ecoflex		x	0%	100,00%		x					

Version
20081203

Contact:
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OnCap™ BIO L for PLA Cast Films

Standard processing issues	PolyOne Solutions
· Slip · Slip & Antiblock · Antistat	· OnCap™ SL BIO L 8711 · OnCap™ ABSL BIO L 8713 · OnCap™ AS BIO L 8712

Brittleness	PolyOne Solutions
· Impact Improvement · Transparent Impact Improvement · Plasticiser	· OnCap™ IM BIO L 2585 · OnCap™ IM BIO L 2127 · OnCap™ PZ BIO L 4752

Application Perfermance Improvement	PolyOne Solutions
· Optical Brightness · AntiFog · UV barrier · Laser Marking · Denasting	· OnCap ™ OB BIO L 0234 & 8769 · OnCap™ AF BIO L 8463 & 9526 · OnCap™ UVF BIO L 4626 & 4627 · OnCap™ LM BIO L 6617 · OnCap™ ABAS BIO L 3494

OnCap™ BIO L for PLA Blown Film

Standard processing issues	PolyOne Solutions
· Slip · Slip & Antiblock · Antistat	· OnCap™ SL BIO L 8711 · OnCap™ ABSL BIO L 8713 · OnCap™ AS BIO L 8712

Narrow Processing Window	PolyOne Solutions
· Melt Strength Enhancer · Reactive Melt Strength Enhancer	· Experimental Products · OnCap™ VB BIO L 0368 & 9637

Application Perfermance Improvement	PolyOne Solutions
· Optical Brightness · UV barrier · Plasticiser	· OnCap ™ OB BIO L 0234 & 8769 · OnCap™ UVF BIO L 5308 · OnCap™ PZ BIO L 4752

OnCap™ BIO L for BOPLA Film

Standard processing issues	PolyOne Solutions
· Antistatic / Antiblock · Slip	· OnCap™ ABAS BIO L 3494 · OnCap™ SL BIO L 8711
Narrow Processing Window	**PolyOne Solutions**
· Melt Strength Enhancer · Reactive Melt Strength Enhancer	· Experimental Products · OnCap™ VB BIO L 0368 & 9637
Application Perfermance Improvement	**PolyOne Solutions**
· Optical Brighteners · UV barrier	· OnCap ™ OB BIO L 0234 & 8769 · OnCap™ UVF BIO L 5308

OnCap™ BIO L for PLA Injection Moulding

Standard processing issues	PolyOne Solutions
· Mould Release · Melt Flow Improver · Antistat	· OnCap™ SL BIO L 8711 · OnCap™ MF BIO L 5711 · OnCap™ AS BIO L 8712

Brittleness	PolyOne Solutions
· Impact Improvement · Transparent Impact Improvement	· OnCap™ IM BIO L 2585 · OnCap™ IM BIO L 2127

Application Perfermance Improvement	PolyOne Solutions
· Optical Brightness · UV barrier · Laser Marking · Platiciser	· OnCap ™ OB BIO L 0234 & 8769 · OnCap™ UVF BIO L 4626 & 4627 · OnCap™ LM BIO L 6617 · OnCap™ PZ BIO L 4752

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PolyOne Sustainable Solutions

PHBV compound for bathroom accessories

- Design Criteria
  - Based on PHBV
  - Suitable for Injection Moulding technology
  - Impact resistance, scratch resistance
  - Durable in bathroom environment
  - Need to withstand Dishwasher conditions

- Commercialised by Design Ideas

PolyOne

Case Study
Specialty Engineered Materials

PHBV-Based™ Biopolymer Compounds

Working with PolyOne, Design Ideas chooses a proprietary, bio-based polymer compound to create bathroom accessories that offer consumers an environmentally sound option

Situation

With the slogan, "We Make Things Interesting™", Design Ideas, Ltd. is a fast-paced, growing product design firm that conceives and creates home and office accessories. To further its own corporate social responsibility goals and meet growing consumer demand for environmentally responsible products, the company sought to develop a "green" solution for the house wares industry, ultimately focusing on a line of bathroom accessories. The objective was to develop products – including a soap/shampoo dispenser, toothbrush holder, wastebasket and cup – differentiated not only on the basis of renewable content and biodegradability, but high-end aesthetics as well.

Andy Van Meter, CEO of Design Ideas, said, "We take pride in making our products in a socially responsible way. In the case of the new bathroom accessories line, we were having difficulty finding a source of resin that could meet our sustainability goals while delivering on the functional requirements of the application. Many candidates could not stand up to the moist, warm conditions of a bathroom."

In addition to being environmentally responsible, the material needed to provide excellent injection molding performance. It also had to offer stiffness, durability, chemical and heat resistance (for automatic dishwashing), and come in vibrant, eye-catching colors.

The PolyOne Difference

Design Ideas approached PolyOne with their challenge. After collaborating closely with Design Ideas and its molder, PolyOne worked together with a supplier of PHBV (poly-3-hydroxy butyrate-co-valerate)-based biopolymer resin – derived from 100 percent annually renewable resources such as starch – to develop the solution. PolyOne characterized the base resin and conducted a series of experiments to look at material refinements that would afford the right combination of processability and physical properties while retaining ultimate biodegradability. In addition, PolyOne pre-colored the compound to provide lot-to-lot color consistency and superior part appearance.

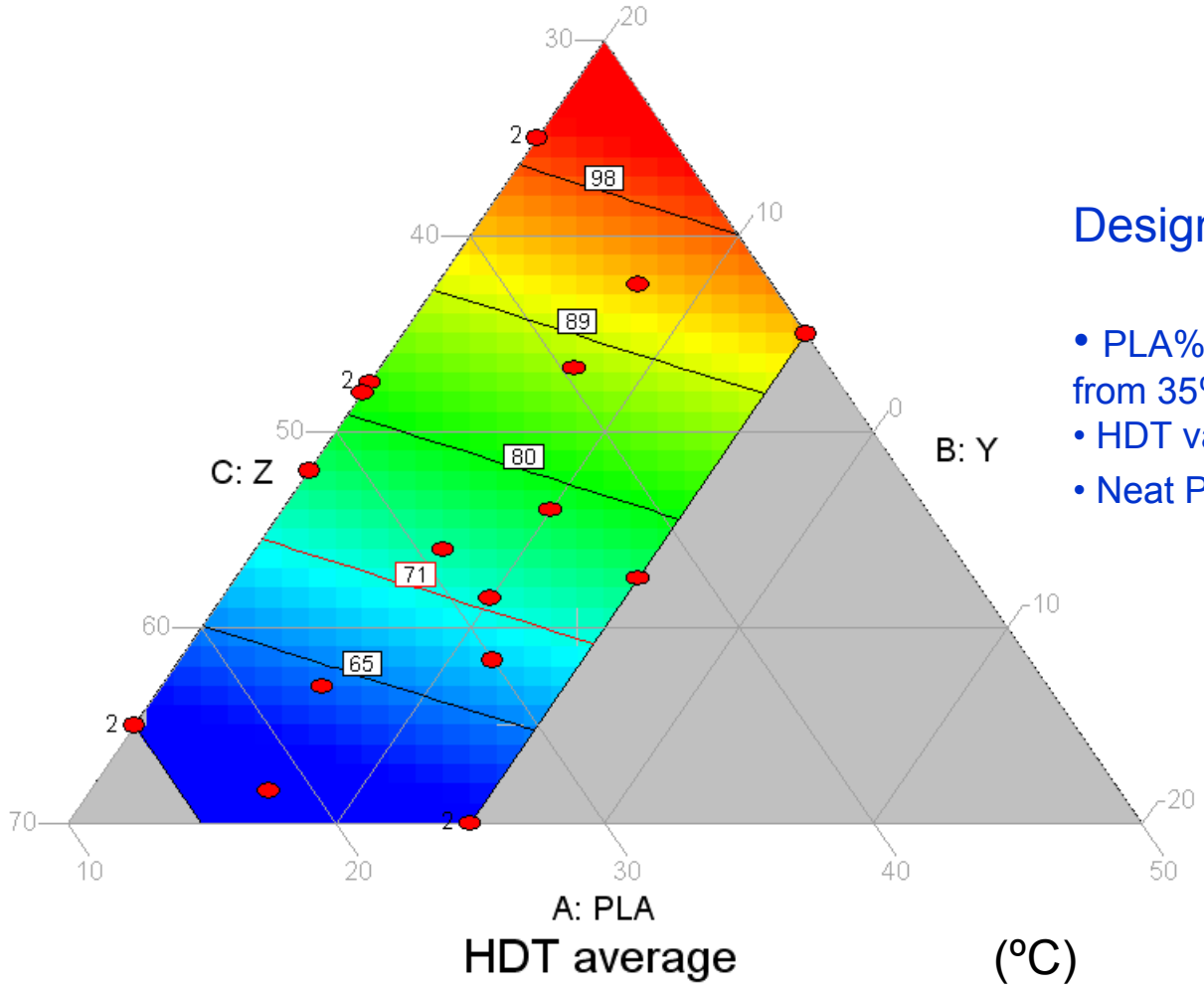
The PHBV-based technology leveraged for Design Ideas is another example of PolyOne's innovative, eco-responsible solutions. When exposed to microorganisms in compost or soil, the PHBV-based material decomposes into carbon dioxide, water and biomass. However, it will not deteriorate in the open air or with ordinary use. The PHBV-based biopolymer can withstand temperatures of 110 C/230 F, and will continue to perform for years under normal conditions.

Heat Resistant PLA compound

- Design Criteria
  - PLA based
  - Translucent (not transparent)
  - As high as possible renewable based content

- PolyOne consideration
  - Use biobased polymers / additives
  - Use potential biobased polymers / additives

Heat Resistant PLA compound P1 A



Design of Experiments:

- PLA% in the blends studied ranges from 35% to 72%
- HDT value ranges from 101 ºC to 57 ºC
- Neat PLA HDT is ~ 54 ºC

Testing Methods: Deflection Temperature Under Flexural 66 psi Load: ASTM D648

Heat Resistant PLA compound P1 A

A:PLA	B:Y	C:Z	HDT average
			Degree C
70.0	25.0	5.0	58.9
65.0	15.0	20.0	59.7
68.3	18.3	13.3	60.1
65.0	15.0	20.0	60.9
63.0	23.0	14.0	62.1
61.7	30.0	8.3	62.6
58.5	31.5	10.0	62.7
52.0	28.0	20.0	69.1
57.5	37.5	5.0	69.6
47.5	32.5	20.0	76.5
48.0	32.0	20.0	81.3
56.0	31.0	13.0	82.2
54.0	36.0	10.0	83.3
46.8	40.5	12.8	89.7
35.0	45.0	20.0	96.5
45.0	50.0	5.0	96.9
45.0	50.0	5.0	96.9
42.5	45.0	12.5	98.3
35.0	45.0	20.0	100.6

some components of materials Y and Z could be bio-derived in the future
renewable content between 70 – 92 %

Heat Resistant PLA Compounds

- Improving two different angles
  - Increase the **biobased** content of **Engineered Compounds**
  - Increase the **performance** of **biobased polymers**

- Customer Benefits
  - Ability to fulfil sustainable target through biobased polymers
  - Performance **and** biobased in one solution
  - Price in the range of engineered materials
  - Available in commercial quantities
  - No special PLA grade needed
  - G rades for Injection Moulding & Extrusion
  - Use in Consumer Products, Consumer Electronics

Conclusion

- Biopolymers have some great key attributes

- Biopolymers need improved properties in many performance areas
  - Color concentrates improve the aesthetics
  - Additive masterbatches improve the performance
  - Compounds can shift the paradigms of bioplastics performance

- Compounds & masterbatches are a necessity to a successful bioplastics industry.

Thank You

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