Packaging Applications Using Nanotechnology

Derek Lam
San Jose State University
2/10/10
Email: derek531@gmail.com

What is Nanotechnology?

Nanotechnology is the ability to measure, see, manipulate and manufacture things between 1 and 100 nanometers. A nanometer is one billionth of a meter; example is a human hair is roughly 100,000 nanometers wide which means a nanometer is really really tiny. Nanotech is the engineering of functional systems at the molecular scale level. Nanotechnology refers to the projected ability to construct items from the bottom up, using techniques and tools that are being developed today to make complete, high performance products at subatomic levels.

Nanotech is the construction and use of functional structures designed from the atomic or molecular scale, with at least one characteristic dimension measured in nanometers. Their size allows them to exhibit novel and significantly improved physical, chemical, biological properties, phenomena, and processes because of their size. When characteristic structural features are intermediate between isolated atoms and bulk materials in the range of about one to 100 nanometers, the objects often display physical attributes substantially different from those displayed by either atoms or bulk materials.

Nanotech can provide us with a never before known or understanding about materials and devices and will most likely have an impact on many fields. By using structures at the nanoscale as a tunable physical variable, we can greatly expand the range of performance of existing chemicals and materials. Alignment of linear molecules in an ordered array on a substrate surface (self-assembled monolayers) can function as a new generation of chemical and biological sensors. Switching devices and functional units at nanoscale can improve computer storage and operation capacity by a factor of a million.

Entirely new biological sensors facilitate early diagnostics and disease prevention of cancers. Nanostructured ceramics and metals have greatly improved mechanical properties, both in ductility and strength.

History

Nanotechnology is essentially a modern scientific field that has been constantly evolving as more interest in the subject has been increasing and more research is being presented to the scientific community. The first time nanotechnology was introduced to the community was in 1959 at a talk given by Richard Feynman, a physicist at Caltech on the topic "There's Plenty of Room at the Bottom." In the talk Feynman never really mentioned the topic "nanotechnology," Feynman sort of suggested that it will eventually be possible to precisely manipulate atoms and molecules. Nanotechnologies primary development didn't occur till the eighties and early nineties.

Why develop nanotechnology?

Since the human species started learning how to chip stone, our primary goal has been to figure out a way to gain better control over the structure of matter. The quality of all human made goods depends on the arrangement of their atoms. The cost of our products we develop ultimately depends on how difficult it is to get the atoms and molecules to connect together the way we want it to. The amount of energy required and the amount of pollution it gives off depends on the methods we use to place and connect the molecules into a given product. The goal of nanotech is to help improve our control over how we build things, so that our products can be of the highest in quality and while causing the lowest impact on the environment.

Nanotechnology has been identified as essential in solving many of the problems facing humanity such as:

1. Providing Renewable Clean Energy
2. Supplying Clean Water Globally
3. Improving Health and Longevity
4. Healing and Preserving the Environment
5. Making Information Technology Available To All
6. Enabling Space Development

Top Ten Reasons For Using Nanotech in Food Packaging:

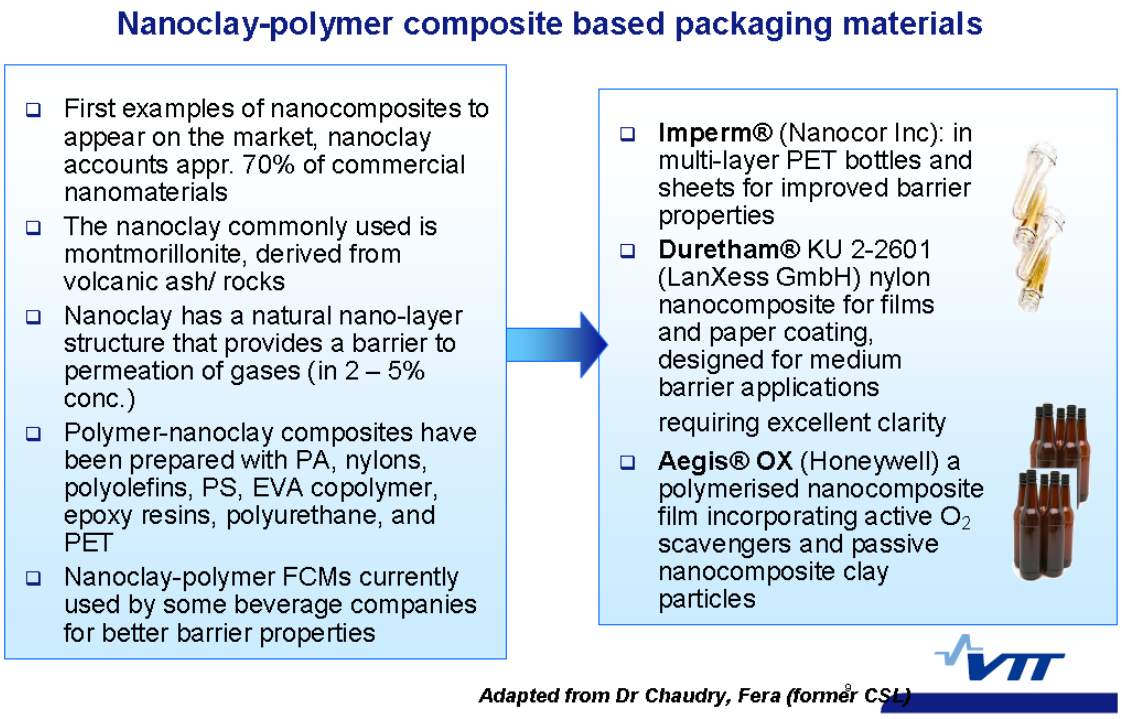
1. Contamination Sensor
2. Antimicrobial Packaging
3. Improved Food Storage
4. Enhanced Nutrient Delivery
5. Green Packaging
6. Pesticide Reduction
7. Tracking, Tracing; Brand Protection
8. Texture Enhancer
9. Flavor Enhancer
10. Bacteria ID and Elimination

Current and Projected Applications of Nanotechnology

- Cosmetics and personal care products ~60%
- Paints & coatings ~10%
- Catalysts & lubricants
- Security printing
- Textiles & sports
- Medical & healthcare
- Food and nutritional supplements ~10%
- Food packaging
- Agrochemicals
- Veterinary medicines
- Water decontamination
- Construction materials
- Electrical & electronics ~10%
- Fuel cells & batteries
- Paper manufacturing
- Weapons & explosives

Adapted from Dr Chaudry, Fera (former CSL)

**source: www.nanotechproject.org/consumerproducts*



Nanotech & Food Packaging

Today, nanotech R&D of food packaging and the monitoring of nanotech food packaging is a major focus in the food industry. Packaging that incorporates nonmaterial's can be made to be "smart," which means it can respond to environmental conditions or repair itself or alert a consumer about contaminations and or the presence of pathogens. According to the Nanotech Europe 2009 analysts, the current US market for what is called "active, controlled and smart packaging," estimates $38 billion is invested in food and beverage packaging and the analysts are predicting it will surpass $54 billion by 2011.

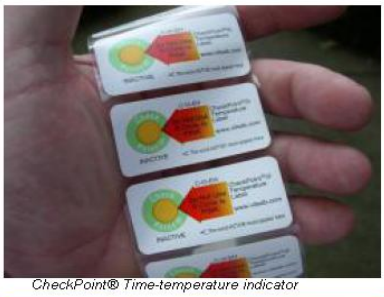
How will nanotech be used for food production and processing?

Industry analysts predict that nanotechnology will most likely be used to transform food from the atom up. Thanks to nanotechnology, tomorrow's food will be designed by shaping molecules and atoms. Food will be wrapped in "smart" also known

as safety packaging which is able to detect spoilage or harmful contaminates. In agricultural use, nanotechnology will be used to reduce pesticide use, while improving plant and animal breeding, and creating new nano-bioindustrial products.

The food and agricultural industry have been investing billions of dollars into nanotechnology research, and currently there are already a number of nano food products on the market. Because of their not being a law making nano labeling mandatory everywhere in the world, it is impossible to tell how many commercial food products now contain nano ingredients. According the Helmut Kaiser Consultancy Group, a pro-nanotechnology analyst, they estimated that there are now over 300 nano food products available on the market worldwide. The Helmut Kaiser Consultancy Group estimated that the global nana food market in 2005 was worth $5.3 billion US dollars and they predict it will rise to $20.4 billion US dollars by 2010; by 2015 we should be expecting nanotechnology to take up 40% of the food industry.

Current examples of intelligent packaging concepts for consumer packages



CheckPoint® Time-temperature indicator

OxyEye® Oxygen indicator

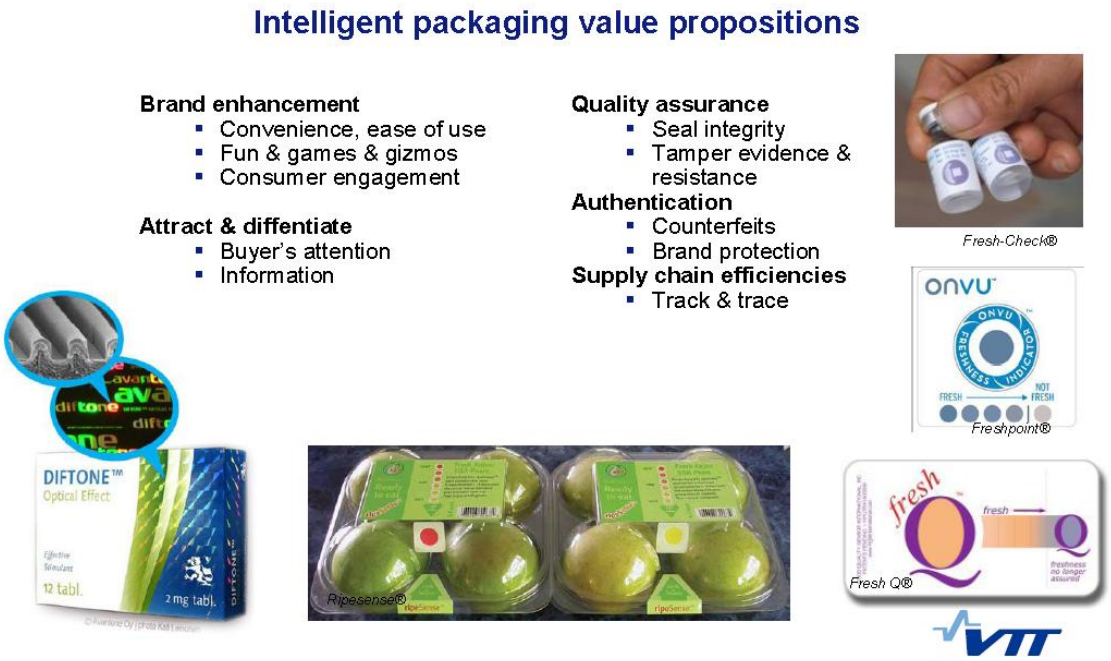
- Mostly label type, quality assurance applications
- Typically optical response
- Applications often restricted by;
  - too high cost
  - limited performance
  - added-value for retailer

Wondersensre® Oxygen indicator

Timestrip® Time-temperature indicator

19

http://fshn.illinois.edu/food_processing_forum/presentations/d6_Smolander_presentation.pdf *(Maria Smolander, International Forum on Emerging Technologies in Food Processing September 23-25 2009 University of Illinois)*

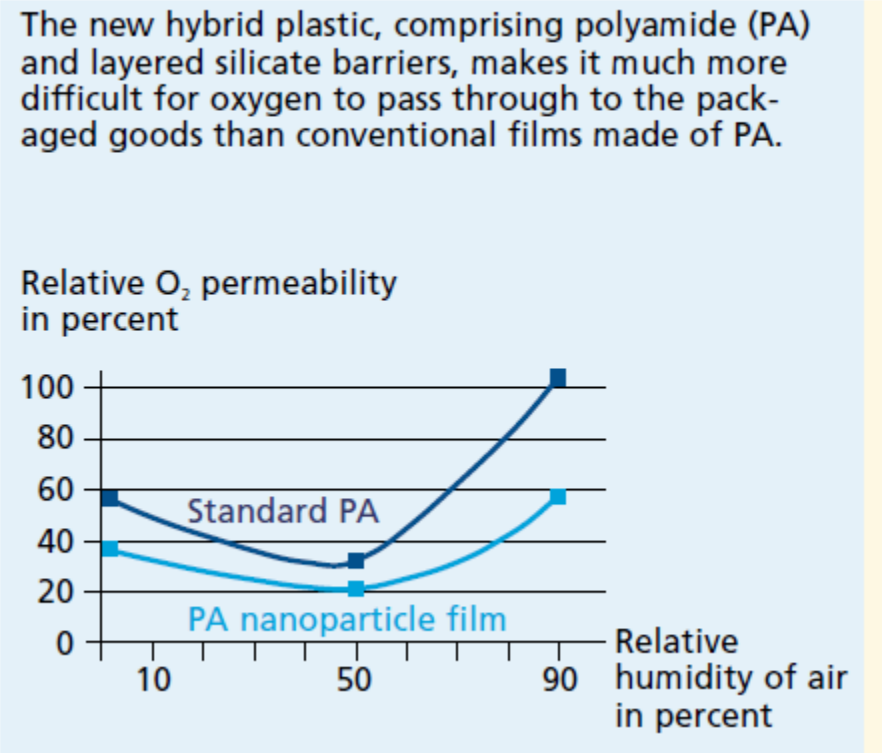


http://fshn.illinois.edu/food_processing_forum/presentations/d6_Smolander_presentation.pdf *(Maria Smolander, International Forum on Emerging Technologies in Food Processing September 23-25 2009 University of Illinois)*

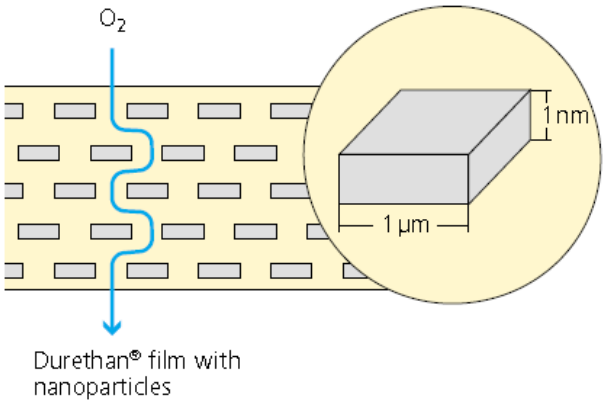
Nanomaterials in Food Packaging

The use of nanomaterials in food packaging is already a reality. Nanotechnology can be used in plastic food packaging to make it stronger, lighter or perform better. Antimicrobials such as nanoparticles of silver or titanium dioxide can be used in packaging to prevent spoilage of foods. Another addition is the introduction of nanoparticles of clay into packaging to block oxygen, carbon dioxide and moisture from reaching the food, and also aids in preventing spoilage. Chemical giant Bayer produces a transparent plastic film called Durethan which contains nanoparticles of clay. Durethan is

an engineering plastic based on polyamide 6 and polyamide 66; these particles offer an excellent combination of properties which include high strength and toughness, abrasion resistance, chemical resistance, and resistance to cracking. Durethan is used in various industries and applications, including packaging film for the medical field and food packaging. The nanoparticles are spread throughout the plastic and are able to block oxygen, carbon dioxide and moisture from reaching fresh meats or other foods. The advantage of using nanoclay is it also makes the plastic lighter, stronger and more heat-resistant. Durethan film material with nanoparticles combines the advantages of polyamide 6 and ethylene vinyl alcohol (EVOH) to produce an inexpensive but still very airtight packaging material. The embedded nanoparticles prevent gases from penetrating the film and also keeping moisture from escaping.



(http://www.research.bayer.com/edition_15/15_polyamides.pdfx)



Oxygen detour
Just a few nanometers (µm) thick and one micrometer (mm) wide, the layered silicate particles embedded in the plastic film present a barrier to oxygen. O_2 molecules first have to take a long detour around the nanoparticles before reaching their destination.

(http://www.research.bayer.com/edition_15/15_polyamides.pdfx)

An example is bottles made with nanocomposites which minimize the leakage of carbon dioxide out of the bottle; by minimizing the leakage of CO2 in the bottle this will cause an increase in the shelf life of a carbonated beverage without having to use heavier glass bottles or more expensive cans. Another example is food service bins made out of silver nanoparticles embedded in the plastics. The silver nanoparticles kill bacteria from any food previously stored in the bins, which will minimize harmful bacteria.

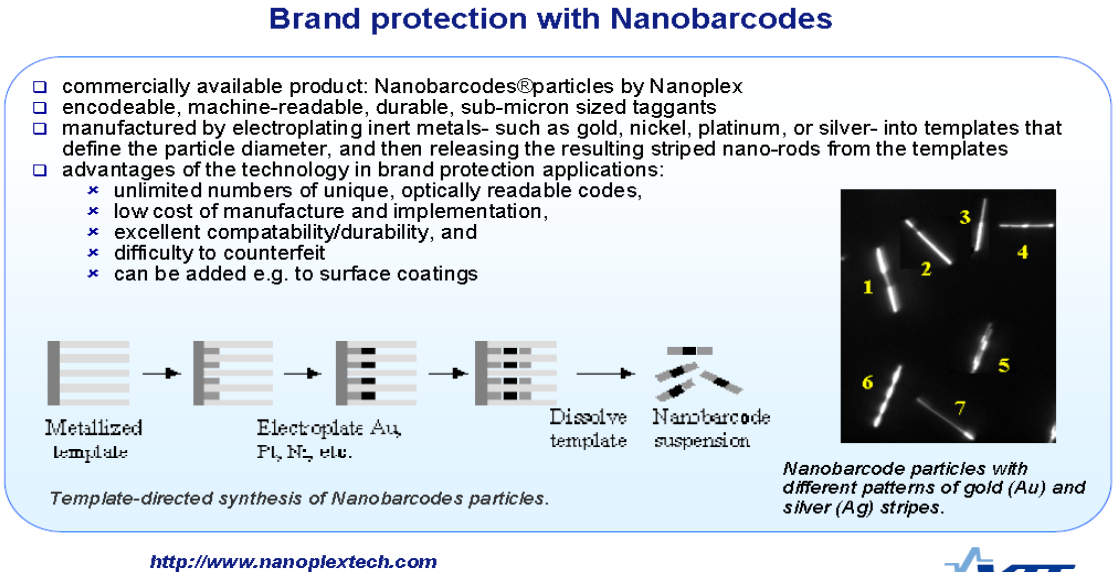
Other Food Packaging Products

Currently underdevelopment are nanosensors, these sensors are being added in plastic packaging to detect gases given off by food when it spoils and the packaging itself changes color to alert you that the food in the package has gone bad. Plastic films are being created to allow food to stay fresh longer; these films are packed with silicate nanoparticles to reduce the flow of oxygen into the package and the leaking of moisture out of the package. Nanosensors are also being engineered to detect bacteria and other contaminates such as salmonella on the surface of food and at a packaging plant. By having nanosensors this will allow more frequent food package testing at a much lower

cost than it is to send samples to a lab to be analyzed. This point-of-packaging testing if conducted properly has the potential to reduce the chance of contaminated food reaching grocery store shelves. Another nanosensor being develop is to detect pesticides on fruit and vegetables. This is very useful in a packaging plant because now you can check the quality of your products.

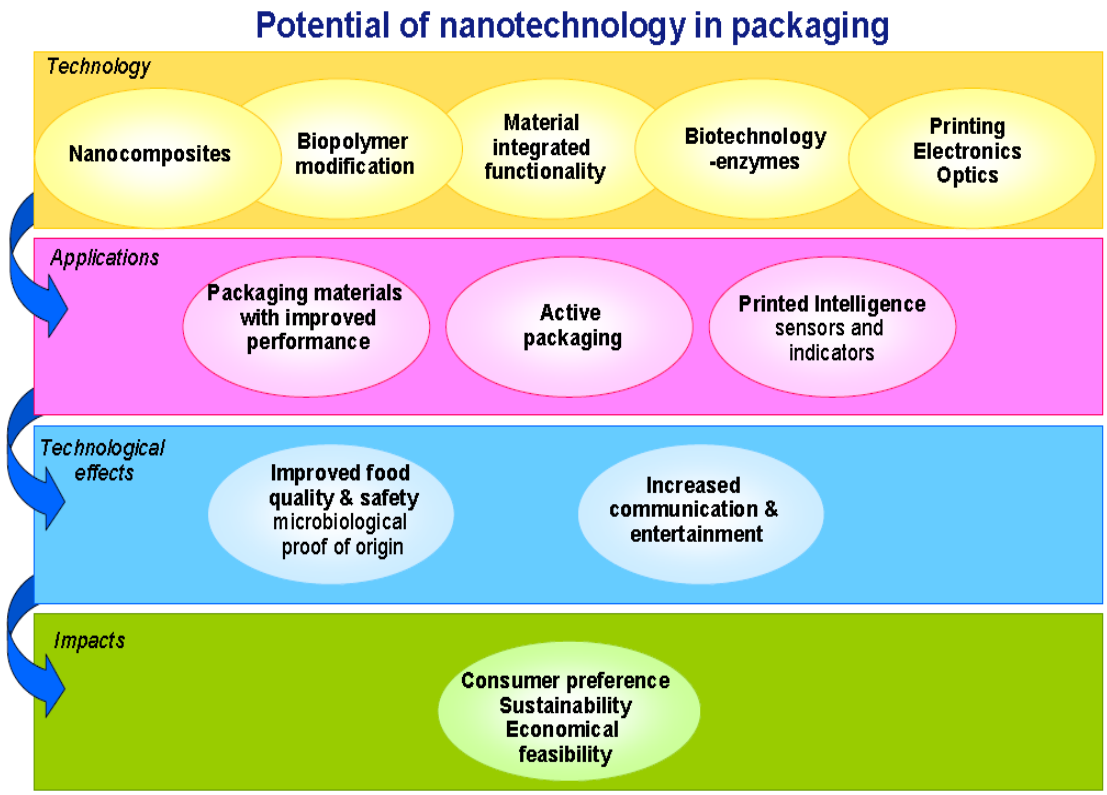
'Smart' packaging and food tracking

Nanotechnology in packaging will help dramatically extend the shelf life of food packaging. Mars Inc. is a company that currently has a patent on an invisible edible nano wrapper which will act as an envelope for foods to prevent gas and moisture exchange. 'Smart' packaging which contain nano-sensors and anti-microbial activators are being engineered to be capable of detecting food spoilage and releasing nano-anti-microbes which will extend food shelf life, by doing this it will enable supermarkets to keep food for even greater periods of time before its sale date. Food tracking devices such as the Nano-sensors embedded into food products as tiny chips that are invisible to the human eye, would also act as electronic barcodes. These sensors would emit a signal that would allow food, including fresh food to be tracked from paddock to factory to supermarket and beyond.



http://fshn.illinois.edu/food_processing_forum/presentations/d6_Smolander_presentation.pdf *(Maria Smolander, International Forum on Emerging Technologies in Food Processing September 23-25 2009 University of Illinois)*

Interactive 'smart' food, Kraft and Nestle foods are the companies currently designing 'smart' foods that are intended to interact with the consumers so they can personalize their food, by changing color, flavor, and nutrients on demand. Kraft is developing a clear tasteless drink that contains hundreds of flavors in latent nanocapsules, by using a microwave you would be able to trigger the release of the color, flavor, concentration and texture of the individual's choice. The technique of nanoencapsulation, or creating nanocapsules, involves coating a nanoparticle so that its contents are released in a controlled way.



http://fshn.illinois.edu/food_processing_forum/presentations/d6_Smolander_presentation.pdf (Maria Smolander, International Forum on Emerging Technologies in Food Processing September 23-25 2009 University of Illinois)

Conclusion

As we can see from all the research conducted, clearly nanotechnology offers tremendous opportunities for innovative developments in food packaging that can benefit both consumers and industry. The application of nanotechnology shows considerable advantages in improving the properties of packaging materials, but we are still in the early stages and will require continued investments to fund the research and development to better understand the advantages and disadvantages of nanotechnology use in packaging materials.

Cited Sources:

- **AZoNanotechnology Article (May 13, 2004): Nanotechnology and Food Packaging, www.azonano.com/Details.asp?ArticleID=857**
- **Australian Government Department of Innovation, Industry, Science and Research: Fact Sheet on Nanotechnology and food and food packaging, www.nantechnology.gov.au**
- **Connexions: The Early History of Nanotechnology, module by: Devon Fanfair, Salil Desai, Christopher Kelty, http://cnx.org/content/m14504/latest/**
- **Global Research, October 30, 2008: Nanotechnology-the new threat to food, by Georgia Miller, www.globalresearch.ca/PrintArticle.php?articleId=10755**
- **Nanotechnology Law (January 04, 2007): Regulating nanotech in food packaging, http://nanotechlaw.blogspot.com/2007/regulating-nanotech-in-food-packaging.html**
- **Use of nanomaterials in food packaging poses regulatory challenges, by Colin Finan, www.eurekalert.org/pub_releases/2008-06/poen-uon062408.php**
- *http://fshn.illinois.edu/food_processing_forum/presentations/d6_Smolander_presentation.pdf (Maria Smolander, International Forum on Emerging Technologies in Food Processing September 23-25 2009 University of Illinois)*
- *http://www.research.bayer.com/edition_15/15_polyamides.pdfx*