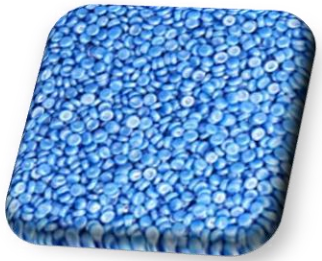
Advancing 3D Printing by Process Simulation

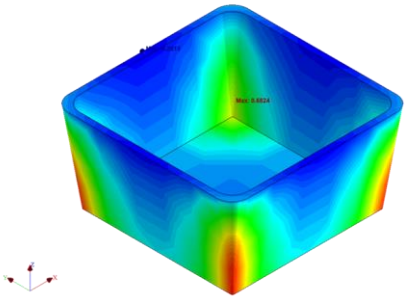
Dr. Carl Schirmeister, Business Development Manager
Dr. Massimo Nutini, CAE Engineer

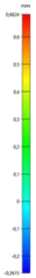
Material Meets Engineering (MME) Conference
Frankfurt, 30th June, 2022

Digital Manufacturing by 3D Printing



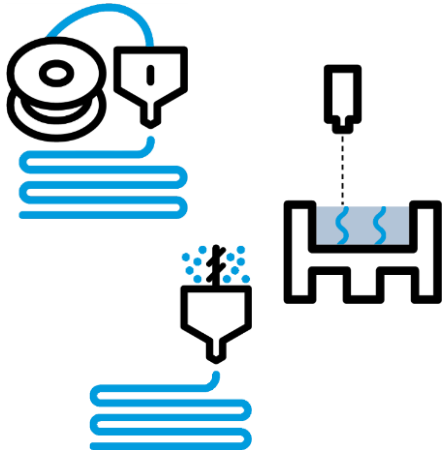
Material





Software

3D Printer

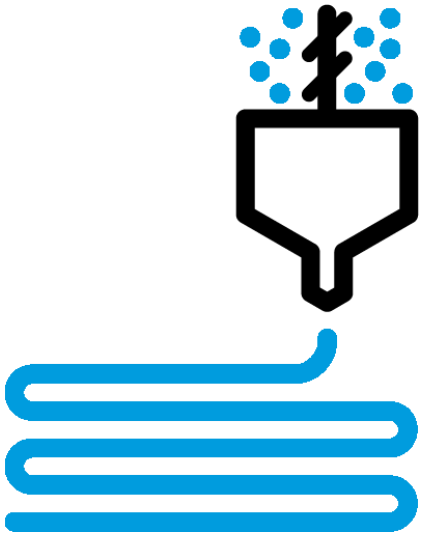


Material-Related Challenges in Extrusion-Based 3D Printing

III. Interlayer fusion

II. Warpage

I. Build plate adhesion



Technology-based process and application-specific material development for 3D printing

LyondellBasell
Our legacy of Innovation on the Path to Additive Manufacturing

Beon3D

Hoechst, a predecessor company, **initiates industrial-scale production** of polyethylene (PE) in Frankfurt, Germany.

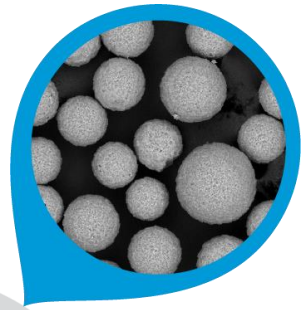
1955

Production is started at the **first *Hostalen*** high density polyethylene (HDPE) process plant.

1975

Predecessor company scientists Karl Ziegler and Giulio Natta are **awarded the Nobel Prize for their breakthrough discoveries** in the creation of PE and polypropylene (PP).

1963



The ***Spheripol*** process, currently the most widely used polyofins process technology, **is introduced by predecessor company Montedison**.

1982

LyondellBasell announces construction of the new ***Hyperzone* PE plant** in La Porte, Texas, which utilizes the company's new proprietary technology.

2016

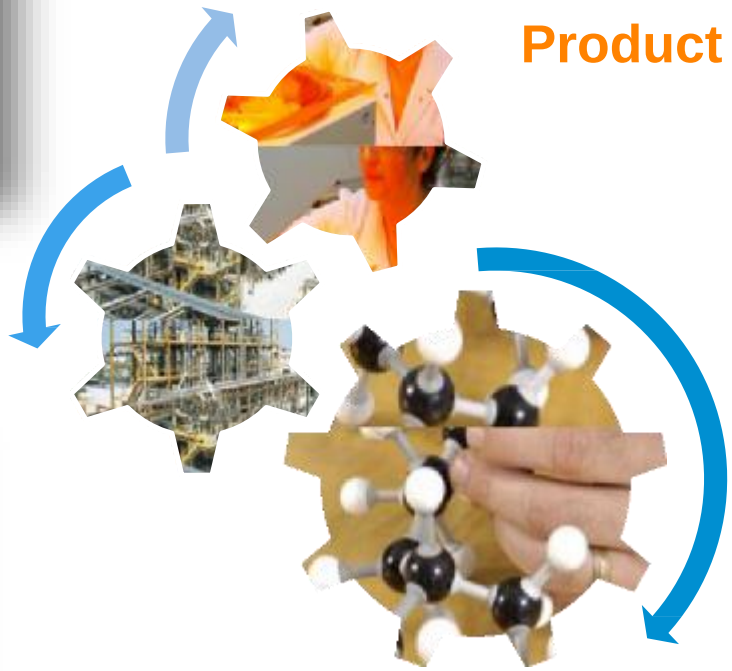
Launch of ***Beon3D*** for additive manufacturing

2020

#1

- Global producer of polypropylene compounds
- Producer of polyethylene in Europe
- Producer of polypropylene in North America and Europe

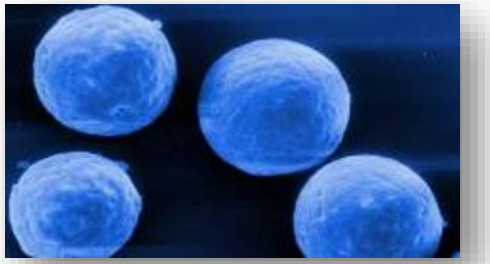
LyondellBasell Research & Development Engine



Product

Process

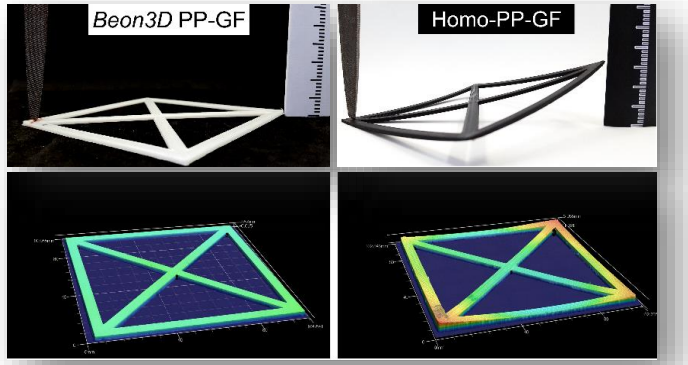
Catalyst

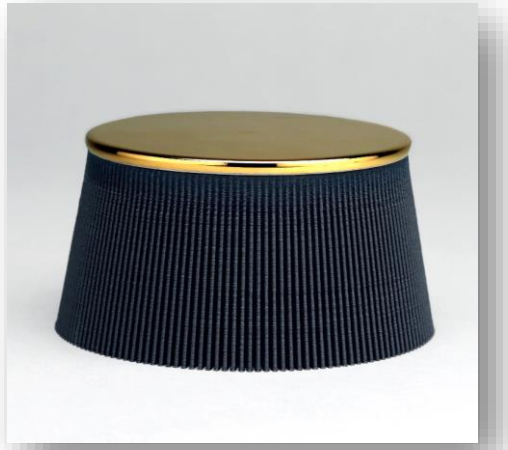


Creating polyolefins with higher material performance, improved versatility and broader properties able to successfully replace traditional materials

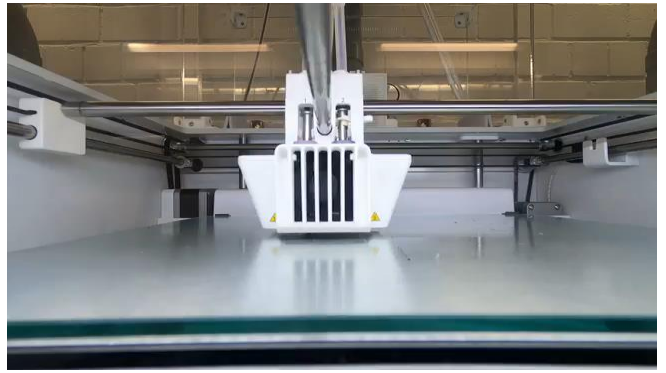
Beon3D – Tunable Material Performance for Industrial 3D Printing

- ✓ **Low Warpage**
- ✓ **Enhanced build plate adhesion**
- ✓ **Wide process windows for an industrial environment**
- ✓ **Optimized mechanical properties**
- ✓ **Low density – high resistance**

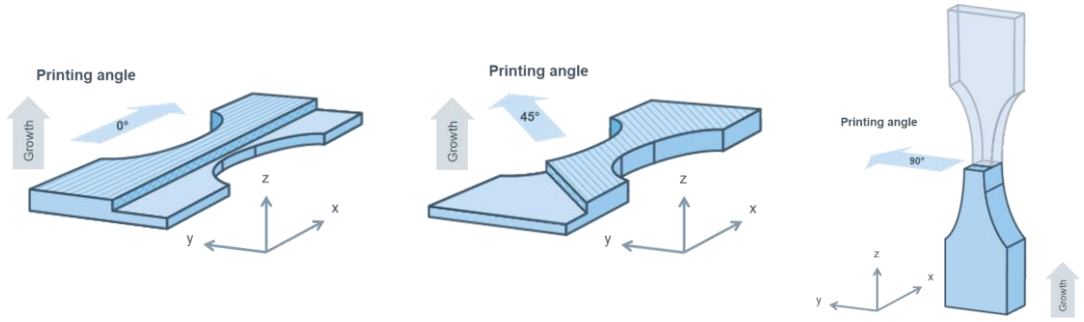




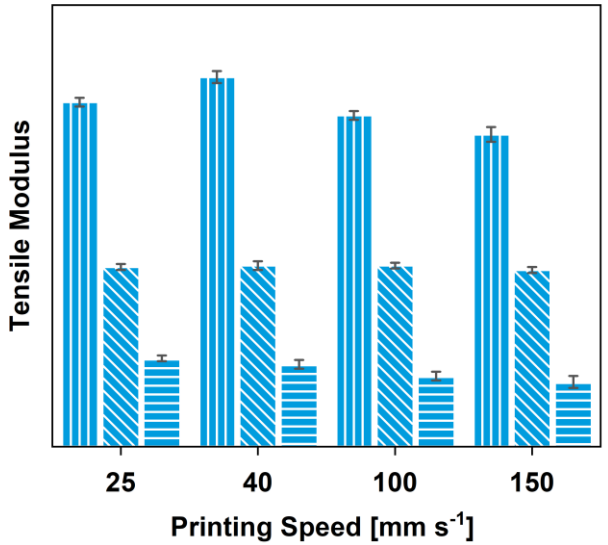
Copyright: Prof. A. Rösner, HS Niederrhein
Gilded china lid: Porzellanmanufaktur Fürstenberg

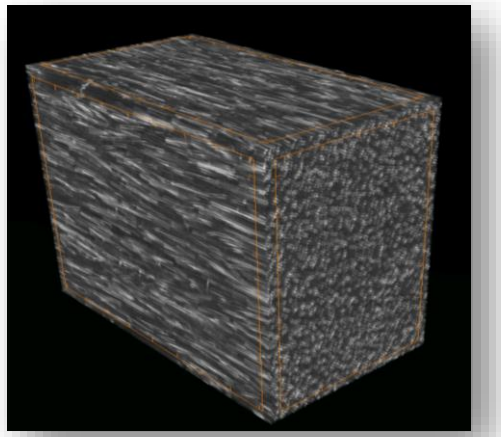


Beon3D – Tunable Material Performance for Industrial 3D Printing

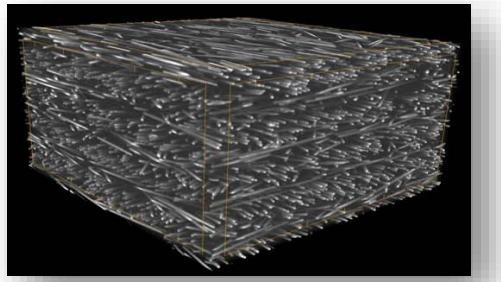


Material	Tensile Modulus 0° [MPa]	Tensile Modulus ±45° [MPa]
***Beon3D* PPG 2290S**	3000	1200
***Beon3D* PPG 2291S**	5600	2400





µCT scan 0° 3D printing



µCT scan ±45° 3D printing

- ✓ **Digital tuning of glass fiber orientation and mechanical properties**
- ✓ **Advancing industrial 3D printing by enhanced manufacturing speed**

Competence Center 3D Printing, Frankfurt

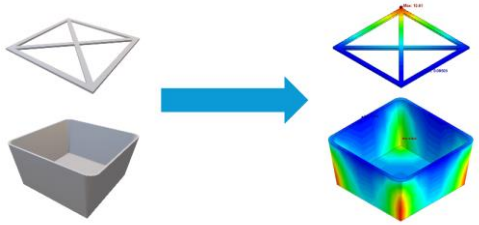
- **Material development**

3D printing ***innovation room****, R&D Frankfurt*

- **Process development**

Filament extrusion *line, R&D Frankfurt*

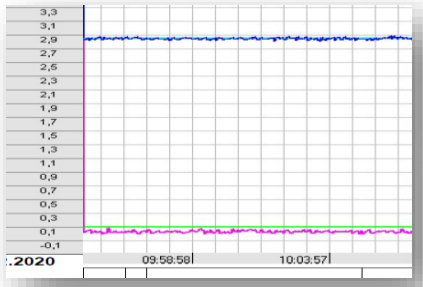
- **Process simulation**

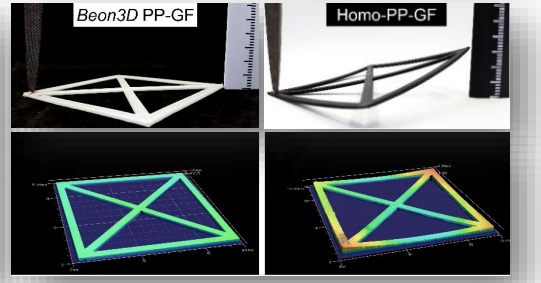


Simulation *of warpage, enhanced printing pathway, and mechanical properties*

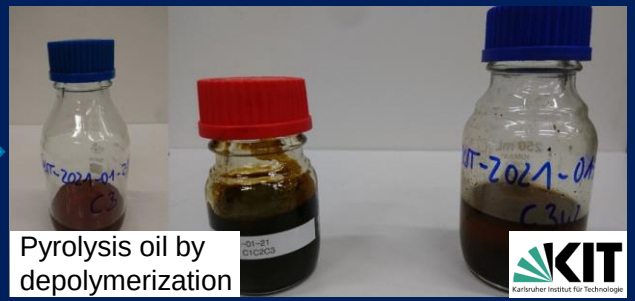
- **Method and device development for quality assurance**

Filament release documentation & warpage quantification





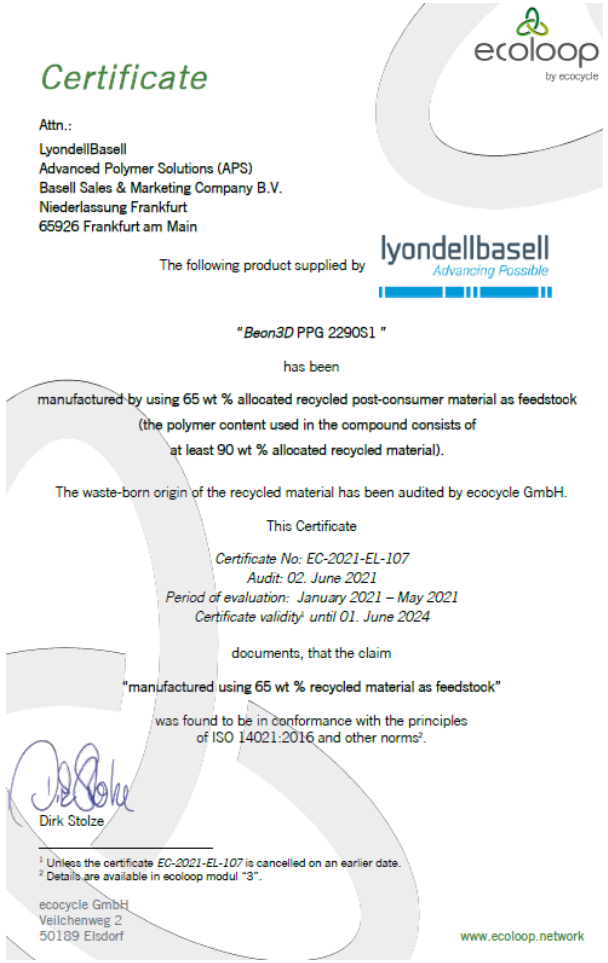
Greentech Festival – Certified Molecular Recycled PP Compound



lyondellbasell

- Cracking (Wesseling)
- Polymerization
- Compounding (Bayreuth)
- Filament extrusion (Frankfurt)

92% Automotive PCR content via mass balance approach



ecoloop
by ecocycle

Certificate

Attn.:
LyondellBasell
Advanced Polymer Solutions (APS)
Basell Sales & Marketing Company B.V.
Niederlassung Frankfurt
65926 Frankfurt am Main

The following product supplied by lyondellbasell *Advancing Possible*

"*Beon3D* PPG 2290S1 "

has been

manufactured by using 65 wt % allocated recycled post-consumer material as feedstock
(the polymer content used in the compound consists of
at least 90 wt % allocated recycled material).

The waste-born origin of the recycled material has been audited by ecocycle GmbH.

This Certificate

Certificate No: EC-2021-EL-107
Audit: 02. June 2021
Period of evaluation: January 2021 – May 2021
Certificate validity[1] until 01. June 2024

documents, that the claim

"manufactured using 65 wt % recycled material as feedstock"

was found to be in conformance with the principles
of ISO 14021:2016 and other norms[2].

Dirk Stolze

[1] Unless the certificate *EC-2021-EL-107* is cancelled on an earlier date.
[2] Details are available in ecoloop modul "3".

ecocycle GmbH
Veilchenweg 2
50189 Elsdorf

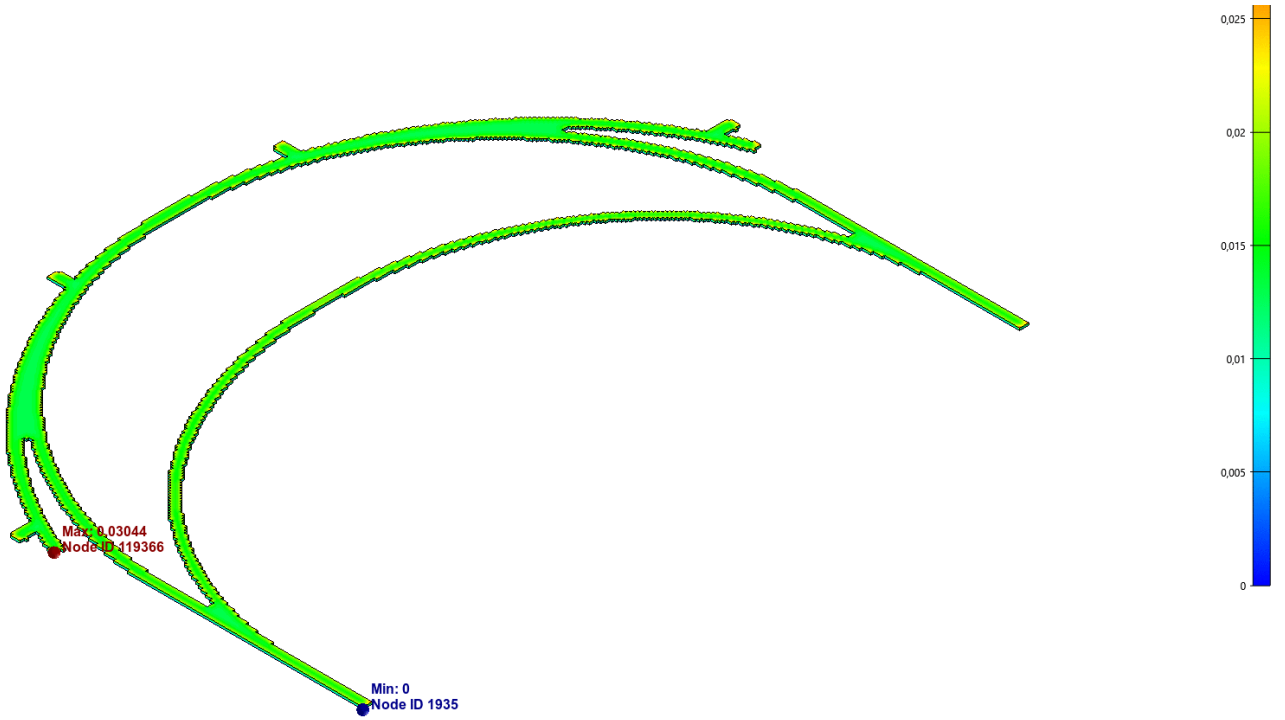
www.ecoloop.network

3D Printing Process Simulation – CAE contribution

Beon3D

Role of CAE tools (Process simulation):

- **Predicting warpage → optimizing process conditions for warpage reduction**
- **Determining local material properties → Optimizing process conditions to obtain tailored material properties**



CAE: How does a simulation work?

- ✓ **How a basic process simulation works**

  ✓First layer fixed on the plate

  ✓ Progressive Activations of the layers when the bead is passed. Bead movement obtained from machine files (gcode)

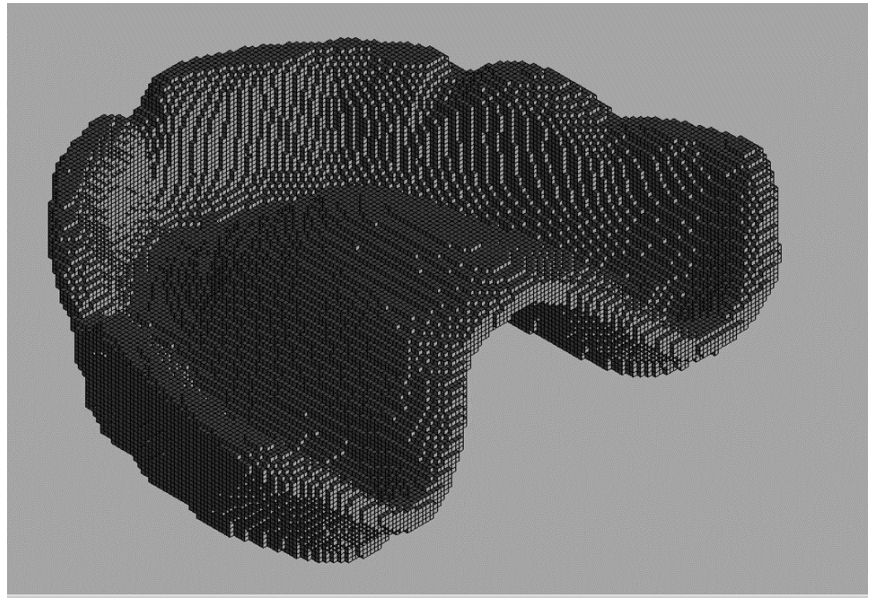
  ✓ Subsequent Thermo-mechanical analysis of the layers, including temperature evolution, material thermal expansion and relaxation

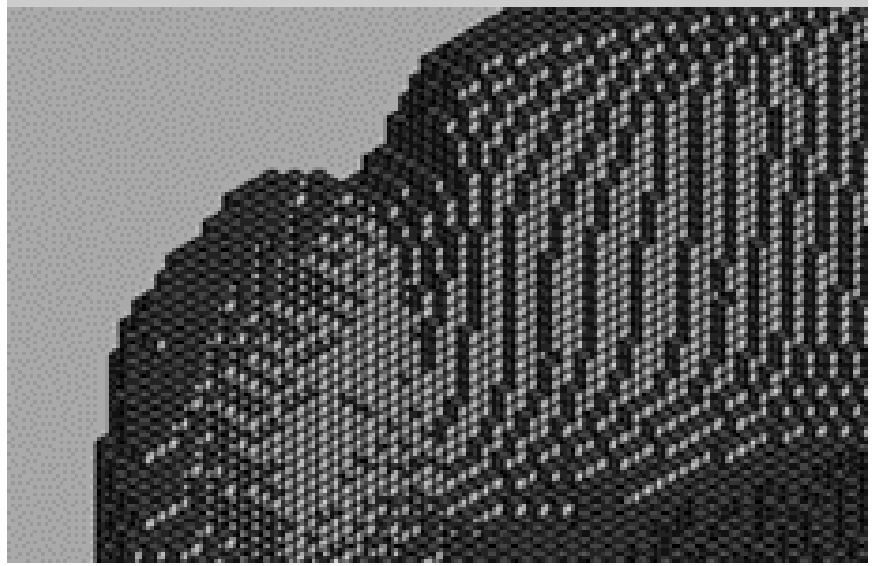
  ✓After all layer depositions were simulated, release of the boundary Conditions; thermal exchange with the outside continues, shrinkage and relaxations still occur

- ✓ **Mainly Temperature-dependent thermo-mechanical properties requested in input: Thermal conductivity, specific heat, specific volume**

- ✓ **Mechanical properties requested in input: Elastic Modulus, Prony Series (Viscoelasticity model), WL coefficients (Temperature-dependence)**

- ✓ **Software used: Digimat AM by MSC Software**



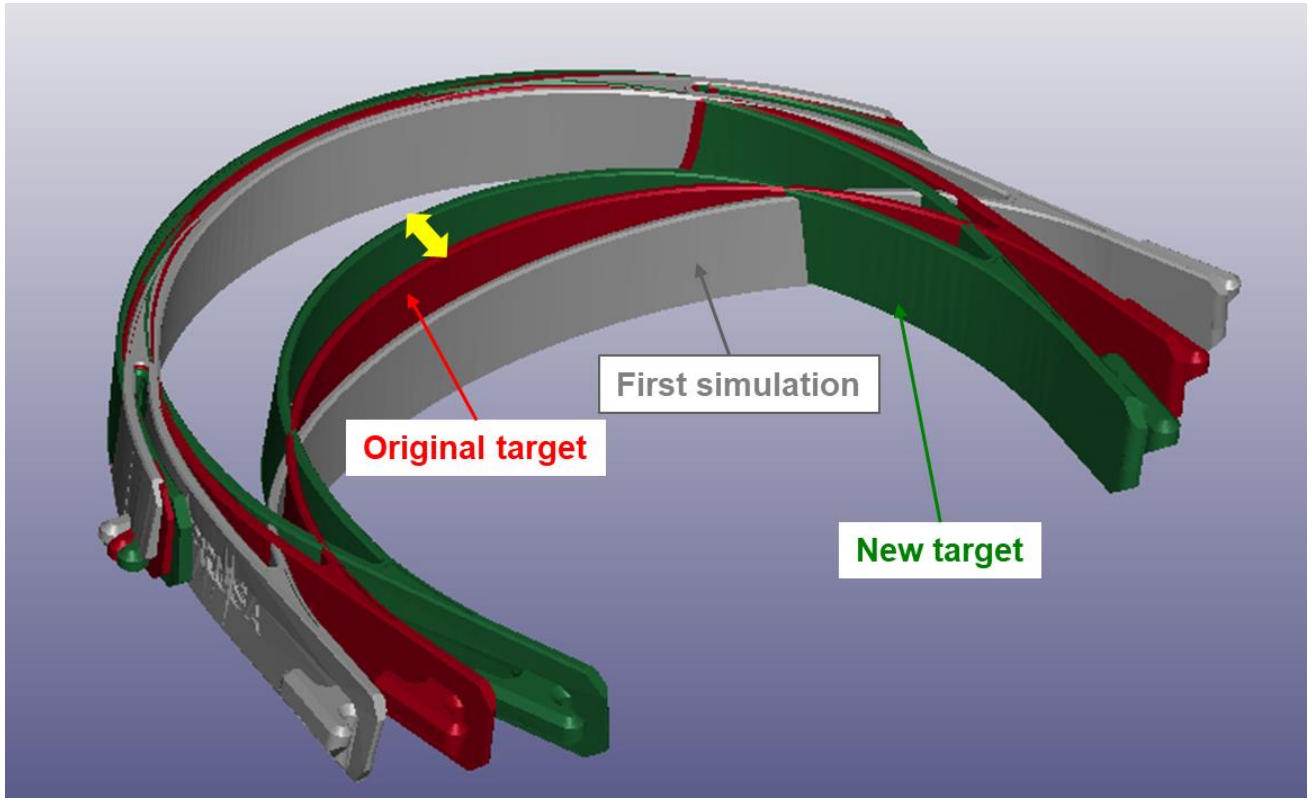


CAE: How does an optimization work?

Beon3D

✓ Example: Prusa HeadBand

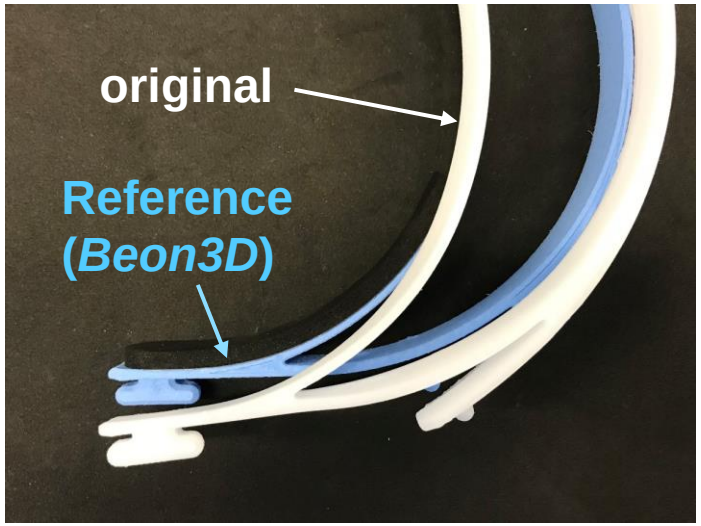
Courtesy from prusa3d.com

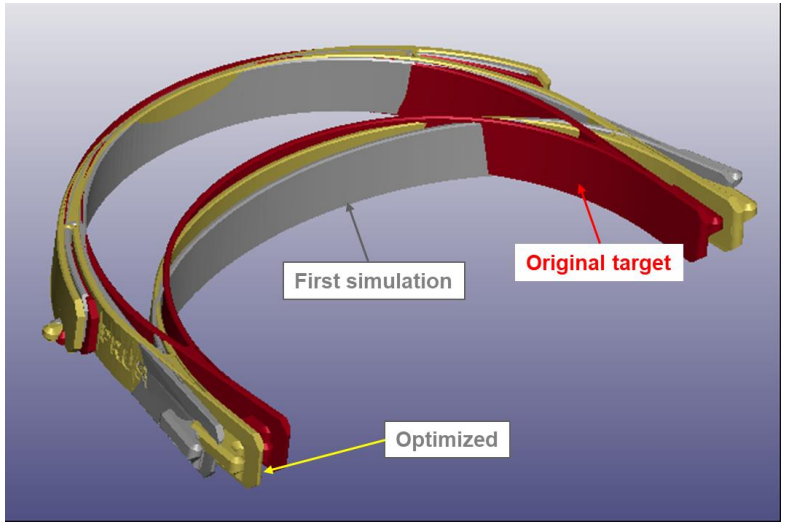


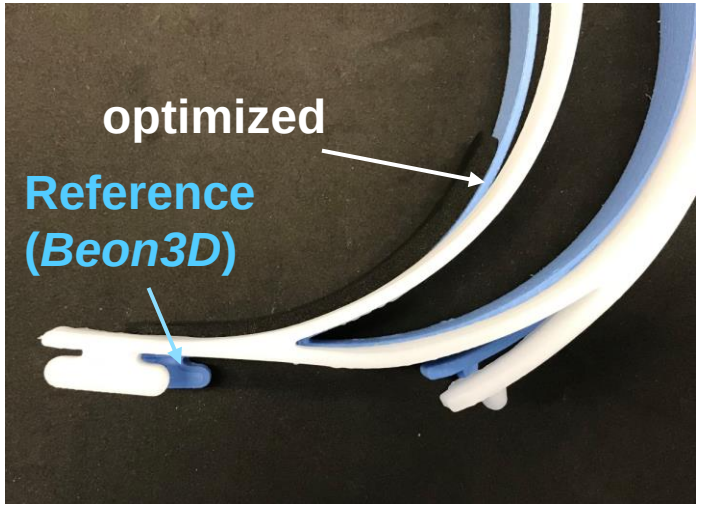
✓ The shape optimization is based on the compensations of the deviations from the desired target as obtained from the process simulation

CAE: How does an optimization work?

✓ Example: Prusa HeadBand



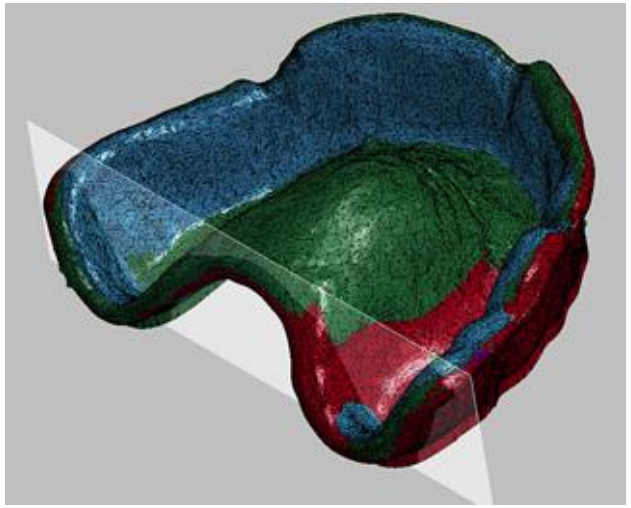




✓ **For this activity, executed in collaboration with Faculty of Medicine of Freiburg Hospital, the optimization led to Zero Rejection of the manufactured parts**

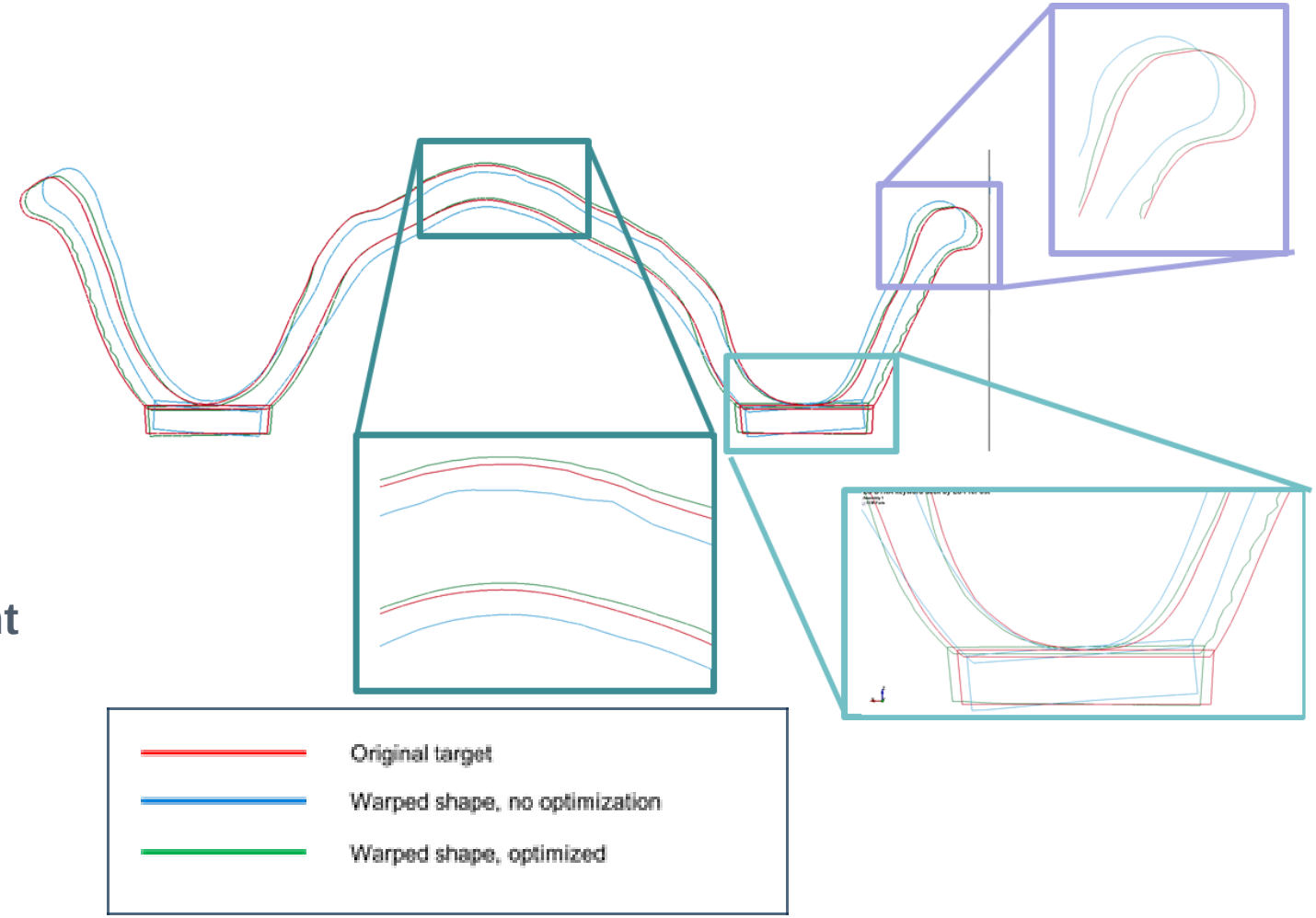
CAE: How does an optimization work?

- ✓ **Example: Surgical Guides for prosthetic-driven oral implant placement (activity in collaboration with Faculty of Medicine of Freiburg Hospital, Prof. Dr. Spies)**



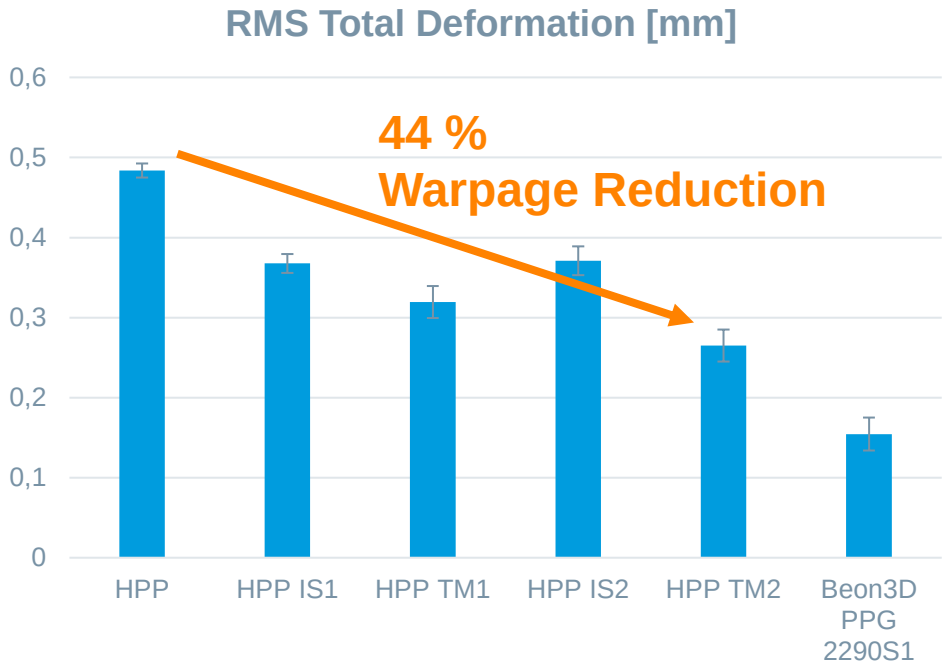
- ✓ **Two simulations methods («TM», «IS») were used based on different modelling approaches**

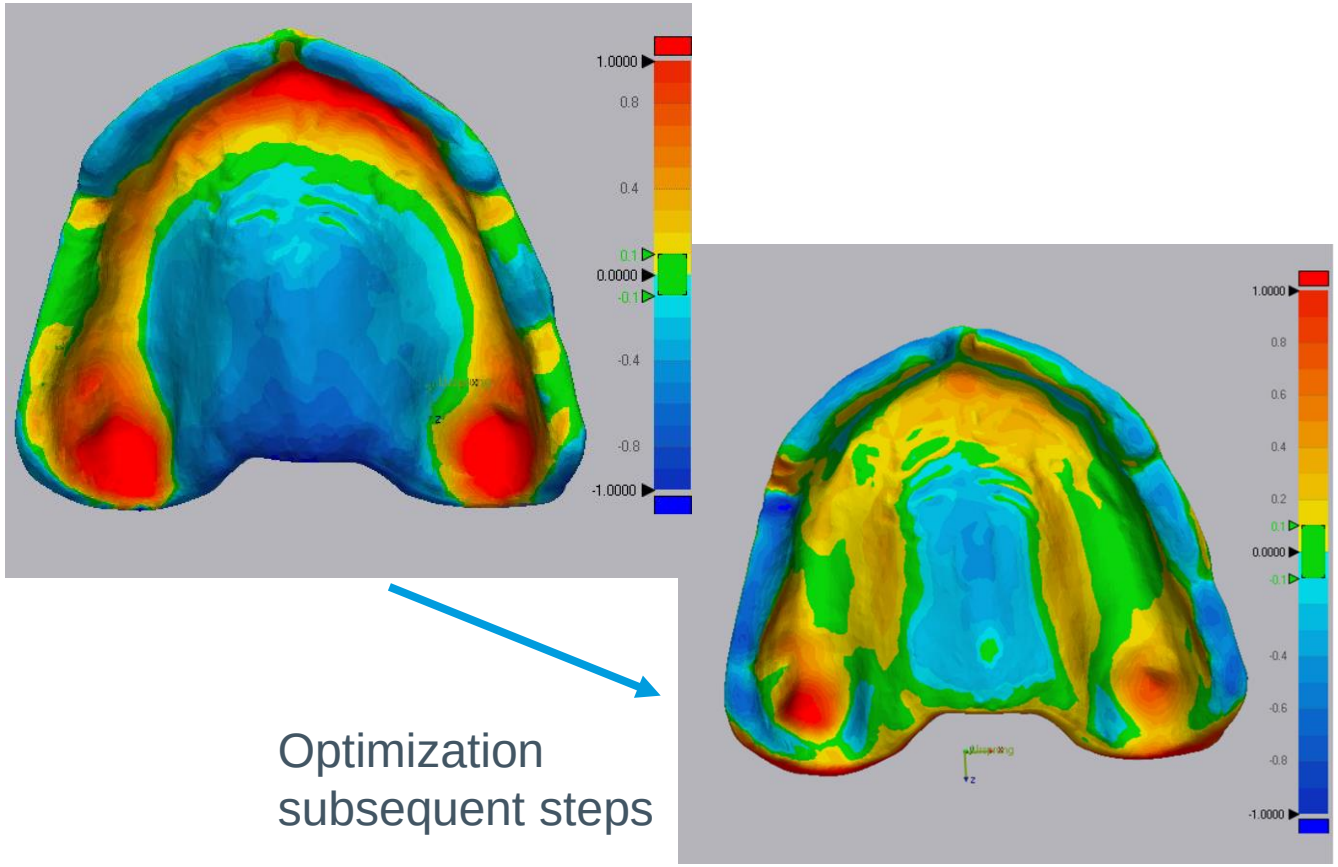
- ✓ **For both simulations optimization was carried out**



CAE: How does an optimization work?

- ✓ **Example: Surgical Guides for prosthetic-driven oral implant placement (activity in collaboration with Faculty of Medicine of Freiburg Hospital, Prof. Dr. Spies)**

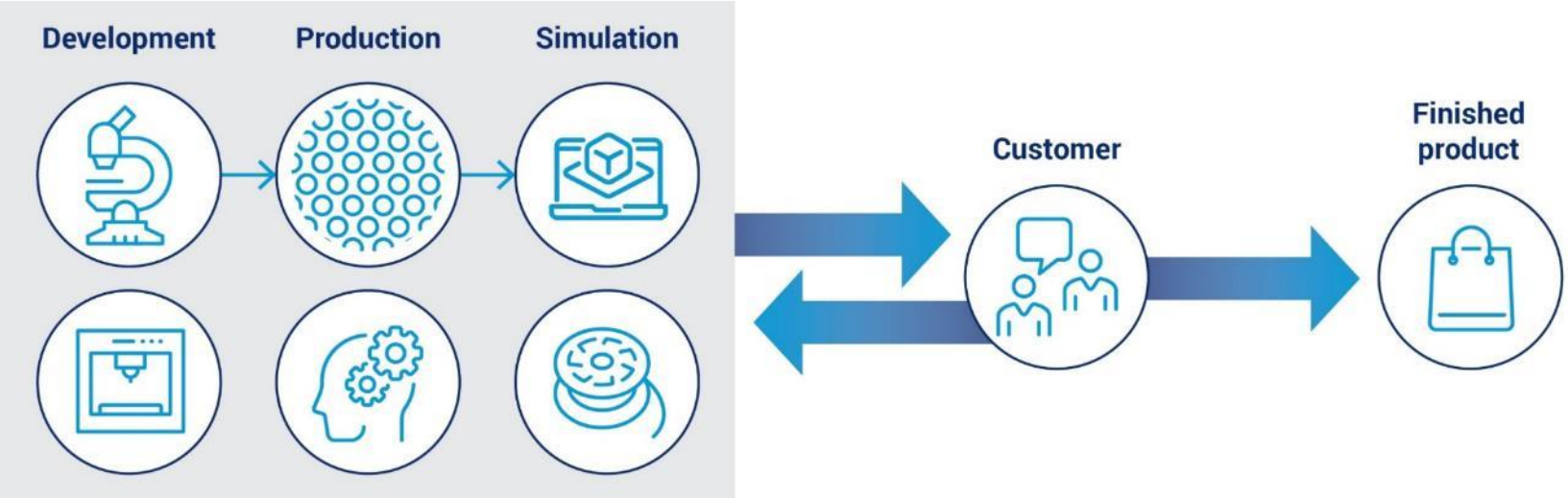




(Courtesy from Freiburg University)

Legenda:
HPP: Healtcare PP not optimized
HPP TM: Healtcare PP optimized, ThermoMechanical model
HPP IS: Healtcare PP optimized, Inherent Strain model

LyondellBasell Advancing Additive Manufacturing



3D printing comprehensive tailor-made solution

LyondellBasell enabling your innovation success by:

- Comprehensive polymer chemistry knowledge
- Deep simulation expertise
- Developing tailor made products for our customers

lyondellbasell
Advancing Possible

Thank you for your attention