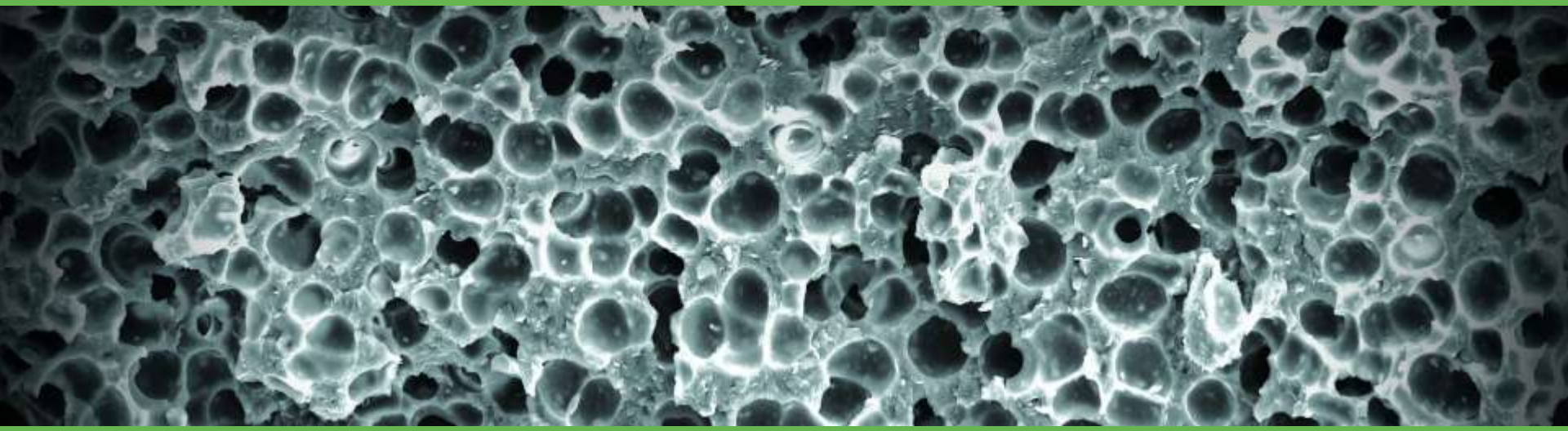
MuCell® Foam Injection Moulding



Trexel GmbH, Wiehl (D)

MuCell Processes
TREXEL INC.

- ⇨ **Company Trexel**
- ⇨ **Mode of Operation / Technical Equipment**
- ⇨ **Impact of the Part Quality / Economics**
- ⇨ **Simulation**

MuCell Processes TREXEL INC.

Trexel - history

- In 1979, Gordon Brown from Kodak request the requirement of “using less material and cost to produce product having comparable mechanical properties of that using conventional process”.

- Dr. Nam Suh at MIT proposed that product having micro-cells of diameters (about 10 μm) smaller than internal critical defect can improve the mechanical properties.

- In 1993, MIT authorized Trexel for commercial processing developing

- Since 2011 cooperations with company Arburg, Engel and Krauss Maffei for direct sales of full MuCell Injection molding machines – one stop shop – no license modell since 2006

MuCell Processes TREXEL INC.

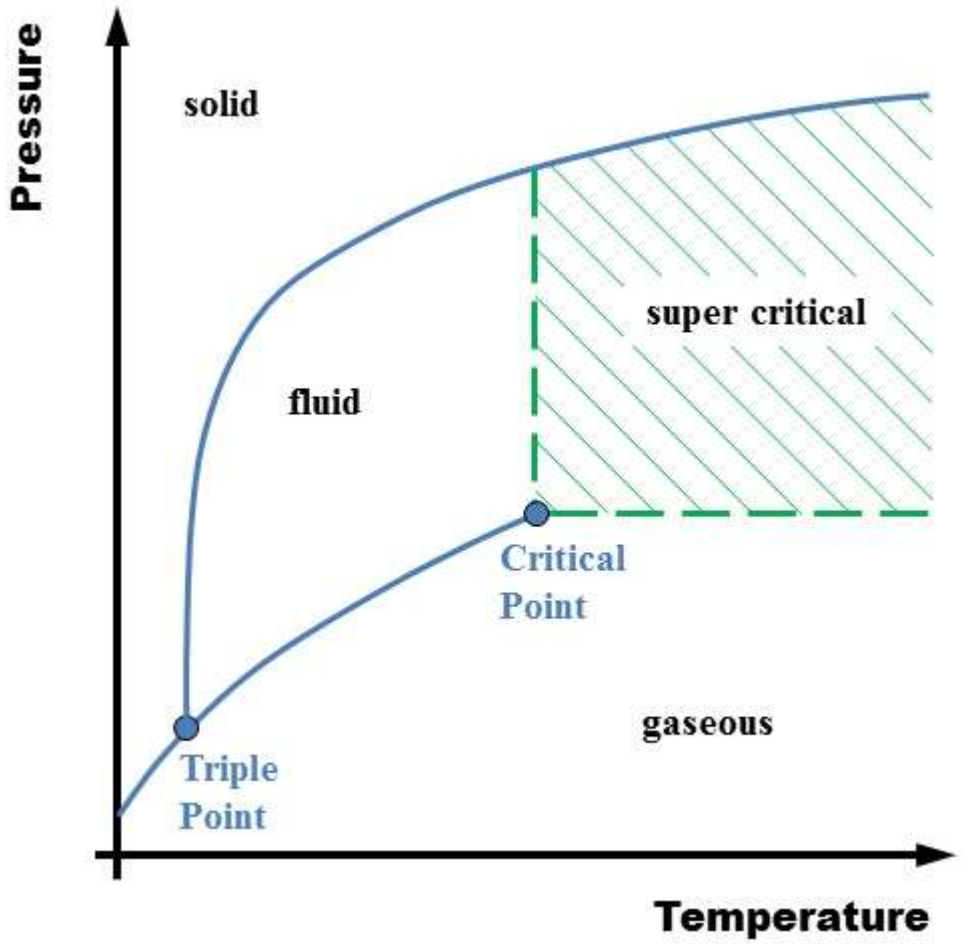
Two Main Characteristics describe the MuCell® Process

1. Lowering of the viscosity of thermoplastic resins by controlled feeding of gas (either N_2 or CO_2) into the melt

2. Creation of a microcellular Structure in the part core by gas expansion in the cavity (Injection Moulding) or after the die (Extrusion)

MuCell Processes TREXEL INC.

Super Critical Fluid (SVF)



	T_C	P_C
N_2	-147 ºC (-233 ºF)	34 bar (500 psi)
CO_2	31 ºC (88 ºF)	71 bar (1050 psi)

T_C = Critical Temperature
P_C = Critical Pressure

Graph: Definition of a super critical status of a pure component

MuCell Processes TREXEL INC.

The MuCell® Injection Moulding Process

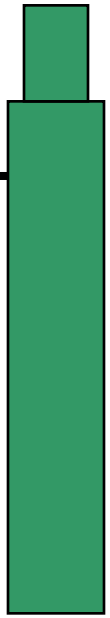
MuCell Interface Kit® (MIK)

SCF

SCF

Gas

SCF System
(Picture: SII-TE-10)



Gas
(N_2 / CO_2)

Inject SCF?

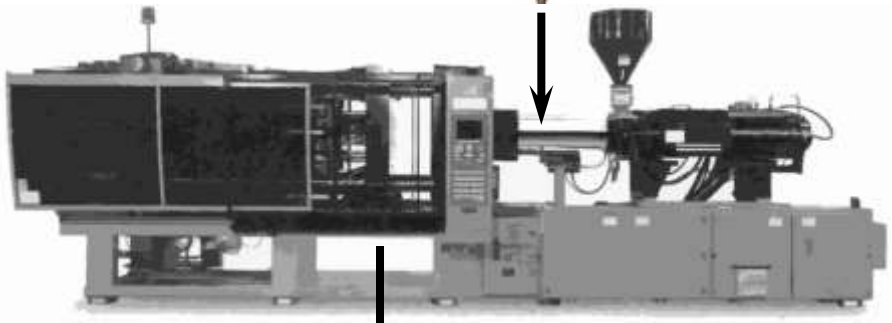
No

SCF

Yes

SCF

SCF Injector



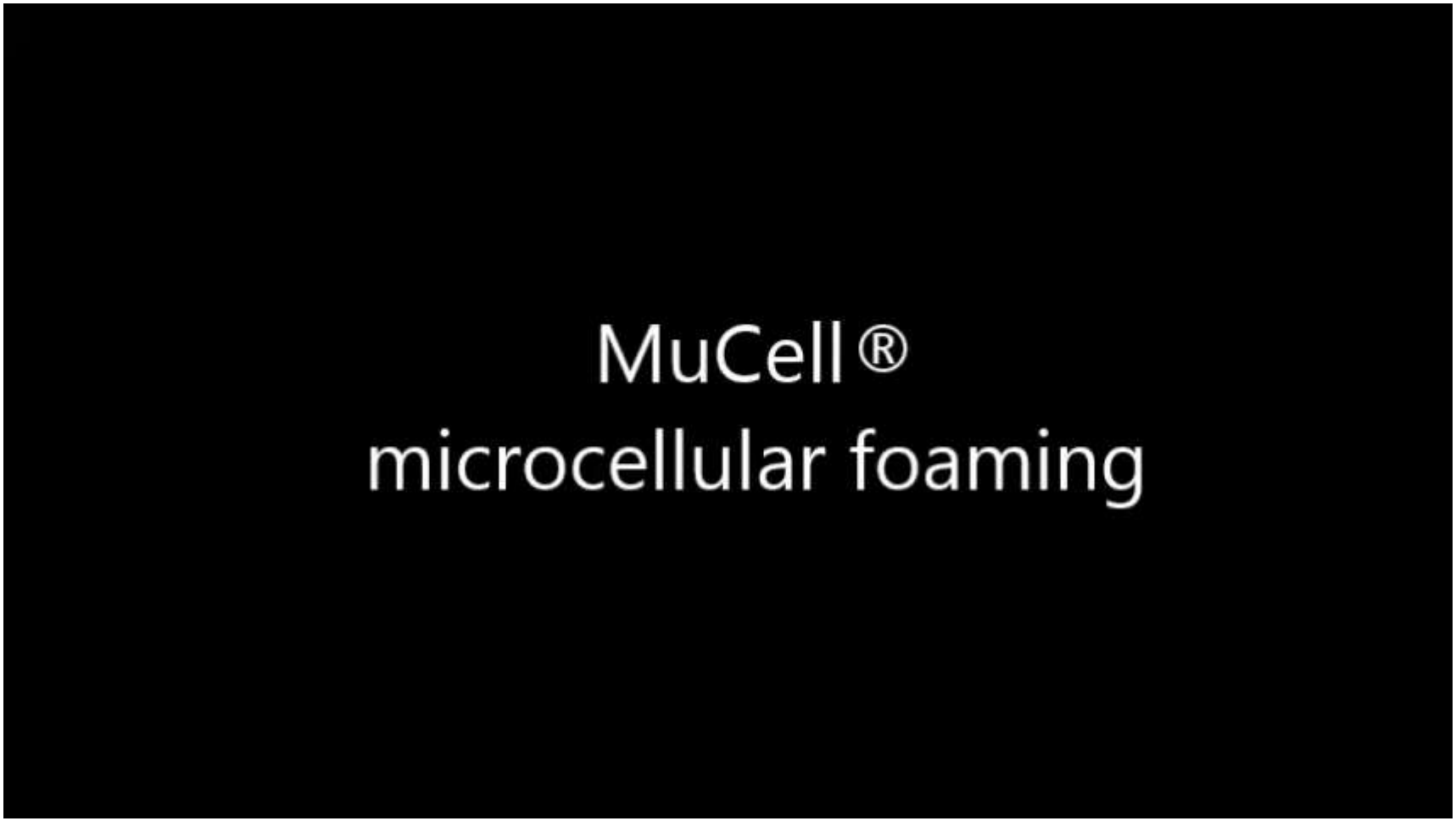
MuCell® Machine

MuCell® Part

MuCell Processes
TREXEL INC.

The MuCell® Process

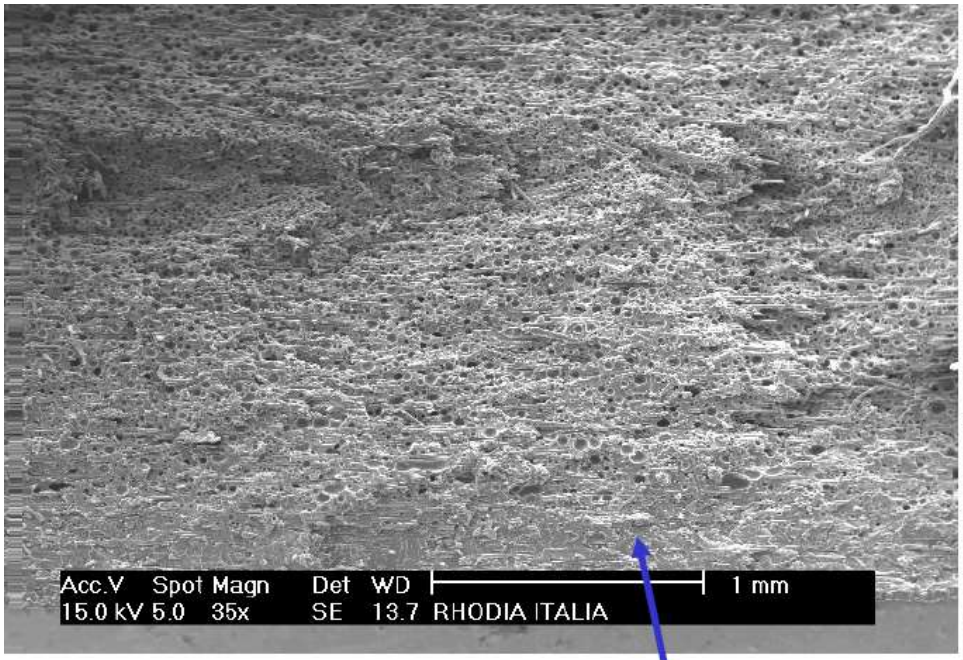
Creating a single phase solution – injecting the SCF into

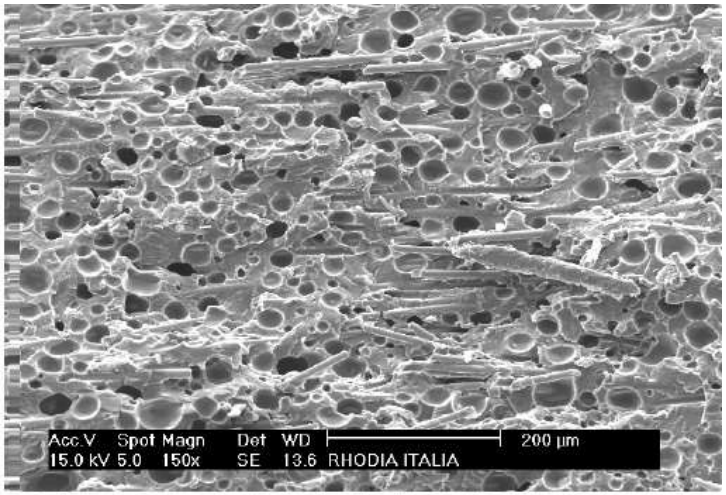


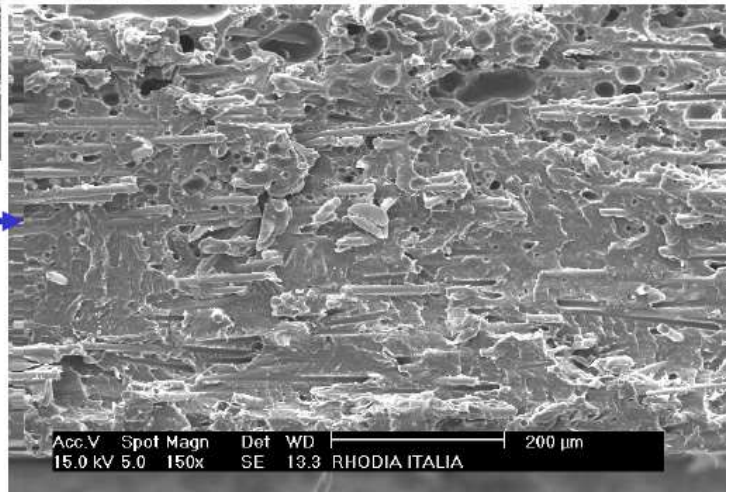
MuCell Processes
TREXEL INC.

MuCell® Moulding Technology

Scanning Electron Microscope (SEM) microstructure







Surface

Source: Rhodia

Material: Nylon 66 with 35% glass fibers

MuCell Processes TREXEL INC.

MuCell® Applications

Office-Equipment

Automotive

Industry & Electric/ Electronic

Packaging

Semi conducter

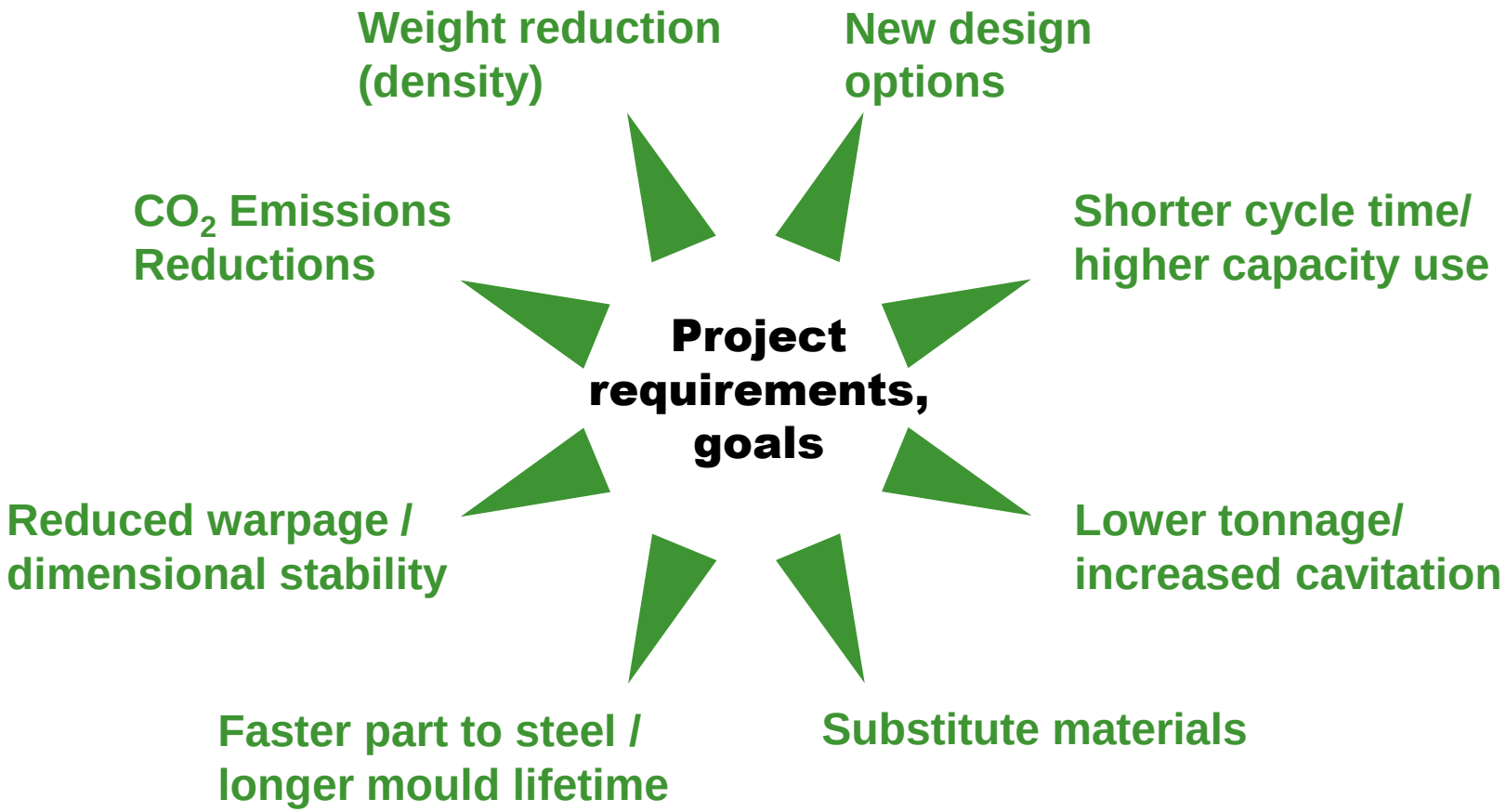
MuCell Processes TREXEL INC.

MuCell® Appearance Applications

- ⇨ **Modified nylons (PA 6, PA 6/6, PBT) offer new possibilities**
- ⇨ **Mould based solutions**
  Heat & Cool …
- ⇨ **Appearance parts in mass production with IMD Technology**

MuCell Processes TREXEL INC.

Strategic Benefits with MuCell®



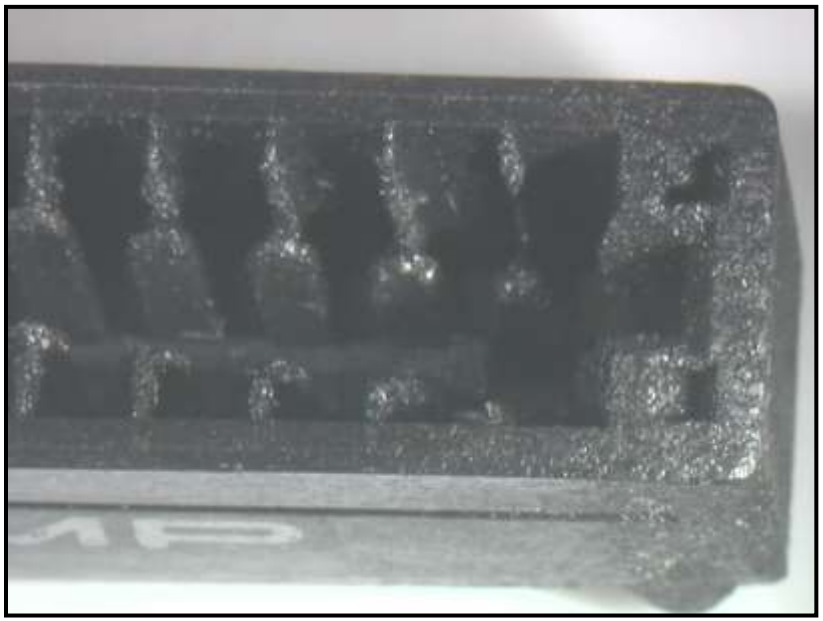
The volume of new process potentials with MuCell® offers the chance to have a positive influence on the cost structure of a company

MuCell Processes TREXEL INC.

Plasticizing effect – improved flow

Solid at 30 °C Tool Temp.

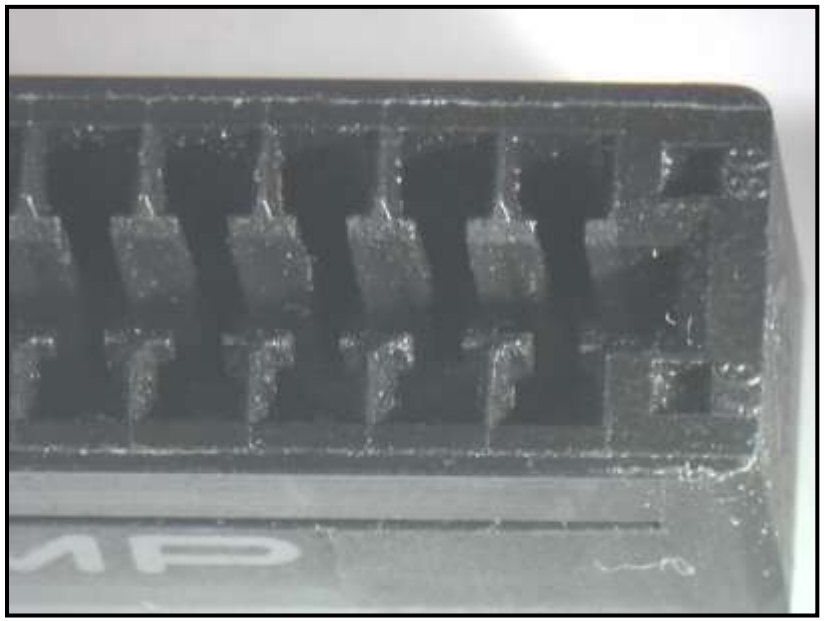
- Mould was cooled such that solid parts were no longer filling the mould



Material: Valox 420 SEO (PBT GF30)

MuCell® at 30 °C Tool Temp.

- With same parameters and MuCell® on, the parts could easily fill



Material: Valox 420 SEO (PBT GF30)

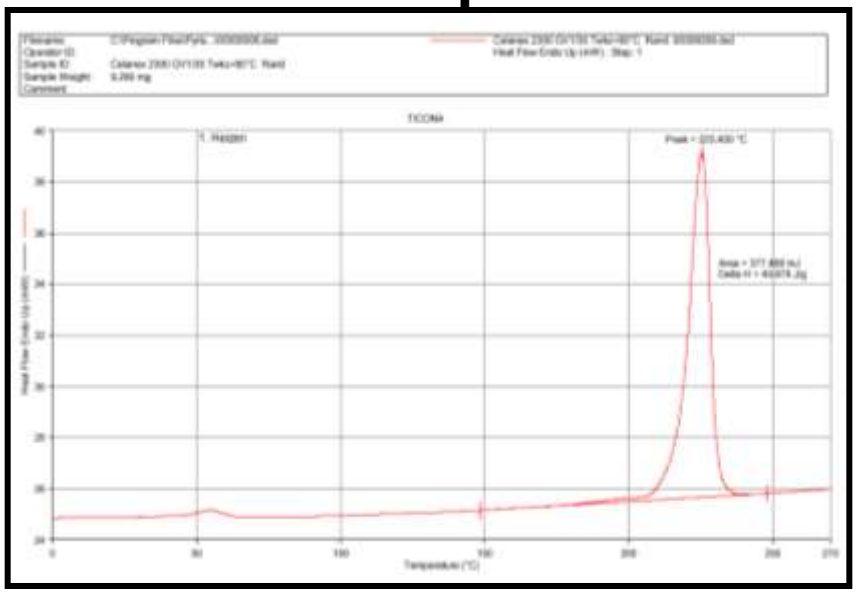
MuCell Processes TREXEL INC.

Microcellular Foam Properties

Ticona

⇨ **Without foam**

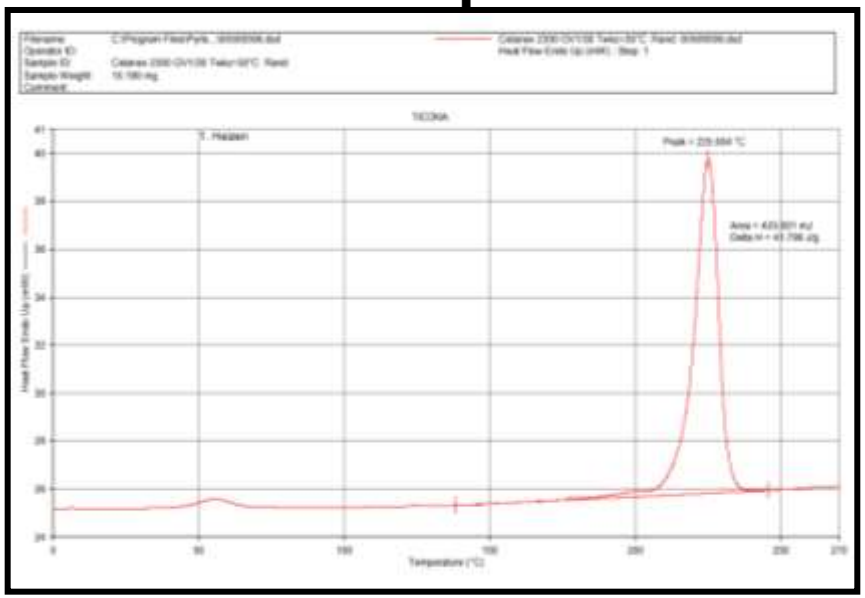
DSC - Curve: PBT GF 30 with mould temp. 80°C



Melting temperature : 225,4°C
Heat of Fusion (ΔH): 40,67 J/g

⇨ **10% physical foam**

DSC - Curve: PBT GF30 with mould temp. 30°C



Melting temperature: 225,0°C
Heat of Fusion (ΔH): 41,93 J/g

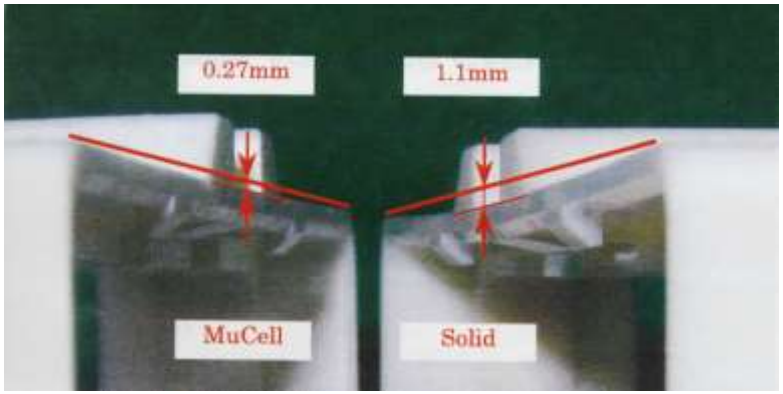
Crystallinity Level is identical

MuCell Processes TREXEL INC.

Abolition of parameter hold

The parameters hold pressure p_H and hold time t_H are deleted by the MuCell® Foaming Process.

- Part formation by cell growth, independently of part weight
- Counteraction against shrinkage not by additional packed mass
- Equal pressure distribution in the cavity (significant less difference in pressure levels near injection point and far injection point)

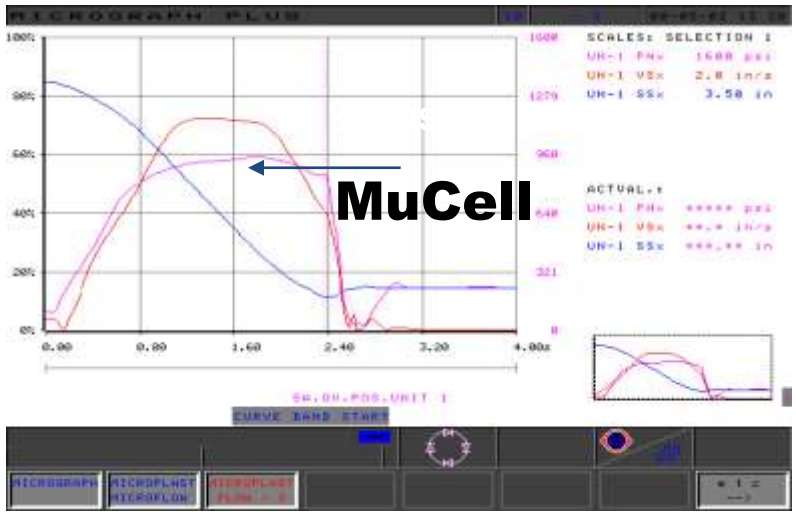


Example:
Connector Housing
(PBT GF30)

⇨ **Decoupling of part dimensions and part weight**

MuCell Processes TREXEL INC.

Reduced Injection Pressure

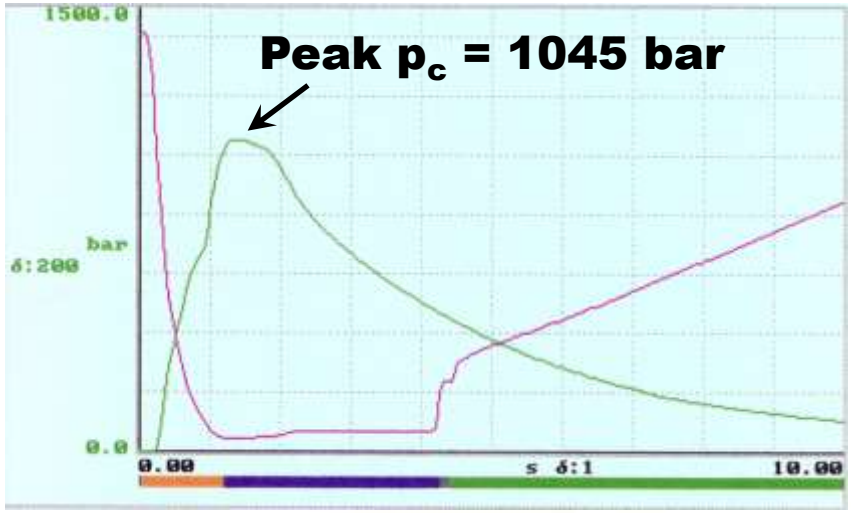


- **34% Reduction in Hydraulic Injection Pressure**
- **Related to lower Viscosity**

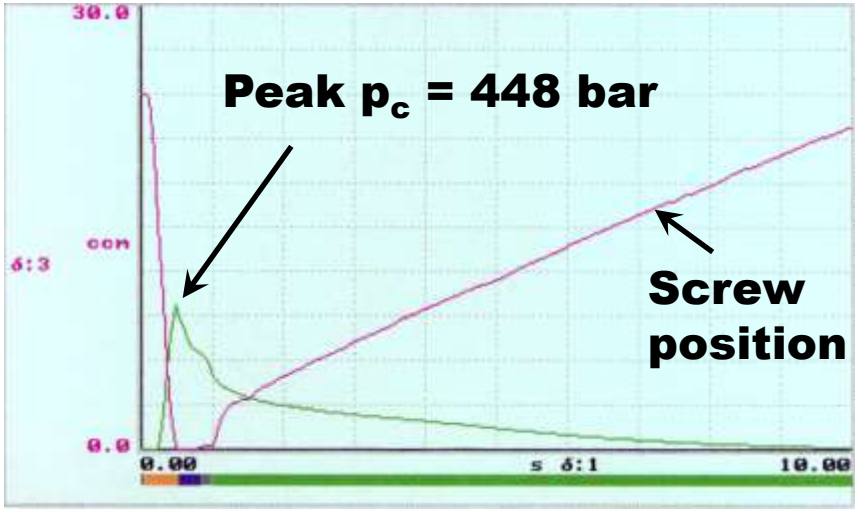
MuCell Processes
TREXEL INC.

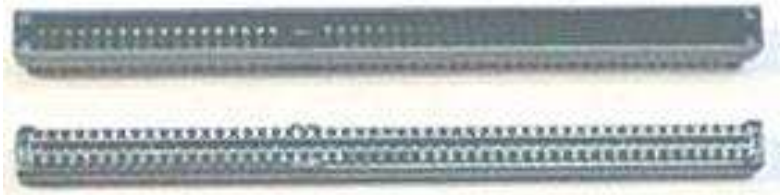
Lower Cavity Inner Pressure

Solid



MuCell®



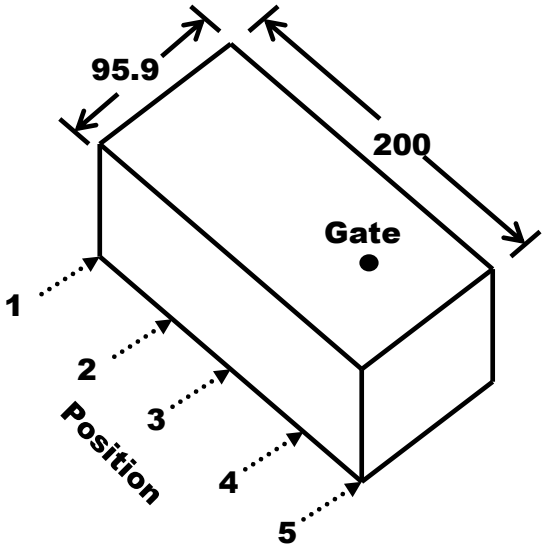


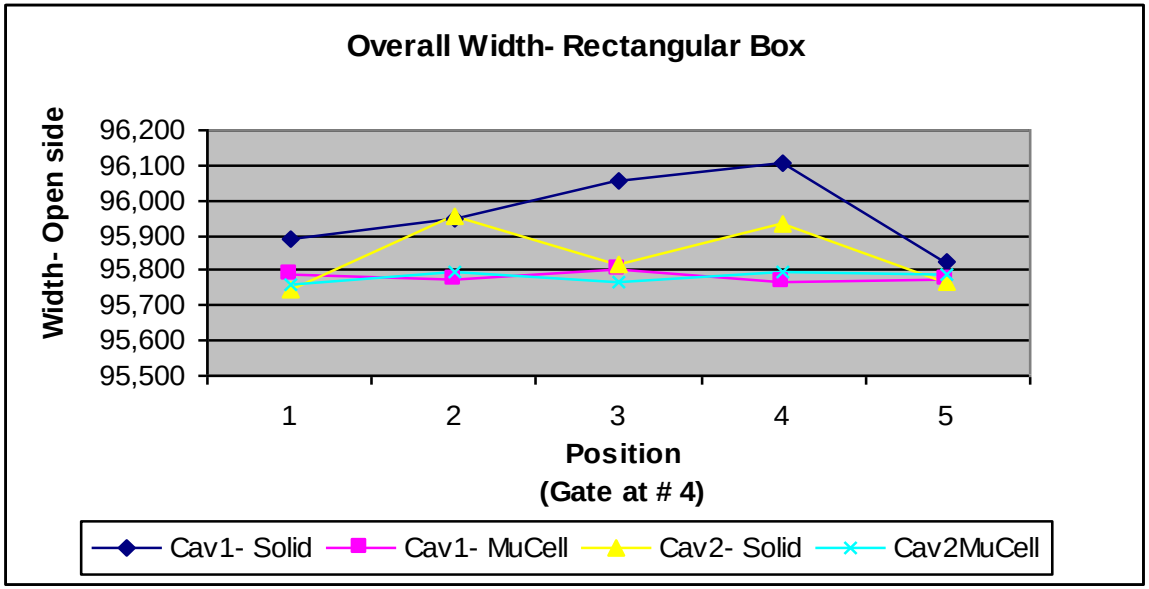
Data Com Connector

- ☞ **57 % reduction in peak cavity pressure**
- ☞ **Due to viscosity reduction, less resin volume, no pack & hold pressure**

MuCell Processes TREXEL INC.

Strategic Benefit Quality
(faster product release)

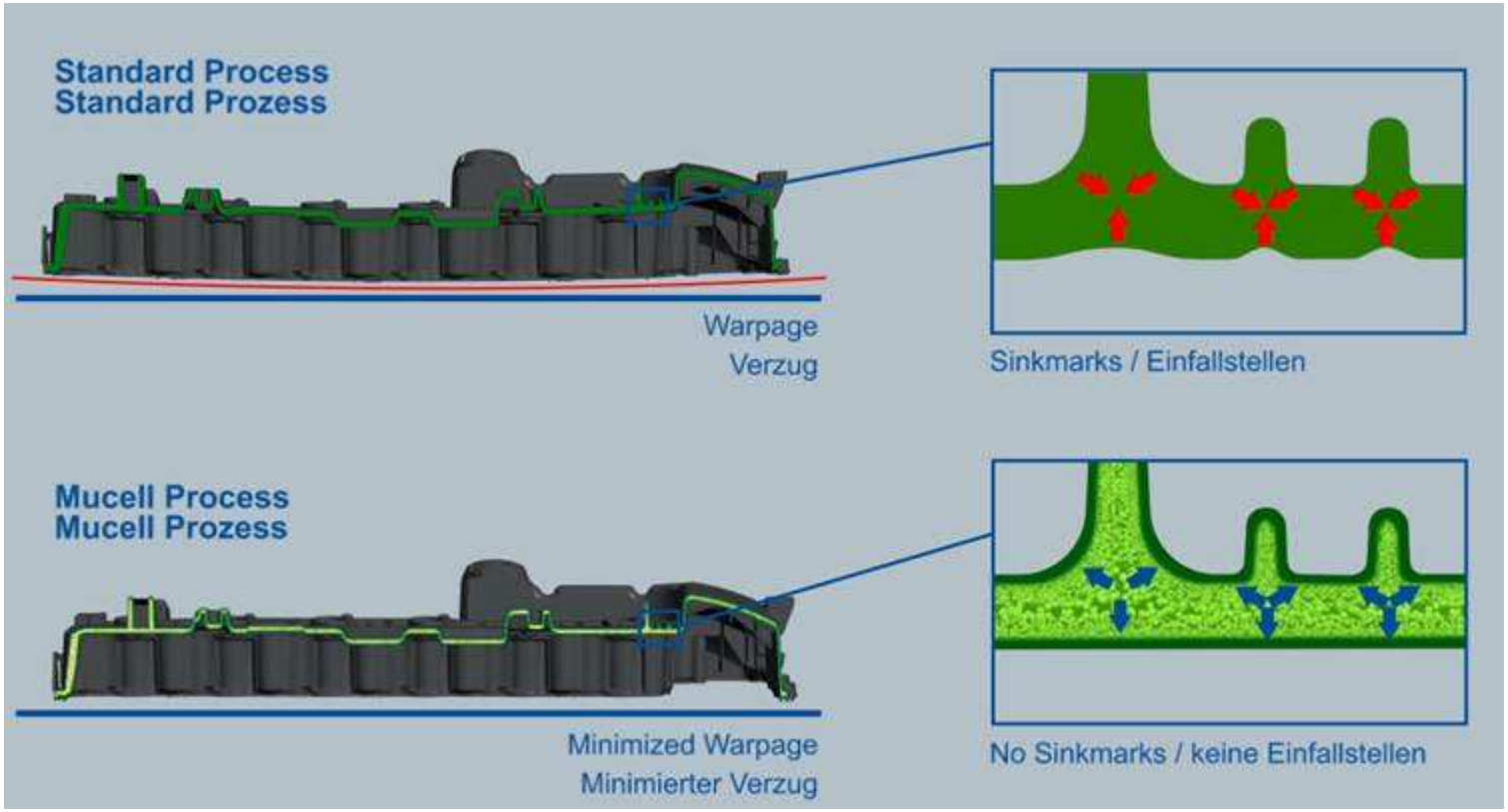




More consistent & predictable MuCell® dimensions simplify mould design & reduce the number of costly iterations

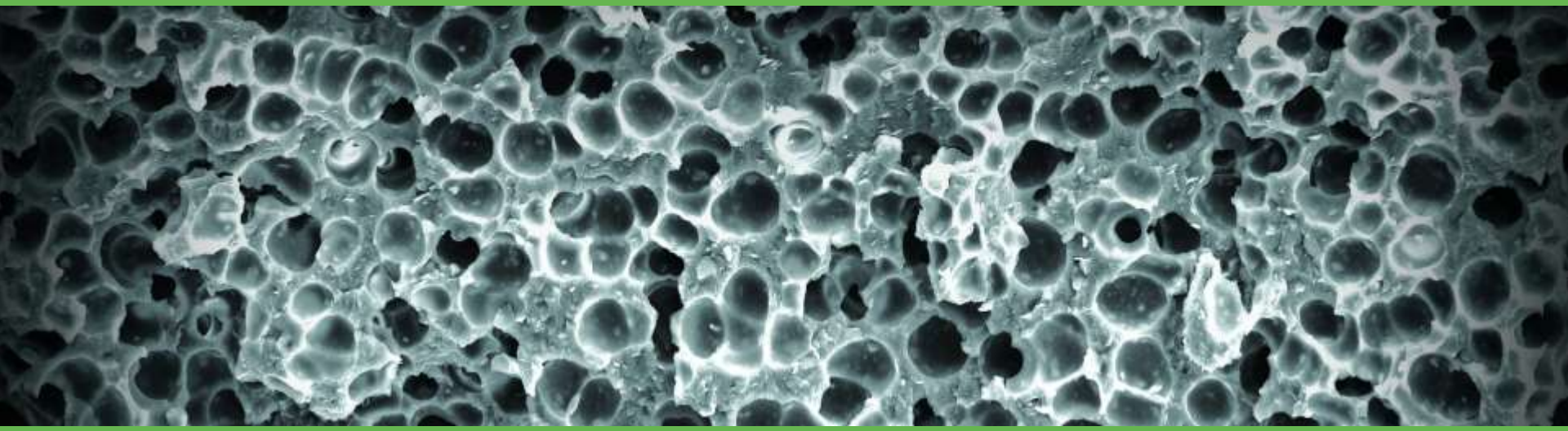
MuCell Processes TREXEL INC.

Standard Injection Molding vs. MuCell



MuCell Processes
TREXEL INC.

MuCell® - on the market



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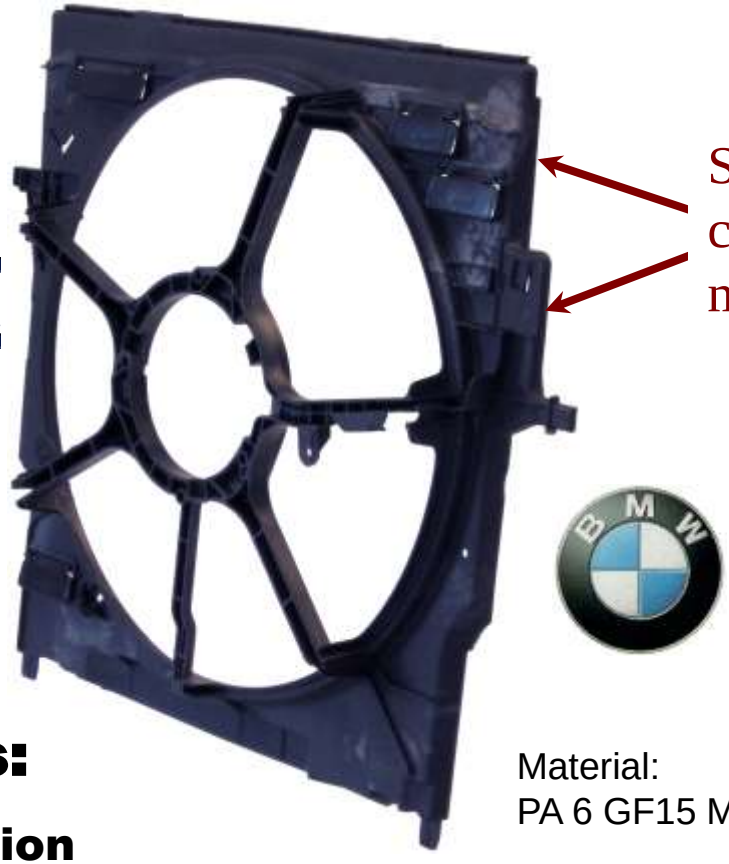
⇨ **Examples**

MuCell Processes TREXEL INC.

MuCell® Fan Shroud

G.G.S. Plastic Engineering



Shroud + hinge combined in one mould

Material:
PA 6 GF15 MN25

MuCell® Benefits:

- ☞ **8 % weight reduction**
- ☞ **20 % cycle time reduction**
- ☞ **30 % smaller machine size**
- ☞ **Fatigue-to-failure improved by 400 %**

MuCell Processes TREXEL INC.

MuCell® Climatic Control Housing

BEHR

DAIMLERCHRYSLER

MuCell® Benefits

- **Shorter cycle times due to quality improvement**
- **Clamp force reduction**
- **Easier to assemble**

MuCell Processes TREXEL INC.

Daimler W212 Door Trim

Johnson Controls

Winner 2009 in category Interiors

MuCell® parts:

- **Carrier:**
  - Thinner wall thickness by lower viscosity
  - 10 % density reduction by MuCell
  - Tandem-Mould Technology plus MuCell (with > 50 % cycle time red.)
  - Wall thickness to rib ratio = 1:1
- **Map Case:**
  - Wall thickness to rib ratio = 1:1
  - Deletion of one tool and an additional assembling process (by MuCell Design)
  - Advantages with IML Technology (lower pressure levels)

MuCell Processes TREXEL INC.

Mercedes Benz : Project MFA (B Class …)

- **weight saving by design + density**
- **reduced warpage, easy assembly**

2 parts out of 11

PÖPPELMANN

MuCell Processes TREXEL INC.

High Gloss Frame with MuCell®

Screen DVD player

JOHNSON CONTROLS

GROUPE PLASTIVALOIRE
L'ENTREPRISE PARTENAIRE

MuCell Processes
TREXEL INC.

Mercedes Benz – W246

Head Lamp Housing

AUTOMOTIVE LIGHTING

JIT PLASTIC s.r.o.

DAIMLER

- **Clamp Force reduced by 50%**
- **more design freedom**
- **reduced warpage**

MuCell Processes

TREXEL INC.

IP Carrier Golf VII

- **500g weight reduction per part !**

MuCell Processes
TREXEL INC.

Airbag Cover Volkswagen Polo

- **elimination of sink marks**
- **clamp force reduction**

TRW Automotive

AFE

MuCell Processes
TREXEL INC.

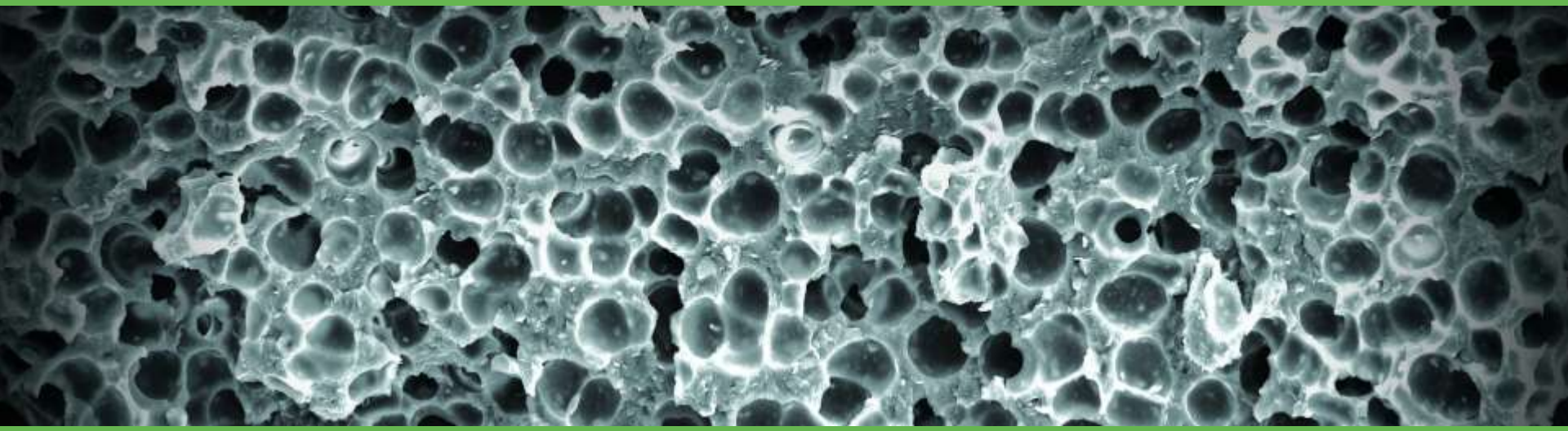
Cockpit Covers Mercedes Trucks

Blinds and covers of the new Mercedes-Benz Actros are produced with softtouch-surfaces applying the Dolphin-method

ENGEL be the first.

MuCell Processes TREXEL INC.

MuCell® - Positive Impact on Economic Efficiency



Trexel GmbH, Wiehl (D)

⇨ **Calculation Tool**

MuCell Processes TREXEL INC.

MuCell Cost Analysis Input Worksheet

Trexel can provide a detailed cost analysis including such items as return on investment, detailed part savings in both material and operational costs, piece part pricing both solid and MuCell and detailed payback analysis. For Trexel to complete the MuCell cost analysis the following information is required:

Company:		Contact:	
Address:		Tel. #:	
		Fax #:	
		Email:	

Part Name	
Type of Material	
% Filler / Filler material	
Cost of Resin / Kg or lb	
# parts / year	
Total cycle time (seconds)	
Hold Time (seconds)	
Part weight (g)	
Total shot weight	
# of cavities	
Machine Size (tonnage)	
Machine Hourly rate / $	
Screw size (mm)	

MuCell Processes TREXEL INC.

Example Calculation Cam Cover

Material: PA 6.6 GF35

Production volume	=	250.000 parts/a
Part weight	=	1.000 g
Number of cavities	=	1
Cycle time in solid	=	57 s
Clamp force in solid	=	800 t

MuCell Processes TREXEL INC.

Example Calculation Savings
(MuCell® vs. Solid)

Weight reduction = 9 %

Cycle time reduction = 31 %

	Solid	MuCell
Injection time:	3 s	1.5 s
Pack&Hold time:	7 s	0.5 s
Cooling time:	35 s	25 s
Mould movement:	12 s	12 s
Total cycle time:	**57 s**	**39 s**

31.6 % faster cycle time with MuCell

Reduction in machine size = 38 %

MuCell Processes TREXEL INC.

Example Calculation Input Data

MuCell Processes TREXEL INC.

45 Sixth Road - Woburn, MA 01801
Phone: +1-781-932-0202
Fax: +1-781-932-3324

Rate the following or **Input** a number:
(Cells Shaded in Yellow are required)
(Cells Shaded in Gray are optional)
(Cells Shaded in Blue cannot be changed)

The MuCell Cost Analysis Workbook

ustomer Name	Automotive Moulder
ocation	Anywhere
se Metric System	yes

Application #1	
art Name	Cam Cover (Example)
ype of Material	PA
Filled/Filler Material	35%
of Parts/year	250.000
otal Cycle Time (seconds)	57
art Weight (g)	1000,0
of Cavities	1
ost of Resin- PA ($/kg)	3,17
achine Size (Metric) needed for Solid	800
achine-Hour Rate ($/hour)	91,34
National Average for 800-tons ($/hour)	91,34
of Production Hours Needed for Solid	3.958
anned production hours/IMM/year	5.640

MuCell Process Benefits	
ycle Time Reduction	31%
eight Reduction	9%
achine Size Reduction Possible	38%
achine Size (Metric) needed for MuCell	500
ssume New Machine-Hour Rate	yes
New Hourly Machine Rate using Smaller ress ($/hour)	68,14
National Average for 500-tons ($/hour)	68,14
aterial Subsitution Possible	no
ost of Alternative Resin- ($/kg)	3,17
of Production Hours Needed for MuCell	2731

Machine Configuration	
For Solid Production:	
Total Production Hours	3.958
# of Machines Needed	0,70
# of Molds Needed	-
Machine Size (Metric) needed for Solid	800
For MuCell Production:	
Total Production Hours	2.731
# of Machines Needed	0,48
# of Molds Needed	-
Machine Size (Metric) needed for MuCell	500
Reduction in Initial Capital Cost due to	
- Smaller Machine Requirement	-
- Less # of Machines	-
- Less # of Molds	-

MuCell Technology Costs	
Screw size	90 mm
MuCell Package for 90 mm screw	160.000 US$
- # of MuCell Packages needed	1
Comments:	
MuCell Package includes: SCF System, MuCell Interface Kit, Recycling Connection Kit, Operating Licenses in accordance with Paragraphs 6, 7, 8,and 10 of Trexel's Terms and Conditions of Sale, 5 days of applications support and training	
Platform Supplier	Arburg
- Cost of MuCell Option/Press	94.500 US$
- # of Units	1
Type of Blowing Agent	Nitrogen
- Cost of Nitrogen ($/kg)	0,91
- % Nitrogen Used	0,50%

CONVERSION TABLE	
Convert $/lb	1,30
to $/kg	2,86
Convert lbs	0,660
to g	300
Convert $/kg	1,70
to $/lb	0,77
Convert g	75
to lbs	0,165

MuCell Processes TREXEL INC.

Example Calculation ROI Analysis

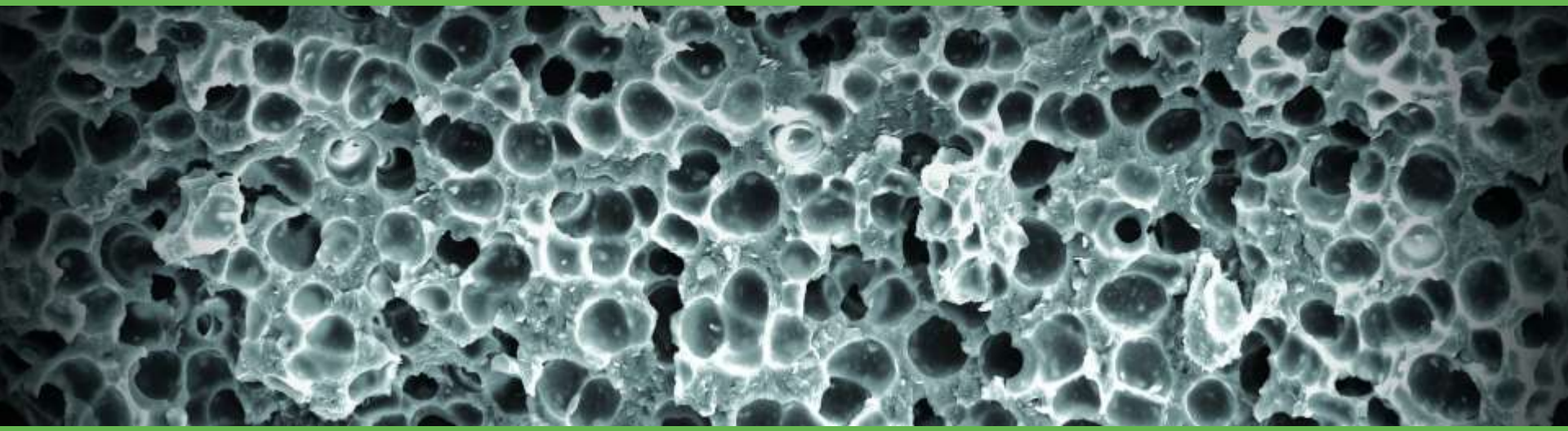
ROI Analysis for Automotive Moulder

Year		0	1	2	3	4	5	6
Capital Costs								
MuCell Hardware Costs		(254.500)						
- MuCell Package from Trexel	(160.000)							
- MuCell Option from machine OEM	(94.500)							
Other Capital Costs		(10.000)						
Reduction in Initial Capital Cost due to Smaller Machine Requirement, Less # of Machines and/or Molds		-						
TOTAL Capital Costs		**(264.500)**						
Operations								
Operational Savings (Cycle and Tonnage)								
Application #1- Cam Cover (Example)			175.439	175.439	175.439	175.439	175.439	175.439
Application #2-			-	-	-	-	-	-
Application #3-			-	-	-	-	-	-
Application #4-			-	-	-	-	-	-
Material Savings								
Application #1- Cam Cover (Example)			71.381	71.381	71.381	71.381	71.381	71.381
Application #2-			-	-	-	-	-	-
Application #3-			-	-	-	-	-	-
Application #4-			-	-	-	-	-	-
Other Operational Savings								
Other Operational Costs								
N2/CO2 Cost			(1.438)	(1.438)	(1.438)	(1.438)	(1.438)	(1.438)
TOTAL Operational Savings		**-**	**245.382**	**245.382**	**245.382**	**245.382**	**245.382**	**245.382**
Net Cash Flow		**(264.500)**	**245.382**	**245.382**	**245.382**	**245.382**	**245.382**	**245.382**

Payback (years)	**1,08**
NPV @ r= 10%	**804.201**
ROI	**304%**
IRR	**91%**

MuCell Processes TREXEL INC.

MuCell® - Positive Impact on Project



Trexel GmbH, Wiehl (D)

contact : Martin Jacobi - m.jacobi@trexel.com

MuCell Processes TREXEL INC.