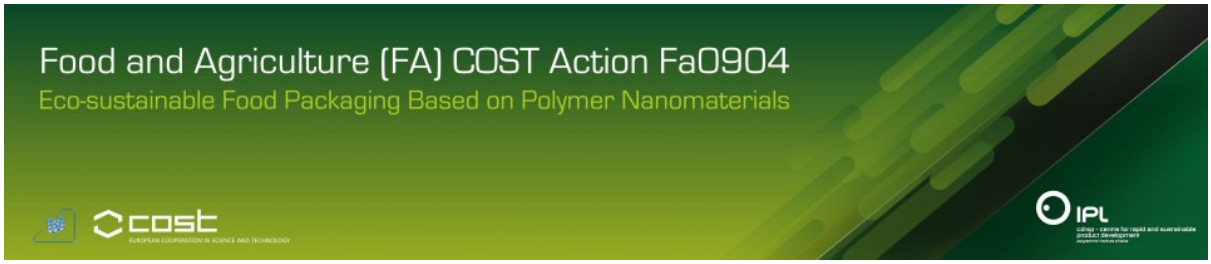

Eco-sustainable Food Packaging based on Polymer Nanomaterials: The Industrial Challenges

Editor: Geoffrey Mitchell

Institute Polytechnic of Leiria

Mitchell, Geoffrey Robert

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CONTENTS

INTRODUCTION

This international workshop on "Eco-sustainable Food Packaging Based on Nanomaterials: The Industrial Challenges" was held as part of the programme of activities of the COST Action FA0904. The event was held at the Centre for Rapid and Sustainable Product Development in Marinha Grande, Portugal to facilitate participation by the local industry as well as by global players reflected in the key-note lecturers. The ambition was to identify the key areas which researchers within the COST action should focus on to solve the challenges presented by industry today and make these available to all within the COST action. The latter ambition is the purpose of this small booklet.

The **International workshop on Eco-sustainable Food packaging: the industrial challenges** was held on Thursday and Friday 4 and 5 July 2013 at the Centre for Rapid and Sustainable Product Development, Institute Polytechnic of Leiria Portugal. There was an excellent participation from over 40 academic scientists and industrialists drawn from eight European Countries. There were excellent Keynote and Contributed Lectures together with some very interesting posters. There was a lively discussion both in the formal sessions and during the breaks. Ana Tojera from CDRSP, Portugal and Zehra Ayhan from Mustafa Kemal University, Turkey kindly kept effective records of the presentations and in particular the issues raised after each presentation during discussion. These records formed the basis of a presentation that both made at the end of the workshop and the ensuing lively discussion. Both components of this activity are presented in Chapter Four.

This work was also supported by the Portuguese Foundation for Science and Technology through the Strategic Project PEST-OE/EME/UI4044/2011.

I would like to thank all my colleagues at CDRSP for their assistance in organising this workshop in particular, Ana Tojeira, Ana Prates, Lina Durão, Margarida Filipe and Mauro Sousa.

On behalf of all the participants of the workshop I would like to thank Ana Tojeira and Zehra Ayhan for their sterling work in producing an overview of the key issues and summarising the final discussion session which are both reproduced in Chapter 4.

Geoffrey Mitchell - Conference Chair

geoffrey.mitchell@ipleiria.pt

Marinha Grande, July 2013

1. COST Action FA0904

The COST Action FA0904 aims at exploiting the potentiality of polymer nanotechnology in the area of food packaging treating in a complete way the demanding needs of the users, such as health, environment, taste, cost and the specific requirements of the food industry. The Chair of the Action is Dr Clara Silvestre of the CNR Institute of Chemistry and Technology of Polymers, Pozzuoli, Italy. The envisaged direction is to look at the complete life cycle of the PNFP by the combined efforts of leading research and industrial groups. The Action will identify the barriers (in research and technology, safety, standardisation, trained workforce and technology transfer) that prevent a complete successful development of PNFP and will indicate the strategies to proceed further. Already 54 partners including 13 companies and coming from 23 countries have shown interest in the Action, which will be organized in 4 Working Groups:

•WG1-Development of new safe PNFP;

•WG2 Development of new processing technologies including modelling and simulation;

•WG3-Development of new strategies to identify any critical interaction of PNFP with food;

•WG4-Ethics, Standardization, Science-society dialogue.

The final workshop of the COST Action will take place on 26-28 February at Sala Marconi CNR, Pizzale A. Moro 7 Roma Italy.

Electronic versions of this book can be downloaded at no cost at cdrsp.ipleiria.pt/cost

2. CDRSP

The Centre for Rapid and Sustainable Product Development (CDRSP) is a research centre hosted by the Polytechnic Institute of Leiria (IPL) based in the industrial zone of Marinha Grande, Portugal. CDRSP was rated as "Excellent" by an international panel, the highest level awarded in the last research assessment carried out by the Portuguese Foundation for Science and Technology (FCT). As a consequence of this FCT evaluation, the centre became an IPL unit with administrative, academic and scientific autonomy.

CDRSP aims to contribute to the advanced of science and technology leading to more suitable, effective and efficient products, materials and processes, this way generating added value for the industry, and promoting awareness in society of the role and importance of rapid and sustainable product development. To fulfil this mission, the centre carries out scientific and technological research, providing consulting, training and research services in the strategic areas of rapid and sustainable product development.

The key research themes of CDRSP are:

- ✓ **Emerging technologies** – production technologies to exploit the potential of emerging technologies (in particular bio- and multi-scale technologies); leveraging simulation and modelling techniques to address manufacturing challenges; flexible, rapidly responsive production systems for customized manufacturing. Additive manufacturing and regenerative medicine.
- ✓ **Advanced materials** – materials with novel functionalities enhancing new manufacturing technologies and processes and the opportunities to manufacture entirely new materials-based technologies and products. Smart Materials, sustainable polymers, functional graded structures.
- ✓ **Sustainable manufacturing and manufacturing of green technologies.**

CDRSP was launched in 2007 and since 2010 it has received ~ €9M / year from National European and International Agencies and from Industry.

In 2014 CDRSP will open a new building housing purpose built laboratories to match its world leading research aspirations.

3. Participants

First Name	Surname	Institution	Country
Neill	Dutton	Paramelt	The Netherlands
Iain	Ferguson	Cooperative Society	UK
Rumiana	Kostilova	Bulgarian Academy of Sciences	Bulgaria
Juris	Bitenieks	Riga Technical University	Latvia
Luoic	Hilliou	University of Minho	Portugal
Isabel	Coelhoso	University Nova de Lisboa	Portugal
Donatella	Duraccio	ICTP CNR Pozzouli	Italy
Raluca	Dumitriu	Romanian Academy of Sciences	Portugal
Zehra	Ayhan	Mustafa Kemal University	Turkey
Ana Rita	Ferreira	University Nova de Lisboa	Portugal
Henrique	Almeida	Centre for rapid and Sustainable Product Development, IPL	Portugal
Giorgio	Mancini	ISMAC - CNR UOS Genova	Italy
Ana	Gomes	Embalnor Lda	Portugual
Marilena	Pezzuto	Institute of Chemistry and Technology of Polymers, Pozzuoli	Italy
Atonella	Marra	Institute of Chemistry and Technology of Polymers, Pozzuoli	Italy
Maria	Gil	Escola Superior de Turismo e Tecnologia do Mar, IPL, Peniche	Portugal
Artur	Mateus	Centre for rapid and Sustainable Product Development, IPL	Portugal
Paulo	Bártolo	Centre for rapid and Sustainable Product Development, IPL	Portugal
Geoffrey	Mitchell	Centre for rapid and Sustainable Product Development, IPL	Portugal
Nuno	Alves	Centre for rapid and Sustainable Product Development, IPL	Portugal
Marco	Domingos	Dias de Sousa Lda	Portugal
Carlos Manuel	Viegas Lamarosa	Iber-Oleff, Marinha Grande	Portugal
Paulo	Tiago	Frubaça	Portugal
Marina	Tomás	Campotec Lda	Portugal
Clarisse	Boto	Vitacress	Portugal
Ana	Tojeira	Centre for rapid and Sustainable Product Development, IPL	Portugal
Rui	Soares	Centimfe	
Imran	Khan	Centre for rapid and Sustainable Product Development, IPL	Portugal

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Sofia	Baptista	Centre for rapid and Sustainable Product Development, IPL	Portugal
Margarida	Franco	Centre for rapid and Sustainable Product Development, IPL	Portugal
Flávio	Craveiro	Centre for rapid and Sustainable Product Development, IPL	Portugal
Miguel	Gaspar	Centre for rapid and Sustainable Product Development, IPL	Portugal
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Tânia	Viana	Centre for rapid and Sustainable Product Development, IPL	Portugal
Sara	Biscaia	Centre for rapid and Sustainable Product Development, IPL	Portugal
Rúben	Pereira	Centre for rapid and Sustainable Product Development, IPL	Portugal
Juliana	Dias	Centre for rapid and Sustainable Product Development, IPL	Portugal
Telma	Ferreira	Centre for rapid and Sustainable Product Development, IPL	Portugal
Daniela	Rocha	Centre for rapid and Sustainable Product Development, IPL	Portugal

4. Summary of Issues Identified at Workshop

HIGHLIGHTS

Zehra, Ayhan
Mustafa Kemal University, Turkey

Ana Tojeira
Centre for Rapid and Sustainable Product Development

Challenges for Food Packaging

- Improve barrier properties for longer shelf-life
- Improve resistance to processing conditions
- Economic, accessible, available and stable
- Life cycle assessment to develop and improve product and/or process
- Cost and market price
- Customers perception about materials and technology, and labeling
- Proper waste management infrastructures
- Recyclability
- Design packaging parameters for each fruit and vegetable
  - Respiration rate
  - Permeability of material
  - Storage temperature
  - Initial quality of the product, etc.

Market demands for Food Packaging

- Smaller sizes
- Recyclable
- Competitive prices
- Innovative design
- Extended shelf life with improved safety
- Changes of consumer profile
- Sustainability (more eco-friendly materials)
- Use of renewable and new materials (eg. PLA)
- Consideration of priorities of developing and developed countries in terms of packaging
- Mono-materials with improved properties (to replace multilayer materials)
- Consideration of eco-indicators (human health; ecosystem quality and resources)

New materials and Processes for Food Packaging

- PHA composites based on food industry by-products
- Organic fillers to improve mechanical and barrier properties of biodegradable properties
  - eg. Mica and nanoclay filler in K-carrageenan/pectin
- Edible coatings, active and intelligent packaging applications to improve the quality and shelf-life of fruits and vegetables and fresh seafood
- Use of Electrospinning in coating process for food packaging
- Active materials (eg. antioxidant, anti-microbial) to improve food quality and safety
- Best ecological options (eg. Glass for water versus PET (LCA))
- Novel three-phase nanocomposites (eg. gold/clay/epoxy)
- Reduction in permeability by controlling the morphology of the polymers

Packaging Trends

- Waste
  - Recycling, incineration with energy
- Consumers
  - Convenience, safety and waste reduction
- Retail
  - Infrastructure, shelf life and safety
- Manufacture
  - Energy, environmental impact
  - Reduction of material (thinner walls)
- Distribution
  - Improve infrastructure, product integrity, reduced losses
- Sources
  - Polyolefins and paper
  - Bio based will grow (PLA, PHA, PHB, cellulose and starch)

Future directions in Research

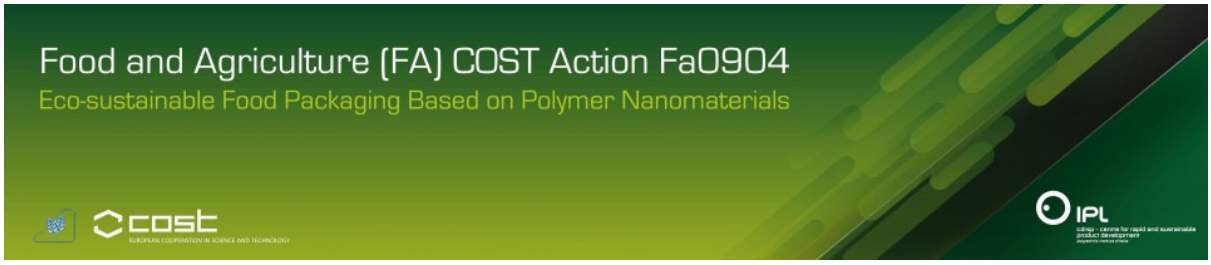
- Development of edible films and coating / active and intelligent packaging for fresh seafood
- More bio-based and nano-based materials
- Application of new materials to food (real case studies)
- More interdisciplinary studies

Discussion

- Will food packaging decrease food waste?
- Do consumers like longer shelf-life?
- Where the benefit of packaging occurs?
- Is a better product available or in development?
- What will be the new material/technology impacts on the society?
- Can biodegradable materials replace current materials?
- Are new materials recyclable? Do they need new development in recycling stream?
- Are there ethic issues regarding the use of food source for food packaging?

Note added by Editor: My thought after the discussion was that nobody placed any value on food packaging. For example no producer or reseller made a feature that the properties of their product arose from the high quality packaging which maintained the freshness or flavour of the produce. Until this happens most consumers will see packaging as waste. If producers valued the packaging, consumers will value and welcome technological advances.

5. Programme



'International Workshop 'Ecosustainable Food Packaging: the Industrial Challenges'

Centre for Rapid and Sustainable Product Development, Institute Polytechnic Leiria

Programme of Lectures – Thursday, 4 July 2013

09:45	Welcome and Introductions		
Chair	Geoffrey Mitchell		CDRsp/IPL Portugal
10:00	Neill Dutton	Global Packaging – Drivers for Change	Paramelt, The Netherlands
11:00	Ana Gomes	Challenges in food packaging from Embalnor's point of view	Embalnor Lda, Portugal
11:30	Break	Exhibition Area and Posters	
12:00	Louic Hillou	Development of polyhydroxyalkanoate composites based on food industry by-products for compostable packaging	Institute for Polymers and Composites / I3N, University of Minho, Portugal
13:00	Lunch	Exhibition Area and Posters	
Chair	Paulo Bártolo		CDRsp/IPL Portugal
14:00	Iain Ferguson		Cooperative Society UK

15:00	Maria do Carmo Martins	Packaging needs for fruits and vegetables	Centro Operativo e Tecnológico Hortofrutícola Nacional Alcobaça, Portugal
15:15	Donatella Duraccio	COST Action FA0904	Institute of Chemistry and Technology of Polymers, Pozzuoli, Naples, Italy
15:30	Break	Exhibition Area and Posters	
16:00	Isabel Coelhoso	Design of biodegradable films for food packaging	Requimte/CQFB Universidade Nova de Lisboa
17:00	Raluca Dumitriu	Electrospun fibrous coatings for food packaging application	Institute of Macromolecular Chemistry, Iasi, Romania
17:30	Close of Session		
20:00	Workshop Dinner Quinta de Santo Antonio do Freixo		

Programme of Lectures – Friday, 5 July 2013

Chair	Rumiania Kostilova		
09:30	Henrique Almeida	Evaluating the impact of glass and PET packaging for bottled water	CDRsp/IPL, Portugal
10:30	Rui Soares	Trends in Packaging with Engineering and Tooling	Centimfe, Marinha Grande, Portugal
11:00	Maria Manuel Gill	Packaging for sea food	Escola Superior de Turismo and the Technology of the Sea/IPL Peniche Portugal
11:30	Break	Exhibition Area and Posters	
12:00	Paulo Bartolo	CDRsp	CDRsp/IPL
12:30		Tour of Laboratories	
13:00	Lunch	Exhibition Area and Posters	
Chair	Donatella Duraccio		ICTP/Pozzuoli Italy
14:00	Rumiania Kostilova	Mechanical properties at macro, micro and nanoscale and the role of the structure of polymer nanocomposites	Bulgarian Academy of Sciences, Institute of Mechanics, Sofia, Portugal
14:30	Juris Bitenieks	Structure and properties of liquid crystal modifier and montmorillonite clay containing recycled polyethylene terephthalate hybrid composites	[a]Institute of Polymer Materials, Riga Technical University, Latvia
15:00	Break		
15:30	Marilena Pezzuto	Development of new nanocomposites based on iPP for food packaging applications	Institute of Chemistry and Technology of Polymers, Pozzuoli, Naples, Italy

16:00	Geoffrey Mitchell	Controlling permeability via morphological control:	CDRsp/IPL, Marinha Grande, Portugal
16:30	Ana Tojeira and Zehra Ayhan	Report back, Summary of Workshop and Discussion	CDRsp/IPL Mustafa Kemal University, Turkey
17:00	Closing remarks		
17:10	Close of Workshop		

Keynote Lectures background green

Posters

Posters should be on display from the Coffee Break on 4 July in the Exhibition Area.

P1	Giorgio Mancini	New non-releasing polymeric antioxidants for safer food packaging	CNR-ISMAC: Genova, Italy
P2	Ana Tojeira	X-ray scattering studies of biodegradable polymers	CDRsp/IPL Portugal
P3	Geoffrey Mitchell	Controlling the morphology of polymers on multiple scales	CDRsp/IPL Portugal
P4	Raluca Dumitriu	Electrospun fibrous coatings for food packaging application	Institute of Macromolecular Chemistry, Iasi, Romania
P5	CDRsp	The Green Pot	CDRsp/IPL Portugal
P6	CDRsp	QuickMilk Baby Milk Express machine	CDRsp/IPL Portugal

The exhibition area contains a number of posters and examples of CDRsp projects concerned with rapid manufacturing in the production of plastic and metal parts for a variety of applications.

6. Abstracts

Global Packaging – Drivers for Change

Neill Dutton[a]

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Paramelt are a medium sized supplier of functional coatings and adhesives to the packaging industry. The product portfolio encompasses packaging waxes; water based and hot melt adhesives as well as aqueous heat seal and barrier coatings. The company has grown rapidly over the last 20 years and now operates from sites in North America, China and Europe.

Recent years have seen an increasing rate of change on the global stage, not only in terms of shifting economic climate, but also in the complex interplay between regions, altering patterns of resource use as well as changing consumer demands and regulatory controls.

The rapidly changing balance between petrochemicals and fuel, food and biomaterials, urban and rural labour demand, amongst other factors, combine to create an increasingly complex and dynamic operating environment.

This shifting situation presents significant challenges within the packaging supply chain and has seen dramatic swings in materials availability and relative cost structures over recent years.

This paper aims to investigate a number of the main economic, demographic and resource trends in relation to the packaging industry to try and gain an insight to the key factors driving change in the industry in the medium term. Through drawing out a number of these key challenges, especially in terms of material use and product functionality it is hoped to highlight some of the major capability gaps where nano-technology may make a critical contribution to the future requirements of the packaging industry.

Development of polyhydroxyalkanoate composites based on food industry by-products for compostable packaging

Loïc Hillioua, Mara Cunhaa, José A. Covasa, Maria A.M. Reisb, Catarina S.S. Oliveirab, Anouk F. Dukeb, Ricardo Pereirac, António A. Vicentec

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The high cost, small processing window and poor mechanical properties of polyhydroxyalkanoates (PHA) hamper their use in demanding packaging applications such as thin films. We report here on the first year of activity of a national project aiming at developing new PHA based composites for packaging applications.

New PHA obtained from mixed microbial cultures were designed to meet specific valerate contents. Model mixed cultures were first used and a process was optimized using cheese whey, a by-product from the dairy industry. The mixed microbial cultures concept will be briefly presented together with the preliminary PHA properties, prior to the scaling up of the production.

A second action of the project aimed at developing PHA composites using beer spent grain fibers obtained from by-products from the beer brewing industry and commercial PHA. The screening for the compound composition and processability was performed using a mini extrusion line coupling a small scale (30-100 g/hour output) twin screw extruder to a slit die to shape small films, further drawn down with a haul off. With such small scale equipment, various compositions were tested and characterized in terms of rheological melt properties and processability, along with the small film mechanical properties. As a result of this screening, two composites were selected for scale up of the compounding and further used in a film blowing lab scale line to produce thin films. The mechanical and structural characteristics of blown films will be reported.

Acknowledgements: The authors thank Fundação para a Ciência e a Tecnologia (Portugal) for funding through **project** PTDC/AGR-ALI/122741/2010.

Cost Action FA0904 (2010-2014) "Ecosustainable Food Packaging Based on Polymer Nanomaterials"

Donatella Duraccio, Clara Silvestre, Sossio Cimmino

Institute of Chemistry and Technology of Polymers (ICTP)-CNR, Italy

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COST ACTION FA0904 was launched in 2010 with the aim at constituting an international scientific and technology network on issues related to Ecosustainable Polymer Nanomaterials for Food Packaging (PNFP), for preservation, conservation and distribution of high quality and safe food.

The ACTION FA0904 aims at exploiting the potentiality of polymer nanotechnology in the area of food packaging treating in a complete way the demanding needs of the users, such as health, environment, taste, cost and the specific requirements of the food industry.

Participants from 33 countries are involved in the Action activities, which is organized in 4 Working Groups: WG1-Development of new safe PNFP; WG2-Development of new processing technologies including modelling and simulation; WG3-Development of new strategy to identify any critical interaction of PNFP with food; WG4-Ethics, Standardization, Science-society dialogue.

The description of the achievements reached in the first three years of the Action will be provided.

Design of biodegradable films for food packaging

A. R. Ferreira[a], V. Alves[b], I. Coelhoso[a]

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The choice of packaging materials with appropriate gas and water vapor barrier is crucial, as it prevents product deterioration and maintains its overall quality during storage and handling. Thus, the use of renewable resources to produce biodegradable materials that can maintain product quality and reduce waste disposal problems is growing.

Biopolymers, namely polysaccharides, have been studied, for the production of thin films and coatings.

Blends of kappa-carrageenan and pectin are able to form cohesive and transparent films [1]. But, in order to enhance their water resistance and barrier properties, impermeable particles (mica flakes and organic nanoclays) were included in the polymer matrix [2, 3].

Microbial biopolymers are better alternatives due to their high production rates. The only disadvantage is the use of expensive substrates for their production.

A new extracellular polysaccharide (EPS), produced from glycerol, a surplus from biodiesel production, by the bacterium *Enterobacter* A47 was recently patented [4]. The new EPS revealed the capacity to produce transparent films with a high hydrophilic character.

Ongoing work is focused on the design of blends of EPS and. chitosan with enhanced resistance to liquid water and specific barrier properties to water vapour and gases, in order to meet the needs of target food products.

Acknowledgements: The authors acknowledge FCT-MCTES for funding the project PTDC/AGR-ALI/114706/2009 and for the scholarship SFRH/BD/79101/2011 of A. R. Ferreira.

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[4] Fucose-containing bacterial biopolymer, Inventors: M. Reis, R. Oliveira, F. Freitas, V. Alves. International Publication Number WO 2011/073874 A2, **2011**.

Electrospun fibrous coatings for food packaging application

Raluca P. Dumitriu[a], *Gabriela E. Hitruc*[a], *Geoffrey Mitchell*[b], *Cornelia Vasile*[a]

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In the recent years, the interest for designing advanced materials for food packaging, which behave as protection or preservation materials, are multifunctional (active or bioactive), extend the shelf-life, provide safety and improve quality of the products and subsequently consumers' health has increased significantly. Inclusion of bioactive compounds such as polyphenols, vitamins, polysaccharides, minerals is considered for obtaining new bioactive food packaging materials with possible health benefits, having antioxidative, antimicrobial, anticarcinogenic, antihypertensive, antimutagenic properties. Antioxidant activity is required for a bioactive packaging material in order to retard the natural processes of the food leading to its spoilage by reducing oxygen and moisture.

To achieve the goal of obtaining new bioactive coatings for food packaging we prepared and studied electrospun fibres of microscale diameters based on poly(ε-caprolactone) and vitamin E. The electrospinning conditions required for obtaining fibres were optimised in respect with device parameters and solutions properties. Since the quantitative presence of vitamin E in the fibres and the antioxidant properties have been previously demonstrated, the present study deals with further examination of composition (FTIR spectroscopy) and investigations oriented mainly on the morphology/topography changes (SEM, AFM) and water sorption capacity of the obtained electrospun meshes.

Mechanical properties at macro, micro and nanoscale and the role of the structure of polymer nanocomposites

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Experimental mechanics at macro, micro and nanoscale gained increasingly importance in polymer nanocomposite characterization and determined their industrial applications as packaging materials [1,2].

The key point of this study is the investigation of rheology, scratch and friction behaviour, nanoindentation hardness and elasticity of polymer nanocomposites filled with multiwalled carbon nanotubes (MWCNT) and clay nanolayers. Different techniques and methods for characterization of mechanical properties of polymer nanocomposites at micro and nanoscale are presented. The structure at the nanoscale is visualized by AFM and SEM. The important role of nanofiller structure organization and interfacial polymer-nanofiller interactions for mechanical properties improvement is discussed.

Results of practical interests are obtained for polypropylene and epoxy nanocomposites. Structure-property relationships are discussed in respect to the interfacial interactions and the formation of a percolation structure of the nanofiller in the matrix polymer. Significant improvement of nanomechanical characteristics (nanohardness ~23% and Young's modulus ~14%) is found at very low nanofiller contents (around the flocculation threshold), while ~45% improvement is observed above the mechanical percolation for the polypropylene/MWCNT composites [2]. A better dispersion of amine-functionalized carbon nanotubes and organoclay in epoxy resin is observed, which produces much higher reinforcement on the epoxy resin, compared to the non-functionalised nanofillers. The effect is related to the formation of interface epoxy layer around the amine-functionalized carbon nanotubes [3].

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Structure and properties of liquid crystal modifier and montmorillonite clay containing recycled polyethylene terephthalate hybrid composites

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Currently polyethylene terephtalate (PET) is used in large quantity in diversity of applications as in packaging, fiber production and other molded goods. Recycled polyethylene terephtalate (RPET) composite materials can be obtained from the waste products of PET, generally various packaging materials. Addition of montmorillonite clay (MMT) as well as liquid crystalline modifier (LCM) enhance barrier and mechanical properties of RPET products such as high performance films and bottles for packaging.

In the current research the effect of LCM and MMT additions on the structural and certain exploitation properties of RPET has been evaluated. RPET has been supplied by the main post-consumer soft-drink bottle reprocessor in Latvia – JSC "PET Baltija". As modifiers commercial organically modified MMT clay (OMMT) from Laviosa Chimica Mineraria S.P.A. (Italy) and LCM, synthesized in the laboratory, have been used. Polymer hybrid composites have been obtained by melt mixing of RPET with OMMT (1 to 5 wt. %) and LCP (5 wt. %) by using twin screw extruder. Mechanical, rheological, barrier and structural characteristics of RPET/LCM/OMMT hybrid composites have been characterized by means of tensile stress-strain testing, rotation viscosimetry, water vapour sorption analysis and differential scanning calorimetry.

Results of the investigations testify that LCM and OMMT affect Young's modulus and yield strength of the hybrid RPET nanocomposites synergetically. Certain improvements of barrier characteristics are also obseved along with rising LCM and OMMT content in the matrix. Besides it has been observed that addition of LCM considerably improve processability of RPET by increasing viscosity of the material.

The research is carried out within the framework of the ERDF project Nr. 2010/0209/2DP/2.1.1.1.0/10APIA/VIAA/028

Development of new nanocomposites based on iPP for food packaging applications

Marilena Pezzuto[a], *Donatella Duraccio*[a], *Antonella Marra*[a], *Sossio Cimmino*[a], *Geoffrey Mitchell*[b], *Clara Silvestre*[a]

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In the field of packaging, isotactic polypropylene (iPP) films hold a prominent position because of their transparency, brilliance, low specific weight, chemical inertness and good processability. Unfortunately, iPP, like other polyolefins, is characterized by low barrier properties, which results in poor protection of the packaged food [1.2]. To overcome these iPP drawbacks, films of iPP/hydrogenated oligocyclopentadiene (HOCP) were introduced some years ago in the packaging sector [3]. It was found that for given conditions of preparation, the films presented reduced permeability to oxygen and to aroma, compared to those of the pure iPP. In order to further improve properties of iPP/HOCP blends for food packaging application two different clay were added: an unmodified and a modified clay. The final composition of all ternary systems, iPP/HOCP/clay, is (70/30)/1, that indicates that there is 1g of clay per 100 g of iPP+HOCP and the ratio between iPP and HOCP is 70/30. In this work the study of the properties of iPP/HOCP/clay in dependence of clay and preparation conditions will be reported. For the systems containing unmodified clay two different preparation procedures have been used: i) mixing the three components together in the blender and ii) mixing the iPP with a masterbatch formed by HOCP and unmodified clay. The results show that depending on clay molecular characteristic and processing conditions nanocomposites different phase structures and materials with different properties (morphological, rheological and mechanical, as well as barrier properties) can be obtained.

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Controlling permeability via morphological control: A safe approach for food packaging

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Some 60 years ago it was food packaging that made the development of self-service stores and subsequently supermarkets a practical proposition. The packing provides physical and barrier protection for the food content and offers security to the consumer. This initial success story has continued with many technological developments which have enhanced the effectiveness of food packaging in preserving and protecting the food and reducing waste. At the same time food packaging has been under increasing close scrutiny with regard to recycling, contamination of food from chemical migration and the use of materials from sustainable sources and via sustainable processing. We propose that these multiple requirements of high performance packaging coupled to the need for recycling and enhanced sustainability can only be meet by the use of polymer films with controlled morphology. By this we mean the controlled distribution and orientation of structural elements such as crystalline lamellae, glassy domains or heavily cross-linked regions which will significantly impact on the permeability of gases through the film. It is the case that the controlled morphology of polymer films is essential for the production of transparent packaging which dominates much of the market in terms of foods stuffs. The requirement to control the polymer morphology in specific ways to limit the permeability in turn generates further challenges for processing of polymer films for this application. We present examples where the required morphology can be achieved and discuss the limitations which are intrinsic to such processes.

New non-releasing polymeric antioxidants for safer food packaging

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Polyolefins, due to their good mechanical and sealing properties, low cost and low reactivity, are largely used as food-contact packaging materials. Common stabilizers for polymers are derivatives of sterically hindered phenols and amines. Their low molecular weight combined to poor compatibility with the polyolefin matrices, lead to their easy diffusion and volatility, and consequent physical lost during material processing and storage and/or migration into food during shelf-life.

To overcome these drawbacks, we explore new families of non-releasing macromolecular stabilizers [1-3]. Several 1-olefin bearing highly efficient stabilizing moieties were designed and novel random copolymers of ethylene or propylene with the synthesized functionalized comonomers were prepared by exploiting metallocene catalysis.

The macromolecular stabilizers were melt blended with additive-free polyolefinic matrices. Thermo-oxidative tests on films containing the macromolecular antioxidants showed a longer induction time before O2 uptake and higher degradation temperatures than the neat polyolefin matrix and films containing molecular antioxidants. Aging texts showed that the macromolecular additives constitute also a protection against photo-oxidation. Specific migration tests demonstrated the absence of any product containing the antioxidant moiety into food simulants.

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