PPS Newsletter

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November 2007 Information to Polymer Processing Society Members

More than 1200 abstracts submitted for PPS-24 in Salerno

The Chair of the organizing committee Prof. Giuseppe Titomanlio reports that more than 1200 abstracts have been submitted for presentation in the Annual Meeting (PPS-24) in Salerno, Italy, this coming June 15-19, 2008. The difficult task of reviewing and selection is currently in progress.

Asia/Australia Regional Meeting PPS-2007 held in July in Shanghai, China

The Asia/Australia Regional Meeting PPS-2007 was held in Shanghai, China, which had already hosted a successful annual meeting in June 2000 (PPS-17). The meeting took place in July 12-14, 2007 at the Shanghai Everbright Convention and Exhibition Center in the center of a booming commercial district. Shanghai is China's largest city, gateway to the Yangtze, and is China's leading center of commerce, finance, as well as science and technology. The technical program covered all important polymer processing operations, with 6 plenary and 40 keynote speakers. More information can be found at http://www.pps-2007.com. Special thanks are due to Profs. Xi Xu, and Jie Yin and the Secretary Xinling Wang for all the hard work they put to make this a successful event.

The Bund or commercial center in booming Shanghai, China.

View of down-town Shanghai, with the Museum of Chinese History in the center.

Shanghai Jiao Tong University, one of the Organizers of the AA-RM PPS-2007 meeting.

Europe/Africa Regional Meeting PPS-2007 held in August in Göteborg, Sweden

The Europe/Africa Regional Meeting PPS-07 EA was held in Göteborg (Gothenburg), Sweden, which had already hosted a successful EA regional meeting again in August 1997. The meeting took place in August 28-30, 2007 at the Campus of Chalmers University of Technology. More information about the technical program and its various sessions can be found at http://www.pps07ea.info. Special thanks are due to Dr. Hroar Skov and Prof. Mikael Rigdahl for all the hard work they put to make this a successful event.

The harbour in beautiful Gothenburg, Sweden, a short walking distance from the site of PPS07-EA meeting.

View of the entrance of Chalmers University of Technology, site of the PPS07-EA meeting.

Poseidon statue in front of the museum in downtown Gothenburg, Sweden, where the PPS07-EA meeting took place in August 2007.

Future Meetings

In its continuing effort to be a truly international society, PPS strives to have meetings every year in different parts of the world. The following list of upcoming meetings is a good indication of these efforts.

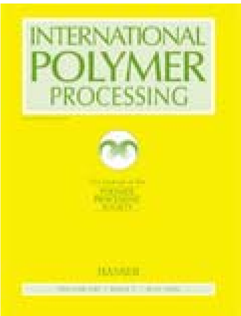
2008 Meetings
Annual Meeting PPS-24, Salerno, Italy – June 15-19, 2008 (http://www.pps-24.com). Conference Chair: Prof. Giuseppe Titomanlio

Americas Regional Meeting 2008, Charleston, South Carolina, USA, October 26-29, 2008 (http://caeff.ces.clemson.edu/pps2008/index.php/). Conference Chair: Profs. Hirt, Ogale

2009 Meetings
Annual Meeting PPS-25, Goa, India – March 1-5, 2009 (http://www.pps-25.com). Conference Chair: Prof. Ashok Misra

2010 Meetings
Annual Meeting PPS-26, Calgary, Canada – July 4-7, 2010 (http://www.pps-25.com). Conference Chair: Prof. Sundararaj

IPP Journal New Special Issues



The PPS Journal "International Polymer Processing" (IPP) continues its pursuit of excellence increasing publishing to 5 issues/year. A special issue on Polymer Coatings (Guest Editor Prof. Benkreira) has appeared in March 2007 and another special issue on Bioplastics (Guest Editor Dr. Huneault) appeared in the December 2007 issue. Previous issues are now on-line at http://www.polymer-process.com. To download papers from this site, use your PPS membership number. In response to PPS member requests, papers in IPP will now have a DOI number, as well as a Hanser document number, which allows quick access to a paper for the on-line journal website.

Other Meetings of Interest to PPS Members

MECHANICS OF TIME DEPENDENT MATERIALS CONFERENCE, MARCH 30-APRIL 4, 2008, MONTEREY, CALIFORNIA, USA
For information visit: www.ae.utexas.edu/MTDM08/

11th ANNUAL EUROPEAN CONFERENCE ON FORMING PROCESSES, ESAFORM 2008, APRIL 23-25, 2008, LYON, FRANCE
For information visit: http://esaform2008.insa-lyon.fr/

ANTEC SPE, MAY 4-8, 2008, MILWAUKEE, WISCONSIN, USA
For information visit: www.4spe.org

XVth INTERNATIONAL CONGRESS ON RHEOLOGY AUGUST 3-8, 2008, MONTEREY, CA, USA
For information visit: http://www.rheology.org/ICR2008/

PPS Membership Website

A complete list of all PPS members, their addresses, phone numbers and e-mails, is available at the PPS membership website: http://pps.mcmaster.ca.
The user ID is "ppsmember" and the password "ppsmember".

Next Newsletter – April 2008

If you have comments on how to improve this newsletter or want to share some information in the next one, please contact the Newsletter Editor Prof. Evan Mitsoulis at mitsouli@metal.ntua.gr. The next issue of the Newsletter is due in April 2008.

Papers of General Interest to PPS Members

As noted in the previous issue of the PPS Newsletter, papers of general interest will appear in the Newsletter for the benefit of PPS members. In this issue a paper is presented on Biopolymers by Dr. Michel Huneault, the 2007 Morand Lambla award winner, from the National Research Council (NRC) of Canada.

What does the BIO really mean in BIOplastics?
A personal viewpoint on biobased plastics

Michel A. Huneault
National Research Council of Canada

The BIO prefix is trendy these days. Vegetables have a BIO label when they are grown without too much help from chemists and genetic engineers. Ethanol has now changed name to BIO-ethanol even though it is made using the same sugar fermentation process that has been used for ages. For some reason, the BIO prefix creates a soft positive image that marketing departments are eager to use. But what does the BIO really mean in Bioplastics? To separate the hype from the reality, we need to understand what and who is driving this industry and we need to know the pros and cons. This text (humbly) aims at giving some perspective on biobased plastics.

Introduction

Bioplastics or more precisely biobased polymers are defined as polymeric materials partially or totally derived from annually grown resources by opposition to petroleum-based resources. It is noteworthy that this definition is based solely on the origin of the feedstock. It does not imply that the material is biodegradable (a common confusion) and does not imply any specific manufacturing route. Because the expression “biobased polymers” is relatively new and catchy, we get the feeling that it is a new field and that it is environmentally friendly. Both of these claims necessitate some clarifications. Before the 20th century, most materials used by mankind had a natural origin. The first plastics developed a century ago such as cellophane would also fit today’s definition of a biobased polymer. Production of cellophane involved strong solvents and was far from being “environmentally friendly”. Compared to the cellophane process, the development of petroleum-based polymers during and after WWII had clear environmental benefits, at the time. Today, the shift back to biobased resources is based mainly on long-term economic and environmental sustainability and has been facilitated by the rapid growth of biotechnologies in the last few decades. It is now possible by fermentation and enzymatic treatment to produce biobased “monomers” that will be used for synthetic polymer fabrication or to directly produce chemicals in genetically-modified plants or bacteria. The whole chemical industry has been shifting its attention to a long list of so-called “biobased chemical building blocks” that includes not only monomers but all sorts of chemicals such as acids and diacids, glycerol, sorbitol and polyols. Great efforts in this area have been directed toward the concept of the biorefinery. Just like a petroleum refinery, the biorefinery will “crack” its cellulosic/polysaccharide feedstock into basic chemical building blocks for use by the chemical industry.

Review of current and future biobased materials

The first development in “modern” biobased thermoplastics was that of polyhydroxyalcanoates (PHA) by ICI in the 1980s. PHA was produced in bacteria using a fermentation process. Even though from a biotechnology point of view, the project was a breakthrough, the product named Biopol never met much success because of its high cost, low processability and poor properties.

The ICI technology was spun-off to Zeneca and then sold to Monsanto who also invested heavily trying to use its genetic modification strategies to improve yield. Monsanto even developed a research program to produce PHA in plant cells but later abandoned the project because of the high cost, high energy consumption and the magnitude of the required polymer purification infrastructure. The latest company developing PHA technology is Metabolix who has made a joint venture with ADM, a leading agricultural product manufacturer. According to company claims, a PHA plant in Clinton, Iowa (USA) with a 50kt/y capacity will start production in 2008. Time will tell if this new breed of PHA will become a success-story.

In great part due to the unmet promises of PHA, the polymer community was highly skeptical on the potential of biobased thermoplastics. This has changed drastically following the successful commercialization of polylactides or PLA by NatureWorks LLC. The lactide monomer used to produced PLA is obtained through a biotechnological route that starts with corn starch. Contrarily to PHA, PLA fabrication uses conventional polymer synthesis techniques (ring-opening polymerization). This enables more control on the polymer structure. Overall the yield of polymer (kg polymer per kg of sugar) for PLA is much better leading to better economics. PLA is a rigid and transparent material that competes directly in applications where PET is used. In the foreseeable future, PET will not be displaced in the most technical packaging applications because of its higher temperature resistance and superior barrier properties. There is lots of room for PLA in less demanding short-lived applications however. NatureWorks has a production plant in Blair, Nebraska with a production capability of 140 kt/y.

Another breakthrough that confirmed the trend toward the use of biobased chemicals came from Dupont in the form of the biobased monomer 1,3 propane diol (PDO). PDO is also derived from corn sugar through a fermentation technology. It is a diol that is now used in the synthesis of polyesters such as Dupont's Sorona^{TM} PTT fiber materials. It is also being used in the fabrication of Hytrel^{TM} thermoplastic elastomers. In 2007, Dupont has switched from petroleum-based PDO to biobased PDO. Contrarily to PLA, the resulting products are "partially biobased" since the co-monomers such as terephthalic acid are petroleum-based. The Sorona PTT polyester is around 37% biobased on a mass basis and slightly less than 25% on a molar carbon basis. This minor fraction occupies, of course, the major portion of the marketing strategy for these products. PDO is currently produced in Loudon, Tennessee in a 45 kt/y plant. In the polyol area, other production plants are under construction to produce biobased propylene glycol (Cargill-Ashland joint venture) and biobased diols for polyurethane foam production.

Another class of biobased polymers is starch-based thermoplastics. These materials comprise starch, a petroleum or biobased oil used to plasticize the starch and a second polymer that is used to control the material's hygroscopy. Starch-based thermoplastics are currently produced by Novamont in Italy (20 kt/y) and Plantic in Australia (10kt/y). Currently available starch-based thermoplastics are readily compostable. Their poor water resistance and limited mechanical resistance however limit their use to relatively non-demanding applications.

Surprisingly, the next large-scale biobased material production may be polyethylene! Converting ethanol to ethylene is a relatively easy chemical modification. In Brazil, ethanol produced from fermentation of cane sugar has been used extensively as a fuel for cars for around 30 years. Ethanol production costs in Brazil are the lowest in the world. The rising cost of ethylene has prompted Braskem to plan a 100-200 kt/y ethanol-based polyethylene plant by 2009. Also in Brazil, Dow Chemicals and Crystalev are planning the construction of a 350 kt/y plant of ethanol-based LLDPE for 2011. The biobased polymers in this case would be identical to current petrochemical-based ones.

Motivations and driving forces

What have been the driving forces and the motivations behind the development of current biobased chemicals? These can be separated in three categories: Economic, Political and

Environmental. The economic motivation is straightforward in a context of rising demand for petroleum resources. The development of biobased chemicals offers potential cost reduction and feedstock sustainability for polymer manufacturers. For a stagnating agricultural industry that has excess capacity, the potential markets offered by non-food products are means toward greater value-addition and increased outputs. This combination of forces has led to unprecedented ventures between agricultural-based businesses and traditional synthetic plastics industries. The successful development of PLA for instance was the result of efforts initiated by Cargill and Dow in the mid-90s. The production of PDO discussed above is now carried out through a joint venture of Tate & Lyle and Dupont.

On the political side, the biobased products have been pushed by North-American and European agricultural lobbies as a way to increase demand for their products. In this area, farming subsidies are playing an important role by decreasing the cost of the feedstock. This distorts the cost structure and leads to anomalies such as the fast development of the corn-based ethanol industry despite an energetic balance that is at most very poor. Political support has taken another form in the US by the adoption of a law entitled "US Farm Security and Rural Investment Act (2002)". According to this law, the purchasing agents of the US government must give preference to biobased products whenever available. The United States Government is the world's largest purchaser of goods and services, $225 billion annually. It is noteworthy that it is not environmental claims but political push that has given biobased products this preferred status.

This brings us to the third motivation: the environmental benefits. Annually grown resources necessarily involve conversion of atmospheric carbon into organic carbon. Thus, the carbon emissions related to the biobased product fabrication can be "credited" for the amount of carbon dioxide that has removed from the atmosphere during the growth of the agricultural feedstock. Therefore, the production of biobased products starts with a carbon emission "credit". This aspect has rapidly been perceived by consumers as a positive step toward decreasing the environmental impact of plastics. Several retailers such as Wal-Mart have responded to consumer demand by requesting biobased materials especially in packaging in the hope of enhancing their corporate image. Of course, environmental benefits are measured through life-cycle analysis (LCA) rather than through public perceptions. The environmental benefits of biobased products must be examined case by case since processes and energy requirements differ from one to the other. The LCA must include the impact of the agricultural production as well as that of the chemical manufacturing process. One important issue that was rapidly noted in the fabrication of PHA and PLA was that their production required more energy than most conventional resins. The total energy required to produce 1 kg of PHA was estimated to 90 MJ, three times the amount required to make polyethylene (29MJ/kg). In the case of PLA, the yield is more favorable but still the energy required for the early PLA productions (2003) was estimated to 56MJ/kg. After considering the carbon credit due to its biobased origin, PLA manufacturing lead to emissions of 2 kg CO_2/kg_{PLA} which is 50% lower than PET manufacturing but similar to polyethylene. NatureWorks recently claimed that their 2006 production was almost carbon neutral (i.e. carbon emissions = carbon credits). Careful examination of the LCA shows that by far the most important carbon emission reduction was obtained by buying "wind-power certificates". This is an accounting operation by which, for a certain premium, you exchange your coal-fired power-plant energy for "clean" energy produced elsewhere, by wind mills for example. The validity of this approach is certainly debatable since at the end, the same emissions have been produced. It does raise a valid point however: its the emission associated with your energy requirement that is important rather than the energy itself. In the ideal fully integrated biorefinery, energy recovered from un-used biomass will be used to minimize reliance on fossil energy and to really decrease overall emissions.

A few words on biodegradation

Some biobased materials such as PHA, PLA and most starch-based thermoplastics, are biodegradable and have obtained public attention in part because of this property. Biodegradable polymers are polymers that can be assimilated by microorganisms leading to the transformation of organic carbon into inorganic carbon (carbon dioxide or methane). Compostability is the ability to biodegrade in a specific composting environment without adverse effect to plant or animal life. Typical large-scale composting is carried out in aerobic humid environment kept around 58^{o}C. While biobased chemicals are pushed by suppliers mainly for cost reduction and availability, biodegradable plastics are demanded for specialized applications, for example in biodegradable agriculture films or in biomedical applications. Unfortunately, the current positive public perception toward biodegradation is largely related to the perception that it could be an effective litter control method. In other words, that biodegradability will make littered plastics disappears from our view. This is relatively superficial and does not address the more global issues of resource usage and global warming gas emission. In fact, a complete shift to biodegradable plastics would be a huge drawback for the environment since it would put an end to recycling efforts, it would generate additional consumption to replace the non-recycled plastics and would lead to dramatically increased emissions of CO_2 and in the worst case of methane (a stronger global warming gas) due to the biodegradation process. A sounder approach in the use of compostable plastics would be to use them only as means to facilitate organic waste composting. Around 35% of our waste is organic in the form of food scrap, yard trimming, etc. While glass, plastics and paper recycling programs are operating with relative success, composting of organic waste is for the moment a relatively marginal waste management strategy. One important difficulty in the composting strategy is to obtain an organic stream that is fully compostable. A mixed stream of plastics and food for example is not appropriate for composting because it contains plastics that will not compost and that will need to be separated at the end. Similarly, the plastic in the mixed food/plastic waste is more difficult to recycle because of high washing and separation costs. The reasoning behind the use of compostable plastics is that when it is impossible to separate organic waste from plastics, it would be convenient to compost them together. The benefit of composting is that it closes a loop by sending compost back to enrich the soil that was used to grow the food (and eventually the plastic). The economic forces behind composting are relatively weak however. Compost is just worth between 25 and 50 $/ton. When you compare that to the 500$/t that you can get for recycled PET flakes, it is clear it makes more economic sense to recycle plastics than to compost them. It also ends up being better in terms of energy consumption as well as in carbon emission. The benefits of compostable plastics depend on the complete life-cycle analysis that will balance the extra emissions with the reduction in fertilizers usage due to the reuse of the compost. It is clear that if biodegradable plastics are not used to facilitate the composting of organic waste, they have very little advantages to balance the extra emissions. Compostable plastics will remain a minor portion of the plastic's market because in most applications, the society and the environment benefits more from durability and recyclability than from biodegradation. It is important to remember that the development of biobased products is driven by many other factors as discussed earlier. The production of biobased plastics will grow regardless of the future demand for compostable or biodegradable plastics.

Conclusions

The successful development of new biobased polymers, such as PLA, captured a lot of media attention and has switched the mindsets toward bioplastics. The use of biomass to make materials is part of a major shift in the chemical industry toward the development of the so-called "biobased chemical building blocks". The development of new biotechnological routes, the increasing cost of petroleum resources, the positive environmental perception and renewability of biomass will continue to drive the development of new biobased chemical feedstock for polymer production. Because the BIO in bioplastics refers to the biobased feedstock, bioplastics cannot be associated to a certain set of properties. Some new biobased materials will sound very familiar (e.g. ethanol-based PE, biobased polyurethane) since the biomass will be converted into monomers that are already used to manufacture synthetic polymers. Others like PLA, PHA and starch-based thermoplastics, are newer materials that will be prompting new investigations to unveil their structure-processing characteristics. The biodegradability of some biobased materials will create opportunities in specialized markets such as agricultural films or compostable cutlery but most of the push for biobased products will be driven by the cost reduction potential and sustainability of biomass.

Further reading.

To get an idea of the wide range of biobased materials being investigated:

International Polymer Processing, Vol 2007, Issue 5 (Special issue on Bioplastics). Download at http://www.polymer-process.com/

To hear more about the environmental and economic impact of bioplastics

Tillman U. Gerngross and Steven C. Slater, *How Green are Green Plastics*, Scientific American, August 2000, pp 37-41.

Crank M., Patel M., Marscheider-Weidemann F., Schleich J., Hüsing B., Angerer G., Wolf O. (editor), *Techno-economic Feasibility of Large-scale Production of Bio-based Polymers in Europe* (2005). Download report at http://www.biomatnet.org/secure/Ec/S1944.htm

Erwin T.H. Vink, David A. Glassner, Jeffrey J. Kolstad, Robert J. Wooley, Ryan P. O'Connor, *The eco-profiles for current and near-future NatureWorks® polylactide (PLA) production*, Industrial Biotechnology, Spring 2007, pp 58-81.