Materials sell by properties!
What sells PHB?

(Using biobased PHB to mould fine structures, to produce impact resistant composites, and to substitute metalworking

Abstract

PHB chains are absolutely linear, absolutely regular, and absolutely isotactic. Plastics processors can use these unique properties to:

- mould parts with very fine structures or to produce parts with surface shapes down to below 0,2 µ at temperatures as low as at 180°C.

- produce long natural fiber composites with unique impact strength.

- mould parts that could be produced so far by metalworking only.

- degrade parts at the end of their service life by simply exposing them to microbial environments like composts (earth to earth).

Materials sell by properties!

What about PHB (polyhydroxybutyrate)?
By all means, it has been around for more than 3 billion of years!

- is PHB just another bioplast?
- is there anything PHB can do better?
- does it help processors solving specific needs?

What sells PHB?

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All materials sell by their properties. Plastics are no exception. PHB, polyhydroxybutyrate, is a bioplast isolated from biomass. Is it just another bioplast, or does it have properties that are missing in other thermoplasts? Are there properties that help processors to solve specific needs? What sells PHB? I will try to answer such questions in the next few minutes.

Sexy properties of PHB:

- of renewable resources → shares with many others
- fully biodegradable: → shares with many others, except that PHB is degraded only by "being chewed up" by microorganisms and stays stable for years and can be recycled

  Degrades only when disposed at end of live
  aerob → home compost, garden soil, forests, grasslands
  anaerob → bottom of lakes, river sediments, sanitary sinks

→ PHB for outdoor, gardening, sports
-> other properties of PHB are based on biochemistry

At first sight, PHB appears to be just another bioplast. It shares the property of renewable resources with other bioplasts. It also shares the property "biodegradable" with others except that the degradation mechanism of PHB is different. PHB is degraded only by being "chewed up" by microorganisms. For this it is stable for decades and can be recycled. However, when actively disposed into aerobic or into anaerobic microbial environments it is totally recycled. Aerobic environments include home composts, garden soil, woods, and grasslands. Anaerobic environments include bottom of lakes or seas, river sediments or sanitary sinks. Because of this wide range of degradation routes PHB servers the specific needs of outdoor articles, garden uses, or sport or hygiene articles.

Properties of PHB due to biochemistry:
(PHB has been there for over 3 billion of years!)

- absolutely linear
- absolutely regular, absolutely isotactic

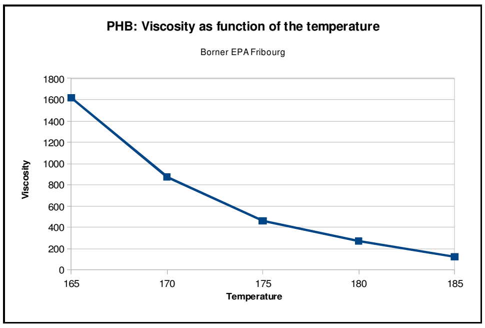
Other properties of PHB are due to its biological origin. PHB has been there for more than 3 billion of years. During this time evolution did not develop PHB to become a thermoplast, but to function inside the cells. The thermoplastic properties are just a consequence of the chemical structure.

To function inside the cells the polymer chains need to be absolutely linear, absolutely regular, and absolutely isomeric or isotactic. If this is not guaranteed, the cells will die. Absolutely linear, absolutely regular, and absolutely isotactic are properties unique to PHB, not found in any other thermoplast. Are these properties a buying argument?

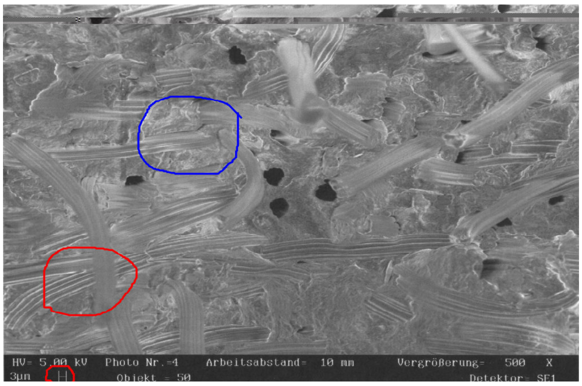
What are the consequences of being absolutely linear:

→ no chain entaglement: adjustable melt viscosity

What does absolutely linear mean for plastics processors? It simply means that the chains can not entangle in the melt. Basically they behave like boiled spaghetti: fluid when hot and solid when cold. That means that the melt viscosity is a simple function of the temperature.



Within a temperature range of only 20°C, that is between 165 and 185°C, the viscosity drop fourtyfold, from highly viscous to water like. The processor simply has to choose a given temperature to adapt the viscosity. The next slide shows what can be achieved by having a "liquid" melt.



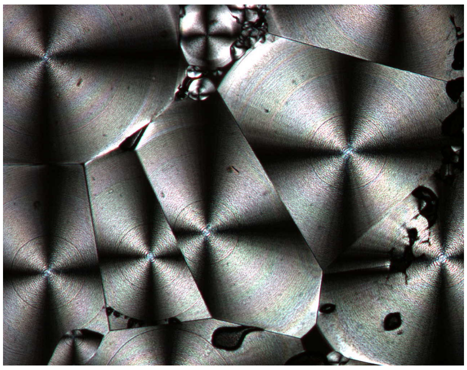
The picture shows the surface of a natural fiber composite. The bar at the left at the bottom (red) represents 3 µ. If you compare this bar with the imprints of the fibers, best seen a left (red) you easily can see that structures of well below one µ are clearly displayed.

What is the take home lessen regarding the absolute linearity of PHB? The molder easily can adjust the viscosity by simply changing the temperature profile on the machine. Thus he can mold complex structures, glossy or interesting surfaces. This is something designer long have been waiting for.

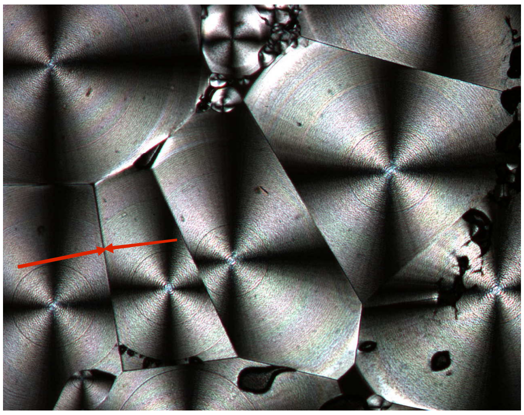
absolute linearity of PHB (adjustable melt viscosity):

→ to mold complex structures
→ shiny surfaces
→ optically interesting surface structures down to below 1μ

How do the terms made exclusively of C4-subunits, being absolutely isotactic, and having a Tg below 0°C translate into plastics? It means that, as long as the ambient temperature is higher than 0°C, the polymer chains crystallize till there is no free amorphous mass left. The next slide shows the result.

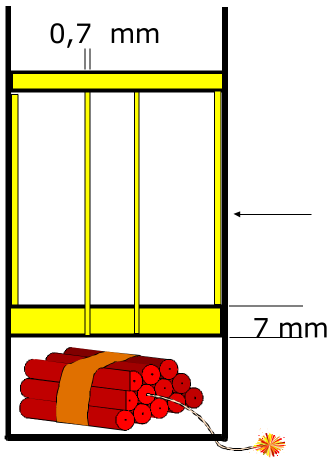


This is a cut trough PHB. Yes, it is a cut through a thermoplast, not through a metal. In spite of this it is allowed to ask if PHB might not be a metal, albeit one with a low melting point. I will show that indeed this is the case. However, before doing so I have to point to the difference between native PHB as scientists describe it and compounded PHB I am talking about.



If you look carefully at the picutre you can discover tiny fissures between the crystals. This is a consequence of the different densities of the melt and the crystals. A close look at this picture explains what all science papers on PHB state: "PHB changes properties over time and becomes brittle like corn flakes". "Changing properties" is what one experience during the transformation of the amorphous phase to the crystalline one. At room temperature this phase ends only after 6-12 months. "Brittle" describes the fissures. We at Biomer tackled these problems by dramatically reducing the crystal size. This shortens the crystallization time to minutes instead of months and by gluing the crystals together. When I am referring to PHB I refer to this compounded PHB.

In plastics crystallinity generally translates into pieces being hard and creep resistant. This is particularly true for PHB since the crystals of PHB are stabilized by myriad's of hydrogen bonds. These hydrogen bonds are responsible for the fact that PHB is insoluble in most solvents. Only after weakening the H-bonds by heating PHB becomes soluble.



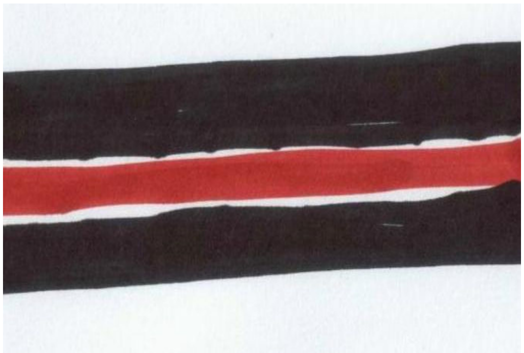
This is a smoke grenade. Smoke grenades are launched by putting them into a mortar, that is a tube with a driving charge at the bottom. The grenade is ejected by ignitiating the charge. Until a few years ago the grenades had to be made of metal. This meant cutting, polishing, soldering, etc., in other words a lot of metal work. With PHB you simply mold.

The cup has a wall length of 9 cm and a wall thickness of only 1 mm is produced in a single shot. This is possible because of the adjustable viscosity. The bottom is 7 mm thick. It perfectly withstands the explosion. Rather interesting is the inner pillar. Its role is to transmit the acceleration from the bottom to the top. It is a hollow tube that has a wall thickness of only 0,7 mm. It withstands the acceleration without bulging. For assembly reasons the pillar has to be screwed to the bottom and to the top. When designing the mold the designers simply transferred the design of the metal M14 screws used in the metal grenade to the plastic part. They could do it because even the tiny treads of the PHB screws do not yield. This all is possible only because of the extreme crystallinity of PHB. At last now one can ask if PHB is not a hidden metal.

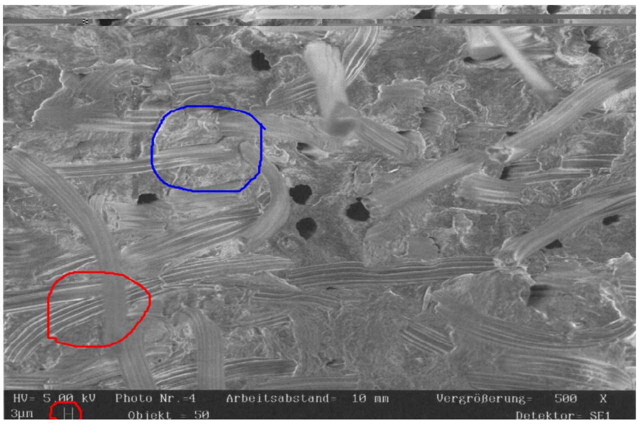
Consequences of the crystallinity of PHB in long natural fiber composites:

- hard
- creep resistant
- extremely shock absorbing

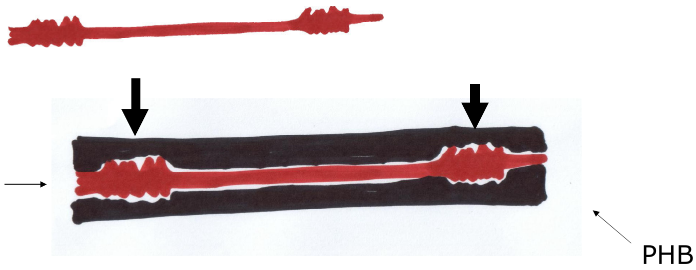
The crystallinity of PHB also allows to produce long natural fiber composites that are extremely shock resistant.



When one embeds fibers into the melt of PHB then the PHB matrix recedes from the hydrophilic fibers. Thus the fibers are free to move. It is possible to tear out small fibers with tweezers.



With long fibers the situation is different. At points where the leaves were attached before harvesting the fibers the fibers are thicker. The diameter increase only slightly, but exceeds the voids around the fibers. Such a situation is seen at the place encircled in blue.



PHB shrinks and cedes from fibers
However it is clamped at thicker parts,
allowing them to stretch

Here you see a slightly exaggerated picture of such a natural fibers composite to show the principle. The fiber still is free to move, but the movement is stopped at the thicker parts by pure mechanical means. There the hard crystal engulf the fibers like clamps.

If one now hits such a composite the fibers will take up the stroke and starts to vibrate. Doing so they absorb the impact. I was told that a 5 mm thick PHB/sisal composite would able to withstand pistol bullets fired from 1 m distance.

This is another example of what the hard crystals of PHB can be used for.

What sells PHB:
- of renewable resources
- fully biodegradable
- absolutely linear
- absolutely regular and Tg below 0°C

I tried in a few words to summarize some key properties of PHB that might interest users:

Of renewable resources, biodegradable, linear, isotactic. What does it means for plastics processors?

What sells PHB
Or there anything PHB can do better
than other thermoplasts? My answer is Yes:

- **durable with a switch for biodegradation (outdoors)**
- **easily adaptable melt viscosity (design)**
- **metal like behaviour (creep resistant)**
- **composites (shock resistant)**

- **added benefit: of renewable resources!**

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So, is there anything PHB can do better than other thermoplast?

I think yes. PHB is a durable bioplast having an switch for degradation, it has an adaptable melt viscosity, and it behaves like metals. If any of these properties are used in a part one has an added benefit: it is bio!