Issued by Norner AS
November 2022

NORNERNEWS 22

Circular economy initiatives

Our new Polymer Exploration Centre

Polymer industry expertise

norner™
The Polymer Explorers

The Polymer Explorers

Contents

4 Four at Norner

6 Our own inauguration

8 Chemical recycling

10 Catalyst innovations

12 In-situ additivation

14 Light diffusion agents

16 Norner battery technology centre

18 Mono material solutions

20 Processing pilot centre

22 Recycled food packaging

24 Medical device

26 Pharma packaging services

28 Sustainable fishing gear

30 Novel waterproofing membranes

Transitions towards a circular net zero industry

Dear reader

Norner is created on a vision to be The global market leader of Industrial R&D services in Polymers by exploring opportunities and discovering Sustainable solutions. For almost five years now, I have enjoyed working with my highly competent colleagues and excellent customers worldwide. I can assure you that this vision is alive, more than ever.

After more than two years with Covid-19, Europe and most other countries worldwide can now enjoy a more normal situation. During these two years, Norner has been in continuous development. 2021 was another record year. And 2022 will be even better. Norner has never welcomed so many new colleagues as we had in 2021. Key competence from all over the world. Over the last five years, we have also invested an all-time high in new laboratory equipment and pilot lines and have never been in a stronger position to support the business growth of our customers.

Unfortunately, the pandemic was followed by another crisis in Europe and elsewhere, and we can only hope that the situation normalizes as quickly as possible. Europe and several other countries are now facing the "perfect energy storm" when it comes to lack of energy. The Winter of 2022/2023 will be challenging, but the future scenario is also challenging. The prospect of a green shift may have contributed to oil and gas investments falling, but without producing an equally strong increase in renewable investments. On the other end, we are wasting resources by not reusing, recycling and taking out the valuable resources that are wasted. It is now really time to accelerate the transitions towards a circular net zero business.

Our business focus, innovations and investments address climate change, renewable energy solutions, resource scarcity and plastic waste. These are the top focus areas of Norner. This is also reflected in our new organization by creating strong business units for the Polymer Industry and Consumables, and strengthening our focus and investments in emerging businesses; Health Care, Automotive/Infrastructure and Energy.

For Norner, 2022 will be a memorable year. At the beginning of 2022, we successfully moved into our new Polymer Exploration Centre. Located in Porsgrunn, near the railway station with an excellent connection to Oslo, as well as near Torp international airport. We eagerly look forward to welcoming you to further explore new and sustainable solutions together, in the new 4600 square meter centre with laboratories, pilot hall and offices.

The following years will be critical to succeed with the transitions towards a net zero industry.

Enjoy the reading!
- Kjetil

New employees at Norner

Norner has opened the new Polymer Exploration Centre and our team is also continuously growing. We are very proud to welcome our new colleagues who will bring valuable expertise across the Norner organization.

Ada Meyer
Proj. Controller/Grp. Leader

Håkon Pettersen
Engineer

Janne Olsen Frenvik
Principal Researcher

Karina Asheim
Researcher

Krishna Kumar
Senior Engineer

Mari Thuve Øwre
Director Energy

Naveen Singh
Senior Researcher

Pål Mofossbakke
Engineer

Ragne Marie Skarra
Senior Researcher

Reza Rashedi
Senior Researcher

Stine Rørvik
Adm. Consultant

Trym Tempelen
Engineer

Valeriya Føreland
Project Controller

Norner in Denmark

Since 2019, Finn Elbæk Jørgensen, through his company Elbæk Consult, has been Norner's representative in Denmark. Finn lives and works from Odense, a central location in relation to Norner's customers. Odense is located between the traditionally large plastics industry in Central and West Jutland and the pharmaceutical/medical industry in the greater Copenhagen area.

In Denmark, in these years, there has been a strong focus on sustainability in almost all industries, and one of the reasons for the fine growth Norner has had in Denmark is that Norner has been able to contribute good services in this important area. In addition, Finn has made Norner known as a provider of major development projects and a large selection of laboratory services and consultancy. Finn is also very active in various networks in the Plastic Industry and the Danish Material Network, where a lot of knowledge sharing and "contact sharing" takes place.

4 Four at Norner

Asbjørn Iveland
Principal Researcher
From: Øvrebø, Kristiansand, Norway
Lives in: Stathelle, Bamble, Norway

I was born in a small town called Øvrebø (outside Kristiansand). When I grew up, all my childhood friends became truck drivers and mechanics, but that i did not find interesting. Chemistry has always fascinated me, and I discovered there was a chemistry class offered in Kristiansand. After studying there for two years, I joined Statoil in Bamble. I realized after working there for five years that I wanted to gain more in-depth knowledge of chemistry. Therefore, I applied for a Master's degree at the University of Oslo. Upon completing my Master's, I returned to Grenland in 1996 and was hired as a Researcher in Borealis.

I very much enjoy living in this region called Grenland. In my opinion, this is a place that has it all, with a scenic archipelago and proximity to ski areas and mountains. Forest hiking and mountain hiking are two of my favorite activities, and due to its close connection to nature, Grenland gives me the opportunity to do this often.

At Norner, electron microscopy and infrared spectroscopy are my main areas of expertise. Even though I have been employed here for many years, I still feel that the job has evolved considerably over the years. I enjoy working at Norner because I am always learning something new. Each day we face new challenges, issues and customers. The work environment is fantastic, and I have a lot of friendly and helpful colleagues. It is probably those two factors that make me most excited about coming to work every day.

Science has always been my passion. I knew that my education would be based on chemistry and mathematics. In a job, I wanted to be able to use both my practical and theoretical skills. Therefore, I chose to study Industrial Chemistry and Biotechnology at NTNU in Trondheim. Upon completing my studies, I got the opportunity to be a part of Norner and moved to Grenland.

Grenland is a great place to live and a very pleasant area. I like that it's close to my hometown, so I can make frequent trips home to see my family. Being a nature lover and hiking enthusiast, I appreciate the city's close connection to nature. In addition, I spend a lot of time with my family at the cabin that is located just a few hours away from Grenland.

As of today, I have two areas of work in which I am involved. This means that half of my time is spent testing mechanical properties, like how much a certain material can withstand before it is damaged. The other half is spent analyzing the lifespan of materials in various environments. My role at Norner also entails being the ISO 17025 quality manager.

Getting to do so many different things every day is what makes working at Norner so rewarding for me. There are many exciting and diverse projects where you can learn something new every time. Also, there are a lot of helpful people here who are always willing to teach you new skills. This makes the work environment enjoyable as well and is the main reason why I love being a part of Norner.

Henriette Skarpeid
Senior Consultant/Engineer
From: Søgne, Kristiansand, Norway
Lives in: Porsgrunn, Norway

Naveen Singh
Senior Researcher
From: India/USA
Lives in: Vessia, Porsgrunn, Norway

When I finished high school, I knew I wanted to be an engineer. I was hooked the moment I discovered polymers. This led me to study Polymer Engineering and Technology. Following college, I worked at GE Plastics analyzing polymers. After working there for about 2.5 years, I moved to the US and got a Ph.D. in Polymer Science and Engineering at the University of Massachusetts Amherst.

While in the USA, I worked for several companies, including 3M, Berry Global, Stress Engineering Services, and Reckitt. After 15 years in the US, I moved to Norway and started my career at Norner as a Senior Researcher. I research recyclable polymers, polymers in batteries, and how to utilize polymers to produce new products.

Norway is a very family-oriented country, and I often feel like it's a country made for children. This was one of our main reason for moving here. Grenland area itself is very quiet compared to the places I lived in the US. I spend a lot of time in nature here, and like that nature is so easily accessible. The close connection to industry also allows me to work closely with many local customers, and I get to meet so many people from different parts of Norway and even the world.

In terms of polymer research, Norner is very well positioned. It is unique to work with a company that operates so broadly in this field, spanning the complete polymer value chain. Despite working with polymers for many years, I have found that there is still so much to learn. With Norner, you'll find people with 30-40 years of experience in the field who are always willing to teach. This desire makes it easier to establish a closer relationship with those who work here and grow together as a team.

I grew up in a beautiful city in Iran called Isfahan. I followed in my father's footsteps in chemical engineering and polymer production. As early as 18 years old, I got involved in polymer research via my studies at university and my part-time work in my dad's factory producing phenolic resins.

I got my Engineering Diploma in my hometown, Isfahan, where I studied Chemical Engineering, specializing in Polymers. At the age of 22, I was awarded a scholarship by the French government in order to continue my studies in France. As part of my ten years in France, I completed my Engineering diploma, Master's and a Ph.D. degree in Chemical Engineering, specialization in Polymers at École Nationale Supérieure des Industries Chimiques (ENSIC), taught at the university and worked as a researcher and project manager for a well-known company called Bel Group.

At the age of 32, I applied for and was hired at Norner as a Senior Researcher. I followed my husband's dream of settling in Norway. At the time, he lived in Porsgrunn. This opportunity made moving here very easy.

Norway is a great place to live. I appreciate Norway's social structure, its values, and its sustainable investments. Norway's family-oriented approach and equal support for health, education, and work are appealing to me. I live in a very pleasant neighborhood in Vessia, Grenland, that is very family-friendly. In addition to being close to nature, mountains, and the sea, Grenland is also a safe, friendly place to raise our kids.

Since my first interview with Norner, I have felt strongly passionate and committed. The environment is very future-oriented. Though there are many seniors here, everyone has a young mentality and is always eager to help. These are the main reasons I look forward to coming to work every day.

Sara Ronasi
Director R&D Catalyst
& Polymer Technology
From: Isfahan, Iran
Lives in: Vessia, Porsgrunn, Norway

The Grand opening!

On April 1st we celebrated the opening of our new Polymer Exploration Centre with all employees.

As a theme throughout the day, we used our values **passion**, **confidence**, **impact** and **imagine**.

We started the celebration with teamwork at Jarseng Sporsstue in Skien where the teams challenged each other in Hammock building and climbing, firewood competition and ice bathing. All done with enthusiasm and good team spirit. The grand opening in the evening was arranged inhouse in Polymer Exploration Centre where we used the whole building as a stage.

Now we are looking ahead and are very proud of our new building with new advanced laboratories and facilities. We are more than ready to welcome, customer and clients to Polymer Exploration Centre.











Pointbreak

Creating technology for tomorrow from experience and knowledge built in the oil and gas industry

Hitec Products has designed, built, and installed various modular sub-sea and offshore electro-hydraulic control systems and chemical injection and process packages for the O&G industry around the world. Since its start in 1997, more than 1600 deliveries have been made.

A few years back, Hitec Products made a strategic decision to expand its business and use its expertise in emerging technologies to accelerate the transition to a circular economy. In 2020, Pointbreak was established to spearhead their new initiative to turn plastic waste into valuable products. Pointbreak's vision is to establish the company as a global technology provider in the chemical recycling of plastics by providing modular systems designed to transform plastic waste into valuable chemicals which will replace virgin feedstock.

Lars Evensen
lars.evensen@norner.no

"Whomever we consulted about our ambitions within chemical recycling, they told us to talk to Norner. [...] We are happy to have signed up Norner as our research partner for technology development."

Tor-Atle Deisz, CEO of Hitec Products and Pointbreak

Norner has long experience in developing polymer solutions for packaging applications and a thorough understanding of solutions used in the packaging sector, which accounts for approx. 40% of global plastic consumption.

Most companies along the plastic value chain are working hard to reduce the environmental footprint of their products and activities. Norner is engaged in numerous projects to develop commercial solutions in the mechanical recycling of plastics. However, the challenges of mechanical recycling, like reduced mechanical- and processing performance and worsening of taste and odor, limit the uptake of such materials in a circular economy. Additionally, a significant volume of plastic waste consists of complex multi-material or complex laminate structures, where various polymers are combined to meet the requirements of various properties like barrier, printability, weldability, glossiness and mechanical performance at minimum weight. The complexity of plastic waste which needs to be recycled and the requirements facing plastic materials to be put on the market makes mechanical recycling unfit for numerous applications where plastics are extensively used today.

The fact that most types of plastic are degraded during repeated

Tor Atle Deisz, CEO of Hitec Products and Pointbreak (left) and Kjetil Larsen, CEO of Norner signs the R&D agreement.

Pointbreak and Norner team during a "polymer value chain" training session at Norner.

For further info please contact:

Siw Bodil Fredriksen
Strategic Advisor, Emerging Technology & IP
siw.fredriksen@norner.no

Lars Evensen
Vice President Polymer Industry BU
lars.evensen@norner.no

processing required in mechanical recycling makes it evident that plastics cannot stay in the mechanical recycling loop forever. Improved stabilization and adding boosters will extend the number of loops a plastic material can endure, but eventually, virgin plastics must be added, and a corresponding part should be recovered through chemical recycling.

"We are developing an advanced technology together with Pointbreak, which we strongly believe will contribute to a more efficient and robust chemical recycling of complex plastic waste. […] And our view is supported by both Innovation Norway and The Norwegian Research Council, who have awarded Pointbreak funding for further research."

Siw B. Fredriksen, Strategic Advisor at Norner

Pointbreak will install a lab pilot unit in Norner's facilities, and validation of the technology will be started in the autumn of 2022 with a dedicated team of Norner experts. The next steps include in-depth process and product studies, as well as modeling and simulation for the scale-up.

Pointbreak has already secured property for the planned semi-commercial demo plant. The demo plant will be utilized, among others, to support licensees of Pointbreak to qualify various plastic waste streams for the technology as well as to train their operators. Further technology development is expected to establish Pointbreak as a global technology provider in the chemical recycling of plastics. This will require significant investment, and when the time is right, Pointbreak will open for a financial partner(s) with ambition in the circular economy.

The technology will produce naphtha as the dominating fraction, and Pointbreak is currently in discussions with potential clients in various parts of the plastic value circle. The market is in constant development; the waste management industry is looking into forward integration, the polymer industry into backward integration, and companies within O&G / refineries are searching for alternative feedstock.

"The future for Pointbreak looks bright, and we are now looking forward to starting on upscaling when the lab pilot has delivered its part. […] It is exciting to dive into what for us is a new technology and a new market; hence it feels safe to make the dive together with Norner, who has deep knowledge in polymers and related markets."

Rune Johansen, Operations manager at Pointbreak

Securing catalyst innovation and supply

To enter any kind of polyolefin production on an industrial scale, the following elements need to be in place:

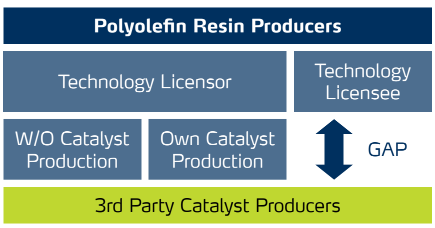
- Feedstock (raw materials)
- Polymerization process technology
- Production assets
- Catalyst (or initiator)

Albrecht Dix
albrecht.dix@norner.no

The impressive growth of polyolefin production capacities in the 21st century in the Middle East (Gulf countries) and North America illustrated that access to cheap feedstock (shale gas boom) and the growing demand for plastics attracted easily large sums of investment funds. Access to process and catalyst technology was usually obtained through licensing agreements.

With the catalyst at the heart of the polymerization, a licensee is thereby uncertain dependent on the licensor and its tolling partners for the supply of this crucial ingredient. What is more, there seems to be a change in licensors' priorities from licensing the technology to building their own capacity alone or in joint ventures. Consequently, access to the latest catalyst technology enabling the production of High Value Added (HVA) products such as PE100, easy processible mLLDPE or rTPOs is often limited to JVs with the licensors only.

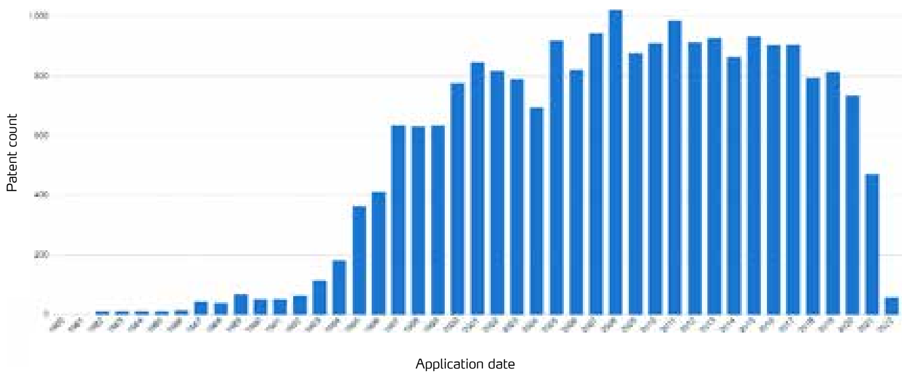
Figure 1 Polyolefin Catalyst Market Structure.



However, increasingly new potential suppliers of catalysts are available on a global scale. To overcome the hurdle of qualifying alternative catalyst supply, Norner acts as an independent validation party, bridging the gap between catalyst manufacturers and PO producers. The range of catalysts and polymerization technologies thereby:

- ZN PE
- Metallocene PE
- Chromium PE
- UHMWPE capable catalyst
- ZN PP
- Metallocene PP
- PE Slurry, uni- and multimodal
- PE gas phase
- PE combining slurry and gas phase
- PE solution
- PE bulk and gas phase, multi reactor set-up

Graph 1 Patents filed related to metallocene catalysts by application date.



It should also be noted that yearly a multitude of patents related to PO metallocene catalysts is being filed. Since 1997 at least 600 (!) have been filed yearly. But with the bulk of patents, especially in metallocene-based polymerization catalysts, already filed at the end of the 20th century, now more than 4000 of these have expired. This opens possibilities for own catalyst developments based on free-for-use complexes. Graph 2 depicts the fast and thorough evaluation of complexes with High Throughput Experimentation at Norner Xplore, a company in the Norner family. Fundamental polymerization parameters such as hydrogen sensitivity, molecular weight capability and comonomer response can be obtained and even more important first pointers towards process fit economy are available through the activity profile (Graph 3) and polymer powder characteristics.

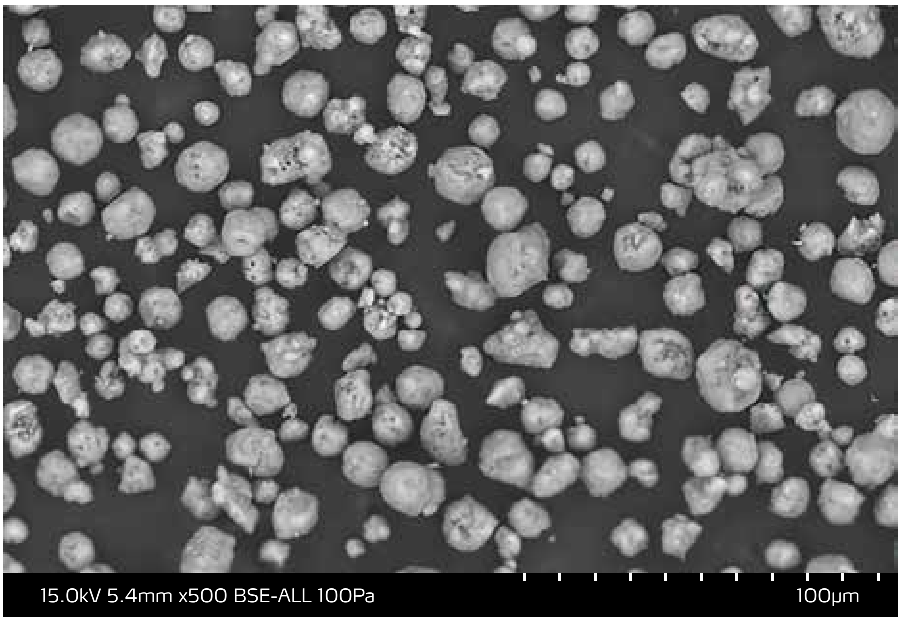


Figure 2 Metallocene catalyst based on silica carrier characterized by Scanning Electron Microscopy.

To bridge the gap from lab-scale R&D catalyst development to commercial production, Norner has access to a catalyst manufacturing process on a pilot scale. This offers an alternative to the catalyst preparation on a lab scale and allows the preparation of larger (0.5kg) catalyst batches. Thereby polymerization pilot trials can be supported and results transferred back to the commercial catalyst producer of choice. Norner can deliver heterogenization of catalytic chemistry on commercially available (or by own preparation) carriers such as $MgCl_2$ or SiO_2 (Figure 2). This opens the possibility for assessing the benefits of alternative carriers in catalyst development. Here Norner can offer the testing either in high-throughput screening mode at Xplore or lab-scale evaluation in semi-continuous mode, with yields up to 3-4 kg, followed by testing of mechanical properties and application performance. Norner is daily mimicking multi-reactor technologies, e.g., for multimodal HDPE or complex advanced heterophasic copolymers of PP.

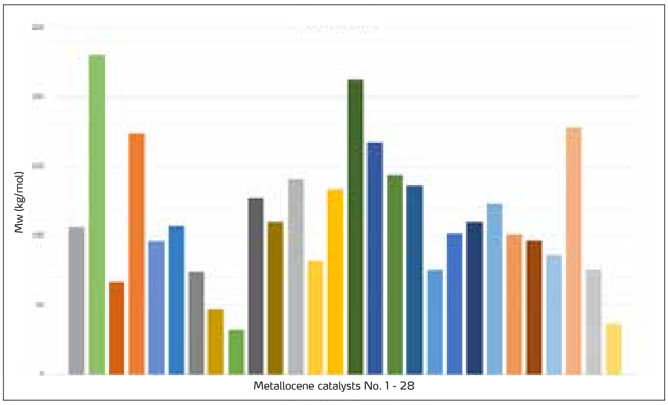
In summary, diversifying the available catalyst toolbox for a polymer producer is no miracle work anymore. Norner can support clients in connecting to 3rd party catalyst producers, speeding up evaluation (qualification) work or developing freedom-to-operate or even new catalysts. The following tools can be used in this process:

- High Throughput Experimentation at Xplore
- Pilot scale catalyst preparation up to 0.5kg
- Catalyst characterization
- Lab scale evaluation with polymer yield up to 3-4kg
- Evaluation of material properties
- Application performance

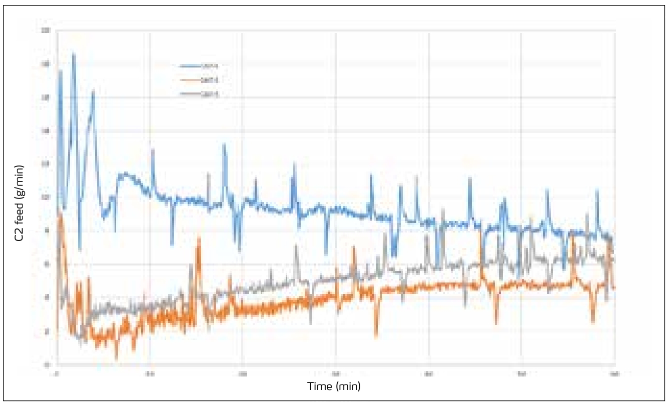
For further info please contact:

Albrecht Dix
Principal Business Developer
albrecht.dix@norner.no

Lars Evensen
Vice President Polymer Industry BU
lars.evensen@norner.no



Graph 2 Fast Screening with HTE – here is the molecular weight capability of 28 metallocene catalysts at a defined process condition for PE copolymer.



Graph 3 Comparison of activity profile for silica carrier-based metallocene catalysts (semi-continuous bench scale polymerization)

In-situ additive technology:
Less is more

Polyolefin discovery and innovations have undoubtedly revolutionized people's life. Nevertheless, the related polymer materials and their uses are under growing scrutiny due to their environmental footprint, being pushed toward a circular plastic economy. Industry and academia are engaged in several initiatives to tackle it and to maintain polyolefin as an everlasting successful endeavor.

Cesar Barbosa
cesar.barbosa@norner.no

Recycling solutions are probably the most sought approach to moving from linear to a circular and more sustainable solution. However, polymer modification by additives and how these can be integrated in the catalyst and process development, also offers additional opportunities to be pursued.

The use of additives through the combination of a specific substance(s) and polymers (e.g., polyethylene and polypropylene) helps to enhance or even create new polymer properties. Figure 1 shows how broad the additive role or function spans.

Traditionally the additives are mixed with polymer powder between the reactor and the extruder or added separately to the extruder. In the extruder, shear/mixing at elevated temperatures takes place, targetting homogeneous pelletized products (Figure 2). It is well known that certain additives are poorly dispersed under this process.

Alternative approaches to this conventional additivation have been proposed in the 80s, with the additive being added earlier in the polymerization stage, which is known as in-situ additivation.

The in-situ method should not change the additive function (stabilization, nucleating effect, etc.). The benefit seems to come from the better additive distribution in the polymer matrix and, consequently, less additive is required in comparison to the conventional additivation. In some cases, homogeneous dispersion improves the thermal, mechanical, or optical properties of the polymer, boosting the polymer's performance.

Norner has explored different in-situ additivation methods, using our bench scale reactors, analytical and mechanical evaluation and small-scale conversion pilots. In-situ stabilization

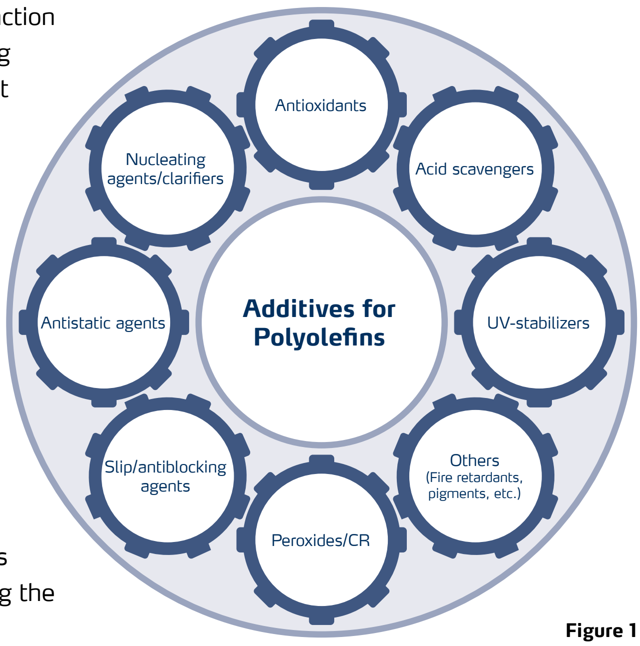
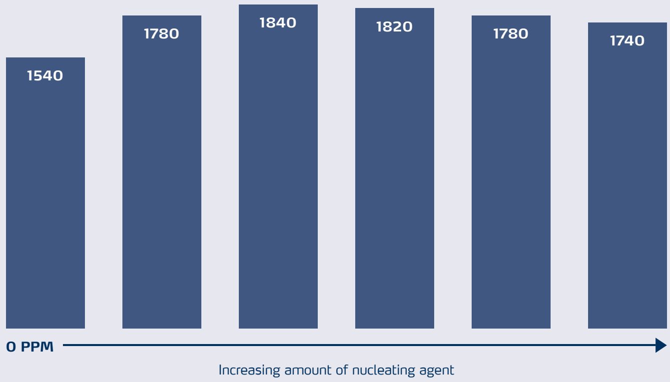
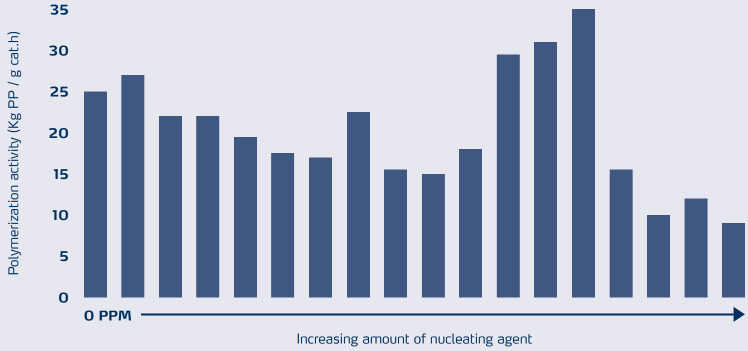


Figure 1

Graph 1 Flex modulus of PP in-situ nucleated



Graph 2 Polymerization activity of PP catalyst screening with in-situ additive*



*Bulk homopolymerization conditions for screening:
T = 70-80°C; Al/Ti (mol/mol) = 50-150; Al/Si (mol/mol) = 0.5-5.0, Reaction time = 35-60 min.

and nucleation have been proven beneficial to the polymer properties, as published in the 2018 edition of Norner News. Graph 1 shows another example of the effect of technology with in-situ additivation for nucleating agents in polypropylene.

At the optimum level, less additive means higher stiffness to the polymer, as was observed in this Norner internal development. Such results require consistent experimental work for the optimization of polymerization conditions and the catalyst–nucleating agent system, as the catalyst is very sensitive to non-typical components in the polymerization medium (Graph 2).

Ideally, a drop-in solution would be a significant benefit, but a careful investigation is required to learn the impacts on the polymerization process when moving to the in-situ technology.

Recently, Norner entered a partnership with the company Xplore, creating an integrated workflow for industrial catalyst and polymer development services. The partnership extends opportunities for accessing high throughput polymerization at Xplore, which enables a fast and reliable screening over a large number of polymerization parameters and levels, which can be relevant for the evaluation of in-situ additivation.

Therefore, opportunities and challenges are present, and Norner can offer a suitable development route, providing a full support package for companies who consider installing in-situ technology.

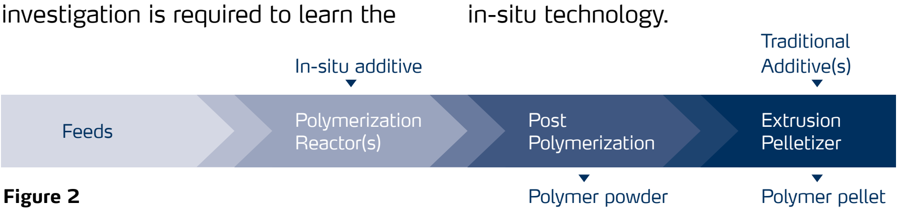


Figure 2

For further info please contact:

Cesar Barbosa
Senior Researcher
cesar.barbosa@norner.no

Lars Evensen
Vice President Polymer Industry BU
lars.evensen@norner.no

Opportunities and challenges with In-Situ additivation

- Pushing in-situ to the extreme, a more environmentally friendly process with cost savings (less electricity and additives) can be achieved if the plant extruder can be fully omitted.
- Process modifications for in-situ required in some technologies.
- Mapping and optimization of in-situ additive on catalyst performance and polymerization process.
- New areas for development (additive, catalysis, process technologies).
- New or improved polymer applications (based on enhanced mechanical and/or optical properties.)

Norner capabilities to support the technology implementations

- FTO studies on selected technologies.
- Tuning/optimization of catalyst and nucleation systems.
- Cost comparisons to clients existing (traditional) nucleation systems.
- Design and engineering of modified feed/dosing systems.
- Optimized recipes/formulations.
- Polymer grade performance testing.
- Mapping of benefits for the polymer converter.

Spherolight

Light diffusion agents

From small, monodisperse polymer particles to light diffusing products. This was the challenge of a recent innovation project together with Microbeads AS.

Katrin Nord-Varhaug
katrin.nord-varhaug@norner.no

Steffen Annfinsen
steffen.annfinsen@norner.no

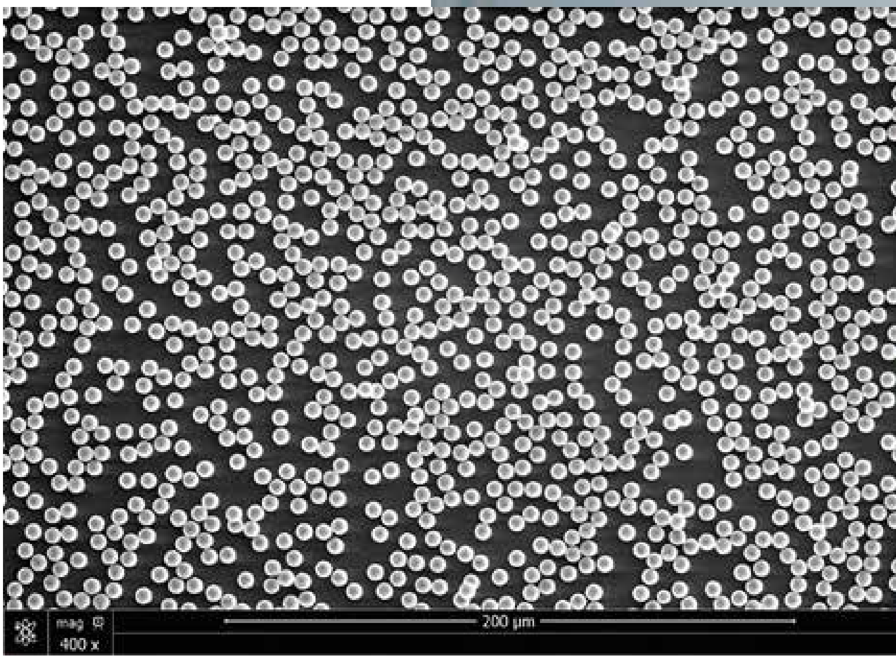


Figure 1 Monodisperse beads developed by Microbeads.

The goal of the present project has been to develop light diffusing polymer beads, tailor-made for products to be used in optical films, LED lighting covers/panels, cell phones, architectural lighting fixtures, signs and light guide applications in the automotive industry. Small, monodisperse polymer particles, Ugelstad beads, has proven to be ideal for ensuring uniform light diffusion. The beads are perfectly spherical polymer particles with very narrow particle size distribution and identical chemical composition and properties. Many of the light diffusing products used in the industry are based on PC or PMMA due to their high transparency and relatively low cost. The beads that have been developed by Microbeads have therefore been mixed with PC or PMMA and injection molded into discs and test bars which have been used for further investigation (Figure 2).

Figure 2 Injection moulded discs, ready for optical investigation.

Development of a method for measuring the refractive index of the beads

When dealing with optical performance products, it is important to know the refractive index of the beads and of the matrix material which the beads are compounded into. It is especially challenging to measure the refractive index (RI) of the small beads. Norner Research has developed a fast and simple method for determining the RI of small beads. The principle of the method is very elegantly illustrated in Figure 3 by mixing the beads (powder) into a solution consisting of two solvents with different refractive indices.

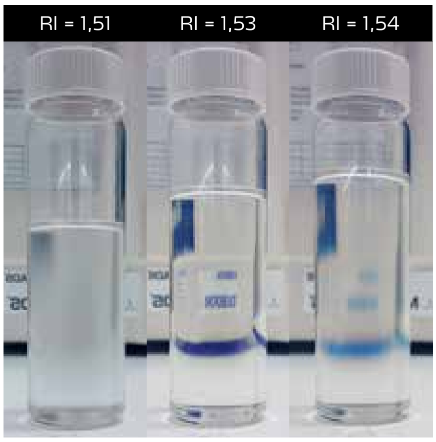


Figure 3 Small beads in a solution for determination of the refractive index of the beads.

Usually, when the powder is mixed into a transparent liquid, the solution will appear opaque unless the solution and the powder have exactly the same refractive index. The refractive index of the solution is determined by the refractive index and volume fraction of each solvent component. By gradually adding a solvent with a higher refractive index to a mixture of beads and solvent with a lower refractive index, the mixture of beads and solution will gradually change from opaque to transparent and to opaque again. By keeping control of the volume fractions of solutions, it is then possible to calculate the refractive index of the beads when the solution appears transparent.

Project highlights

- The project has gained substantial knowledge about how polymer beads refract light waves through a polymer by carrying out systematic experiments with the most commonly used polymers in LED displays.
- Over 100 polymer samples with varying amounts, sizes and compositions of polymer beads have been produced. Different optical properties have been measured and compared with polymer without beads. We have also succeeded in systematically changing the beads' refractive index by changing the chemical composition of the beads.
- A method for measuring the refractive index of particles has been developed, and all particles in the project have been measured.
- Optical measurements of polymer samples with these new beads confirm that a larger difference in the refractive index between the base polymer and the polymer beads increases light scattering but reduces the light transmittance.
- Systematic investigations of how the addition of particles affects various mechanical properties have also been carried out.
- The main project result is that due to the perfectly spherical shape and the identical size and composition of the beads from Microbeads, it is possible to predict and tailor optical properties based on the size and addition level of beads.

Facts

The Spherolight project was funded by the Norwegian Research Council during 2018 – 2022. Microbeads AS has been the project owner with Norner Research, SINTEF and RISE as research partners. Microbeads developed and manufactured all the beads in the project.

Norner Research manufactured all the polymer samples and carried out the characterization of optical, rheological and mechanical properties in addition to measuring and developing a method for identifying the refractive index of the particles. SINTEF performed advanced characterization of the beads, and the Swedish research institute RISE performed advanced light scattering measurements.

Focus on **Battery Materials**

The European Union aims to be climate neutral by 2050. Batteries are an enabler to reach this target. The electrification of the transport sector and stationary energy storage is a key driver in the transition towards climate neutrality.

Siw Bodil Fredriksen
siw.fredriksen@norner.no

Mari Thuve Øwre
mari.owre@norner.no

Emerging Battery Technology

The Norwegian Battery Strategy (June 2022) is a ten-point plan that aims to develop the Norwegian battery ecosystem and attract large investments and factories in the field. Norway has an excellent starting point for building the battery value chain (Figure 1) and the Battery Strategy points out several strengths within the Norwegian Industry.

Current Battery Focus Areas

Norner is a global leader in industrial polymer R&D services and is excellently positioned to support the emerging Norwegian and European battery industries.

Norner will support needed development within Battery Separator Films (BSF), Electrolytes, and Recycling in the Norwegian battery ecosystem.

Norner aims to develop a state-of-the-art pilot center focusing on technology development and pilot production of battery components. Such services will enable faster technology development for our customers.

Norner Test Capabilities on Separator Film

The separator film in Li-ion batteries is a microporous membrane with a thickness typically 5-25 µm and a pore size of less than 1 µm. The separator plays a key role in the battery's safe performance by preventing a short circuit between the anode and the cathode. Separators need to be mechanically robust, stable under active battery conditions, and inert to other cell materials.

Separators are preferably made from polypropylene (PP) or

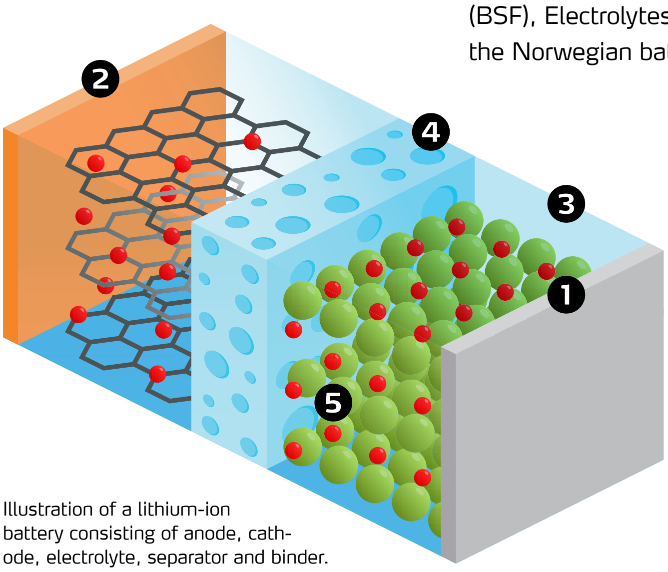


Illustration of a lithium-ion battery consisting of anode, cathode, electrolyte, separator and binder.

1 Cathode is the positive electrode where the material determines the capacity and power of the battery.

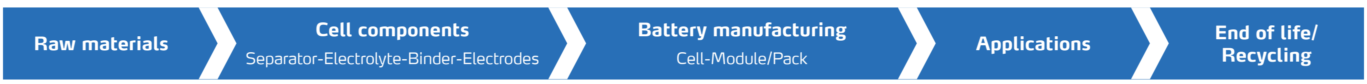
2 Anode is the negatively charged electrode, typically made of graphite.

3 Electrolyte is the medium that transports lithium ions from the cathode to the anode.

4 Separator is a safety device. It prevents electric contact between the cathode and the anode and at the same time allows the electrolyte and Li+ ions to pass through.

5 Binder holds the coating particles together and forms good particle dispersion in solvents during the production of the battery components.

Figure 1 Overview of the battery value chain: from raw materials to recycling/end of life.



polyethylene (PE). To generate pores, the PP separator film is stretched monodirectional which generates small and elongated pores. PE, on the other hand, is mixed with oil to produce a polymer gel in a wet process. The polymer gel is made into a film which is stretched in two directions, the bidirectional stretching of the film gives spherical pores with some variations in dimension.

Scanning Electron Microscopy (SEM) is a key analytical tool for the in-depth study of the pore structure of separator films, including advanced sample preparation techniques like cryogenic and ion-milling. Figure 2 shows the different porosity between separator films made of PP or PE monolayer.

Differential Scanning Calorimetry (DSC) is used to determine the melting temperature of the film, which again determines the maximum application temperature of the battery cell and also the shutoff temperature in the case of PP/PE multilayer separator films. The melting temperature differences between PE and PP films can be observed in Graph 1.

Graph 1 shows an example of melting transitions measured using DSC as shown in the SEM images (Figure 2). There are two PP films with reported porosities of 41 % and 55 %, and one PE film with a porosity of 40 %, and qualitatively observed in SEM.

The overall performance of the separator in the battery depends upon the balance between various properties: mechanical, thermal, porosity, film surface and processing techniques.

Norner offers a full set of industrial datasheet analyses for separator films for both characterizing existing films for improved quality control specification as well as the development of advanced films for new battery chemistries (Table 1). Norner also develops custom analyses and test methods according to specific needs, such as electrolyte wettability studies beyond standard water wettability.

Norner has the expertise and facilities to be a technology development partner in separator films for different cell chemistries for customers in the battery value chain.

FUTURE MATERIALS | NORSK KATAPULT SENTER

Future Materials Battery Catapult
Battery Separator/Electrolyte/Recycling

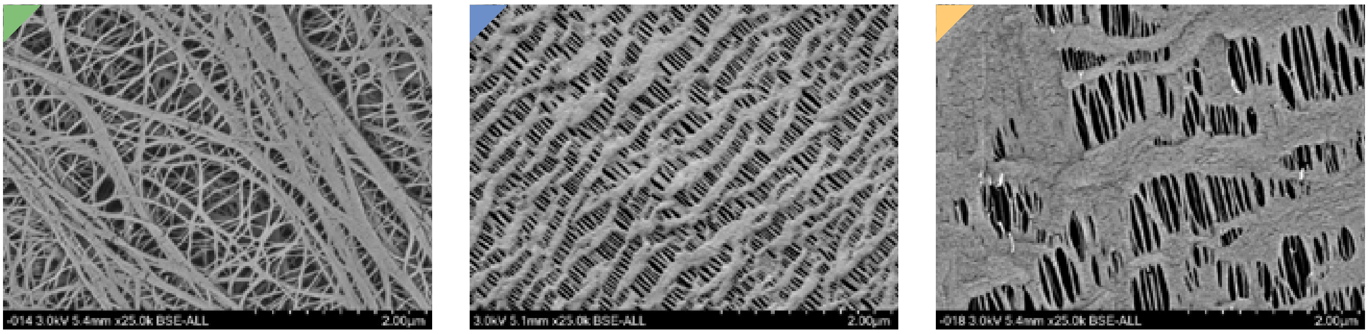
Norner is one of five owners of Future Materials Norwegian Catapult Center which is a national test and development center that offers test facilities, competence, and a professional network for developing sustainable advanced materials. This center has a high focus on battery technology.

Norner is engaged in two Future Materials Norwegian Battery Catapult Center projects together with relevant industry partners. These projects focus on test- and development pilot for battery separator film, electrolyte, and direct recycling of lithium-ion batteries, both used batteries and inhouse production scrap.

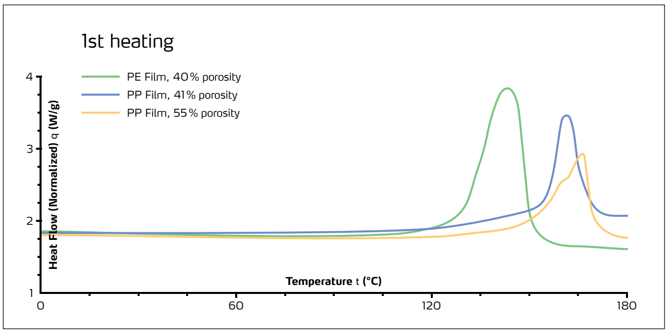
Test Group	Property
Physical	Permeability, Thickness Porosity, Wettability
Mechanical	Tensile Strength Puncture Strength
Thermal	Dimensional Stability Shutdown Temperature Melt Temperature
Material Characterization	FTIR, TGA, DSC, SEM, Sp. Gravity

Table 1 Overview of Norner's test capability for separator film.

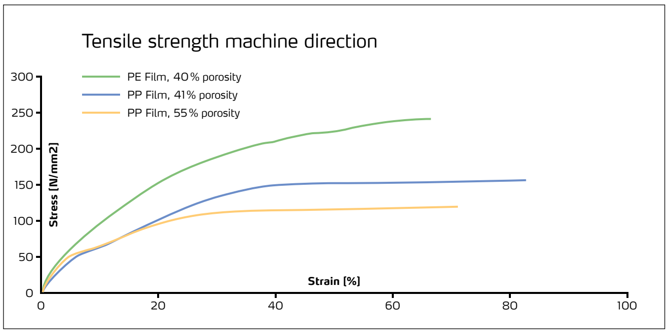
Figure 2 Three SEM images of seperator film surfaces. Left: PE film, porosity 40 %. Center: PP film, porosity 41 %. Right: PP film, porosity 55 %.



Graph 1 DSC Curves for the first heating, at a rate of 10°C/min, of three separators. A high melting temperature, as offered by PP, is highly desirable, with PE providing the shut-off capability in the case of any thermal runaway.



Graph 2 Tensile stress vs. strain curves for the three separators. The two PP films have the same thickness, 25 μm, while the PE film is 14 μm thick.



Recyclable **Mono-material** packaging

New 7-layer blown/cast film extrusion line at Norner.

The focus on plastics recycling has never been higher and its importance is emphasized by the high EU targets and the retail sector's strive for more recyclable packaging and recycled content. A key part of this trend is developing mono-material packaging.

Ole Jan Myhre
olejan.myhre@norner.no

Norner has been involved in the development of mono-oriented (MDO) films with polyethylene (PE) as well as polypropylene (PP) for more than 20 years. Such MDOPE films have proven key to the current transition from multi-material flexible packaging into recyclable PE mono-material solutions.

Still, we see a wide range of multi-material laminates being used for the flexible packaging of food and non-food products in bags, pouches, sachets, etc. These structures can consist of OPET, Alu, PP, PA, and PE and are not easy or even possible to recycle by mechanical recycling. Therefore, the development of mono-material laminates is demanded by brand owners and retailers.

In a recent development Norner carried out MDOPE and lamination trials for the development and comparison of mono-PE laminates with conventional ones.

For several years, Norner has carried out a wide range of trials and projects with industrial customers to evaluate different raw material recipes and coex strategies. The properties of an MDOPE film depend on both the type of PE resin used and the processing parameters, like the stretch ratio.

When developing a mono PE laminate, we must consider the properties of both the outer MDOPE film and the extruded sealing layer film. One aspect is the requirement of mechanical properties like tensile strength, Elmendorf tear strength and dart drop impact strength. Both the MDOPE and sealing layer contributes to this. For MDOPE, the resin performance varies significantly for Ziegler vs metallocene catalyst and unimodal vs. bimodal grades and numerous testing of single resin, as well as coextruded recipes, are needed to develop improved MDOPE films for a range of applications.

Still, one of the most critical aspects is the sealing performance which is more challenging with a mono PE laminate than e.g. PET//PE due to the lower melting temperature (Tm) of PE vs PET. A typical strategy is to use HDPE with higher Tm in the outer layer and LLDPE with the lowest possible Tm in the inner layer, although there are also other factors affecting like the shape of the bag and details of the sealing technology.

Another critical aspect is the incorporation of oxygen and moisture barrier properties which ensure the shelf life of the packed food. This can be achieved by using a thin layer of EVOH in the coextruded films. The current guidelines for Design for Recycling, like RecyClass, allow up to 5 wt% EVOH in the laminate. Other strategies include applying a barrier coating which can be either organic, liquid-based, or inorganic, plasma deposited like AlOx.

Our target is to offer better services and development capabilities for our clients. As a consequence, we have now expanded our polymer exploration centre with a new Collin 7-layer coex blown/cast combi-line which enables us to offer a wide range of possibilities for PE and PP multilayer recipes, including barrier materials. The resulting films can be used as the sealing layer film in laminates or the MDOPE layer.

RecyClass

Plastics Recyclers Europe has launched the RecyClass Platform, a comprehensive cross-industry initiative that works to advance plastic packaging recyclability and establish a harmonized approach toward recycled content calculation and traceability in Europe.

Norner cooperates with RecyClass and offers today both recyclability certification services and protocol testing as a RecyClass Recognised laboratory.

For further assistance
PLEASE CONTACT:

Recyclability certification:
Tanja.Radusin@norner.no

RecyClass testing protocols
Ronny.Ervik@norner.no

Film processing pilots at Norner

- Collin 7-layer blown/cast combi
- Windmöller & Hölscher Blown film 3-layer coex
- Hosokawa Alpine MDO
- Collin Blown film lab scale mono
- PM Cast film lab scale mono
- Collin cast film with gel counting

Additionally, a full range of testing and analysis can be made on such films.

Processing Pilot Centre

Norner's move to the new Polymer Exploration Centre has been completed, and in the new premises, Norner has expanded with new processing equipment for serving the exploration of polymeric films and advanced compounds even better.

Asbjørn Noraberg
asbjorn.noraberg@norner.no

In the application pilot centre, Norner currently has four twin screw extruders for your small or large compounding development jobs. In Norner's portfolio, there are currently the following machines:

- ThermoFischer Scientific Prism16, L/D:25
- ThermoFischer Scientific Prism24, L/D:35
- Coperion ZSK26, L/D:40, with equipment for de-volatilization, ventilation, filtration, side feeding
- Coperion ZSK18 MEGALab

The Coperion ZSK26 is equipped to be used for recycling trials, and it is possible to use this machine for the purpose of assessing, qualifying and even upgrading recycled materials.

The new Coperion ZSK18 MEGALab can run in 3 different L/D configurations 60, 40 and 20. Being able to utilize different lengths of the machine yields large flexibility in processing conditions. Norner has acquired several sets of screws for different compounding jobs. The maximum allowable temperature on the machine is 450°C, enabling the processing of even tough engineering plastics. The machine is equipped with feeders for:

- Pellets
- Powders
- Wood and short glass fibers
- Fluffy nanoparticles
- Liquids

In connection with the new ZSK18, a flexible option to allow dry cooling has been acquired. This enables Norner to process moisture-sensitive materials on all compounding machines, in addition to traditional water string cooling.

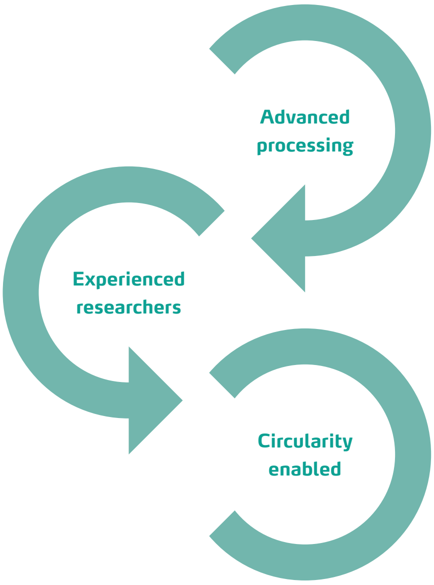
To give added value and hands-on understanding to your research jobs, Norner has an extensive portfolio of conversion machinery. This is accompanied by testing according to international standards, but also application

tests to assess the real-world performance of your products. Norner's film center consists of:

- Monolayer cast film machine
- Monolayer blown film machine
- Large scale 3-layer co-ex blown film
- 7-layer combined blown and cast film line
- MDO stretching unit

New as of 2022 is the 7-layer combined blown and cast film line. It is based on a BL 600 P design, delivered by Collin Lab and Pilot Solutions. The line is composed of seven extruders, all with L/D:30. There are five extruders at 25 mm diameter and two extruders at 30 mm diameter. All seven extruders may be used for both cast and blow film production.
Blown films can be produced at a lay-flat of 550 mm and in a thickness ranging from 10 µm to 500 µm, depending on material and process.
Cast film is produced via a flat film die width of 550 mm and slot opening of 0.3 to 2 mm. This allows the final thickness of cast films in the range of 10 µm to 2 mm. The line is equipped with pressurized water giving a large range of temperatures on the chill rolls, which enables the production of flat films, either by calendaring or conventional cast film process. We can process standard polyolefins, PET, PA, EVOH and various other polymers to make, i.e., barrier films. The line has been highly automated to facilitate good monitoring of the process and repeatability in your projects.

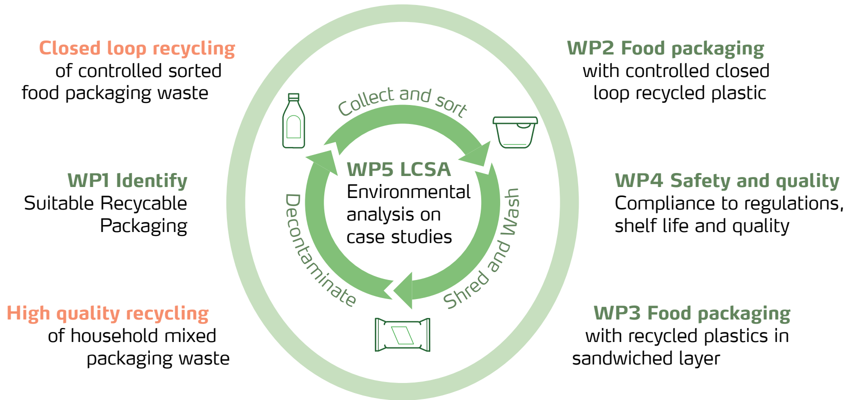
Norner is equipped to do MDO stretching of the produced films and may offer services to assess your films in terms of mechanical characteristics, sealing properties, barrier properties and chemical characteristics. Norner can also do thermoforming of the produced films to enable article testing with the desired material combination.



RecyFoodPack

bama
BEWI
mcc
Mills
Nofima
norner
NORSUS
TOMRA

Plastic packaging accounts for 40% of all plastic consumption in Europe. Of this fraction, food and beverage are again about 40% or 8 million tons. The use of recycled plastic in food packaging is limited by legislative food safety requirements, the plastics packaging recycling quality requirements and sorting and collection infrastructure.



Yvonne Hed
yvonne.hed@norner.no

RecyFoodPack aims to

- Safeguard food safety and quality
- Developing innovative plastic packaging systems that increase the use of recycled plastic
- Contribute to achieving Norway's circular economy target

The RecyFoodPack project will develop a comprehensive knowledge platform for sustainable and safe food packaging materials based on Norwegian post-consumer plastic waste streams to demonstrate the suitability of mechanically recycled plastics for food contact packaging.

This project is important for the industrial partners to gain knowledge and insight into what actions are needed to increase the use of recycled plastics in their products, and at the same time:

- Preserve food quality and safety
- Lower carbon footprint (LCA)
- Keep properties
- Ensure profitability

The RecyFoodPack project is working with two main approaches

1 Controlled sorting of food packaging (closed loop strategies, reversed vending machines).

2 High-quality recycled household waste for food packaging behind a protective layer or functional barrier.

The project has selected case studies based on different plastics and processes to gain a wide understanding of the issues related to each case. The case studies selected are based on injection molded PP, thermoformed PET trays and LD/LLDPE films. The work includes the use of recycled materials and the effect on material and food content:

- Food safety and quality based on sort control, to gain knowledge in need of the type of functional barriers for different collection systems
- Type of functional barriers needed for different non-intentionally added substances (NIAS) present in recycled materials.
- Effect of different food types on the recycled plastics, for example, the effect of taste/odor transfer

The project has following steering committee members:

Ole Jan Myhre (Norner Research AS), Thomas Eie (Bama Industri AS), Mette Olsen (Bewi Norplasta AS), Eirik Bergh (MCC AS), Bente Jackwitz (Mills AS), Helga Næs (Nofima AS), Cecilia Askham (Norsus AS), Geir Sæther (Tomra Systems ASA). Funded by The Research Counsil of Norway, Sirkulærøkonomiprogrammet, Grant no 320461.

from previous content.

- LCA analysis of the different scenarios, sorting and functional barrier solutions
- Label solutions
- Identify, demonstrate, and implement necessary upgrading measures.

Closed-loop case studies

Changes to the EU regulation (282 /2008) for "recycled plastic materials and articles intended to come into contact with foods" are expected soon. Here, the definition of "closed loop" will be restricted to packaging that doesn't reach the consumer. Such systems can more easily be approved by EFSA due to a lower risk of cross-contaminations. A typical example is returnable transport crates which are kept in a closed system by a system's owner.

In RecyFoodPack we focus on consumer packaging and closed-loop systems for rigid packaging. Performance of PET trays or PP thin wall injection moulded packaging will be studied and compared to high-quality recycled PET tray materials and rigid PP from household waste.

Kindergarten collection

A collaboration with a local kindergarten was initiated to increase the knowledge and value of plastics recycling at an early stage and to collect rigid PP for research. The kindergarten families collected rigid PP and brought it to the kindergarten. This type of sorting is an attempt to mimic a reversed vending machine case that is based on consumer sorting of rigid PP packaging.

The collected rigid PP contained mostly injection molded articles such as for example yogurt cups, margarine tubs and ice cream boxes.

The collected rigid PP materials were recycled in Norner's recycling pilot center and will be tested and compared to both stricter sorting (closed loop IM PP) and mixed household waste rigid PP with and without functional barriers.

This study will give new insight into how consumer-sorted rigid PP food packaging can have benefits to be collected in reversed vending machines, like PET beverage bottles. At the same time, the system is compared to high-quality recycled household waste PP and strict closed-loop recycling.

Your development and test partner for **Medical Devices**

A variety of plastic materials exists. As a well-trusted plastic material expert, Norner can fill your knowledge, need and support you in choosing the best plastic material for a cost-efficient manufacturing process meeting the functional, sustainability and safety requirements of your product.

Siri Stabel Olsen
siri.stabel.olsen@norner.no

Material of choice

You can achieve several different features depending on the material used.

Norner uses its expertise developed over decades to help you choose the right material to meet the desired requirements for the different parts of your medical device or well-being product. Norner aligns with the leading polymer producers bringing you cost-efficient solutions. Some examples of the material choice consideration which might be relevant to you:

- What are the optimal mechanical properties for the intended use?
- Must the material be of a medical grade quality?
- Must the material withstand disinfection/sterilization?
- Is the selected material compatible with high-volume cost-efficient processing?
- Is the selected material suitable for recycling?
- Do you want to “Re-design for Recycling” with Norner?

Processing and prototyping

Norner pilot plant consists of the most relevant processing machinery relevant for the health industry.
We combine material expertise with processing expertise to achieve the best possible manufacturing process for your product or product parts. You can have your plastic prototype parts made at Norner.

Norner can also manufacture low-volume series for pre-commercial purposes.

ISO-13485

Norner is ISO 9001 certified. Recently we started the process of becoming ISO-13485 certified. Thereby you can trust that all activities in a project collaboration are performed according to the same high quality and documentation standards as the regulatory bodies put on you as a manufacturer of medical devices. We expect to be certified in 2023.

Norner has several pilot lines for blown and cast film extrusion up to 7 layer. This is a very flexible set up for product development.

Testing

Norner has a significant testing capability for polymer raw materials, polymer product parts and finished products. These are test methods we are well equipped to perform:

- Testing and verification of mechanical, physical, thermal, and optical properties.
- Impact and tensile properties.
- Sealing and welding performance.
- Environmental Stress Cracking.
- Creep, Tensile creep, and fatigue.
- Thermo-mechanical analysis.
- Heaet resistance and conductivity.
- Optical.
- Wide range of application testing on film/moulded parts/pipe etc.
- Advanced application testing.
- Microscopy including SEM.

You might have test needs where no standard exists. Norner also performs tests to replicate or mimic real application environment and regularly develop customized test methods.

Sustainability

It is becoming increasingly important for Medtech- and well being products designed to minimize negative climate impact and undesired effects on humans and nature. Norner has the competence and development tools to:

- Develop polymer- parts and products with a minimum amount of material to meet functional requirements,
- Achieve high performance with recyclable polymer material.
- Polymer product composition that allows recyclability
- Include recycled polymer as part of polymer parts
- Medical grade material to ensure safety for end-user
- Alternative polymers to PVC

Full-service provider for the **Pharmaceutical Packaging Industry**

When your goal is safe, functional, cost-efficient and sustainable packaging solutions, Norner is your partner to achieve that goal.

Siri Stabel Olsen
siri.stabel.olsen@norner.no

Morten Lundquist
morten.lundquist@norner.no

Pharmaceutical plastic packaging solutions need to fulfill EU and US regulatory demands. Authorities will regulate solutions to be safe, pure, non-leaching, functional, cost-efficient, and sustainable. Design for recycling will come more and more into focus. In 2030, all plastic packaging in the EU shall be reusable or recyclable. Norner Healthcare has taken the challenge to be a full service provider of services in all relevant aspects of the plastics pharmaceutical packaging industry.

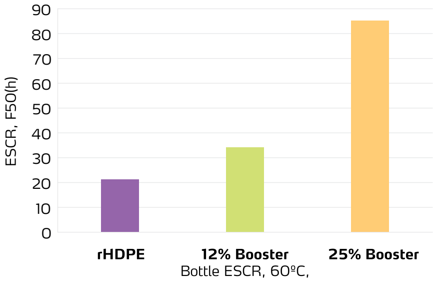
Materials

Norner's polymer material and additivation competence have developed over several decades and is continuously being enhanced. We collaborate with the majority of the global polymer material and additive manufacturers being in an excellent position to serve our clients with the most cost-efficient, clean and sustainable medical grade materials available on the market. This also includes technology for adding booster materials for enhancing properties to enable the reuse of recycled materials.

Challenge: You seek optimal barrier properties for your packaging. With the combination of Norner material, processing, and testing capabilities, we can develop solutions meeting your requirements. We also take advantage of the vast amount of barrier data we have generated over many years for various packaging design- and material solutions with our proprietary barrier simulation software.

Norner Booster Material Technology

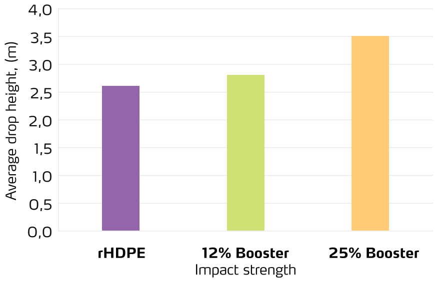
For high content Post Consumer Recyclate (PCR) in bottles



Bottle ESCR, 60°C, 2% Arcopal

325 %

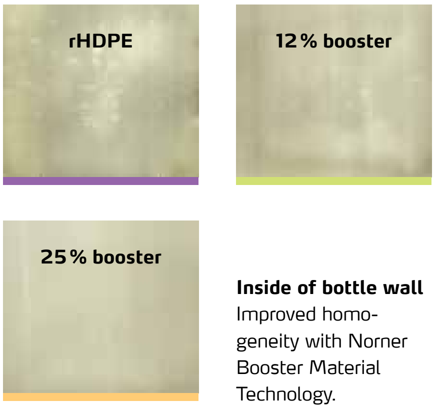
Higher bottle Environmental Stress Crack Resistance (ESCR)



Impact strength

35 %

Higher bottle impact strength



Inside of bottle wall
Improved homogeneity with Norner Booster Material Technology.

Oxygen Transmission Rate Instrument (OTR)

Pharmacopeia Testing at Norner

European Pharmacopeia Monographs

- EP 3.1.3 Polyolefins
- EP 3.1.4 Polyethylene for containers without additives
- EP 3.1.5 Polyethylene for containers with additives
- EP 3.1.6 Polypropylene for containers and closures
- EP 3.1.15 Polyethylene Terephthalate for containers for preparations, not for parenteral use

US Pharmacopeia General Chapters

- 661.1 Plastic materials of construction
- 661.2 Plastic packaging systems for pharmaceutical use
- 671 Containers performance testing

Sustainability

The sustainability aspect is also becoming increasingly important in the healthcare industry. Downgauging, mono-material solutions, design for reuse and circularity shift from less sustainable materials to polyolefins are all areas where Norner can be of value. At Norner's recycling pilot centre, we have unique facilities for upgrading pharma packaging waste for reuse.

Challenge: You would like your rigid packaging to become lighter and keep the same mechanical strength and barrier properties solution. This can be achieved with Norner Booster Material Technology (figure 1).

Testing

All relevant analytical, mechanical and lifetime requirements can be tested in our laboratories. This also includes testing directly on product prototypes. We also provide regular test services as part of your QC to confirm compliance with the Pharmacopeia monographs for PE, PP and PET raw materials. We offer testing according to the methods given in Ph. EU Monograph 3.13-3.1.6, 3.1.15 and USP <661.1>, <661.2> and <671>.

Processing

Norner Application Centre and its competence in the processing of thermoplastic materials is unique. The Application Centre can facilitate full-scale tests with a variety of mono and multilayer processing machines for blow and injection molding, blown and cast film, thermoforming as well as compounding extruders. Based on your design and functional requirements, we can test and optimize polymer recipes and process parameters to fit the target performance.

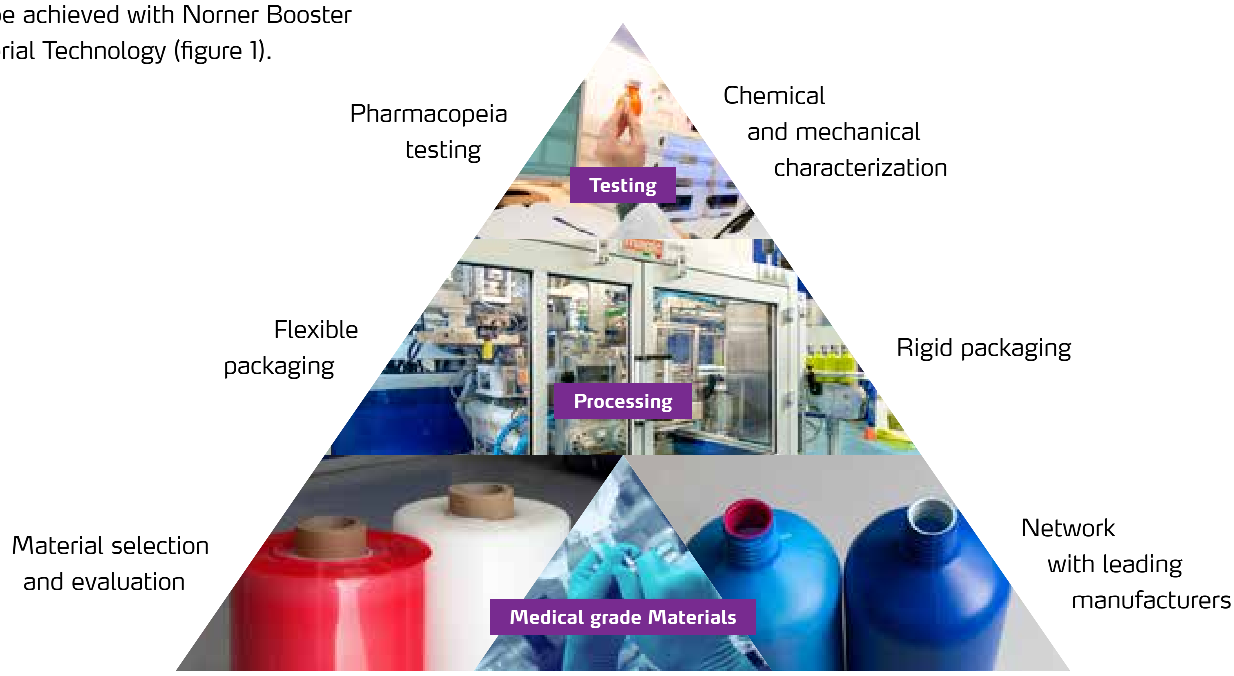


Figure 1 Norner's range of expertise

Dsolve project

Dsolve

SFI Biodegradable Plastics for Marine Applications

Research partners: Arctic University of Norway, Norner Research AS, SINTEF Ocean, SINTEF Industry, Norsus, SALT Lofoten AS plus three international research partners.
Other partners: About 14 industrial partners from fisheries, aquaculture, and gear suppliers, as well as several public agencies and organizations from the fishery and aquaculture sector are also participating in the centre.

Photo by Erling Svensen.

Marine litter is a global problem. Fishery and aquaculture industries represent a major source of marine plastic litter. The traditional plastics used for fishery and aquaculture industries have a long lifespan in the marine industry and lead to plastic pollution and ghost fishing when they are lost in the sea. Recent research and industrial development have revealed the potential to develop biodegradable materials to replace the conventional plastics commonly used in the marine sector, especially those used in fishing and aquaculture industries.

Thor Kamfjord
thor.kamfjord@norner.no

Ravindra Reddy Chowreddy
ravindra.chowreddy@norner.no

The solution

The goal of Dsolve is to replace traditional plastics with new biodegradable materials for fishery and aquaculture applications. The use of such materials would help to reduce the amount of marine plastic litter and its associated effects (macro-/microplastics and ghost fishing) in the marine environment. The new biodegradable materials will maintain the same properties as conventional plastics during their use but are completely degraded by the microorganisms when it is lost in the marine environment.
The biodegradation of plastic is a complex process that results in an extensive reworking of the carbon-containing compounds in the plastic by living organisms.

Biodegradation of plastics is the microbial conversion of all its organic constituents to carbon dioxide (CO2) (or carbon dioxide and methane in conditions where oxygen is not present), new microbial biomass and mineral salts within a timescale short enough not to lead to lasting harm or accumulation in the open environment. Carbon-carbon bonds cannot easily be broken, neither abiotically nor enzymatically. Therefore, polymers with only a carbon-carbon backbone will undergo the breakdown process extremely slowly in the open environment, thus hindering the conversion to CO2, CH4 and new microbial biomass. Polymers that contain heteroatoms like nitrogen, oxygen or phosphorus are often more readily broken down, e.g., by hydrolyzing enzymes. Further on, the biodegradation will depend on parameters such as crystallinity, surface-to-volume ratio and additives present in the polymer. With respect to the environment, the key parameters are temperature and the presence of microbial degraders, which catalyze the breakdown of plastics. All environmental factors that influence the activity of these microorganisms will therefore have an impact on the biodegradation process, e.g., temperature, moisture, availability of essential nutrients and electron acceptors, pH and salinity.

Confusion often exists among consumers between bio-based and biodegradable plastics and the polymers they are composed of, which are sometimes conflated under the term bioplastics. Bio-based polymers (or biopolymers) such as cellulose, starch, and lignin are composed of carbon derived from renewable biological sources such as plants, in contrast to fossil-based polymers. The fact that these plastics are bio-based, however, does not necessarily mean they are biodegradable, and both bio-based and fossil-based polymers can be either biodegradable or non-biodegradable. The origin and manufacturing process of biobased polymers have important environmental implications and should be considered for a full assessment of the overall environmental impact when alternative materials are considered to replace conventional plastics.

For plastic to biodegrade, it must undergo two key steps:

1 The polymer molecules (hydrocarbon chains) need to break down into smaller components of low molecular weight through enzymatic action. This first step depends to a large extent on the material properties of the plastics themselves and the environment in which they are located. In the open environment, this breakdown process typically needs weeks, months, or years to occur.

2 These smaller components must then be converted into CO_2 (or CO_2 and CH_4 under anoxic conditions) and new microbial biomass, which is done by microorganisms. This second step is particularly dependent on the specific environmental conditions and, in the open environment, occurs typically within hours or weeks.

Norner is one of the work package leaders in the Dsolve project. The main objective of our work package is to develop a range of biodegradable plastic materials with controlled biodegradability and the properties needed for products used in fishing and aquaculture industries (e.g., twines and netting, ropes, gillnets, coatings, pots and traps, foils and boxes, pipes and connectors). The developed materials should meet a range of processing and performance requirements, including biodegradability.

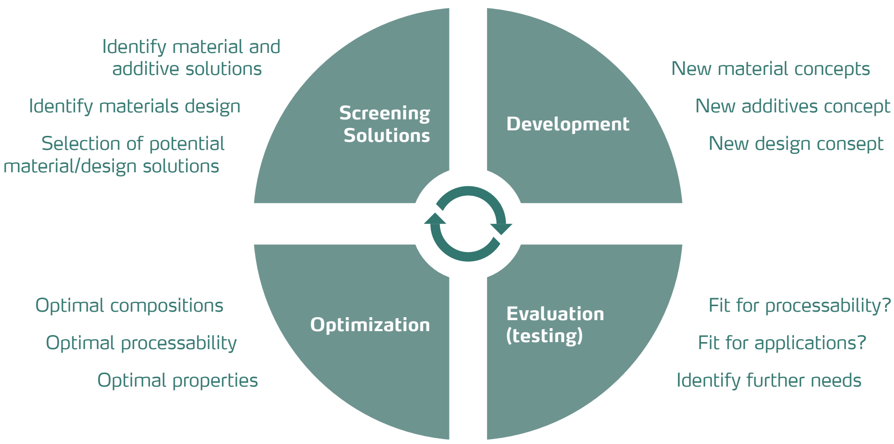
Norner will develop new biodegradable plastic materials systematically. First, various material and product design options will be screened theoretically, and suitable ones will be selected for further development. The new material concepts developed in the Dsolve project will be evaluated for processability and performance, and further development requirements will be identified. The development process will be continued in an iterative manner until optimal materials are achieved.

The complexity of the challenge

Plastic can reach an open environment for a variety of reasons. For most plastic applications, the intended end-of-life scenario is disposal in a managed waste stream, where they can be recycled or composted, if applicable. However, plastics destined for managed waste systems at the end of their life can escape from such systems or reach the open environment as a result of improper disposal or littering.

Some plastic applications, on the other hand, are specifically intended to be used in the open environment. Loss may also be intrinsic to use, for example, dolly rope abrading to protect fishing gears. For applications such as fishing gear, a partial loss is considered unavoidable during normal use in the open environment. Although recovery from the environment for reuse or recycling would be preferable, for some of these applications, it is either impossible or disproportionally expensive. Biodegradable plastics have, in such cases, been proposed as part of a potential solution to plastic pollution. However, their environmental benefits over conventional plastics need to be carefully assessed.

In the context of a circular economy, it is of high importance that biodegradable plastics are not put forward as a solution to inappropriate waste management or littering. The use of biodegradable plastics should be limited to specific applications in the open environment for which reduction, reuse, and recycling are not feasible. Before the introduction of such degradable materials, it is of vital importance that biodegradation and environmental risk under the conditions of specific open environments are assessed. To avoid misuse and confusion, clear and accurate information will be required to address the current misconceptions and confusion related to bio-based, compostable and biodegradable plastics. Biodegradability of plastics should only be encouraged when it is beneficial to the environment and does not interfere with waste management systems, compromise food safety or represents a higher environmental footprint than the conventional plastics being used. The challenge addressed in Dsolve is significant. Currently, the materials fulfilling all the requirements we target do not exist. Through the systematic R&D approach we will explore if it is possible to enable biodegradable polymers to provide high performance when need it – and fast biodegradation when lost. We believe such significant challenges are solved together, and please contact dr. Chowreddy for if you are interested in joining forces.



Centre for Research-based Innovation

The SFI-scheme is intended to promote innovation by supporting long-term industrially oriented research and forging close alliances between research-active enterprises and prominent research groups. The scheme is also expected to enhance technology transfer, internationalization and researcher training. The centres are co-financed by enterprises, host institutions and the Research Council of Norway. The enterprises participate actively in a centre's governance, funding and research. The main criterion for selecting centres is their potential for innovation and value creation. The scientific quality of the research must be of a high international standard.

Photo by K. Cerbule.

NextGen TPO – Sustainable, smart polymer alloy waterproofi membranes fit for the future

With the next generation thermoplastic polyolefin membranes (NextGen TPO) project, Protan aims for a waterproofing membrane with unmatched product performance in all climate zones and a long lifetime, outperforming current solutions.

Henning Baann
henning.baann@norner.no

Protan and Norner aim to develop sustainable, safe and intelligent polymer membrane solutions for waterproofing buildings and infrastructure, fit for the current and future needs of the construction industry. To achieve this, thermoplastic polyolefin materials (TPO) are at the centre of our attention. Sustainability and circularity are moving higher on the agenda in the construction industry. The expected growth in demand for multifunctional, more advanced roof and building constructions – such as rooftop solar systems, roof gardens contributing to biological diversity, with or without food production, and water retention systems in urban areas – will require the development of new and innovative materials and systems solutions.

In this highly ambitious NextGen TPO project, Protan aims to develop an innovative new product portfolio of advanced, sustainable materials that are easy to install, durable, weather/climate resilient, environmentally friendly, and 100 % recyclable. The project combines demanding interdisciplinary research and development activities in materials technology, manufacturing, construction, and installation, as well as in modeling and simulation of product performance.

In 2021, Protan installed two TPO test roofs to better understand the functionality of this material. The roofs have been instrumented with IoT-sensor technology for monitoring temperature and moisture with associated weather data. The roof coverings have also been recorded with a video camera. The roofing membranes are watertight, resilient, and robust. However, the thermal movements are substantial, and this will be a focus area in our coming work.

ng

FACTS

Protan is a Norwegian industrial group that is a world leader in membrane technology for waterproofing buildings and infrastructure. We develop and supply membranes, roof- and ventilation systems, and technical textiles. Our head office is in Drammen, Norway, and we have more than 900 employees and a total turnover in excess of € 200 million. Our largest business area is roofing and membranes. We also specialize in tailor-made, flexible ventilation ducts and waterproofing systems for mines and tunnels. In addition, we supply multi-purpose technical textiles for a range of applications. Protan is also one of the largest roofing contractors in the Nordic region. With over 80 years of experience, Protan has developed innovative solutions that are adapted to a global market and demanding climates.

Throughout 2021, key members of the Protan staff have, in close collaboration with the Norner team, built and strengthened our fundamental understanding and competence in the materials technology of TPOs. This has been an amazing journey for Protan as a knowledge-based business. Together, we have worked systematically and scientifically within a new growth area of Protan. We have developed formulation prototypes that have been assessed with respect to both short-term and long-term properties. This has given us invaluable insights, forming a basis for further product design. Processing and test runs of selected designs have been initiated with subsequent analysis and fit-for-purpose assessment.

Norner's main contributions to the project include the following:

1 Norner is responsible for the characterization and testing of critical short and long-term TPO material and membrane product properties, including relevant accelerated aging methods and generation of data for material durability model development.

2 Norner focuses on critical performance needs of the TPO prototypes: UV and oxidation stability and chemical and mechanical resistance for extended product lifetime, as well as halogen-free formulations for targeted fire ratings. Norner develops formulations for low-temperature flexibility, laboratory tests for welding and weld quality, and solution for tailoring TPO haptics to improve end-use acceptance. Norner will study, develop and test novel high-performance TPO alloys and support Protan in development on a pilot scale. Norner supports competence development by providing training for Protan.

3 Norner will develop predictive durability models based on multiple simultaneous aging factors and test and verify the models using project data. Protan and Norner will collect relevant input data for Protan's LCA models.

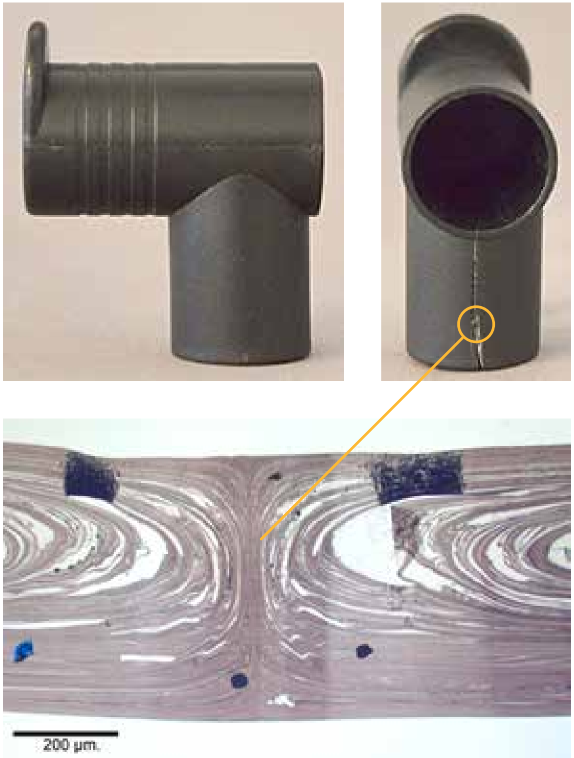
At The Back

Microscopy investigation is a powerful way to identify materials, composition, homogeneity and morphology of plastic parts and products.

A key competence at Norner is failure analysis of plastic products. A wide range of products are produced from plastics where some are critical parts in an engineering environment, and some are more domestic products. Some products cause a huge economic impact if they fail while domestic products cause more irritation for the consumer.

The fact is anyhow that plastic products are failing in all kinds of applications regularly and Norner helps the industry in microscopy investigations and root-cause analysis.

Let's illustrate a typical case of a domestic product. A rack for coat hangers is constructed of metal pipes, joined by plastic fittings. The fittings are made of polypropylene and pigmented black. These joints broke after a few days of using the rack. But why?



Light microscopy image explains the problem:

- The failure was in the moulding weld line.
- The pigment was poorly dispersed.
- The masterbatch carrier was PE, not PP.
- The product had a tendency for delamination

This represents a typical failure that occurs in all kinds of products but could easily be avoided.

NORNERNEWS 22

Norner AS
Dokkvegen 20,
NO-3920 Porsgrunn,
Norway
post@norner.no

Follow us
/NornerAS
/thepolymerexplorers
/norner-as

norner™
The Polymer Explorers

Photos by: Vegard Giskehaug, Protan, Istock and Norner.