GHENT UNIVERSITY – DEPARTMENT OF TEXTILES, EA11

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**Development of a Textile Based Energy Storage Device**

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Description

Textiles are part of our daily life as we use them intensely in various applications. These applications vary from clothing and upholstery to new technical applications in different industries. A new class of textiles, the so-called *smart textiles,* is able to respond to stimuli from the user environment. Smart textile systems consist of five main components i.e. sensors, actuators, a data processor, an energy supply and an interconnection between them. Smart textile systems are mostly applicable in leisure and fun (mp3s, displays on shirts) and for monitoring in sports, personal protective equipment, health and telemonitoring.

The challenge is to produce as many components as possible from textile materials, since their characteristics are : lightweight, flexible, durable and compatible to the skin and body.

This research focuses on the development of an energy supply/storage device of the smart textile system. In addition, portable energy storage devices are becoming indispensable with the current increase in use of portable gadgets that consume power to function like watches, mobile phones, ipods, computers etc. It will be “a dream come true” if we are able to power these devices at any time with stored power in our textiles.

Purpose

A battery is composed of *an anode* (negative electrode), *a cathode* (positive electrode) and *an electrolyte* that allows for the ionic conductivity. Often, separators are used to separate the anode from the cathode to prevent a short circuit. An electrochemical capacitor consists of the electrodes (cathode and anode) and the electrolyte.

An energy storage device which is either **a battery or a capacitor** is to be developed from poly PEDOT:PSS (3,4 ethylenedioxythiophene) (semi) conductive polymer and conductive yarns (silver coated yarns, copper coated yarns and pure stainless steel filament yarns). The device should be simple and well integrated into the textile matrix.

Alternatively, a solid state battery is to be developed from isolative and conductive formulations/inks by screen printing technology, based on a pre-informed design.

In both cases, the student will design and develop the device according to definite specifications, and conduct charge-discharge measurements. We aim at obtaining batteries with energy densities of 70Wh/kg that could supply enough energy to support the e-textile circuit.

**Development and Characterization of a Fibre with Transistor Properties**

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Description

During recent years, intensive research has been carried out in the area of electronic textiles. There is an emerging trend to create garments that host electronic components embedded in the textile substrate as well as electronic textiles made from yarns or fibres already possessing electronic properties. The creation of passive devices, such as textile electrodes that measure body parameters, has proved successful. However, there is a great need for the development of textiles possessing additional active functions.

Hence, we investigated the possibility of developing a textile substrate possessing integrated switching and amplification functions by depositing parts of an organic thin film transistor (OTFT) on fibrous substrates of varying geometries and origins.

Purpose

In our lab we are currently developing an OTFT based on polymeric textile substrates. For that purpose, different functional layers are coated on top of each other using chemical deposition, dip-coating and thermal evaporation. The thesis topic will focus on the development of the semiconductive layer via different techniques as well as their characterization.

**The Feel of Textiles**

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Before buying a textile product, people will always try to touch and experience the feel of the fabric. This makes feel a decisive factor for choosing a textile product. But feel is very personal. Also the evaluation procedure in companies to define feel is mostly very subjective. Therefore, we want to acquire more insight in the experience of feel. We want to know which parameters are important in order to establish a more objective method to determine feel.

In this investigation, you will cooperate with the company Procter&Gamble. They are, inter alia, an important corporation for the production of fabric softeners, but they lack an objective, quantitative way to evaluate treated fabrics. Therefore, various tests should be executed with the goal of understanding the perception of feel. Examples of properties to be measured are the friction coefficient, compressibility and bending stiffness. All these experiments can eventually lead to a model to determine fabric feel.

**Polymeric Surfaces Functionalized with Enzymes Using 3D Bioplotter Technology**

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The research will focus on the development of defined porous 3D polymeric matrices functionalized with enzymes. Such materials find their applications in sensors and scaffolds. For example: tissue engineering or drug release systems require 3D scaffolds with well defined porosity as well as external and internal structures. A 3D bioplotter enables the production of 3D scaffolds which can be further functionalized in a separate step with specific enzymes. The objective is to incorporate biocatalysts onto well-defined porous 3D matrices based on (bio)polymers. Incorporation of biocatalysts onto the surfaces will result in novel (textile) materials with new functionalities. Depending on the biocatalyst, incorporated components will be converted, detected, absorbed or released. Most biocatalysts perform optimally under ambient conditions, and will be damaged by e.g. high temperatures, high or low pH values or high salt concentrations. The challenge is to develop innovative technologies for the production of textile fibres while maintaining the activity of the biocatalyst. The materials will be analysed using classical techniques for (porous) materials including SEM, micro-CT, … . This will enable a feed-back to the material development if required.

**Effect of Ions on Silk Fibres**

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Introduction

Ions from the Hofmeister-series are known to play a crucial role in the silk fibre spinning process of silk moths and spiders. They help in determining the ultimate folding of the fibre proteins and consequently dictate the attractive properties that the ultimate silk fibres have like a high breaking stress, high strain to break and high breaking energy. A better understanding of this process will allow to ultimately spin a protein solution.

Purpose

The aim of this project is to explore the effect of these ions on the ultimate fibre conformation and properties. We will selectively replace and integrate natural occurring ions and study their effect on the conformational change of the proteins with different techniques.

**The Effect of Oxidative Cross-Linking of Silk Fibres**

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Introduction

The general browning of silk over time is a process known as oxidative cross-linking (tanning). This process has been extensively used in the silk industry to increase the silk fibres weight after the sericin removal (degumming). However, tanning does not only increase the weight but also increases the tensile properties of the fibres.

Purpose

Here we focus on the quantitatively cross-linking of raw silk fibres by means of enzymes. The effect of the cross-linking on the mechanical properties of the fibre will be studied in detail.

**3D-Analysis/Reconstruction of the Cocoon Spinning in Silkmoths**

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Introduction

Silk is known as a luxury product. In order to obtain the continuous silk fibre for use in cloths however, countless silkmoths are killed as these break-up the cocoon fibre when emerging. By introducing a new video technique we will be able to reconstruct the cocoon and the spinning thereof.

Purpose

The main goal is to completely reconstruct a silk cocoon built up by a 1.2km silk fibre. This will enable us to get a better insight in how cocoons are spun and how to change this spinning behaviour so that the silkworms can be removed from the cocoon without killing them. This would ultimately lead to a cocoon with a hole. A good knowledge of Matlab is recommended.

**Design of an Artificial Muscle Based on the Movement of a Worm**

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Description

Artificial muscles in the form of fibres offer many application possibilities. The topic of this research work is an artificial muscle based on the structure of a specific type of worm.

Some worms move forward through local contraction / expansion. This effect is obtained due to the specific structure : a core wrapped with “fibres”. Swelling of the core leads to tensile forces in the fibres, which in its turn causes contraction. Such structures are very analogous to certain types of yarns (wrapped yarns). Yarn models allow the simulation of the properties and behaviour of such structures.

Purpose

The purpose of the research is to set up and validate a model in order to simulate the mechanics of structures which are based on wrapped yarns. Simulations can support the design of both artificial muscles and other applications of such structures. The experimental part consists of the collection of practical data for the validation of the model and the evaluation of some possible applications.

**Realistic Numerical Modelling of the Yarn Behaviour in a Weaving Loom**

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Description

During the weaving process of textiles the weft yarns are woven in transversal direction towards the warp yarns. Weaving of the weft yarns can be done in different ways : (1) the weft yarn can be accelerated by a rapier towards the middle of the weaving machine and consequently be taken by a rapier from the other side; (2) the weft yarn can be blown into the fabric. In both cases the weft yarn is taken from the bobbin at a very high speed. For weaving manufacturers (Picanol, Vandewiele, …) it is very important to know the exact path of the yarn, and to calculate the friction when the bobbin is unwound or when interaction with other yarns occurs.

The Department of Textiles developed a code for the simulation of the unwinding of the yarn from a bobbin. The results are validated with high speed images during the weaving process. The calculation times for the simulation of one single yarn are rising significantly though and the weaving manufacturers are also interested in simulating the interaction of several yarns.

Purpose

The aim of the project is to examine whether the unwinding can also be simulated in the commercial finite element code Abaqus and whether the calculation times can be reduced. To that purpose there will be cooperation with the research group Mechanics of Materials and Constructions, which has experience with finite element simulations of materials for more than 10 years. Although the research is reconnoitering, the promoters already have a number of concrete ideas how the yarn could be simulated and which are the advantages and disadvantages of the different ways of modelling.



Picanol weaving loom with bobbins of yarn at the left side

**Composites: Influence of the Abrasion Resistance of Hybrid Yarns on the Properties of Composites**

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Description

In the transport sector composite materials (polymer matrix + reinforcing fibre) are increasingly used because they can combine very good properties with a low mass. In order to reduce the environmental impact, it is necessary to shift to lighter cars and other means of transport. The challenge with composite materials consists in the time-consuming and expensive production process. In the European project 3D-LightTrans, this problem will be tackled by working to a fully automated production line for high-value composite parts (mainly for the automobile industry). To this purpose hybrid yarns are used. These are yarns which contain filaments with a reinforcing function (e.g. glass fibres) and thermoplastic matrix filaments (e.g. polypropylene). With the hybrid yarn a multiple layer or 3D-structure can be woven. After draping and fixing the fabric, it is possible to store the preform obtained and to transport it without specific temperature requirements. This is not possible with a thermohardening preform. Afterwards the final composite structure can be easily produced by molding the preform.

In spite of the many advantages of this automated production line, several problems still have to be solved, e.g. the damage of hybrid yarns during weaving. Damaged yarns reduce the ultimate strength of the composite and therefore have to be avoided as much as possible. As such, the purpose of the thesis is to study the influence of the abrasion resistance of hybrid yarns on the properties of the composite.

Purpose

The aim is to compare the abrasion resistance of different hybrid yarn structures (e.g. twined, comingled and wrapped), with or without coating and consequently study the mechanical properties of unidirectional composites made from these yarns. The experimental part of this thesis (a.o. weaving simulation, coating, composite production, tensile tests, DMA, ...) and the critical assessment of the results obtained are combined with a detailed literature study to obtain a better insight in the issue.

**Design and Mechanical Characterisation of Innovative Nanofibre Composites**

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Description

Since a few years, nanofibres with a diameter of less than 500 nm can be produced in an economical way via electrospinning. These fibres can be used in a wide range of applications such as water and air filtration, wound bandages, composites, … . The latter application will be dealt with in this project. Although it is a frequently cited application, only limited research has been done so far. So it is all relatively new and unknown. Composites reinforced with glass or carbon fibres have a very high strength. However traditional resins used in composites are often rather brittle so the impact resistance is sometimes too limited. Brittle ruptures can occur between the different textile reinforcement layers. An increase of the ductility of the composite structures could significantly enlarge the applications. Nanofibre structures could imply an important added value in increasing the ductility of the composites, especially with polyamide nanofibre structures. In comparison with traditional glass fibres or carbon fibres, they will only provide a limited contribution as far as strength is concerned, but could mean a big step forwards when impact resistance is concerned. On the one hand, the brittleness of the resin can be positively influenced. Because the pores of a nanofibre structure are smaller than those of a macrotextile, a better mixture with the resin will occur. On the other hand, they can also be used as intermediate layer when several glass fibre layers are used and as such limit the brittle delamination between these layers.

Purpose

Different nanofibre structures will have to be produced for this thesis (at the Department of Textiles). By using different types of polyamides, we can start from different starting properties of the nanofibres (e.g. a higher strength of the fibres). By changing the production parameters, the fibre diameter or thickness of the nanofibre structures can be adjusted to the required dimensions. Afterwards composites will be made with these textile structures via resin injection (Department of Applied Materials Sciences). Different samples will be studied. In order to study the ductility of the resin, pure resin samples will be compared with samples which also contain nanofibres, which can be further subdivided depending on the properties of the fibres. To examine the delamination of the glass fibre composites, glass fibre / resin samples will be compared with glass fibre / nanofibre / resin samples. Characterization of the composites will be done via mechanical trials (bending, tensile and impact tests) and via microscopical techniques (optical and electron microscope). The fibre / resin adhesion e.g. can be examined via microscopical techniques, both before and after rupture because of impact.

**Analysis of the Reaction Kinetics of Stabilization and Carbonization Reactions for the Production of Carbon Nanofibres and their Effect on Fibre Properties**

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Description

Since a few years, nanofibres with a diameter of less than 500 nm can be produced in an economical way via electrospinning. These fibres can be used in a wide range of applications such as water and air filtration, wound bandages, composites, … . Especially for this last application, carbon nanofibres offer an interesting potential. The use of carbon structures such as *vapour grown carbon nanofibres* and *carbon nanotubes* in composites is becoming more important during the last years. It has been shown that such vapour grown carbon nanofibres have a positive effect on the stiffness and the ductility of epoxy matrix composites.

So far, the potential of carbon fibres prepared via electrospinning in composites has only slightly been examined although these fibres offer many advantages in comparison with vapour grown carbon nanofibres. First of all, nanofibres produced via electrospinning are much longer than vapour grown carbon nanofibres; also, they can be oriented more easily and in addition, the health risks when using long carbon nanofibres prepared via electrospinning are almost non-existing whereas vapour grown carbon nanofibres can easily be inhalated because of their short length …

Carbon nanofibres are prepared by spinning a precursor (often polyacrylonitrile or a copolymer of it), followed by oxidation and carbonization of the fibres. Optimizing these reactions is of crucial importance to obtain carbon nanofibres with good mechanical properties.

Purpose

For this thesis the precursors will have to be spun first (e.g. PAN). An important part of the thesis concerns the study of the oxidation / stabilization reactions via thermal analysis (differential scanning calorimetry, thermogravimetrical analysis, dynamic mechanical analysis) and spectroscopy (FT-IR, Raman) and thus come to carbon nanofibres with a high strength and stiffness. In a next phase, the nanofibres obtained will be characterized by means of mechanical and thermal analysis.

**Nanofibre Membranes for Water Filtration : Evaluation of Functionalization Methods**

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Description

Nanofibres can be produced through the electrospinning process. Nanofibres are fibres with a diameter less than 500 nm. These nanofibres are collected in the form of a nonwoven. Nanofibre nonwovens have very specific properties such as a high porosity, a high absorption quality, small pores and a large specific surface allowing them to be used as a filter membrane for water purification.



Figure: Steady state polyamide spun nanofibre membrane

To obtain a good pathogenic and biofilm removal, the nanofibre membranes can be functionalized with components which produce oxygen radicals under the influence of light (e.g. titanium dioxide < UV light and phtalocyanines < visible light). These oxygen radicals can disintegrate organic micro-organisms and thus prevent contamination of the membrane.

There are different methods which are suitable for functionalization. Functionalization can occur during spinning or after spinning by immersion, sputtering or sol-gel. The oxygen radical production of TiO2 is a.o. dependent on the size of the TiO2 particles and the position in / on the nanofibres and as such is influenced by the functionalization method which is used.

Purpose

The purpose of the thesis is the evaluation of different functionalization methods for TiO2. These methods relate to : inline-functionalization, post-functionalization, sputtering and sol-gel method. The influence of functionalization on the structure and filtration properties of the membrane will be examined. The functionalized nanofibre membranes will be characterized by means of SEM-images, tensile tests, filtration and contact tests. By studying the disintegration of methylene blue, the activity of titanium dioxide will be examined. The thesis will elaborate on the already available knowledge of the research group on electrospinning and functionalization of nanofibres.

**Electrospinning of Flexible Silica Nanofibre Membranes by Means of Sol-gel Technology**

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Description

Nanofibres with a diameter of less than 500 nm can be produced via the electrospinning process. These nanofibres are collected in the form of a non-woven which has very specific properties such as small pores, a high porosity and a large specific surface. The sol-gel technology is a frequently used technology to produce very pure dense ceramic materials, thin films, powders, coatings on glass, wood, textiles, etc. The combination of the sol-gel method with the electrospinning process seemed suitable for the production of ceramic nanofibres. The combination of the excellent thermal and chemical properties of ceramic materials with the typical nanofibre properties allow that these ceramic nanofibres can be used for various applications such as filtration, catalysis, sensors, etc. The production of these ceramic nanofibres is not optimal yet and the flexibility of these ceramic nanofibres remains a difficult issue. The non-wovens are fragile and tend to fall apart.

Purpose

The purpose of this thesis is to increase the flexibility of silica non-wovens. The work will start with pure ceramic nanofibre membranes. The influence of the nanofibre diameters and a heat treatment on the mechanical properties will be examined. Pure silica flexible nanofibre membranes would be very interesting for various applications because of the chemical and thermal stability. Further, hybrid polymer / silica nanofibre structures will be examined. The addition of a polymer will provide a higher flexibility. Polyamide 6 will be used as a polymer because this is a known polymer to the end user and is suitable for the end applications. Also, the electrospinning process has already been studied thoroughly at the Department of Textiles. Characterization of nanofibre structures will be done via different characterization techniques. The form, irregularities and diameters of nanofibres will be analyzed via SEM. The composition of the hybrid structures can be characterized via SEM / EDX. The mechanical properties of the membranes can be evaluated by means of tensile strength tests and bending tests, DMA.

**Functionalization to pH-Sensitive Nanofibre Membranes via Sol-gel Technology**

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Description

pH-sensitive textile materials which can undergo a change of colour under the influence of a pH-variation are innovative and high-value materials. These pH-sensitive textile materials can be used for various applications such as protective clothing, wound bandages, etc.

Due to the small nanofibre diameters, nanofibre structures produced via electrospinning possess unique properties such as small pores, a large specific surface and a high porosity. This makes such nanofibre membranes very suitable for the use as sensors. The use of a nanofibre membrane can indeed improve the sensitivity and response time which are important parameters for sensor systems. The addition of these pH-sensitive dyes to polymer solutions already led to promising results but sometimes a too high dye release was observed. This could possibly be avoided by using the sol-gel method.

The sol-gel technology is a well-known process in materials engineering and is used for the production of pure dense ceramic materials, thin films, powders, coatings on glass, wood, textiles, etc. The sol-gel method also offers various possibilities for functionalization, including functionalization with dyes. The application of a sol-gel coating on conventional textile materials seemed suitable for the production of pH-sensitive structures. To make advantage of the unique properties of nanofibre structures, electrospinning of sols to which the dye was added will also be dealt with.

Purpose

The purpose of the thesis is the functionalization of sol-gel nanofibres with dyes for the production of colorimetrical sensors. Focus will be on pH-sensitive dyes. The pH-sensitive dyes will be added directly to the sol for the electrospinning process. The influence of the addition of a dye on the electrospinning process will be examined. The nanofibre membranes will be extensively characterized. The fibre diameters, irregularities and the form of the nanofibres will be examined by means of SEM. Focus will also be on a limited dye release and the colour changing properties of the nanofibre structures. These colour changing properties of the membranes will be characterized with UV-VIS spectroscopy.

**Functionalized Polymers for the Production of Colour Changing Nanofibres**

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Description

Over the last ten years the production, morphology and applicability of nanofibres have been intensively studied for various applications such as biotechnology, environmental technology, production and storage of energy, composites and biomedical applications such as regenerative medicine and innovative wound bandages. Nanofibres which undergo a change of colour under the influence of an external impulse can be used as a flexible sensor within several applications because a change of colour gives an easy and quick signal. Especially in the biomedical sector halochromic nanofibres (nanofibres which change in colour under the influence of the pH value) could offer an added value. Wound healing is linked with specific changes in the pH value and in addition nanofibres simulate the natural structure of human tissue. As such pH-sensitive nanofibres can both monitor and stimulate wound healing. The dyes which provide the pH-sensitivity may not migrate from the fibres, though, since this causes sustainability and cytotoxicity problems. A possible solution for this problem is the use of functionalized polymers for the production of nanofibres via electrospinning. This way the dye is bound to the structure in a covalent way which makes migration to the body impossible.

Purpose

The purpose of the thesis is to obtain a better insight in the possibilities of functionalized polymers for the production of colour changing nanofibres. The research will focus on the development of new functionalized polymers via new reaction mechanisms and new dyes, combined with research on the performance of colour changing nanofibres to produce them.

Several polymers will be synthesized via free radical polymerization with variations in e.g. length, type of the monomer and composition. Each of these polymers will be fully characterized and the stability will be examined. In addition, research will be done on the development of a new pH-sensitive dye monomer, starting from existing pH-sensitive dyes, which can be integrated in the polymer.

Further, a spectral analysis of the dye-fibre systems is essential in order to characterize and understand the change of colour. Possible interactions of the dye with the environment, the impulse sensitivity of the nanofibres produced, etc. are essential to obtain a fundamental knowledge which can be used in future for the development of new materials.

Depending on the foreknowledge and the interest of the student, focus can be on the production / characterization of functionalized polymers or on the production / characterization of colour changing nanofibres.

**Colour Changing Textile Materials as New Sensor Materials**

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Description

Textile materials showing a colour changing effect under the influence of an environmental impulse can be used as flexible sensors. The colour change can be registered by the human eye and thus indicate an alarm signal or an environmental change. Producers of dyes for textile applications have been aware since long of the colour changing character of some dyes. In the past this was often considered to be a negative property (colour instability) and no further research took place. More recently, more research results related to the application of colour changing dyes on textiles can be found in literature. This can be seen in the framework of the growing interest in intelligent textiles where focus is on textiles which undergo a change due to a specific impulse in the environment. These materials have become more important because of their possible implementation in a broad scale of high range applications. In order to apply colour changing textile materials as textile sensors, research on the spectral variations under the influence of different kinds of environmental parameters is required. This master thesis will focus on this.

Purpose

The aim of the project is to obtain a better understanding of the interactions between colour changing dyes and textile materials. Focus will be on pH-sensitive sensors. pH-sensitive dyes will be applied to different textile materials. This will be performed through traditional dye processes but also via electrospinning. Electrospinning implies that nanofibres are produced in which the pH-sensitive dyes are incorporated as extra functionality during production. A spectral analysis of the dye-textile systems is essential to characterize and understand the colour change. The aim is to obtain information on the possible interactions, the distribution of the dyes in the textile material, the impulse sensitivity of the dyes and their spectral variation in function of the place of the textile material and of time. This fundamental knowledge is required in order to better understand how colour changing textile systems function. The knowledge which will be obtained in this thesis will be used in future to rationally apply colour changing properties for intelligent textiles. The application possibilities for pH-sensitive textiles are very broad and cover possible medical applications and applications for protective clothing. Depending on the prior knowledge and interests of the student, focus can be on conventional textile materials, electrospun nanofibres or a combination of both.

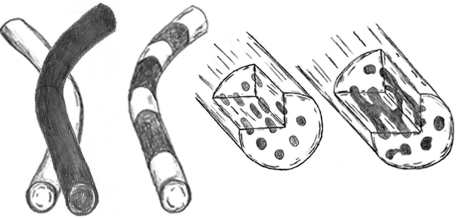
**Electrospinning of Polymer Mixtures for High-Value Applications**

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Description

Nanofibres have a diameter smaller than 500 nm. Nanofibre membranes being made of these fibres have very specific properties such as small pores, a high porosity and a large specific surface. Due to these properties nanofibre membranes can be used in numerous applications such as filtration, bandages, tissue engineering, composites etc. Nanofibres are mainly produced by electrospinning of polymer solutions. Until now these solutions mostly consist of one polymer dissolved in a solvent system. However, to meet the strict requirements set by the high-quality applications, more research is done into electrospinning of polymer mixtures. In this way, biocompatibility can for example be combined with the desired mechanical strength. The electrospinning process of polymer mixtures has not been studied in detail yet, although this knowledge is vital as to obtain nanofibre membranes in a reproducible and stable way.



Purpose

This thesis aims at furthering our knowledge of the electrospinning process of polymer mixtures. At first, the electrospinning parameters will be studied and the preconditions for obtaining a reproducible membrane without drops or other irregularities will be determined. Subsequently, an extensive characterization of the obtained nanofibres will be performed. Fibre morphology is mainly studied through scanning electron microscopy (SEM), which will determine whether the nanofibre diameter is influenced by the polymer mixture. The composition of the obtained fibres is another important factor deserving the necessary attention. On the one hand, the nanofibre structure can consist of fibres that are each composed of one polymer but on the other hand, one fibre can also be made out of different polymers. By dissolving for example one of the two polymers found in the structure, SEM can provide information on the composition of the fibres. Other analysis techniques will be used to study the crystal morphology and composition of the fibres (DSC, DMA, XRD etc.). The results obtained from this research can help forcing the breakthrough of nanofibre mixtures since such profound studies, although indispensable, are still very limited in number. Depending on the student’s interests, this thesis can focus on different aspects of polymer mixture electrospinning. A possible approach can be the study and optimization of the electrospinning process for an innovative polymer blend. Another perspective is the morphological characterization of nanofibres from polymer mixtures and the comparison with nanofibres consisting of only one component.

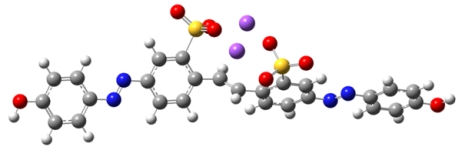
**Relation between Experiment and Computational Model in pH-Sensitive Systems**

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Description

Intelligent textile materials undergo a change of colour under the influence of a certain environment impulse. These materials can be used as simple and flexible sensors because a change of colour can be quickly and rapidly registered by the human eye and as such provide a (warning) signal. Producers of dyes for textile applications have been aware of the colour changing character of some dyes for a long time. In the past however this was considered to be a negative property because dyes for clothing applications need to have a stable colour. More recently, more studies on colour changing dyes in fabrics can be found in literature. In order to use colour changing textile materials as textile sensors, further research into spectral variations and changes of structure of the dyes are required in solutions, powdered and on the textile material. After these thorough analyses, it will be possible to use these materials in a wide range of high-value applications in e.g. both medical applications and applications for protective clothing.



Purpose

The aim of the research is to obtain a better understanding of the interactions between colour changing dyes and textile materials. Focus will be on pH-sensitive systems.

Characterization of these colour changing materials is done by UV/Vis spectroscopy. Another powerful tool for the characterization of dyes and their interaction with the textile material is vibrational spectroscopy (infrared and Raman) allowing us to examine which peaks in the spectrum are sensitive to varying pH and which changes occur in different molecular conditions (solution, textile, …). In order to obtain a fundamental insight in the changing interactions and to assign the registered peaks, computer simulations will be performed of different dyes whether or not in changing circumstances. In this way, the changes in pH-sensitivity can be explained by possible changes in the molecular structure. The simulations build a complement to the experiments performed. This fundamental knowledge is essential to understand how colour changing textile systems work. The basic knowledge obtained through this project will be used in future to use colour changing properties for intelligent textiles in a rational way.

**Research into Monofilaments Based on Ethylene Vinyl Alcohol Copolymers (EVOH)**

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Description

The last decades have seen many developments in the field of artificial turf. New “generations” of artificial turf give an answer to problems of earlier generations. The third generation already meets the requirements of FIFA very well.

A (big) problem remains the interaction of the human skin with the artificial turf. When a player makes a sliding, burns and scrapes still occur. The reason is that artificial turf – contrary to natural grass – does not absorb a lot of heat and thus the skin warms up too much during a sliding. The temperature at the surface of an artificial turf field can reach significantly higher values than on natural grass, up to 65 °C instead of 40 °C for natural grass. This is a very important factor for artificial turf fields which leads to many societal discussions.

If artificial turf could be modified so that the monofilaments absorb water and also possess a certain water adsorption at the surface, an important reduction of burns and scrapes would result from this due to the high specific heat and lubricating effect of water. The absorbed water can cause a serious reduction of the temperature increase and the temperatures at the surface of artificial turf can reach the same values as for natural grass. The monofilaments which are currently used are mainly based on LLDPE and do not absorb or adsorb water.

Purpose

The purpose of the thesis is to study and extrude monofilaments based on water absorbing polymers. An interesting class of polymers which could be suitable are the copolymers EVOH (copolymer of ethylene and vinyl alcohol). First, a literature study will have to be done to make a selection of possible EVOH-copolymers which are industrially available and which possess the highest possible water absorption. In addition, they have to be extrudable. Further, these products have to be extruded followed by an evaluation of the effectiveness of the polymers with different process parameters being examined : temperature, drawing, thickness required, … and the determination of the water absorption of the filaments thus obtained. Based on these results, it should be possible to determine the effect of these monofilaments on the ultimate maximum temperature which can be reached in function of the ambient temperature, the absorbed solar energy and the atmospheric humidity.

**Research into Monofilaments Based on Co-extruded Fibres**

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Description

The last decades have seen many developments in the field of artificial turf.

The development of artificial turf fields started in 1966 with the so-called first generation which consisted of very dense “full synthetic” carpets with short piles without infill material. The second generation of artificial turf was developed at the end of the eighties with longer monofilaments and sand as infill material. The third generation followed in the nineties and consisted of carpets with longer fibres and with sand and rubber as infill material. This illustrates the continuous attempts to improve the performance of these fields. The developments relate to new fibre compositions, new fibre materials and new tufting and fixing techniques. Apart from the advantages and progress which has been made, the problem of long-term properties remains. Attempts are made to develop an artificial turf field which keeps the properties available from the start. Resilience is an important factor in this perspective.

The monofilaments which are currently used are mostly based on LLDPE. Previous experiments show that the mechanical strength of these monofilaments depends on the drawing ratio in the solid phase whereas the resilience of these monofilaments show the best results for undrawn fibres.

Based on former research results, a solution is to produce monofilaments with a multiple layer structure. The inner core of these monofilaments is based on polypropylene (PP) and the outer shell is based on metallocene-LLDPE. Both polymers are compatible and the multiple layer structure thus is characterized by a very good adhesion between both layers. Because of the difference in melting temperature, it is possible to draw the co-extruded fibres in the temperature field between both melting temperatures. The inner core based on PP gives the necessary mechanical strength and the outer shell based on m-LLDPE gives the necessary resilience. These fibres can be fixed in the carpet through melting with a film of m-LLDPE as backing. The department has a semi-industrial production line which has been developed for the production of multilayer monofilaments.

Purpose

The purpose of the thesis is to study and co-extrude monofilaments based on these two polymers. These two polymers belong to the class of polypropylenes and m-LLDPEs. First, a literature study will have to be done to make a selection of possible polymers which are industrially available, which are compatible and which can be drawn. Then these products have to be co-extruded followed by an analysis of the mechanical properties and resilience with different process parameters being examined : temperature, drawing, required thickness of both layers, temperature treatment of the filaments obtained. Based on these results, it should be possible to optimize this new generation of monofilaments.

**Monofilaments Based on Polyesters**

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Description

The last decades have seen many developments in the field of artificial turf. New “generations” of artificial turf give an answer to problems of earlier generations. The third generation already meets the requirements of FIFA very well. For the development of a next generation of artificial turf fields, the use of monofilaments based on polyesters is envisaged. The big advantage of polyesters is their recyclability by making use of postpolycondensation. Also, more so-called “green polyesters” are being produced based on naturally available raw materials. These green polymers are becoming increasingly important.

Several polyesters nowadays are industrially available, going from traditional PET to more supple polyesters. These supple polyesters are more suitable as basic material for the production of monofilaments destined for artificial turf applications.

Purpose

The purpose of the thesis is to extrude monofilaments and to optimize the process parameters. First, a literature study will have to be done to make a selection of possible polyesters which can possess a good resilience and which are extrudable. Then these polyesters have to be co-extruded followed by an analysis of the properties of these monofilaments with different process parameters being examined : drawing temperature, drawing ratio, temperature treatments after drawing. The purpose is to study the influence of these process parameters on the final mechanical properties and resilience and to connect these correlations with the final internal structure of the monofilaments obtained via FTIR, Raman and DSC measurements. These results can ultimately lead to a new generation of monofilaments.