In BIO4SELF we aim for PLA self-reinforced composite materials with high mechanical performance (impact strength and stiffness), superior to that of current self-reinforced polypropylene (PP) existing on the market.
Project overview

BIO4SELF aims at fully biobased self-reinforced polymer composites (SRPC) and the self-functionalization of the material, aiming to induce inherent self-cleaning, self-healing and self-sensing properties.

PLA is a biobased and sustainable thermoplastic polymer with good technical performance (good stiffness and strength). Currently, PLA use is limited, e.g. for packaging applications, for medical applications (e.g. tissue scaffolds, implants and sutures) and to a lesser extent in textile applications (mainly agro textiles).

Hybrid PLA preforms will be made to consist of reinforcement PLA fibres (high melting temperature and high mechanical properties) together with matrix PLA (low melting temperature). These hybrid PLA preforms will be made with different fibre architecture, e.g. chips with short fibres in random orientations, and fabrics with long fibres in controlled orientations. We will add inherent self-functionalization via photocatalytic fibres (self-cleaning properties), tailored microcapsules (self-healing properties) and deformation detecting fibres (self-sensing).

BIO4SELF aims at fully biobased self-reinforced polymer composites (SRPC). To produce the SRPCs two polylactic acid (PLA) grades are required: a low melting temperature (Tm) one to form the matrix and an ultra high stiffness and high Tm one to form the reinforcing fibres. To reach unprecedented stiffness in the reinforcing PLA fibres, we will combine PLA with bio-LCP (liquid crystalline polymer) for nanofibril formation. Further, we will increase the temperature resistance of PLA and improve its durability. This way, BIO4SELF will exploit recent progress in PLA fibre technology.
To produce such high performance self-reinforced polymer composites (SRPCs), we need two levels of reinforcement: (i) self-reinforcement by combining two PLA grades with different melting temperatures and (ii) reinforcement of the high Tm grade PLA fibre for increased stiffness and temperature resistance. Both reinforcement approaches are now explained in detail.

(i) Self-reinforcement by combining two PLA grades: a low melting temperature (Tm) grade which will melt upon heating to form the matrix phase and a high Tm grade to form the reinforcing fibres, which must remain intact during processing. The objective is to realise the combination of these two grades via various techniques for making intermediates. The resulting intermediates allow the production of components using different manufacturing processes (i.e. compression moulding for yarns/fabrics and tapes and injection moulding for pellets and tapes (via overmoulding)).

(ii) Additional reinforcement of the high Tm grade PLA fibre for stiffness and temperature resistance: innovative approaches will be applied for the development of these ultra-stiff high temperature PLA reinforcing fibres. In particular, we will mix PLA with bio-LCPs (liquid crystalline polymer).
Concept and approach

The need

Recently, there is a worldwide demand for replacing fossil-based with biobased raw materials for the production of polymers, leading to a significant growth of bioplastics in terms of technological developments. However, there are still some drawbacks which prevent their wider commercialization in many applications. This is mainly due to their low mechanical performance and durability when compared to conventional polymers. Enhancement of these properties remains a significant challenge for biobased polymers. Therefore, there is a need to develop biobased, sustainable polymeric materials with high stiffness, high impact and high durability without impairing recyclability at a similar price level of non-biobased solutions.

Proposed solution

The development of self-reinforced polymer composites (SRPC) is proposed as a means to enhance the mechanical performance of biobased polymers. With respect to the performance of SRPC the ease of recycling has to be emphasized, since they represent likely the best recycling option when reprocessing via remelting is targeted. Among biobased polymers, PLA is an ideal material for the preparation of SRPC, as it can be produced with controlled molecular configuration (molecular weight, molecular alignment, crystallinity, ratio between L- and D-lactic acid etc.), resulting in a range of mechanical and thermal properties, including different melting points.
Project Partnership

Fifteen partners participate in the BIO4SELF project, representing academic, applied research and industrial development. The project consortium is transnational, spanning the whole EU and consists of 3 Universities, 3 RTD Centres, 5 SMEs and 4 Large Enterprises. Aiming to ensure that the technologies developed in BIO4SELF can be commercialized post project, the consortium includes organisations from all aspects of the supply chain, from raw materials development to component manufacturing. Each partner brings selected expertise required for realising the objectives of BIO4SELF.

CTB Belgium, DTU Denmark, ITA Germany, ICT Germany, UM Netherlands, NTT Italy, MAIER Spain, ARCELIK Turkey, COMFIL Denmark, TECNARO Germany, FIBROCHEM Slovakia, MIRTEC Greece, IBA Belgium, R-TECH Germany, OSM UK

Picture: The BIO4SELF partners during the M4 meeting.
Early steps towards self-functionalised PLA fibres

Following aspects are covered:

- Odour reduced PLA
- Hydrolytically stable PLA
- Self-healing PLA
- Self-sensing PLA
Odour reduced compounds

The application of melt purification technologies can significantly reduce emission from thermoplastic materials. The main field of the application is the removal of odour intensive monomer residuals from virgin materials. Two technologies are available: stripping-agent assisted degassing and extractive extrusion. Using the stripping-agent process, different solvents are possible, the equipment is lower in price and the inserted shear energy is significantly lower. Yet, biopolymers like PLA require a delicate processing, avoiding increased shear rates and high temperatures. Design and adjustment of the stripping process, offering low shear energy input in the melt, so that no degradation of the bio-composites will occur. Fraunhofer ICT will focus in BIO4SELF on identification of suitable stripping agents for the developed PLA-compounds, ensuring high quality odour free materials and thus a real benefit for consumer products.

Hydrolytic stabilization

The hydrolytic stability of PLA-based polymers during processing, storage and use is of critical importance for a successful market penetration, especially for applications with long lifetime. One of the critical properties defining hydrolytic degradation kinetics in aliphatic polyesters is the carboxyl end group concentration (COOH). One approach is to reduce the COOH content during the polymerization. An alternative, more versatile and with higher level of readiness route, which will be applied in the frame of BIO4SELF, is the chemical modification of -COOH groups with reactive blocking agents prior or during polymer processing.
Self-cleaning

The self-cleaning properties will be promoted by incorporating photocatalytic materials on the outer layer of the composites enabling organic soils’ decomposition. With UV irradiation, Photocatalyst reacts to oxidize/reduce the surface which decompose hydrocarbons and can reduce soil adhesion. The most used photocatalyst is Titanium Dioxide nanoparticles: small particles (5-50 nm) of titanium dioxide (TiO2) act to catalyze oxidation of adsorbed molecules in the presence of above-bandgap ultraviolet light (UV, wavelengths smaller than 390 nanometers). Despite its large usage, the European Commission communication “Towards a European Strategy for Nanotechnology” states that it is requested to take into account the impacts of nanotechnologies throughout their whole life cycle, in order to prevent or minimize potential adverse effects to human health and the environment. In order to overcome the concerns related with the potential risks related with Nanoparticles/Nanomaterials, within BIO4SELF project, photocatalytic organic polymers synthesized by functionalization of existing commercial products will be produced and tested. The effectiveness of the self-cleaning property will be monitored by reducing up to 70% of ‘model soiling’ with fatty acids and triglycerides.

Self-healing functionalization

Self-healing polymers possess the ability to heal in response to damage occurring in the material, offering a new route towards safer, longer-lasting products and components. Especially for PLA and its composites, self-healing functionalization emerges as a critical point, due to the relative brittleness of the virgin polymer. Therefore, in the frame of BIO4SELF we will develop thermally stable microcapsules. These will be incorporated in the PLA material, along with appropriate amounts of Grubb’s first generation ruthenium metathesis catalyst. Upon damage and rupture of the microcapsules, the encapsulated monomer will be released and polymerize to heal the material. It is noted that in order to avoid deterioration of the original mechanical properties due to incorporation of the microcapsules, these will only be applied on the outer layer of the final prototypes aiming specifically at scratch healing.
Self-sensing functionalization

The self-sensing composite is based on a CNT compound tape/filament which is overmoulded with non-functionalized matrix polymer. Due to variation in the CNT network by bending the material the electrical conductivity changes. The strain can therefore be measured as a function of change in the electrical resistance. At Fraunhofer ICT it has been shown, that the correlation between deformation and indicated electrical resistance is reproducible and shows a linear behaviour. A smart self-sensing PLA material will be developed in BIO4SELF to detect overstressing of materials. One way to realise this is to compound CNTs into the polymer, spin the compound to filaments, which in turn will be processed into a fabric. The fabric will be placed in highly stressed areas of an injection moulded component enabling a local reinforcement and a self-sensing at the same time. The principle will be transferred to a complex component with continuous fibre reinforcement.

Melt Spinning Line

PLA with low-melting point for the matrix is currently processed in a melt-spinning-machine at ITA, RWTH Aachen University. The results, used as reference, will be compared to other PLA grades with various additives. At the moment, multifilaments are spun, followed by monofilaments in the upcoming weeks. A schematic layout of the melt-spinning-machine is shown in the picture.
First high temperature PLA filaments.

Centexbel is currently producing the first high temperature PLA filaments using the selected reference PLA grades. The aim is to optimise the melt spinning process in order to maximise the stiffness and strength of the PLA filaments. In addition, fibre materials for the following steps in the process chains are being produced.

Picture: First production runs for high temperature PLA filaments.

PLA Crosslinking via E-Beam irradiation

PLA as sustainable biodegradable thermoplastic is expected to be widely used in the near future replacing many non-biobased and non-biodegradable engineering plastics, but resistance to thermal treatment of PLA is not relatively high above glass transition temperature (Tg), 60 °C, thus it can represent a constraint for further exploitation. However, crosslinking technology would be effective in improving this property and consequently expanding the utilization of PLA. Therefore, within BIO4SELF, E-Beam radiation-induced crosslinking of PLA will be investigated to improve its thermal stability up to 20-30 °C compared to native polymer. The addition of a suitable crosslinker agent (multibranched chemicals) will be investigated keeping in mind the risk management protocol to be implemented in the processing of modified materials. Evaluation of most efficient industrial processing methods are also part of the scope.
The use of nanomaterials has increased in the recent years mainly due to the developments in the nanotechnology field and the added advantages of the nanomaterial. The growing demand of the nanomaterials and their widespread application leads to some emerging risks, which are not fully covered with the existing specific regulations. In the BIO4SELF project, a new kind of nanomaterial, bio-LCP nanofibrils, will be developed and used in several industrial applications. Because of the material unknown safety characteristics, a safety guideline has to be prepared for different stages of the life cycle. The first release of the document will ensure awareness of the partners about the safety-by-design approaches and therefore it will cover a comprehensive literature review of already existing guidelines for the emerging new technology risks (e.g. the new nanomaterial risks). Also a methodology was aimed to be proposed to ensure regulatory preparedness of current guidelines and their future practical applications based on CEN Workshop Agreement (CWA) 16649:2013 risk governance framework. After that, the second release will focus on several industrial applications of the proposed methodology in order to support the further exploitation of the applications by the end users. The first release of the safety guideline covers a comprehensive literature review and also data analyses (e.g. semantic analysis, profiling) to identify and link the similarities between current guidelines and the risk governance framework (CWA 16649:2013). Based on the analyses, several guidelines from European Commission, BAuA (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin / Federal Institute for Occupational Safety and Health) and also several projects from CORDIS database (e.g. NANoREG2 and SCAF-FOLD) were determined which can provide inputs to BIO4SELF project requirements such as safety handling processes and safe-by-design concept. Once and for all, with the integrated safety guideline, a comprehensive framework for the safety handling and use of bio-LCP nanofibrils can be provided and also with industrial applications efficiency of the methodology can be evaluated.
Successful KO meeting in Brussels

BIO4SELF started officially on March 1, on March 1-3 the KO meeting took place in Brussels. All partners participated in the event. Next to the official meeting part, the KO was also used for visiting IBA.

Picture: The BIO4SELF partners in front of IBA proton accelerator during the kick-off meeting.

Meeting at COMFIL, Gjern, Denmark

On May 30th the project partners that are involved in work packages 2 and 3 (COMFIL, CTB, ITA, UM) met with support from WP 4 partner DTU in Gjern, Denmark. The meeting started with a status update on WP 2 and material planning for the hybrid yarn production. After that several WP 3 topics like procedures and material needs to continue in the composite sample production as well as testing were discussed. This included a tour through COMFIL’s facilities and a demonstration of their testing equipment. In the evening some attendees visited the “Himmelbjerget” (sky mountain), the second highest... hill... of Denmark (147 m above sea level).

Picture: “Himmelbjerget” (sky mountain)
General Assembly meeting at M4 in Istanbul

To have a quick follow up of the ‘good intentions’ at the kick off meeting, the first general assembly meeting was already organised at Month 4. It took place at partner ARCELIK in Istanbul. The meeting confirmed the first milestone: first reference PLA materials agreed on and first materials safety guidelines established.

The consortium visited the washing machine production plant of partner ARCELIK. However, given the temperatures (>40°C), a visit to their refrigerator plant might have been more appropriate.

Picture: The BIO4SELF partners during the M4 meeting in Istanbul.

Several partners issued a “press release” for the BIO4SELF kick off.

Following the BIO4SELF project start, several partners issued a press release. This was published on the partners’ websites but got also picked up by magazines and journals. A couple of examples below, to show the wide spreading of the news.

Picture: The press release about the project by partners IBA (above) and ICT (below).
Several partners issued a “press release” for the BIO4SELF kick off.

Picture: The COMFIL press release about the project.

Picture: The ARCELIK press release about the project.

Partner UM got contacted for an article on BIO4SELF in the magazine “Agro en Chemie” (in English: “Agriculture and Chemistry”), which focuses on biobased topics. Following this, both Dietmar (UM) and Guy (CTB) were interviewed. The resulting article is scheduled to be published soon on the website of the magazine.

Picture: Dietmar posing for a flashy picture being made by journalist Richard Bezemer who writes for ‘Agro en Chemie’ (first) and the result (second).
More info on BIO4SELF

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