WELCOME TO our world of plastics

ANNUAL REPORT 2019

Brightlands Materials Center

TABLE OF CONTENTS

EDITORIAL

Brightlands Materials Center is a rapidly growing research and development center with the mission to develop innovative materials solutions that contribute to a sustainable future. Brightlands Materials Center was founded March 2015 by TNO and the Province of Limburg.

2019 has been a year of further growth and expansion. We have increased the number of partners in various projects and programs, and we have enlarged our infrastructural footprint. We moved into a brand new pilot hall for our polymer processing and thermoplastic composites activities. Overall, our total floor space is now more than 1,200 m^2.

Our program teams, consisting of scientists, technicians, and BD managers, are working hard to develop new and innovative materials technologies. We have a young, and very ambitious team supported by quite a number of students!

Our three programs, Lightweight Automotive, Additive Manufacturing, and Sustainable Buildings are continually in the picture with exciting new results, supported by demonstrator products. Highlights have been our own Partner Event and our presence at various industry fairs with our own stands, attracting many new contacts and leads for collaboration.

The outlook for the coming year is promising with quite a number of new opportunities.We are excited to announce that we will launch a fourth program line on Circular Packaging early 2020.

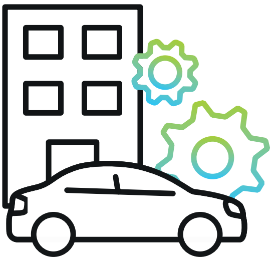
Our drive is to contribute to a sustainable society and to support the ambitions as laid down in the UN Global Development Goals. We believe that collaboration between organizations, connecting people, sharing insights and ideas are crucial to build a sustainable society.

This fourth annual report gives an overview of our progress over the last year. It also gives insight into the development of the roadmaps of our three existing programs. We look forward to hearing from you and to discuss opportunities for future collaboration.

Peter Wolfs & Marnix van Gurp
Managing Directors

BRIGHTLANDS MATERIALS CENTER
our proposition

1. Application driven programs along the value chain



Efficient problem solving
Innovative idea generation

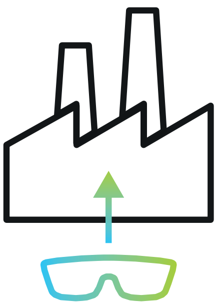
2. Collaborations in shared research programs

Lower costs
Lower risk in innovation

3. A network of global partners embedded in a regional innovation campus

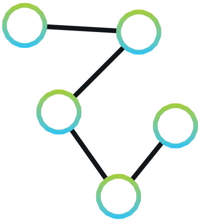
Inspiration
Business opportunities

4. A combination of entrepreneurial activities and fundamental knowledge build-up

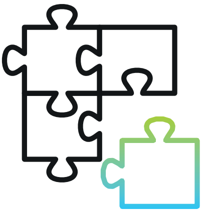


Accelerate your
technology development

BRIGHTLANDS MATERIALS CENTER
our core business



Polymeric materials innovations



Functional demonstrators

our relevance

Market applications

Sustainable developments


Brightlands

PARTNERSHIP in research

Mission

The mission of Brightlands Materials Center is to develop innovative materials solutions for a sustainable future, with inspired talents and in collaboration with industry, academia and entrepreneurs.

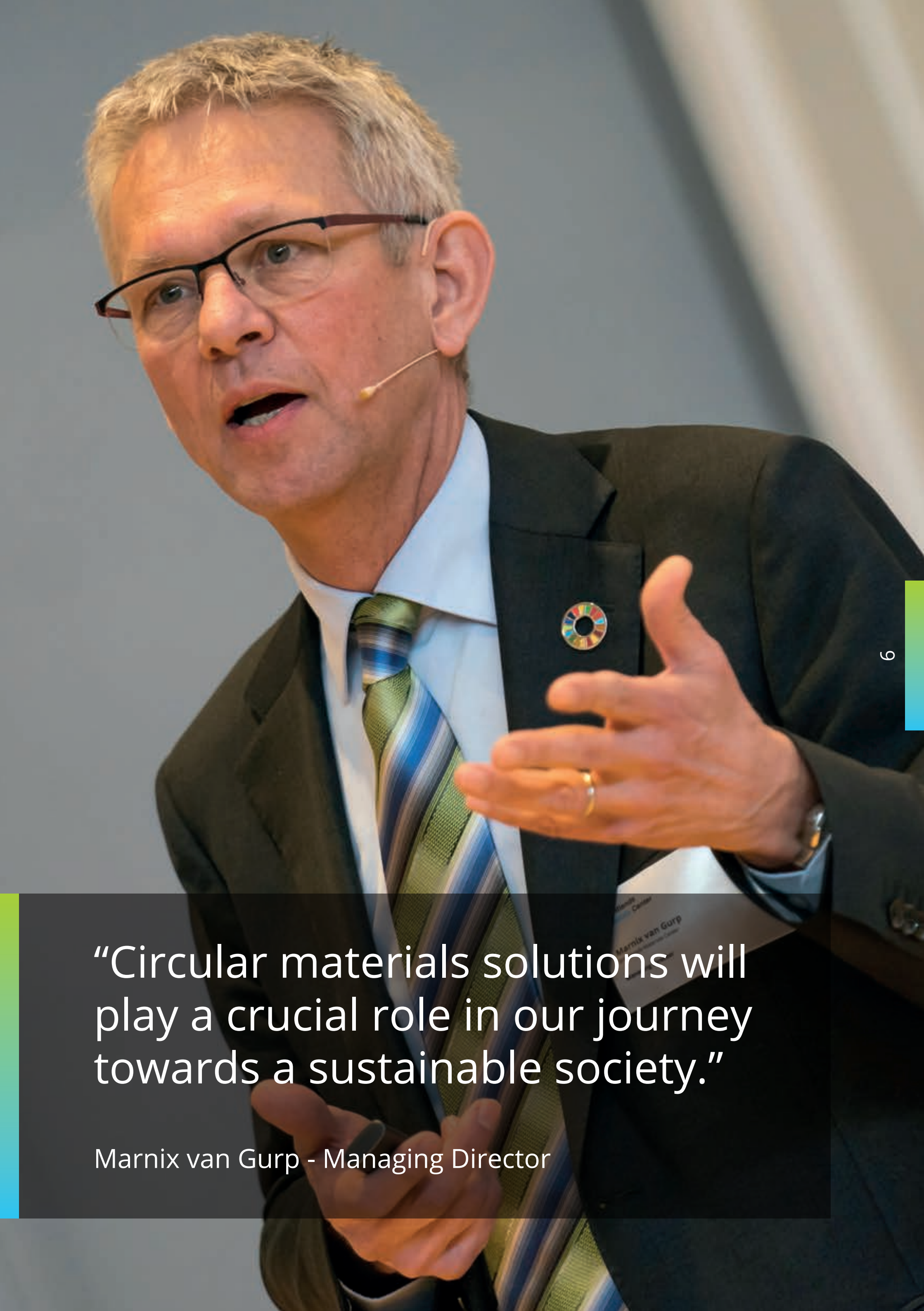
Shared Research Programs

We develop innovative solutions meeting societal challenges and industrial needs in a limited number of shared research programs: Lightweight Automotive, Additive Manufacturing and Sustainable Buildings. In 2020 we will start a new program in the field of Circular Packaging. We use all available knowledge through our partnerships with academia and other knowledge partners to develop new and innovative application technologies required by our industry partners to bring sustainable products to the market.

Business model

Due to the increasing speed of development of new products and new technologies, R&D costs needed so we can stay ahead of the competition in the long run are more and more difficult to bear with the existing company revenues. Our vision is that combining efforts, investments and risks in shared programs is the new strategy to reduce time to market for new product generations.

At Brightlands Materials Center partners complement their own in-house R&D with shared R&D, and with R&D projects, leveraging talents and know-how in a well-structured and professional R&D-like setting. Typically, Brightlands Materials Center results are shared on a non-exclusive basis with program partners according to customized agreements, tuned to each partner’s needs and situation. Whenever appropriate, Brightlands Materials Center also facilitates more dedicated research trajectories.



“Circular materials solutions will play a crucial role in our journey towards a sustainable society.”

Marnix van Gurp - Managing Director

“In order to have an impact on the societal challenges, collaboration in ecosystems between people in companies, knowledge institutes and governments is essential.”

Peter Wolfs - Managing Director

PARTNERSHIP
in research

Strategy

Brightlands Materials Center is well positioned between basic research on the one hand, and commercial product and technology development on the other. Typically, results obtained within Brightlands Materials Center aim for technologies that will appear on the market within three to five years. Brightlands Materials Center defines its activities based on global societal challenges, industry trends, and emerging markets and applications. Brightlands Materials Center likes to work closely with SMEs, to quickly bring innovative ideas to the market.

Brightlands Materials Center is a missionoriented and programdriven organization. Each program has a dedicated road map with a ten-year forward-looking horizon. Program year plans are defined – and regularly updated – in dialogue with industry and academic partners, and through assessment of inhouse competences. Sustainability plays a leading role in the definition of the program strategies.

> “Our vision is that combining efforts, investments and risks in shared programs is the new strategy to reduce time to market for new product generations.”

RESEARCH HIGHLIGHTS

The themes of our research and development programs address major societal challenges such as clean and efficient energy, smart and green mobility, and health and wellbeing. The research themes are inspired by the UN Global Development Goals, in particular Goal 7: Affordable and Clean Energy; 9: Industry, Innovation and Infrastructure; 11: Sustainable Cities and Communities; 12: Responsible Consumption and Production; and 13: Climate Action.

This section gives an overview of some of the results within our programs Additive Manufacturing, Sustainable Buildings and Lightweight Automotive.

"With our developments of thermoplastic composites 3D printing technology we support industrial applications to become lighter, more customizable, less wasteful and locally produced."

Richard Janssen -
Business Development Manager Additive Manufacturing

RESEARCH HIGHLIGHTS
Additive Manufacturing

Program focus

Additive manufacturing (AM) is a production technology that creates a wide range of new opportunities, in particular with respect to unique and lightweight designs, local and ondemand production and customization. It is currently transitioning from a prototyping technique into the manufacturing of functional industrial components and products. Unfortunately, in many cases the quality of the materials in the obtained products is still too limited to meet industry specifications and thus allow the full potential of the manufacturing technology. In order to boost the potential of AM in different application areas, innovations in AM materials are needed. Our program focuses on the following objectives: (1) better understanding of AM product performance and reliability in relation to material and process conditions, (2) enlarging the materials portfolio, and (3) increasing production efficiency and first-time-right production. We do this by exploiting the unique manufacturing freedom of AM which allows a high level of control of the material composition of a printed part. This gives the opportunity to create parts and products that have an integrated functionality which cannot be easily created in another way.

The Additive Manufacturing program is focused on three research activities:

- improving mechanical performance of 3D printed thermoplastic composites
- embedded sensing in 3D printed thermoplastic composites to monitor structural integrity and deformation
- dynamic polymer materials for additive manufacturing

Improving mechanical performance of 3D printed thermoplastic composites

Improvement of mechanical properties of 3D printed parts is one of the current challenges in additive manufacturing to transition from prototypes to functional parts that meet similar requirements, as for example injection molded parts do. In particular, the low strength of 3D printed parts perpendicular to the printed layers limits their application in load-bearing applications. We are investigating different methodologies to quantify, predict and improve the mechanical properties of 3D printed products produced by fused filament fabrication (FFF).

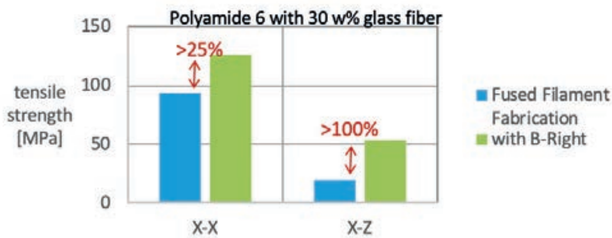


Fig. 1: Tensile strength of 3D printed samples parallel (left) and perpendicular (right) to printing layers; tensile strength is strongly improved by optimizing the processing conditions (proprietary B-Right technology).

One of the outcomes of the research in 2019 was the development of our proprietary "B-Right" technology, optimizing the processing conditions for FFF to improve the mechanical strength perpendicular to the printing layers. For glass fiber reinforced polyamide, a significant increase in strength was obtained using this technology (Fig. 1).

For parts that require even higher mechanical strength, for example to replace metal components in order to reduce weight, we are developing 3D printing of continuous fiber reinforced technology. A smartly designed part with embedded continuous fibers can improve mechanical strength where needed. In 2019, we have significantly strengthened our facilities and capabilities in continuous fiber 3D printing, including the installment of new 3D printing equipment (among others Anisoprint Composers), expanding our materials modelling expertise in fiber reinforced materials and dedicated material and process development. We have investigated the effect of material composition and fiber placement on the mechanical performance of different 3D printed products (Fig. 2).

Fig. 2: Design of continuous carbon fiber placement in 3D printed products

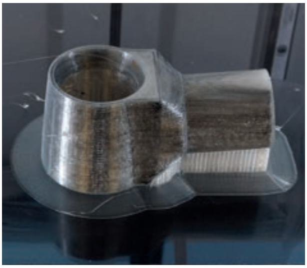


Fig. 3: Demonstrator product of 3D printed lug for personalized bike

One of the applications for which we are developing this application is a personalized bike, in the 100% Limburg Bike project. With a consortium of Limburgbased small- and mediumsized enterprises and companies on the Brightlands Chemelot Campus, we are developing an innovative, customized lightweight racing bike that is built according to the wishes of the future user. The racing bike will be composed using various 3D printing technologies and developments. The materials used are titanium, sealed magnesium and carbon fiber. The frame is customized to the user's specifications and complies with ISO standards and UCI requirements. Each copy is unique and created in the user's desired shape, 3D printing and colors. Our role in the project is to 3D-print the lugs, which are key parts of the frame, to customize the bicycle size to each individual user, with continuous fiber additive manufacturing technology (Fig. 3). In addition, we will also further develop our sensing technology with continuous carbon fibers to monitor the structural deformation and load during cycling. These sensors could potentially be used in the future as a power monitor.

Embedded sensing in 3D printed thermoplastic composites to monitor structural integrity and deformation

The embedding of continuous carbon fibers makes it possible to monitor the structural integrity of a product –.e.g. its deformation – and the changes within the structure over time. This is done by measuring the change of the electrical resistance of the carbon fibers in the composite part. In this way, delaminations, internal deformations and temperature profiles can be more accurately determined at positions inside the part where that was not possible before. Potential applications are found in the automotive industry for testing functional parts, embedded sensors in orthotic applications and structural integrity monitoring in the aerospace industry.

Proof of principle of the sensing mechanisms in different types of 3D printed parts was shown in 2018 (Fig. 4). In 2019, we focused on improving the sensitivity of the signal by changing the designs of the fiber sensor. We have optimized the fiber layout to obtain different types of sensors, with high sensitivity for different ranges of stresses and deformation. We have also investigated the reproducibility of these sensors (Fig. 5).

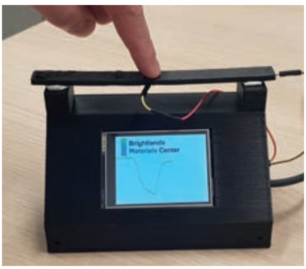


Fig. 4: Electronic signal resulting from the embedded fiber sensor during deformation of the 3D printed beam sample

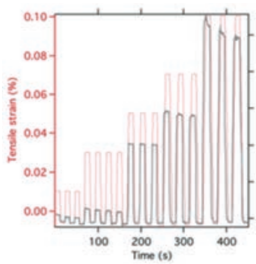


Fig. 5: Reproducible electronic response for the embedded fiber sensor with improved sensitivity at low strains

RESEARCH HIGHLIGHTS
Additive Manufacturing

Dynamic polymer materials for additive manufacturing

Together with partners DSM, Xilloc Medical, Eindhoven University of Technology, the University of Maastricht and NWO we have started a unique four-year project to progress new polymeric materials for use in additive manufacturing and 4D printing. These materials are aimed to bring improved and novel properties to products made from them. The innovative materials are based on the recently developed concepts of dynamic and reversible chemistry.

Dynamic polymers such as vitrimers are a fascinating new class of materials with highly unusual properties. Most well known are their selfhealing properties, which enable the materials to repair themselves after being damaged. Using dynamic materials in 3D printing is novel and is expected to lead to new applications. The main goal of the project is to open up new industrial and biomedical application possibilities with 3D printing by enhancing both the processing speed and the (functional) properties through the development of novel classes of polymeric materials based on dynamic and reversible chemistry.

This research receives funding from the Netherlands Organisation for Scientific Research (NWO, www.nwo.nl) in the framework of the Fund New Chemical Innovations and from the Ministry of Economic Affairs in the framework of the TKI allowance.

“Additive Manufacturing of thermoplastic composites creates opportunities for cost effective small series, lightweight and complex designs, fast changeover cycles, moldless and local manufacturing possibilities.”

Tessa ten Cate -
Program Manager Additive Manufacturing


“Smart Glass plays an important role in Energy Efficient Buildings knowing that almost 50% of a European building façade is made of glass. Together with partners from the industry we develop new materials for energy efficient glazing.”
Eugene Veerkamp -
Business Development Manager Sustainable Buildings

RESEARCH HIGHLIGHTS
Sustainable Buildings

Motive
Studies performed for the European Commission show that buildings consume 40% of the total energy used in the EU, and that they are responsible for 36% of all CO_2 emissions.[1] By improving the energy efficiency of buildings, the European Commission envisages that we could reduce the total EU energy consumption by 5-6% and lower the CO_2 emissions by about 5%.

Investing in energy savings has many benefits, and purchasing power spent on unnecessary energy consumption is simply wasted! Most energy in buildings is consumed for heating and cooling, and energy consumption for cooling will rise dramatically in the near future. The parts of a building that form the primary thermal barrier between interior and exterior, the so-called building envelope, play a key role in determining level of comfort, natural lighting and ventilation, and how much energy is required to heat and cool a building. Within the program Sustainable Buildings, Brightlands Materials Center and partners focus on the development of innovative materials for application in building envelopes. The program's ultimate goal is to develop materials that facilitate the transformation of buildings from energy consumers to energy suppliers. For that purpose, we pursue a two-step strategy: (1) reduce the energy consumption, and (2) address remaining energy needs with on-site renewable energy generation.

The ideal window: Smart infrared regulating glass coatings
An important part of the building envelope are windows. Today's buildings in Europe are mostly equipped with dated and inefficient glazing units. The thermal insulation properties of the average window in the EU are positioned between those of single and double glazing, and the use of coatings to regulate heat radiation through windows

[1] https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

is far from standard. With the most appropriate type of glazing, energy savings can be maximized in all building types and under all climatic conditions. Assuming that all windows in the EU would be exchanged for high-tech, high performance glazing, the total annual energy savings and CO_2 emission reduction would be 75.5 megaton oil equivalents and 94.3 megaton CO_2, respectively.[2]
Current energy efficient glazing systems comprise static infrared reflective coatings to reduce the transmission of solar heat into a building, and/or low emissivity (low-e) coatings to reduce radiator heat loss through the window. These systems are best suited for either hot climates, where solar heat has to be blocked the entire year, or cold climates where reduction of radiator heat loss is desired constantly. Current research and development focuses on adaptive coatings which can switch their properties depending on the building's needs.
These properties are specifically interesting for intermediate climates with hot summers and cold winters. Thermochromic coatings can switch between transmission and blocking of solar heat radiation depending on the temperature of the glass. It has been demonstrated that with these coatings, large energy savings can be obtained in comparison to standard clear glass.3 In 2019, we performed energy simulations on a residential building in several different climate regions ranging from hot to intermediate, and cold climates. We compared the annual energy consumption of the building equipped with double glazing systems comprising: (a) clear glass (no coatings), (b) a static solar heat reflective coating (IRM), (c) a low-e coating, (d) both a static solar heat reflective and low-e coating, (e) our thermochromic coating and (f) both our thermochromic and low-e coating. The results show that for all intermediate climates the combination of Brightlands Materials Center's thermochromic coating and

[2] Potential Impact of High-Performance Glazing on Energy and CO_2 Savings in Europe, TNO, 2019.
[3] M. E. A. Warwick, I. Ridley, R. Binions, The Effect of Transition Gradient in Thermochromic Glazing Systems, Energy and Buildings 2014, 77, 80-90.

RESEARCH HIGHLIGHTS
Sustainable Buildings

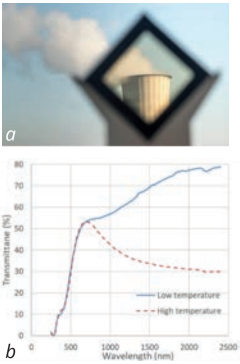


Fig. 6:
(a) Brightlands Materials Center's thermochromic coating on glass, and (b) transmission of Brightlands Materials Center's coated glass below and above the switching temperature.

a low-e coating has the best overall performance due to a combined high reduction in heating and cooling. In the Netherlands this combination shows a reduction of 10% in energy consumption when compared to only using a low-e coating.
In 2019, we optimized the optical properties of our single-layer, solution processed thermochromic coatings on a lab scale. The properties of Brightlands Materials Center's coating exceed those of thermochromic coatings reported for single-layer systems in scientific and patent literature by far (Fig. 6).

Furthermore, we have designed and acquired infra-structure to scale up the coating process from lab to pilot scale. In 2020 and 2021/2022, we aim to scale up the coating from the current 10 × 10 cm^2 glass plates to 50 × 50 cm^2 and 120 × 100 cm^2, respectively.

In addition to thermochromic coatings, we have developed a procedure for producing thermochromic powders and pigments on a lab scale (Fig. 7). In 2020, we aim to scale up the pigment production from the current 5 g scale to 100 g, and demonstrate their application in PVB interlayers. The required infrastructure for this scale up step was designed and established in our labs in 2019.

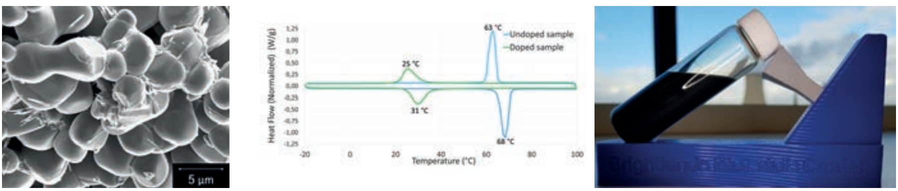


Fig. 7:
(a) Scanning electron microscopy image of thermochromic VO_2 powder, (b) differential scanning calorimetry measurement of undoped and doped VO_2 powder.and (c) picture of pigment dispersion.

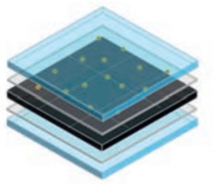


Fig. 8: Schematic build-up of optimized PV cell from top to bottom: cover glass, nano-enabled high refractive index encapsulant, absorber layer, backside encapsulant, back cover.

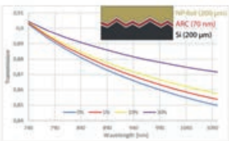


Fig. 9: With ray-tracing simulated light transmission through nano-enabled polymer films with various particle loading and antireflective coating to reach the absorber layer; inlay shows simulated stack with silicon surface structure.

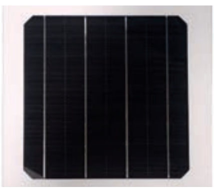


Fig. 10: Monocrystalline silicon mini-PV module prepared with high refractive index encapsulant.

Glass coatings and laminates that improve the efficiency and aesthetics of PV modules

Maximize electricity yield

In the last decades crystalline silicon PV cells have been constantly optimized, and continually increasing cell efficiencies have been reported. Current reported record research cell efficiencies for non-concentrator monocrystalline silicon PV are at 26.1%.[4] What hasn't been optimized yet is the refractive index of the polymer encapsulant. The refractive index (RI) of the encapsulant is intrinsic to the material properties of the polymer film, and at approximately 1.5 it is much smaller than the RI of the silicon absorber (~3.5). This ultimately leads to unwanted reflection losses at the interfaces and therefore reduced light transmitted to the absorber layer.

To reduce reflection losses between encapsulant absorber layers we have developed nano-enabled polymer films with increased refractive index, perfectly optimized to increase crystalline silicon PV cell efficiencies. Therefore, we developed nanometer-sized high refractive index pigments, which we implemented into polyolefin masterbatches. After compounding and extrusion we prepared high refractive index encapsulants for lamination of monocrystalline silicon PV cells (Fig. 8).

To design and tailor the properties of the nanoenabled polymer films for optimum performance we performed optical simulations. We showed that especially in the highly relevant wavelength region between 800 and 1100 nm, a substantial transmission increase can be achieved by using a highrefractive index encapsulant instead of standard encapsulant material (Fig. 9). This can lead to an absolute cell efficiency increase of 1.25%.

With the knowledge of required pigment material, particle size and pigment loading in the encapsulant, we synthesized zirconia nanopigments with an average

---

[4] NREL, Best Research Cell Efficiencies 2020, www.nrel.gov/pv/cell-efficiency.html.

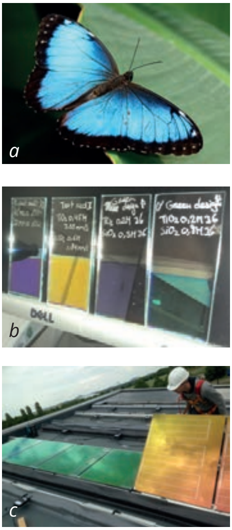


*Fig. 11:
(a) Morpho butterfly,
(b) Colored coatings,
and (c) demonstrator
module comprising
Brightlands Materials
Center's color coatings.*

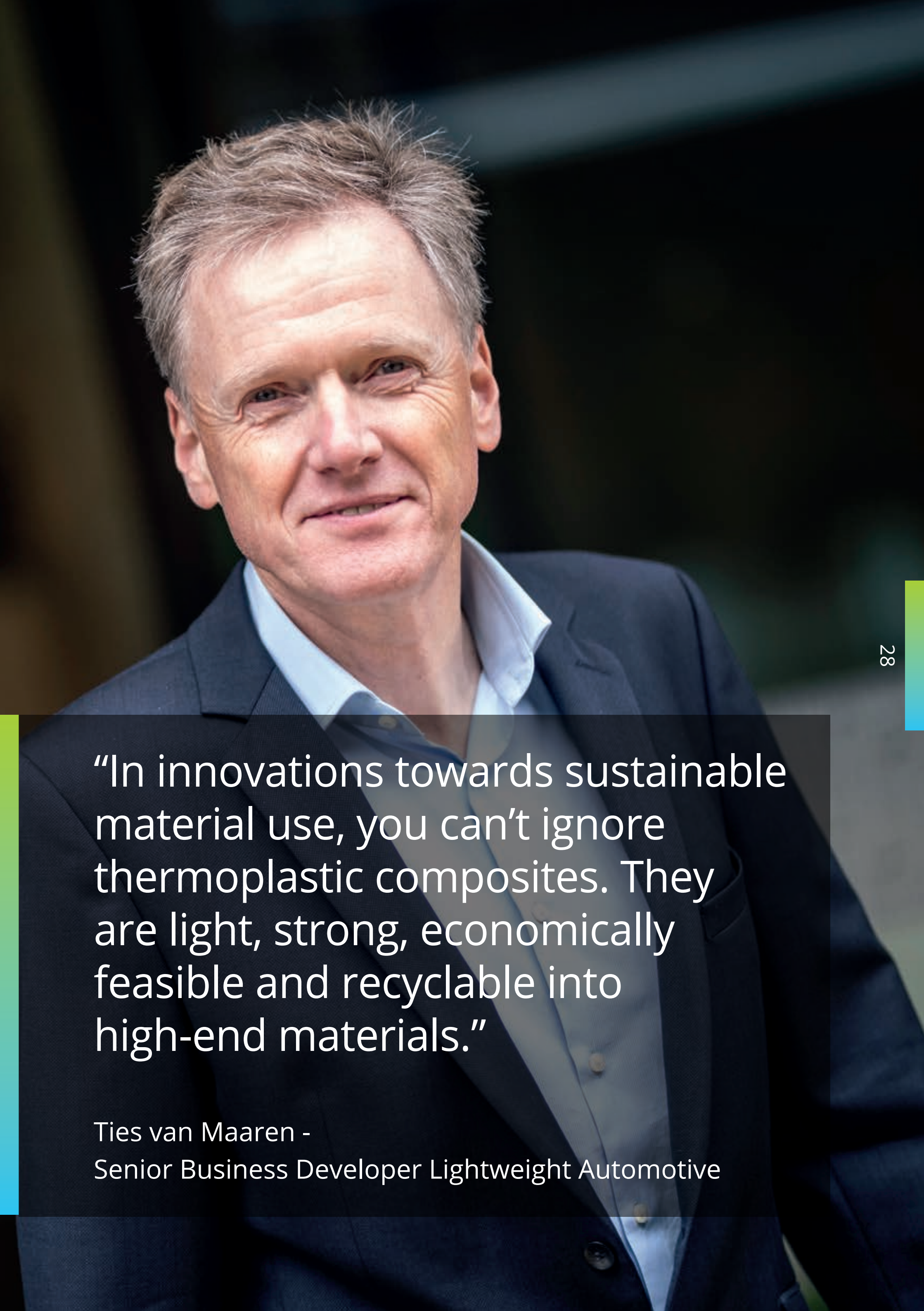
particle size below 10 nm. These pigments were used to prepare masterbatches in polyolefin with high particle loading. Afterwards, the masterbatches were used at defined volume percentages in combination with blanc polymer to prepare 200 µm thick nanoenabled polymer films with defined pigment loading between 10 and 35%. The nano-enabled polymer films were used as laminate in the preparation of 20 × 20 cm^2 monocrystalline silicon PV cells (Fig. 10). These cells were analysed by flash test and their wavelength-dependent optical properties were determined.

Improve aesthetics

Currently, one of the factors limiting the societal acceptance of buildingintegrated PV modules is the aesthetics. Most modules are matte blue or black in color, and the freedom of design is highly limited. Brightlands Materials Center and partners develop colored coatings for use on PV cover glass, that mimic nature. Very vivid colors are realized by using refined thin-film reflectors, which selectively reflect a rather narrow part of the visible light. A striking natural example of this socalled structural color is the metallic blue wings of a Morpho butterfly (Fig. 11a). The advantage of this technology over the use of conventional dyes or absorption pigments is that (1) all colors are achievable using the same coating materials and technology, (2) the light losses are much smaller, leading to aesthetically pleasing solar panels with a high current yield and (3) additional functionalities can be implemented in the same coating stack. Examples of additional functionalities we are currently investigating are anti-soiling and sub-bandgap wavelength reflection. The latter contributes to avoidance of unnecessary heating of BIPV modules.

"If we manage to exchange all windows in the EU with high-performance glazing by 2030, the annual energy savings would add up to 75.5 megatonnes of oil equivalents. This would result in an annual reduction of CO_2 emissions of 94.3 million tonnes."

Pascal Buskens -
Program Manager Sustainable Buildings



“In innovations towards sustainable material use, you can’t ignore thermoplastic composites. They are light, strong, economically feasible and recyclable into high-end materials.”

Ties van Maaren -
Senior Business Developer Lightweight Automotive

RESEARCH HIGHLIGHTS
Lightweight Automotive

Program focus

A major driver in the automotive world is to reduce emissions such as CO_2 and NOx, for instance guided by EC directives. Next to addressing emissions, end-of-life vehicle solutions are becoming more and more important to meet overall life cycle analysis and carbon footprint goals. In the ongoing electrification developments, lightweight continuous fiber reinforced thermoplastics materials can play an important role by reducing weight and extending driving range of traditional fossil-fuel driven vehicles as well as evehicles. The challenge of the combined automotive and materials industry is to have these lightweight materials available for large series production at a competitive cost price. In addition, industries such as automotive and aerospace are in need of predictability of long-term performance of composite parts to facilitate the longer life expectancy of newer generation (e-)vehicles and fuel-efficient aircraft. Recently, more emphasis on sustainability goals and ambitions require a material transition in which materials are used in a more circular approach with both post-industrial and postconsumer material streams being used in a reuse or recycling route. In both cases lightweight continuous fiber reinforced thermoplastics (TPC) are part of the solution.

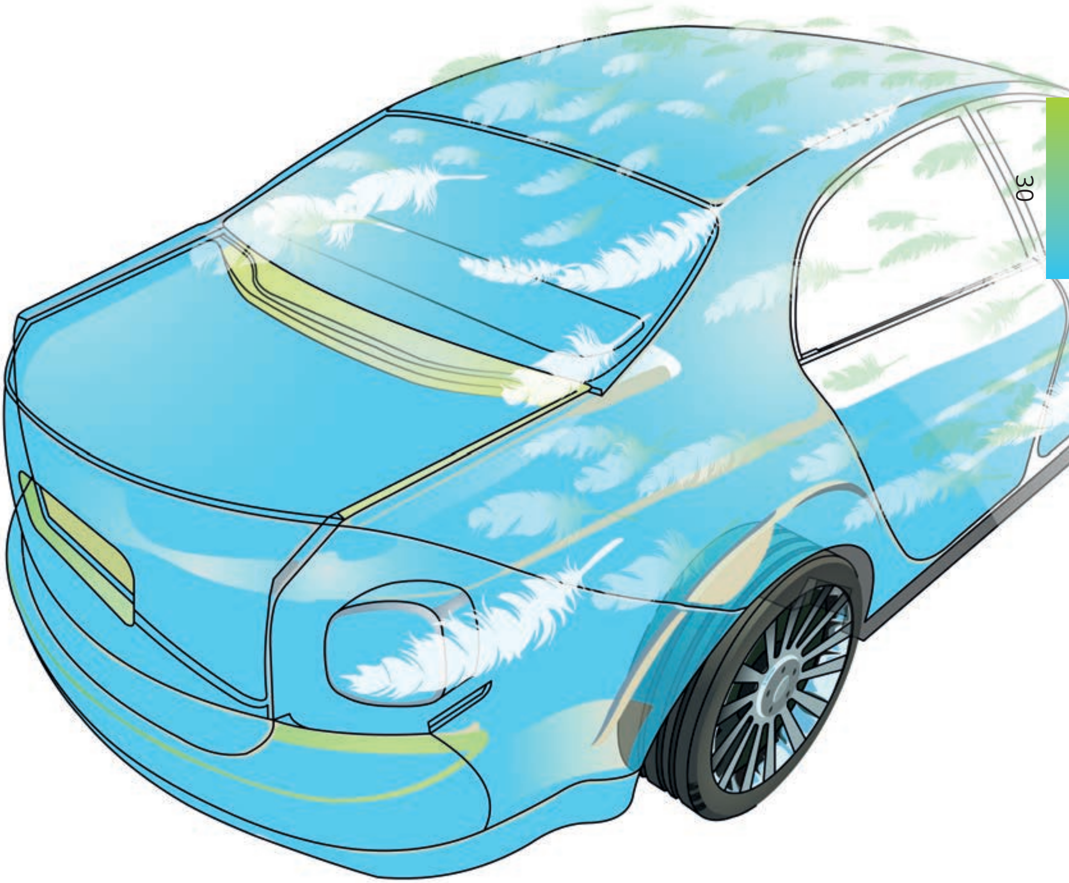
Ambition

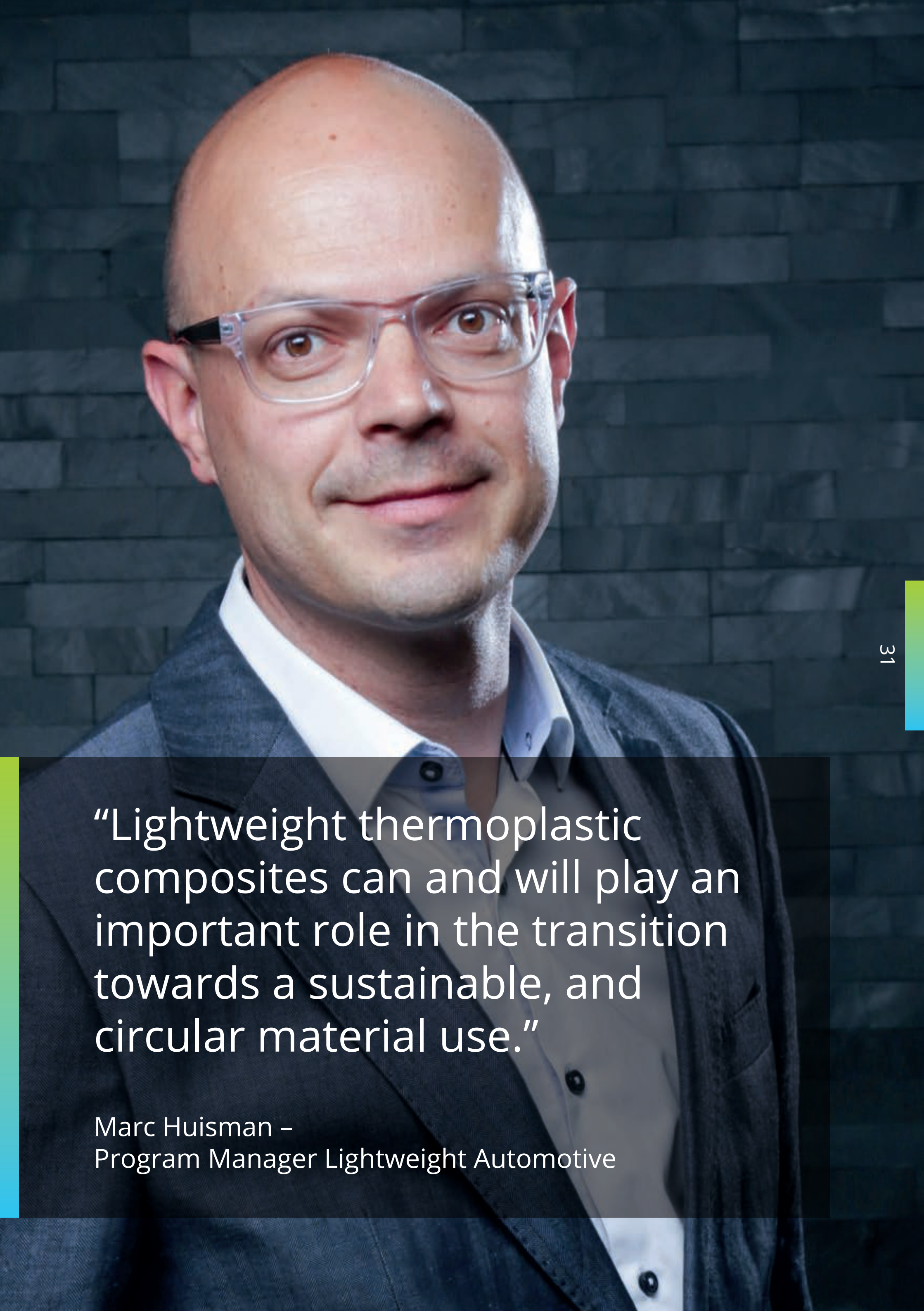
The ambition of Brightlands Materials Center's shared research program Lightweight Automotive is to contribute to sustainable (automotive) mobility by developing innovative solutions based on expertise in the field of polymeric materials such as long and continuous fiber reinforced thermoplastics as well as hybrid material combinations.

Our expertise bridges theory and practice such as

- thermoplastic composite materials and processing technologies: among others overmolding, (renewable) fibers and polymers;

- durability prediction through multiscale, multiphysics modelling, development of test methodologies for adhesion and interface behaviour;
- thermo-mechanical recycling, material design and development for recycling for re-use in high-end applications;
- a dedicated fieldlab for advanced testing and processing of thermoplastic composites and reinforced polymers.





“Lightweight thermoplastic composites can and will play an important role in the transition towards a sustainable, and circular material use.”

Marc Huisman –
Program Manager Lightweight Automotive

RESEARCH HIGHLIGHTS
Lightweight Automotive

*Fig. 12:
Opening event of the processing and testing lab TPC with project partners*

*Fig. 13:
(a) Our new processing and testing lab for TPC with thermoforming over-molding machine, (b) Sample, product demonstrators with simulation*

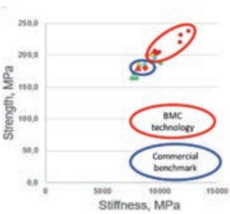


*Fig. 14:
Potential of Brightlands Materials Center's recycling technology in terms of short-term mechanical performance*

Technology developments

In 2019, the main developments for Brightlands Materials Center's program Lightweight Automotive were 1) realization and opening of Fieldlab Thermoplastic Composites at the Brightlands Chemelot Campus; 2) demonstration of the newly designed and customized thermoforming/overmolding machine; 3) various demonstrators developed using in-house developed material processing knowhow for hybrid materials and advanced simulation models; and 4) the processing and material technology to recycle TPC postindustrial waste into long fiber thermoplastics (LFT) was further improved.

The program Lightweight Automotive opened in the field lab "Thermoplastics Composites" on the final location at the Brightlands Chemelot Campus in Geleen (Fig. 12). The new experimental facilities include, among others, a unique thermoforming/overmolding machine (Fig. 13a) customized for R&D purposes, equipped with sample and product demonstrators (Fig. 13b). This enables material process optimization, a testing method and knowhow development for hybrid materials as well as advanced multiscale simulation models.

Evaluation of recycling TPC waste into LFT on larger scale equipment, combined with process optimization and material modification improved the mechanical behaviour by 30% compared to current commercial benchmarks (Fig. 14). Also, in collaboration with TNO's unit Circular Economy and Environment, LCA tools have been developed for the Brightlands Materials Center thermomechanical recycling technology, which confirm benefits in terms of CO_2 and costs of this route.

RESEARCH HIGHLIGHTS
Lightweight Automotive

Projects (private-public partnerships)

- **OP Zuid project “Proeftuin” on Thermoplastic Composites**
  The OP Zuid project “Fieldlab Thermoplastic Composites” opened its facilities in October 2019 at a new location on the Brightlands Chemelot Campus in Geleen. Customized overmolding processing equipment, test and analysis equipment for evaluation of adhesion and functionality of samples and demonstrator parts in overmolding have been developed.

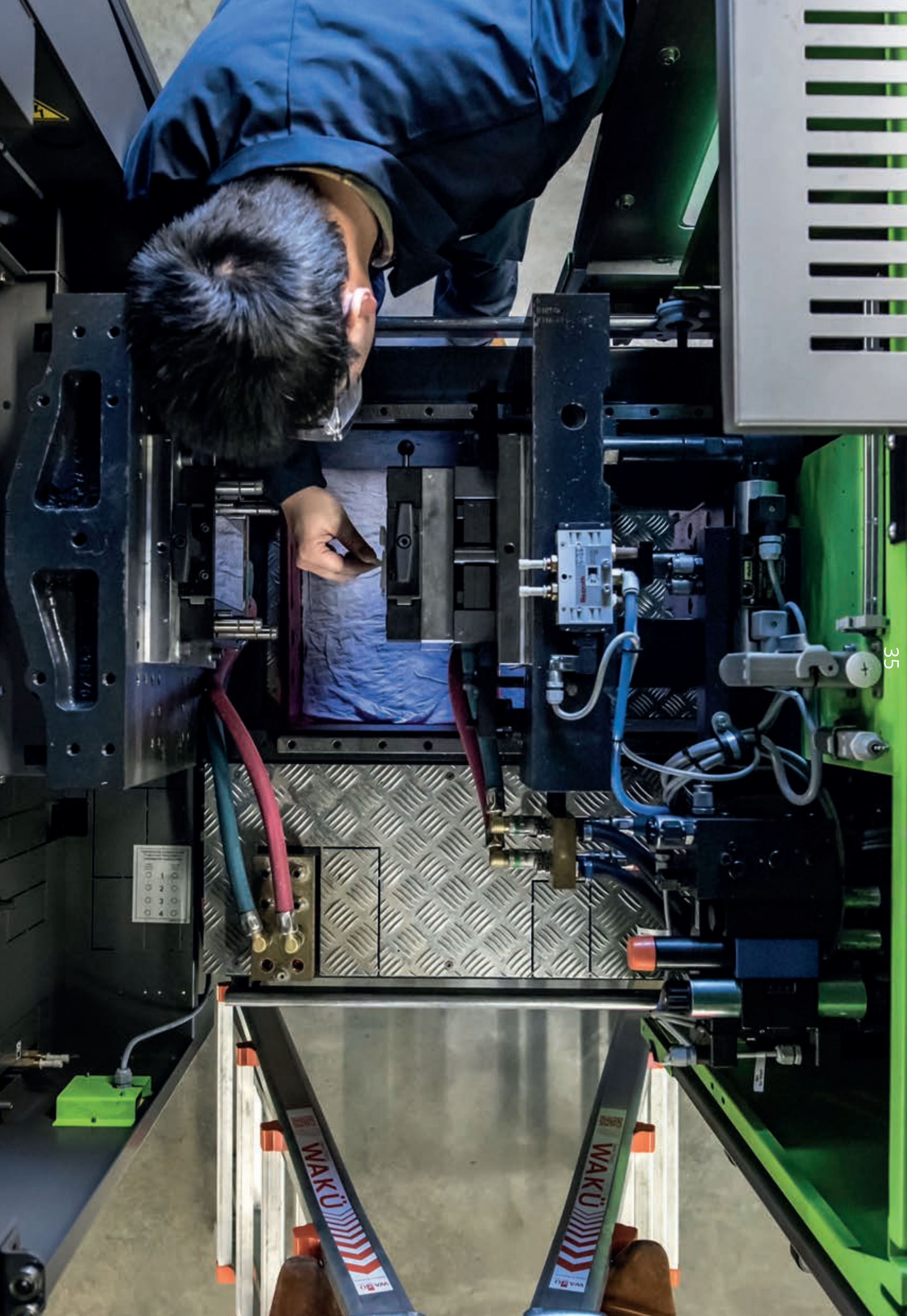
- **Interreg project “Flexlines” on flexible electronics in thermoplastic parts**
  This project started January 2018 together with six partners, and targets the development of a flexible electronics ecosystem. This system will be located at Holst and Imec, and be supported by integrated know-how through the production chain ranging from flexible microelectronics to polymer processing. Brightlands Materials Center develops technology on material properties and processes such as crystallization, deformation, degradation, adhesion and interaction between TFT circuits during injection molding at high melt temperatures. Sample demonstrators with electronic functionality have been developed.

- **NWO project “FAITH” on failure in thermoplastic composites**
  This research project is defined with the University of Twente (Prof R. Akkerman and Prof L. Govaert of the Department of Mechanical Engineering) and comprises two PhDs who started in Q2 2018 and are characterizing and modelling the failure behaviour of overmolded composite tapes and plates as a function of long-term ageing and fatigue loading.

- **TKI project "TOOSDER" on metal-to-thermoplastic composite release mechanisms**
  This is a cooperation between Brightlands Materials Center, TPRC and UT which started with two PD Eng in Q2 2018. The objective is to put forward tool surface designs with improved thermoplastic composite releasability after consolidation. This requires fundamental understanding and quantification of underlying mechanisms that play a role at the metal–polymer interface. Results will be a better understanding of the release as well as the adhesion mechanisms of the interface between the thermoplastic composite and the metal tool.

- **OP Zuid project "Proeftuin" on recycling of thermoplastic composite**s
  The OP Zuid project "Fieldlab Recycling of Thermoplastic Composites" started in 2019. It is a collaboration between eleven partners to turn thermoplastic composite waste into highvalue material. Goals are the establishment of a demanddriven, open innovation research environment enabling solutions for recycling thermoplastic composites, and developing and demonstrating technological recycling innovations involving the complete value chain ecosystem.

- **TKI project "AdhesionADD" on polymermetal adhesion**
  This research project started in Q3 2019 and studies the short- and long-term (scientific and technology aspects of) adhesion behaviour of thermoplastic polymers in metallic and composite hybrid material systems.
  The major goal is understanding, characterizing and improving the adhesion of the two major distinct classes of thermoplastics, namely semicrystalline and amorphous, using modified anhydride additives.


WAKÜ
WAKÜ

CORPORATE HIGHLIGHTS

We have grown considerably over the past year: in people, in partners, in projects, in equipment and in floor space.

CORPORATE HIGHLIGHTS

Partnerships

Partnerships

Over the past year we have set up various projects and partnerships. In total we now have 90 partners in our shared research programs and in various consortia and bilateral projects (of which 55 are in industry).

Infrastructure

We have moved into brand new facilities at the Brightlands Chemelot Campus. We now have 650 m^2 lab and pilot space at two locations (Buildings 220 and 24). We have invested in the acquisition of a variety of new equipment relevant for our programs: we have further increased our number of 3D printers (German RepRap X500, Anisoprint Composer, Ultimaker, Raise3D Pro2, a small-scale SLS powder printer, various DPL printers); smallscale plastics processing equipment (Xplore micro compounder, micro-injection molding), film extrusion, an Engel injection molder with a linear robot for insert molding, an 18 mm twin screw Coperion extruder, Fontijne Press) and testing equipment (Instron universal tensile testers with DIC imaging), various analytics tools (DSC, TGA, rheometry, microscopy, particle size determination, NIR and UV/Vis photospectrometers), various particle synthesis equipment and coating process equipment, a 50 × 50 cm^2 dip coater, a Buhler powder grinder and high temperatures furnaces. Brightlands Materials Center collaborates with Chemelot Innovation and Learning Labs (CHILL) on the use of polymer processing and testing equipment and with Enabling Technologies on the use of specialized analytical equipment.

CORPORATE HIGHLIGHTS

Projects

A number of Europe-funded programs have been running or started last year:

- OP Zuid Proeftuin on Thermoplastic Composites, together with ten industrial parties from the south of the Netherlands, with a total project size of €5.7 m;
- EnEf (Energy Efficiency), an Interreg project with six partners on the development of switchable windows with a project size of €3.4 m ;
- Flexlines, an Interreg project with among others TNO and Imec, on flexible electronics with a project size of €4.5 m;
- DynAM, an NWO TA program with TU/e, UM, DSM and Xilloc on dynamic polymer materials for additive manufacturing with a project size of €3.5 m;
- Reliable GF-3D, a European M-Era.Net project together with Fraunhofer IMWS on 3D printing of fiber reinforced polymeric materials with a project size of € 1.6 m;
- 100% Limburg Bike, an OP Zuid project together with the Belgian Cycling Factory and others on smart bikes with 3D printed composite lugs;
- Fieldlab Recycling TPCs: an OP Zuid project with various SMEs on the recycling of thermoplastic composites – project size is €3.0 m;
- Rolling Solar, an Interreg project with 19 partners on the application of flexible solar cells in public linear infrastructure – project size is €5.7 m.

Universities

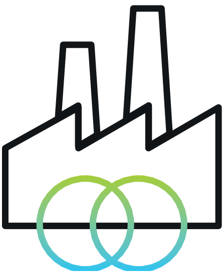
Collaborations are running with the Eindhoven University of Technology (Prof Sijbesma, Prof Anderson, Prof Schenning) and Maastricht University (Prof Moroni) in the field of Additive Manufacturing, with the University of Twente on thermoplastic composites (Prof Akkerman, Prof Govaert), with the University of Hasselt (Prof van Bael) on switchable coatings, with Zuyd University of Applied Sciences on various topics.

CORPORATE HIGHLIGHTS

Facts & Figures

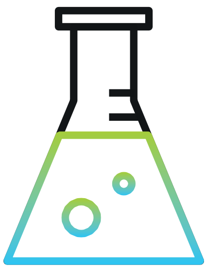
48 Workforce at the end of 2019

13 Nationalities at the end of 2019



55 Industrial partners in projects and programs

17 PhDs/Postdocs



$650m^2$ Labspace

PARTNERS

Industrial Partners

Alligator Plastics
Coroplast
VERBI
سابك sabic
CHEMTRIX Scalable Flow Chemistry
van Wees
Xstream Engineering
PHYSEE
EUROCARBON advanced fibre braiding and weaving technology
embedded ACOUSTICS
MCC INSTALLATIES
eloy
CMB Colorex Master Batch
Plastica THERMOFORMING
XILLOC Patient Specific Implants
SolaRoad
cato COMPOSITE INNOVATIONS
KS consulting bv
DSM BRIGHT SCIENCE. BRIGHTER LIVING.
INPROCESS LSP
ENBI PLASTICS
BELGIAN CYCLING FACTORY
JM
YPAREX
SMILE AGAIN
SGS
INTRON
POLYTEC HOLDING
MULLENS SPORTS AND HEALTH INNOVATIONS
KEMBIT innovation & intelligence
BÜHLER
ALLPLAST
OMT Solutions bv
elacin hearing protection {a sound experience
LAUDY BOUW & ONTWIKKELING
VKB International
Plastic & Product PPRECYCLING
NextDent by 3D SYSTEMS
CeraCarbon
KEDU polymers industries
RayScan
GKN AEROSPACE
VINDICO
POLYSCOPE fresh thinking, great products
AGOR KUNSTSTOFFTECHNIK
KOM
KRIYA MATERIALS
ENGEL
SPACE STRUCTURES
Ford
GLASS FOR GLASS
SOL TECH SOL INVICTUS GROUP
HEXAGON
EVERLAM BRILLIANTLY PROTECTED.
Fokker

Academic Partners

Other Partners


TNO
ONN

PUBLICATIONS

Additive Manufacturing

Journal articles

1. Anastasio, R., Peerbooms, W., Cardinaels, R., & van Breemen, L. C. A., Characterization of ultravioletcured methacrylate networks: From photopolymerization to ultimate mechanical properties, 2019, Macromolecules 52 (23), pp. 9220-9231.
2. Anastasio, R., Cardinaels, R., Peters, G. & van Breemen, L. C. A., Structure-mechanical property relationships in acrylate networks, 30 Sep 2019, Journal of Applied Polymer Science, 11 p., 48498.
3. Hejmady, P., Cleven, L., van Breemen, L., Anderson, P. & Cardinaels, R., A novel experimental setup for insitu optical and Xray imaging of laser sintering of polymer particles, 21 Aug 2019, Review of Scientific Instruments 90 (8), 12 p., 083905.
4. Paolucci, F., van Mook, M. J. H., Govaert, L. & Peters, G., Influence of post-condensation on the crystallization kinetics of PA12: from virgin to reused powder, 26 Jun 2019, Polymer 175, pp. 161-170.
5. Paolucci, F., Govaert, L. & Peters, G., In situ WAXD and SAXS during tensile deformation of molded and sintered polyamide 12, 5 Jun 2019, Polymers. 11 (6), 18 p., 1001.
6. Paolucci, F., Peters, G. & Govaert, L., Plasticity-controlled failure of sintered and molded polyamide 12: influence of temperature and water absorption, 3 Sep 2019, (accepted/in press), Journal of Applied Polymer Science, 48525.
7. Balemans, C., Hejmady, P., Cardinaels, R. & Anderson, P., Towards unraveling the sintering process of two polystyrene particles by numerical simulations, 2019, (accepted/in press) KoreaAustralia Rheology Journal.
8. Hejmady P., van Breemen, L. C. A., Anderson, P. D., & Cardinaels, R., Laser sintering of polymer particle pairs studied by in situ visualization, 2019, Soft Matter 15, pp. 1373-1387.
9. Sol, J. A. H. P., Peeketi, A. R., Vyas, N., Schenning, A. P. H. J., Annabattula, R. K. & Debije, M. G., Butterfly proboscis-inspired tight rolling tapered soft actuators, 2019, Chemical Communications. 55 (12), pp. 1726-1729.

PUBLICATIONS

Conference papers

1. Segers, M., Multi material 3D printing with photopolymers, RapidPro, Veldhoven, March 2019.
2. Janssen, R., Embedding unique functionality in 3D printed parts by materials solutions for additive manufacturing, AMUG, Chicago, USA, April 2019.
3. Gasperini, A., Embedding unique functionalities in composites by continuous fiber printing, 3D Printing Europe, Berlin, Germany, April 2019.
4. Segers, M., Multimaterial AM with photopolymers, Additive International, Nottingham, UK, July 2019
5. Janssen, R., Inspiring innovations in polymer materials for additive manufacturing, PiMW event, Luik, Belgium, October 2019.
6. Stüpp, C., Gasperini, A., ten Cate, T., New developments of short and continuous fiber printing with exceptional mechanical behavior and unique functionalities: Polymers for 3D printing. Düsseldorf, Germany, December 2019.

PhD theses

1. Paolucci, F., Characterisation of crystallisation kinetics and mechanical properties of Polyamide 12, 4 Jul 2019, Eindhoven: Technische Universiteit Eindhoven.
2. Maassen E., Dynamic covalent chemistry for UV curable networks, 2 Oct 2019, Eindhoven: Technische Universiteit Eindhoven
3. Anastasio, R.. UVcured polymer networks: From processing to properties. Eindhoven: Technische Universiteit Eindhoven. (2019)
4. Balemans, C., Computational analysis of polymer powder sintering for 3D printing, 29 Oct 2019, Eindhoven: Technische Universiteit Eindhoven.

Posters

1. Sol, J. A. H. P., Peeketi, A. R., Vyas, N., Schenning, A. P. H. J., Annabattula,R. K., Debije, M. J., Butterfly proboscis inspired soft tapered actuators, International Liquid Crystal Elastomer Conference 2019, Eindhoven, the Netherlands.
2. Morgan, F. et al., Modulating the printability of bioinks through catalyzed imine crosslinking, CHAINS 2018, Veldhoven (the Netherlands), December 2018.
3. Morgan, F. et al., Tuning viscoelastic hydrogels by mixing dynamic crosslinkers, ESB 2019, Dresden (Germany), September 2019.
4. Zhang, H., Majumdar, S., van Benthem, R., Sijbesma, R., Heuts, H., Dynamic polyester network via intramolecular catalysis, CHAINS 2019, Veldhoven, the Netherlands, December 2019.

PUBLICATIONS

Sustainable Buildings

Scientific articles in peer-reviewed journals:

1. Sastre, F. Versluis, C. Meulendijks, N. RodríguezFernández, J. Sweelssen, J. Elen, Van Bael, M. K., den Hartog, T., Verheijen, M. A., & Buskens, P., Sunlightfueled, lowtemperature ru catalyzed conversion of CO2 and H2 to CH4 with a high photon-to-methane efficiency, 2019, ACS Omega 4, 7369.
2. Verkaaik, M., Grote, R., Meulendijks, N., Sastre, F., Weckhuysen, B. M., & Buskens, P., Suzuki Miyaura cross coupling using plasmonic Pd decorated Au nanorods as catalyst: A study on the contribution of laser illumination, 2019, ChemCatChem 11 (19), pp. 4974-4980.
3. Rezaei, N., Isabella, O., Vroon, Z., & Zeman, M., Optical optimization of a multi-layer wideband anti-reflection coating using porous MgF2 for sub-micron-thick CIGS solar cells, 2019, Solar Energy 177, pp. 5967.
4. Rezaei, N., Isabella, O., Vroon, Z., & Zeman, M., Quenching Mo optical losses in CIGS solar cells by a point contacted duallayer dielectric spacer: a 3D optical study, Optics express 26 (2), A39A53.
5. Broers, W., Vasseur, V., Kemp, R., Abujidi, N., & Vroon, Z. Decided or divided? An empirical analysis of the decisionmaking process of Dutch homeowners for energy renovation measures, 2019. Energy Research & Social Science, 58.
6. Rezaei, N., Isabella, O., Procel, P., Vroon, Z., & Zeman, M., Optical study of back-contacted CIGS solar cells, 2019, Optics Express 27 (8), A269A279.
7. Blanker, A. J., Berendsen, P., Phung, N., Vroon, Z., Zeman, M., & Smets, A.H.M., 2018, Advanced light management techniques for twoterminal hybrid tandem solar cells, Solar Energy Materials and Solar Cells 181, pp. 77-8.

Radio and television interviews:

1. Two interviews on “Energy efficient architectural glazing” broadcast by Business News Radio.
2. One TV interview on “Energy efficient architectural glazing” broadcast by 1Limburg.

PUBLICATIONS

Presentations at conferences and symposia:

1. Buskens, P., Solution processed thermochromic coatings for energy efficient glazing. Glass Performance Days 2019, Tampere, Finland.
2. Buskens, P., Solution processed thermochromic coatings for energy efficient glazing. 3rd Advanced Materials in Construction Summit 2019, Berlin, Germany.
3. Buskens, P., Mann, D., Segers, M., Keul, H., & Möller, M., Synthesis of hybrid polystyrenepoly(organosiloxane) particles with complex architectures through use of organotrialkoxysilanes as surfmer. ACS Fall Meeting 2019, San Diego (USA).

Strategic research alliances:

1. Zuyd Hogeschool Lectoraat, Nanostructured Materials
2. Zuyd Hogeschool Lectoraat, Sustainable Energy in the Built Environment
3. Universiteit Hasselt, Anorganische en Fysische Chemie, gastprofessorschap Pascal Buskens

Publications Lightweight Automotive

Conferences papers and presentations

1. Bakr, M., Su, Y., Bossuyt, F., & Vanfleteren, J., Effect of overmolding process on the integrity of electronic circuits, 22nd Microelectronics and Packaging Conference (EMPC) & Exhibition, September 1619, 2019, Pisa, Italy.
2. Bakr, M., Bossuyt, F., Vanfleteren, J., & Su, Y., Use of injection over-molding as a promising technique for embedding printed circuit boards to realize smart plastic products, Poster International MicroNano conference, December 1011, Utrecht, the Netherlands.
3. Feinaeugle, M., Mezera, M., & Römer, G. R. B. E., Laserinduced periodic surface structures on stainless steel molds for thermoplastic composite materials manufacturing. Lasers in Manufacturing 2019, Munich, Germany.

Student theses

1. van der Pluijm, P., Evaluation of the mechanical behaviour of adhesively bonded GF/PA6 steel hybrid material, 2019.
2. van der Meer, A., Influence of temperature on the mechanical performance of the interface of overmolded thermoplastic composites, 2019.

COLOPHON

Editorial team
Marnix van Gurp
Peter Wolfs
Tessa ten Cate
Marc Huisman
Pascal Buskens
Suzanne van Goor
Nicole Bisscheroux

Photography
Wouter Roosenboom

Design and layout
Morres & Company

Contact
Brightlands Materials Center
Urmonderbaan 22 (Gate 2)
6167 RD Geleen, the Netherlands

+31 (0)88 866 96 90

info@brightlandsmc.com

Visit us at
www.brightlandsmaterialscenter.com

Brightlands
Materials Center

INSPIRING

innovations in plastics

www.brightlandsmaterialscenter.com

TNO innovation for life

provincie limburg