New Long Rayon Fiber Reinforced Thermoplastics Utilizing the LFT-D Process

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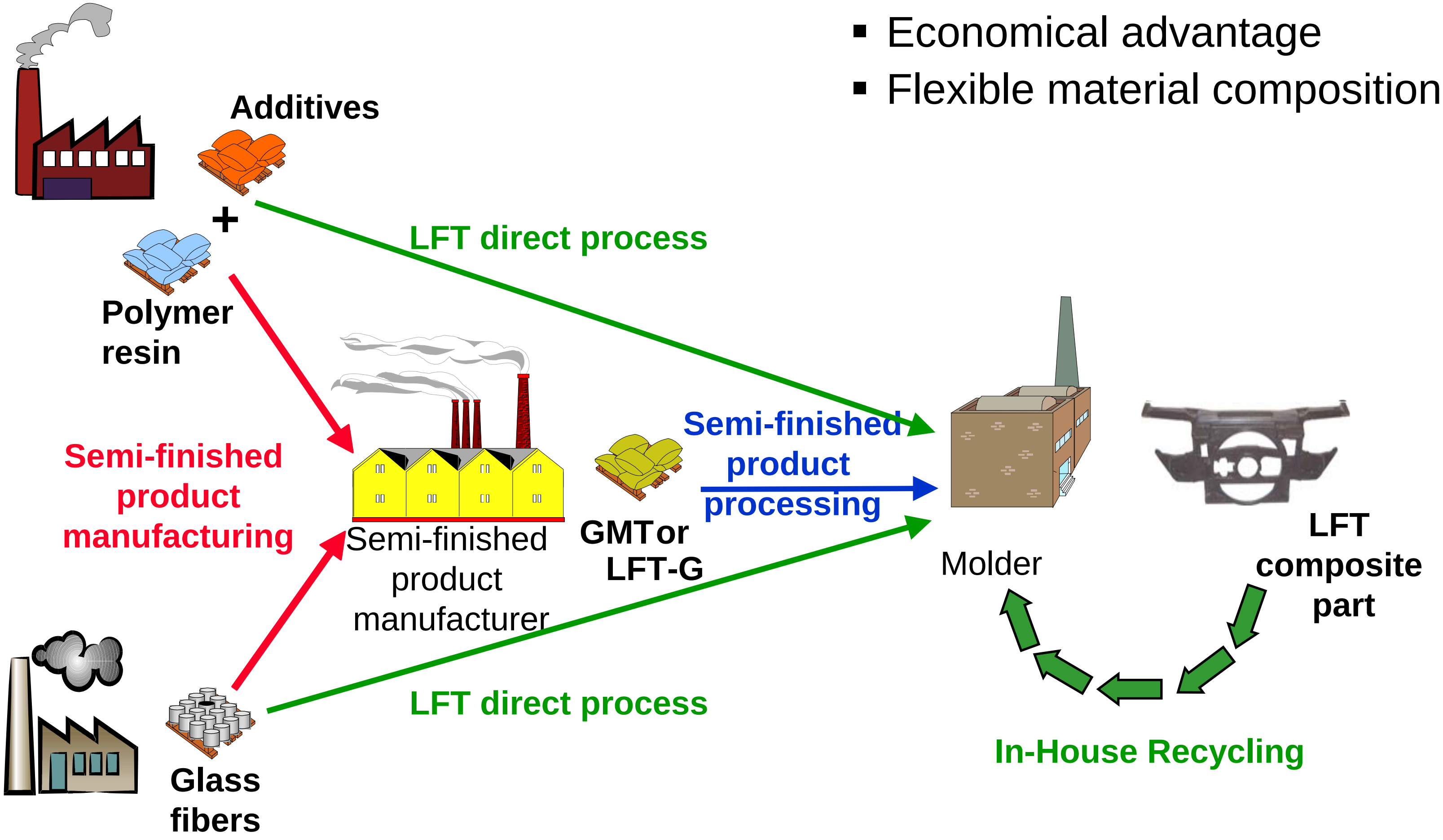
Motivation for a LFT direct process

- Economical advantage
- Flexible material composition



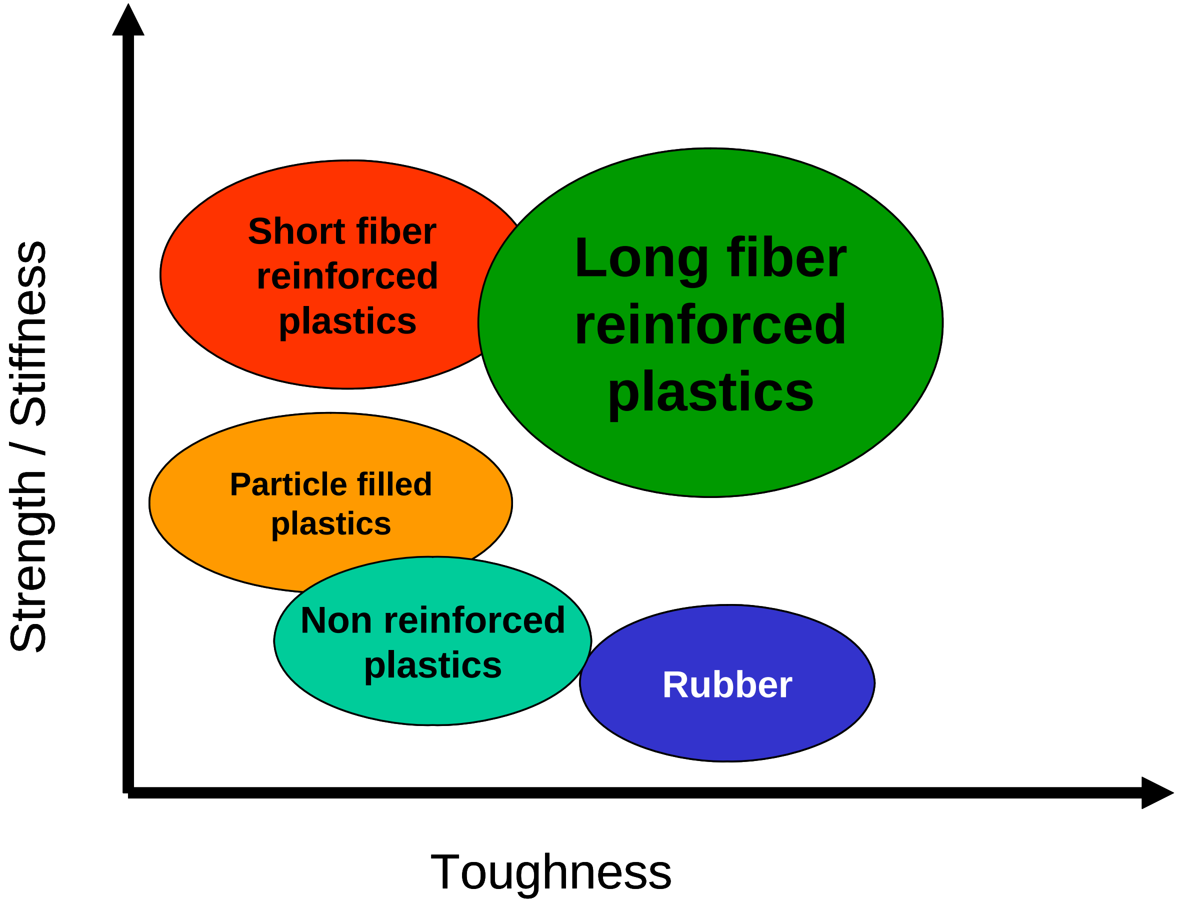
Longfiber Reinforced Thermoplastics – New Material Development

Requirements:

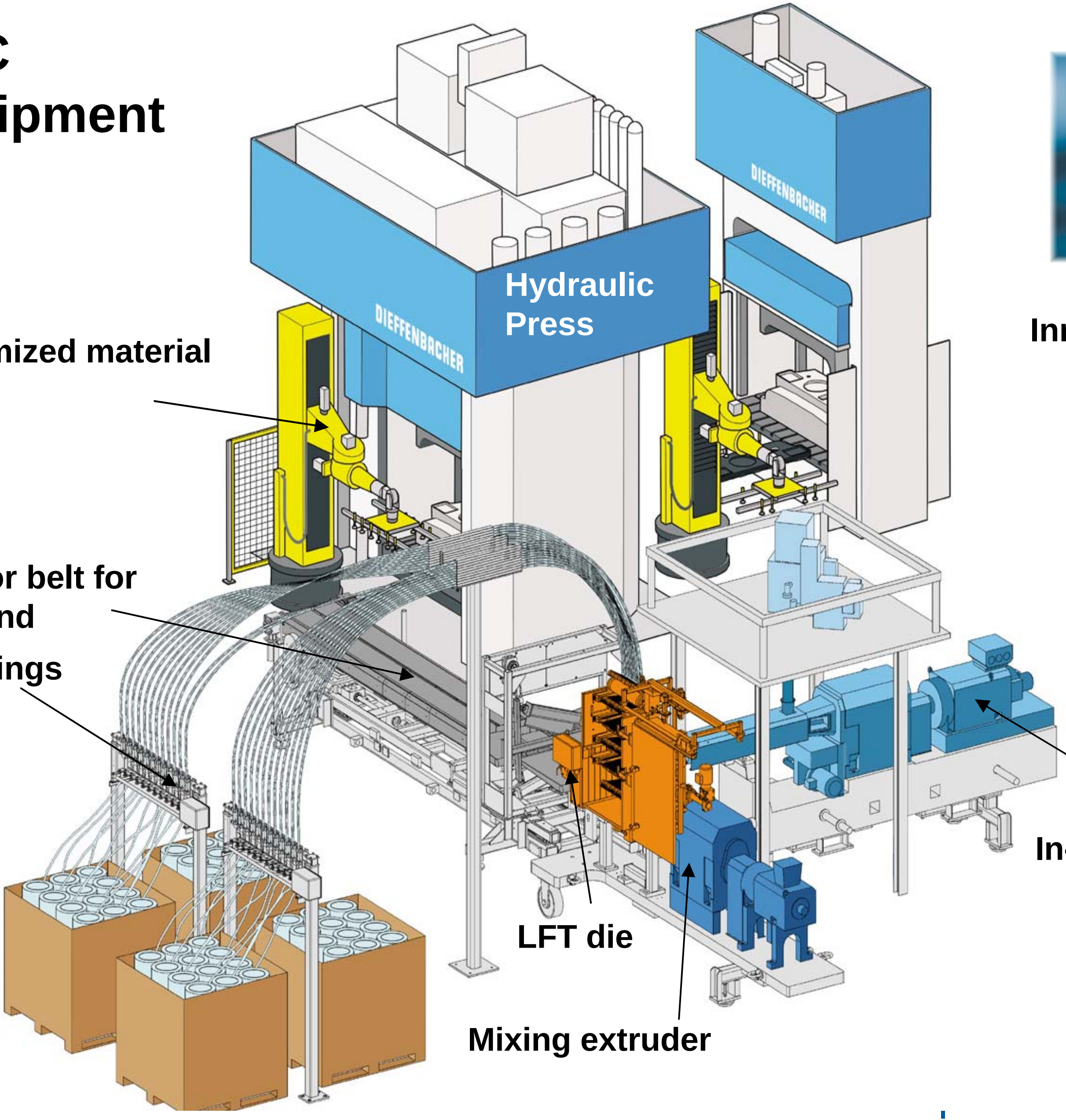
- Mechanical properties
- Material homogeneity
- Reproducibility
- Material data for part design
- Reduction of local material anisotropy

Definition long fibers:

- Injection molding: >1 bis 5 mm
- Compression molding: 10 bis 40 mm



LFT-D-ILC
Base Equipment



Hydraulic Press

Fully automized material handling

Conveyor belt for LFT strand

Provision of rovings

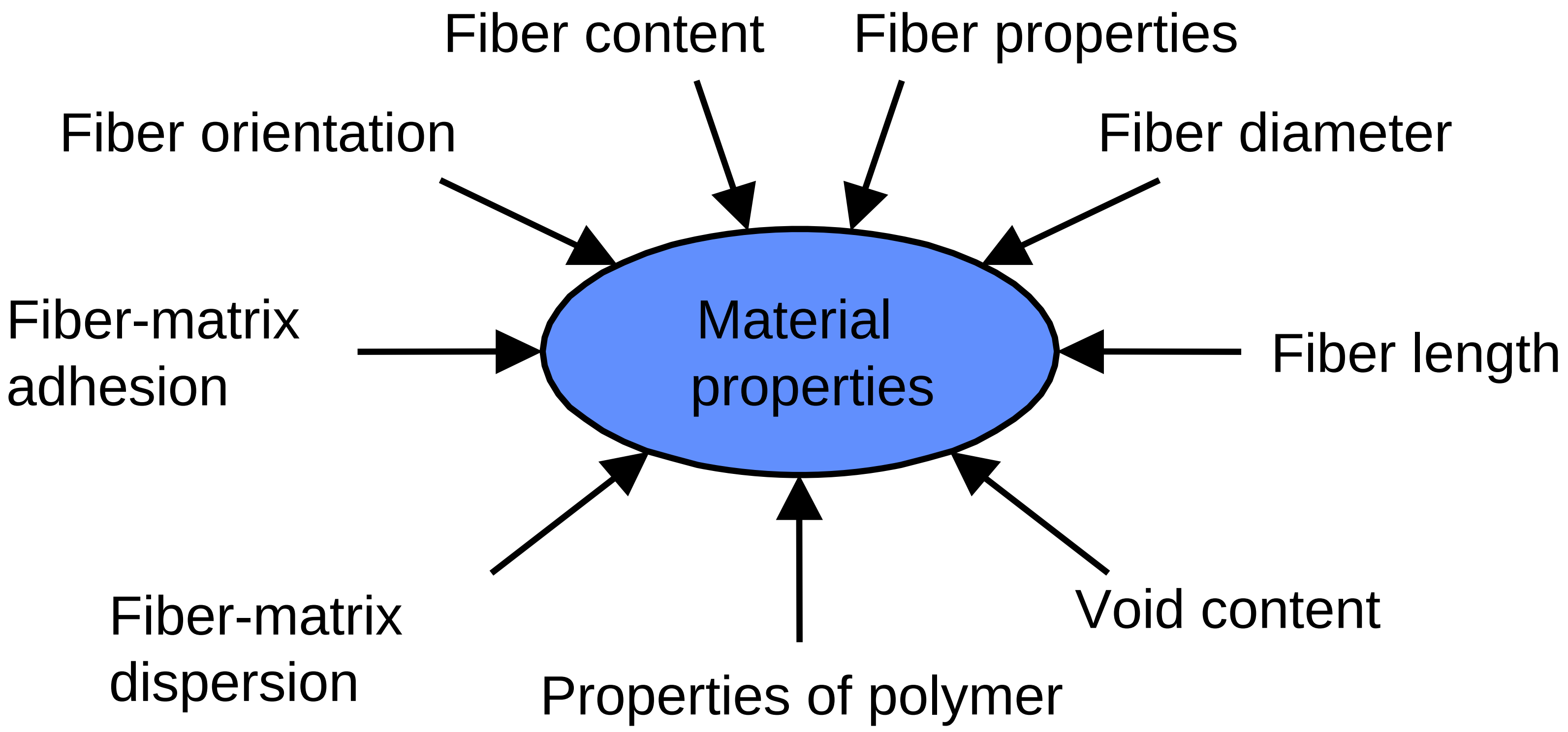
LFT die

Mixing extruder

In-line compounder

AVK-TV
Innovationspreis
2001

Material development tailored to the application



Fiber content

Fiber properties

Fiber orientation

Fiber diameter

Fiber-matrix adhesion

Material properties

Fiber length

Fiber-matrix dispersion

Properties of polymer

Void content

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Material Development Flexibility

- Adjustment of material properties based on requirements
- Possibility of selection of polymer and fiber type
- Material combination just looks complex – well managable
- Individual intensity of backward integration possible (masterbatch)
- Company specific Know-How – Optimized for customer or applications
- Superset line control ensures safe and reproducible production

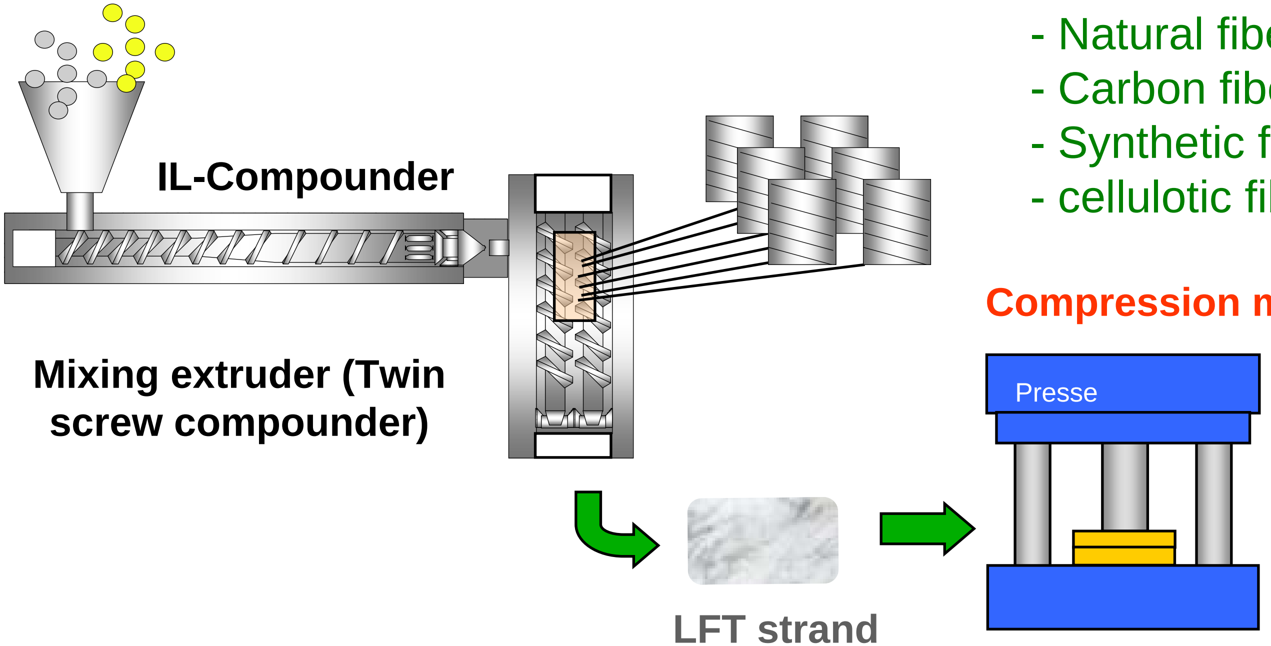
Flexibility for company specific solutions

Polymers:

- Polypropylen
- Nylon: PA 6, PA 6.6 etc.
- Polyethylenterephtalat (PET)
- Styrenic Copolymers: ABS, ASA, SAN etc.
- Blends

Reinforcements:

- Glass fibers
- Natural fibers
- Carbon fibers
- Synthetic fibers
- cellulotic fibers



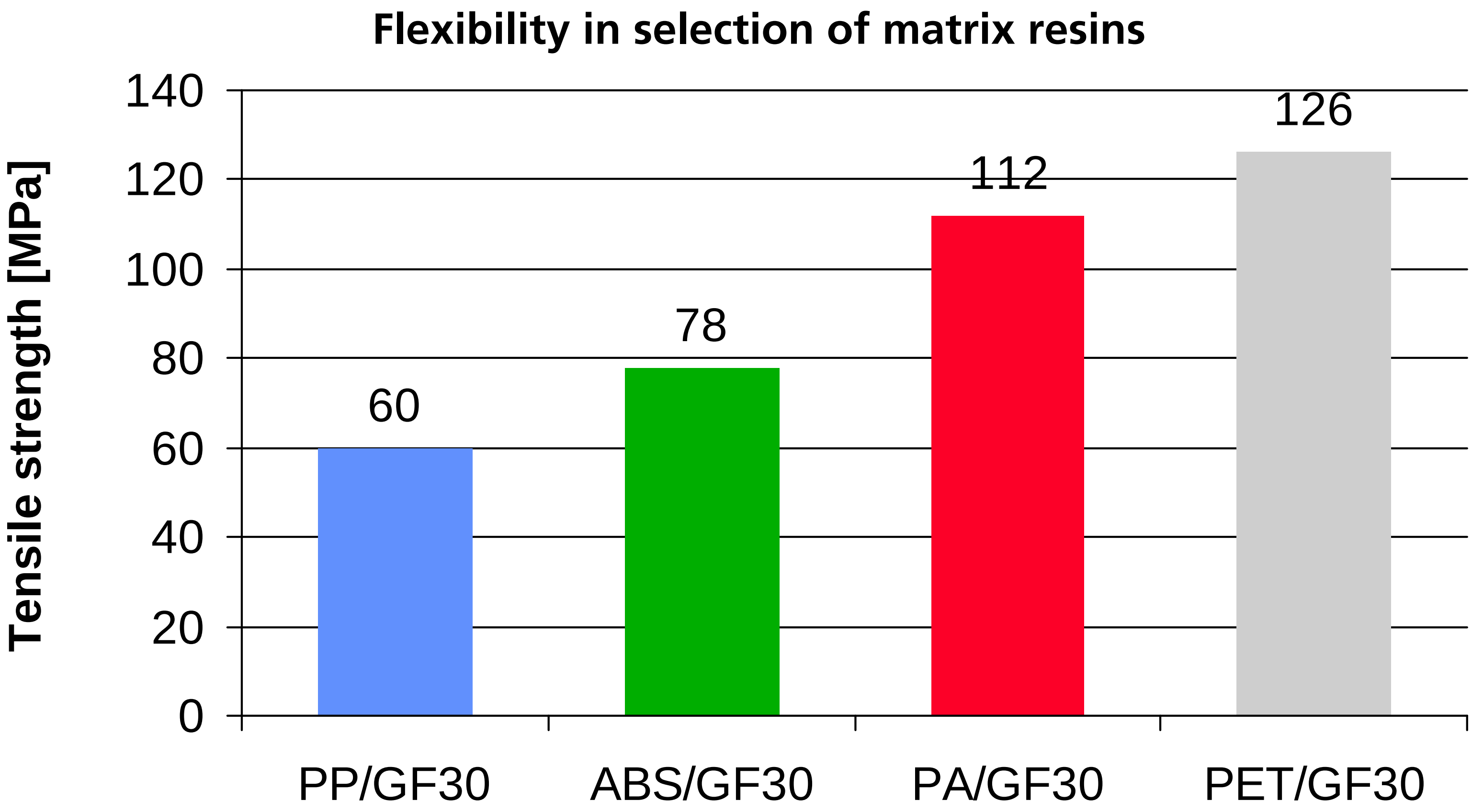
IL-Compounder

Mixing extruder (Twin screw compounder)

LFT strand

Compression molding

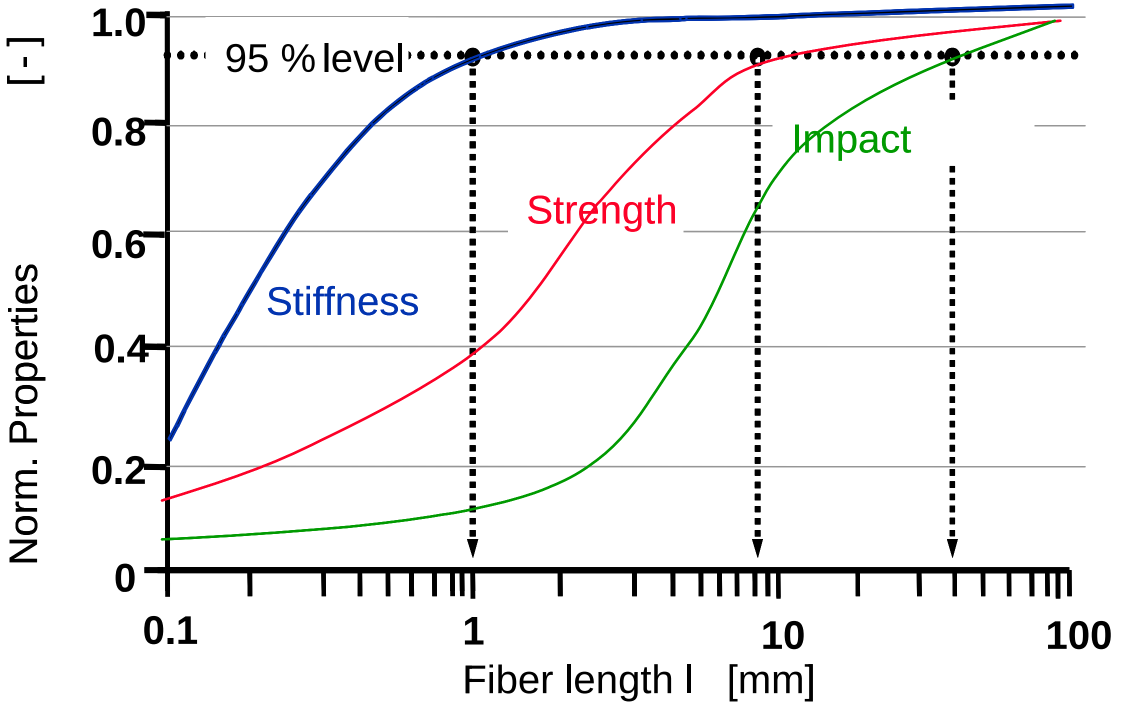
Advanced LFT based on Engineering Thermoplastics



Long fiber reinforced Engineering Plastics offer new applications for LFT´s

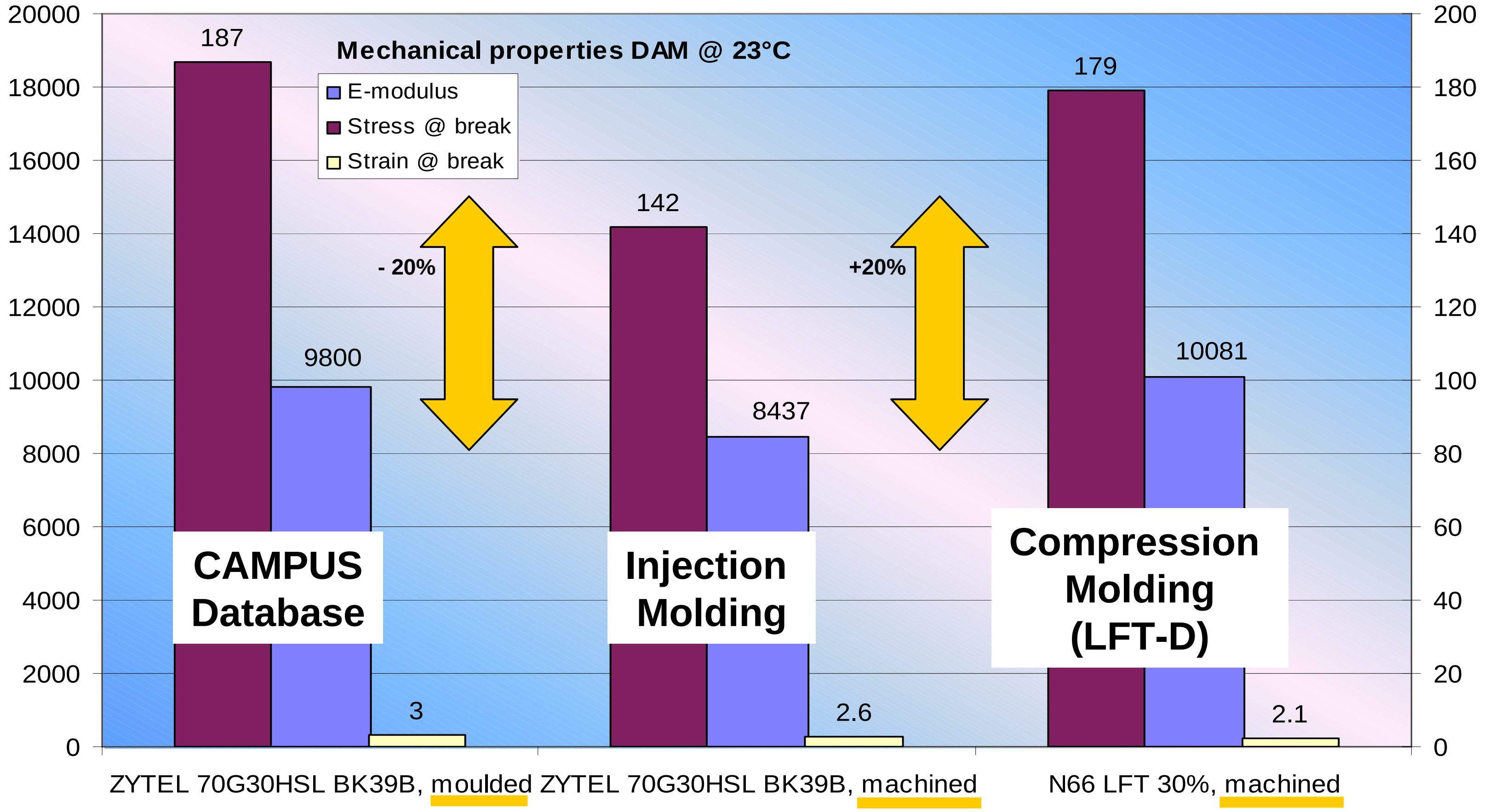
Distribution of Fiber Length – Influence on Material Properties

- **Stiffness:** Fiber length 0,1 to 1mm → Fillers and short fibers
- **Strength:** Fiber length 1 to 10mm → Short fibers
- **Impact:** Fiber length > 10mm → Long fibers



Source:
Schemme, SKZ-Fachtagung
„Karosseriekonzepte mit Kunststoffen,
Würzburg 2002
Based on
Thomason & Vlug

Tensile Properties of Nylon PA6.6/GF30 @ 23°C



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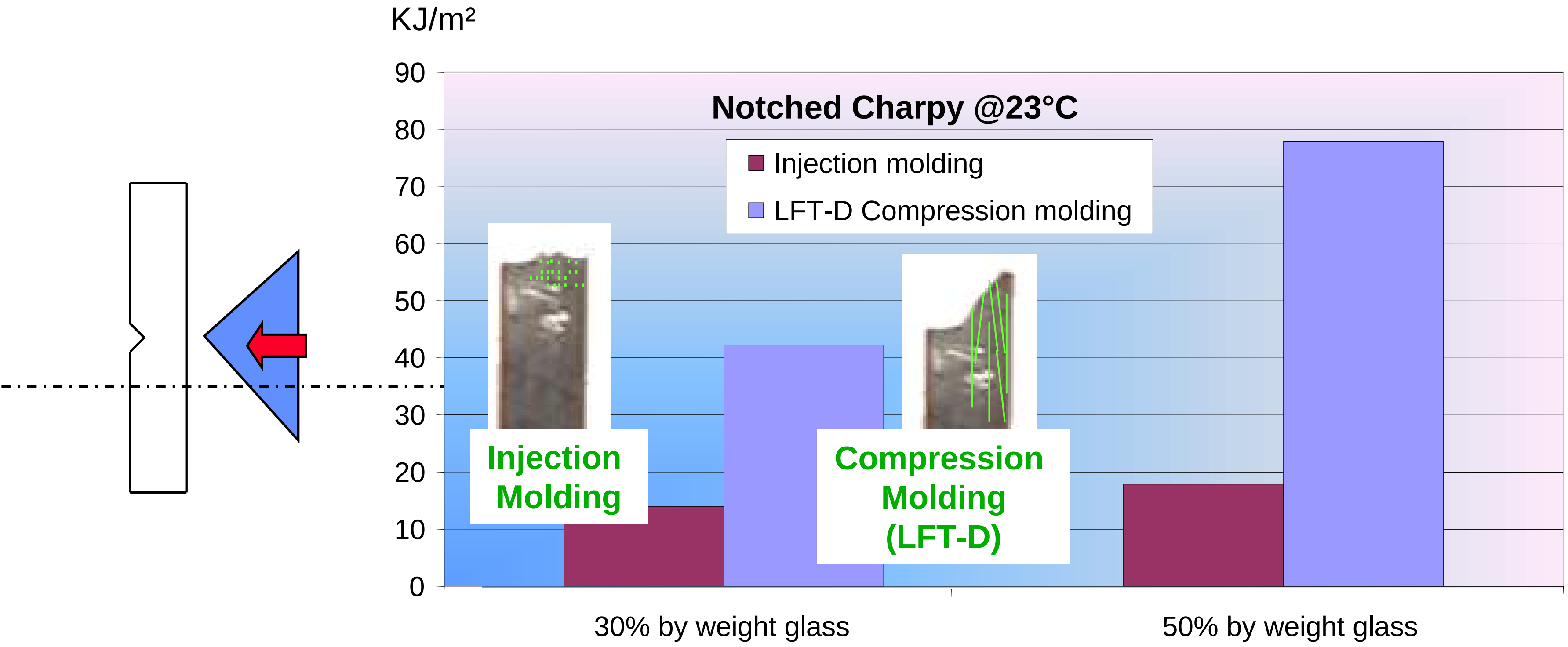
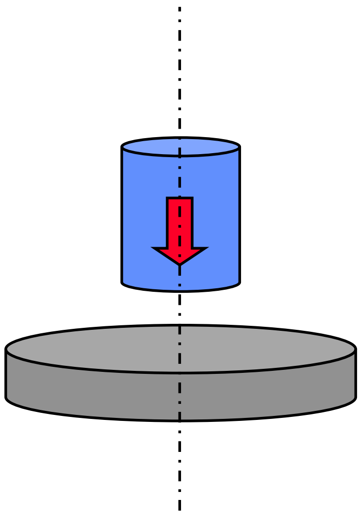
Notched Charpy Properties of Nylon PA6.6 and GF50 @ 23°C

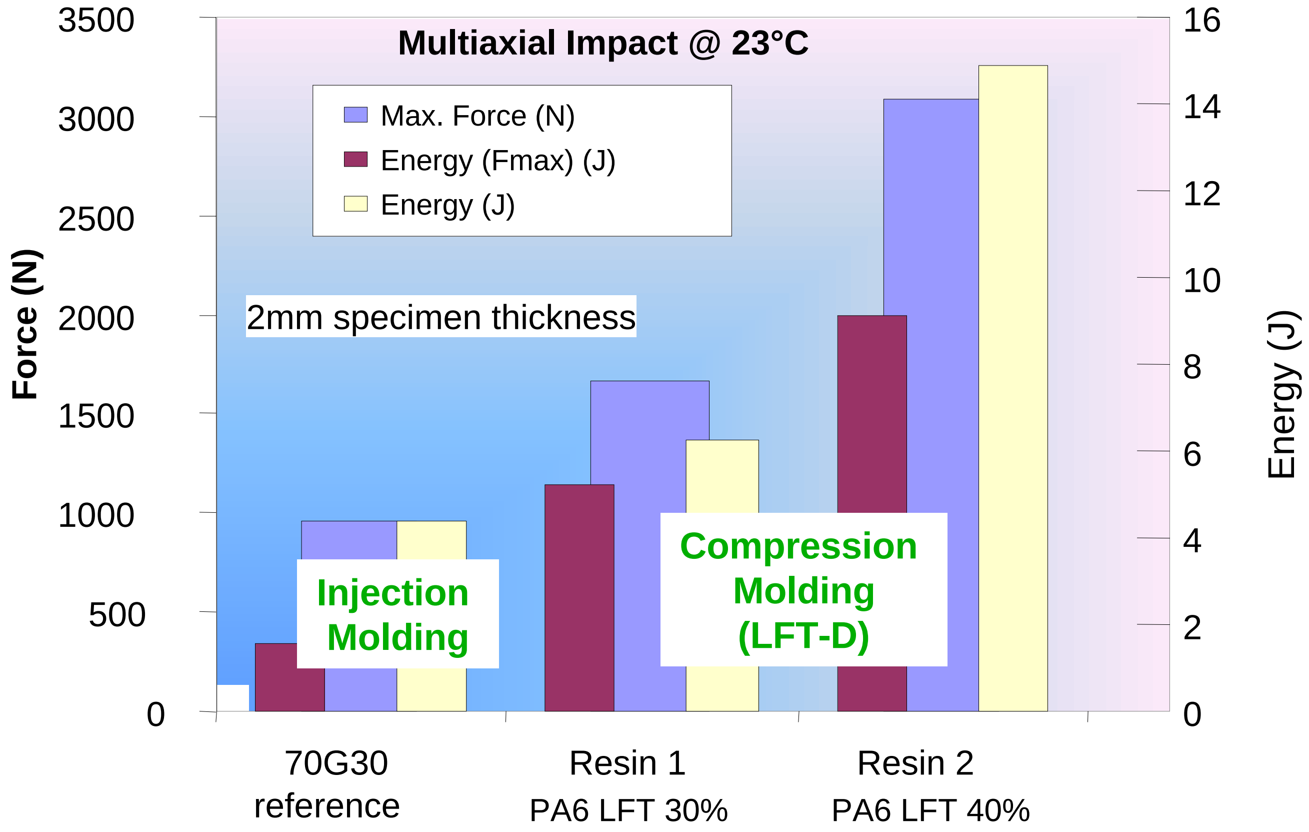
- LFT brings a clear benefit in notched impact
- Notched Charpy performance is trippled



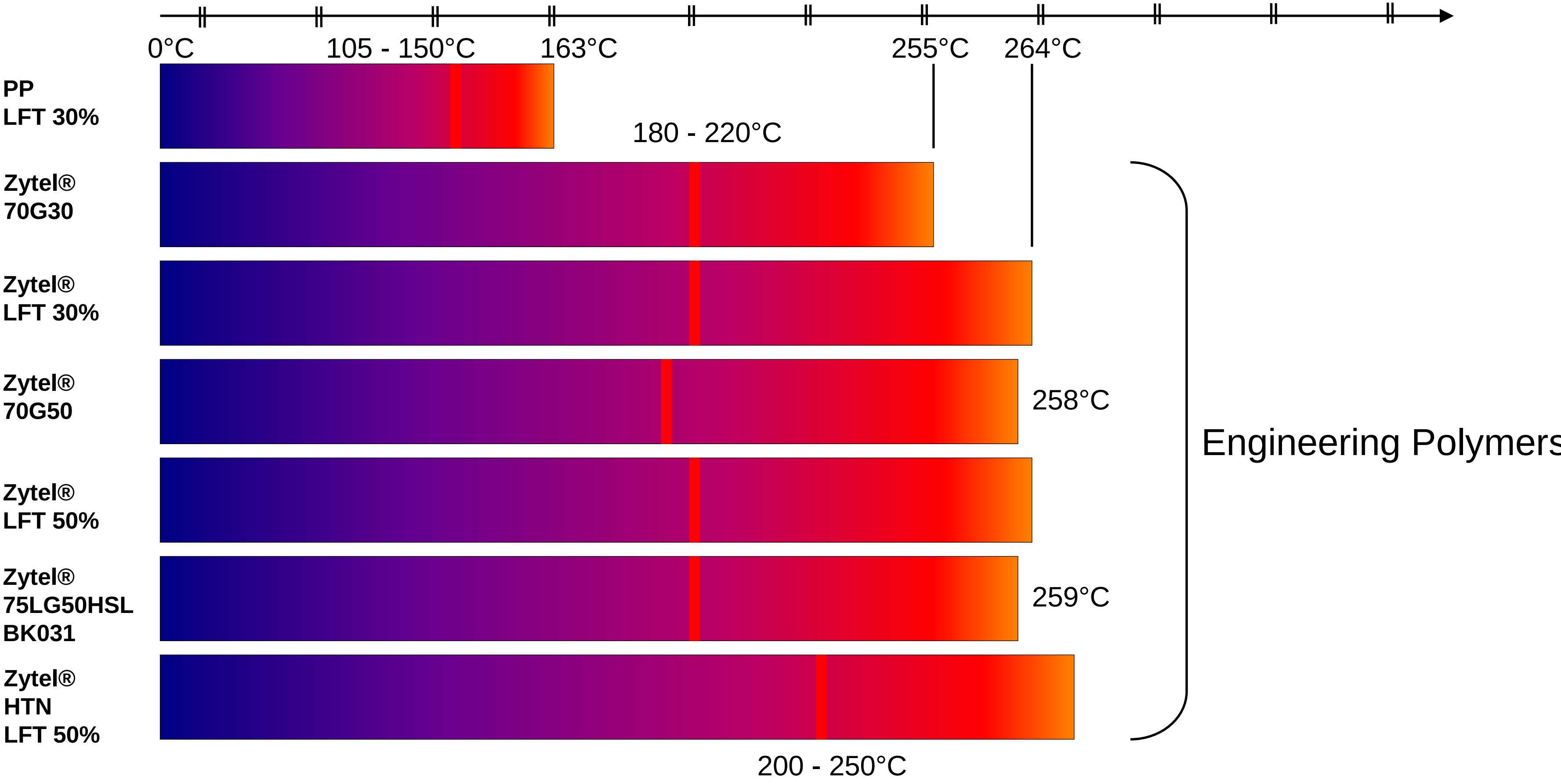
Multi-axial Impact of Nylon PA6.6/GF30 and GF40 @ 23°C

- LFT brings a clear benefit in multi-axial impact



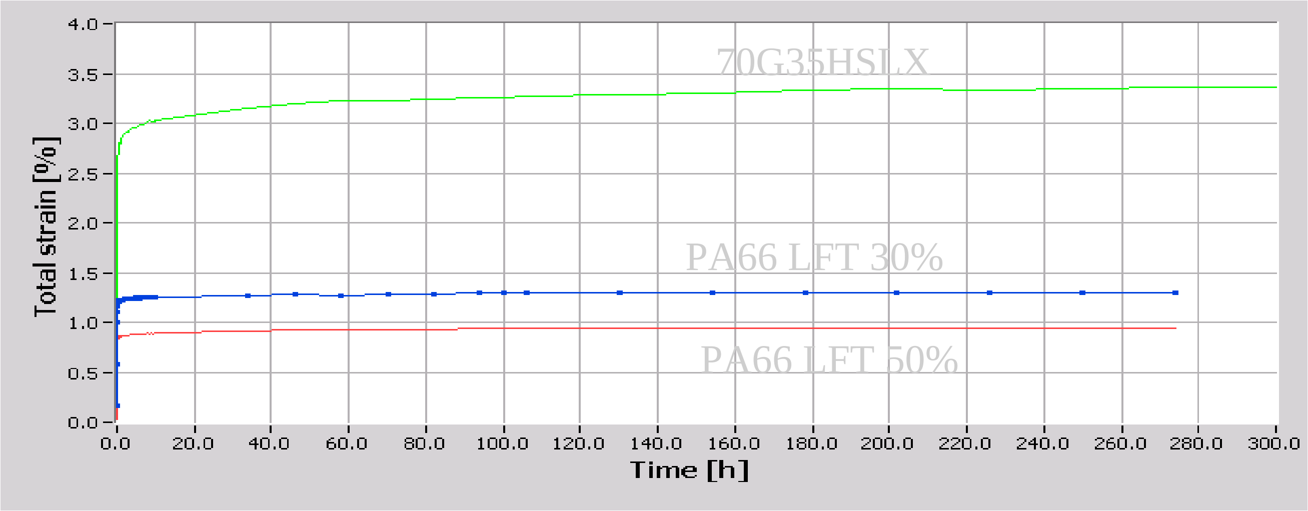


Heat Deflection Temperature @ 1.81 MPA ISO 75-A



Creep Measurements @ 130°C, 4000 MPa

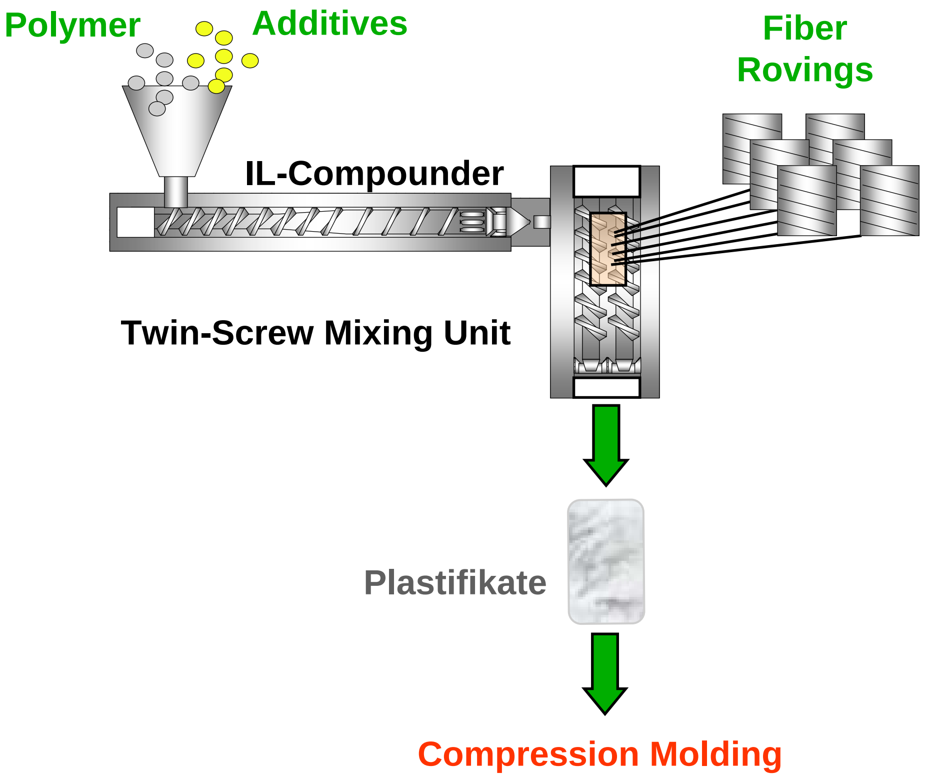
- The LFT in-flow tensile modulus is 20% higher compared to 70G35
- After 1000 hours, the LFT in-flow tensile modulus is 50% higher
- LFT 50% brings another performance increase



Modulus [MPa]	**30% long glass fiber**	**50% long glass fiber**	**Zytel® 70G35**
Tensile	5100	7900	4000
Creep @ 1 [h]	4800	7100	3000
Creep @ 10 [h]	4700	6800	2700
Creep @ 100 [h]	4600	6400	2600
Creep @ 1000 [h]	4500	6300	2400

LFT-D Material Development– Cellulose Fiber Reinforced PP

- **Goal:** Modification of LFT-D-ILC process technology developed for the in-line compounding of glass fibers for the direct incorporation of cellulose regenerated fibers



Polymer

Additives

Fiber Rovings

IL-Compounder

Twin-Screw Mixing Unit

Plastifikate

Compression Molding

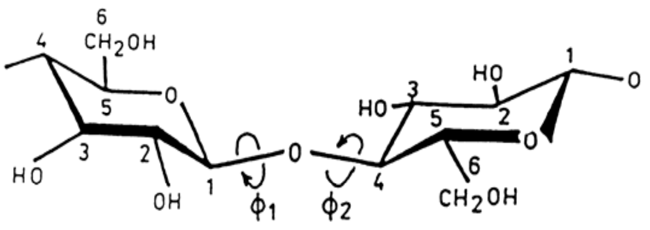
Advantages of engineering regenerated cellulotic fibers

- **Reduced density** compared to glass fibers → weight reduction:
  r_{CRF}= 1,5 kg/dm^3 versus r_{GF}=2,5 kg/dm^3
- High elongation at break results in **high impact resistance** especially at low temperatures (T = -30°C)
- **Low sensitivity regarding splintering** - qualification of RAYON fiber reinforced composites for automotive interior applications
- Combination with biopolymers enable the in-line compounding of 100% **renewable LFT**
- **Reproducible material properties** and **continuous rovings** compared to natural grown fibers

Cellulose

Cellulose is the most commonly existing natural product with an annual growth rate of approx. 10^{10} t

Chemical Structure: clarified by Haworth 1928



Cellulose = Poly (β-(1,4)-Anhydroglucose)
Basic module: AGU = $C_6H_{10}O_5$ (chem.),
Cellobiose (phys.)

Physical structure

- semi-cristalline (Polymorphy)
- fibrillar morphology (streched polymer chain)
- physical structure still in discussion
  Major problem: structural diversity – distinctive structural imperfection

Problems of industrial processing

- Cellulose is not fusible
- Cellulose is not soluble in common solvants
- Cellulose first has to be isolated (chemical pulp manufacture from wood)

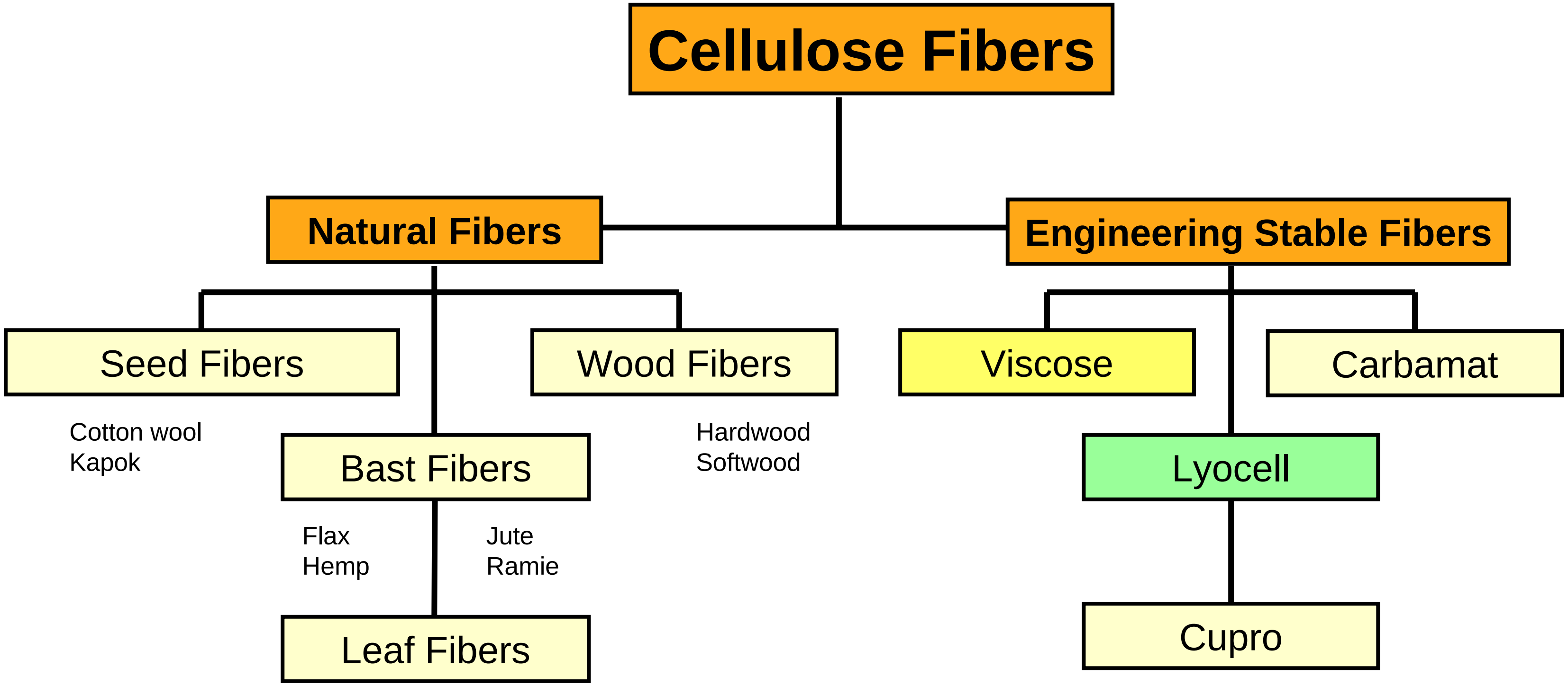
Quelle: Fraunhofer IAP

Properties of hemp yarns of different origin

Material	Source Provider	Yarn count tex	Strenght cN/tex	Elongation %	Modulus cN/tex
Hanf 2.4/1	Rohemp	357.8	12.2	3.88	593
Hanf 5/1	**Rohemp**	**205.3**	**12.9**	**3.80**	**518**
Hanf 10/1	Rohemp	99.5	29.8	3.15	1148
Hanf 10/1 bleached	Rohemp	75.8	17.7	1.95	1154
Hanf 10/1	Hattorf	93.6	17.3	2.77	767
Hanf 5/1	**Polen**	**228.4**	**26.4**	**3.18**	**1349**
Hanf 7.1/1	Polen	256.9	22.9	2.50	1434
Hanf 10/1	Polen	103.4	23.4	2.66	1253
Engineering Cellulose Stable Fiber	**Cordenka**	**244**	**51,7**	**12.5**	

Quelle: Fraunhofer IAP

Cellulose Fibers



Cellulose Fibers

Natural Fibers

Seed Fibers

Cotton wool
Kapok

Bast Fibers

Flax
Hemp

Jute
Ramie

Leaf Fibers

Agave (Sisal and others)
Banana (Manila-Hemp and others)
Lilienfaser (New Zealand-Hemp)
Coco Fibers (Fruit Fibers)
Grass Fibers

Wood Fibers

Hardwood
Softwood

Engineering Stable Fibers

Viscose

Carbamat

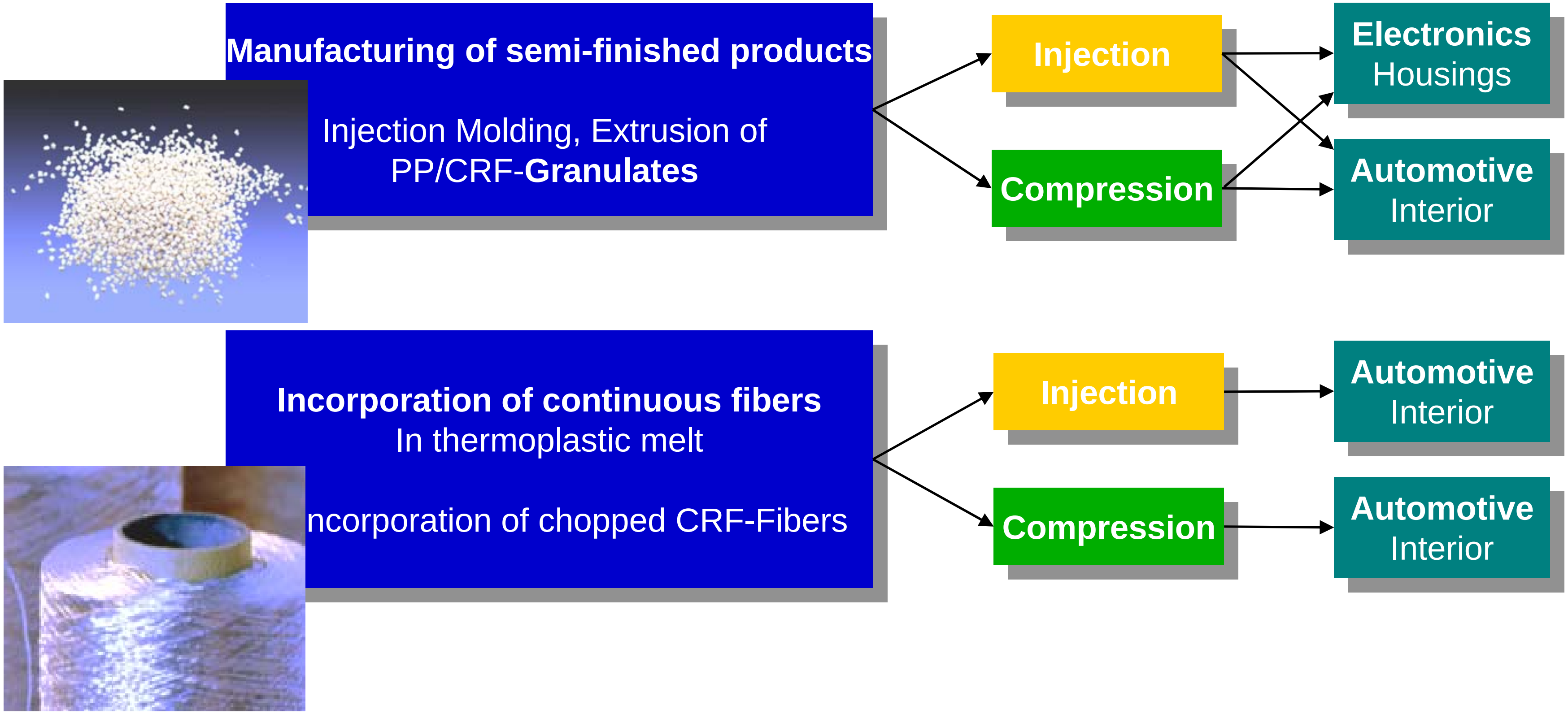
Lyocell

Cupro

Enginnering Stable Fibers
= cellulosic synthetic fibers
= man-made cellulosics
= cellulose-stable fibers

Quelle: Fraunhofer IAP

CRF in Composites - Processing



Manufacturing of semi-finished products

Injection Molding, Extrusion of
PP/CRF-**Granulates**

Injection

Compression

Electronics
Housings

Automotive
Interior

Incorporation of continuous fibers
In thermoplastic melt

ncorporation of chopped CRF-Fibers

Injection

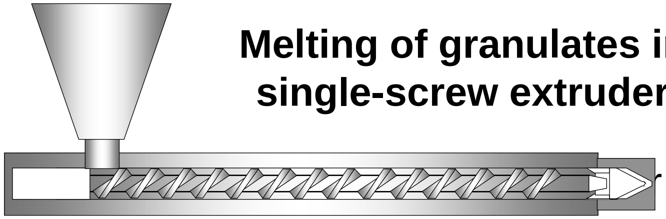
Compression

Automotive
Interior

Automotive
Interior

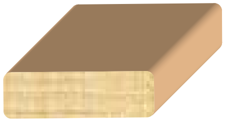
Processing of Granulates by Compression Molding

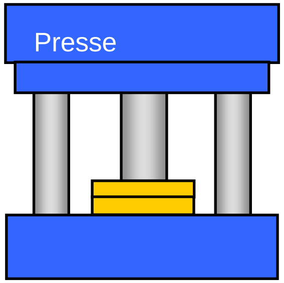

Granulate **PPRayCo25 Basic**



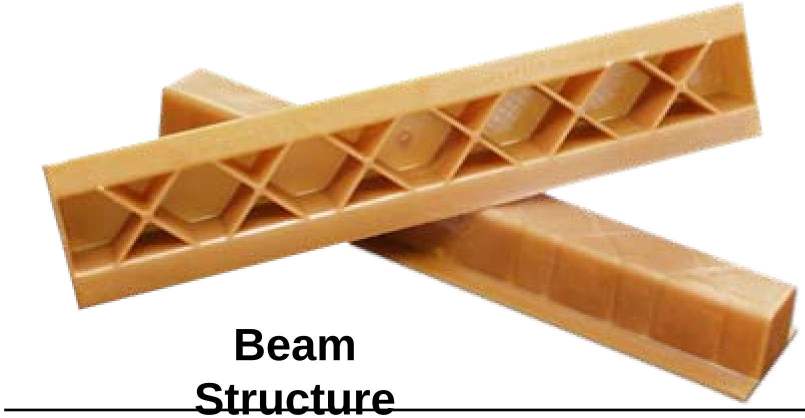
Melting of granulates in single-screw extruder

Plastifikate





Compression Molding



Beam Structure

Material Properties of Injection Molded Parts (Short Fiber Reinforced)

Polypropylene with 25 percent by weight RAYON short fiber reinforcement

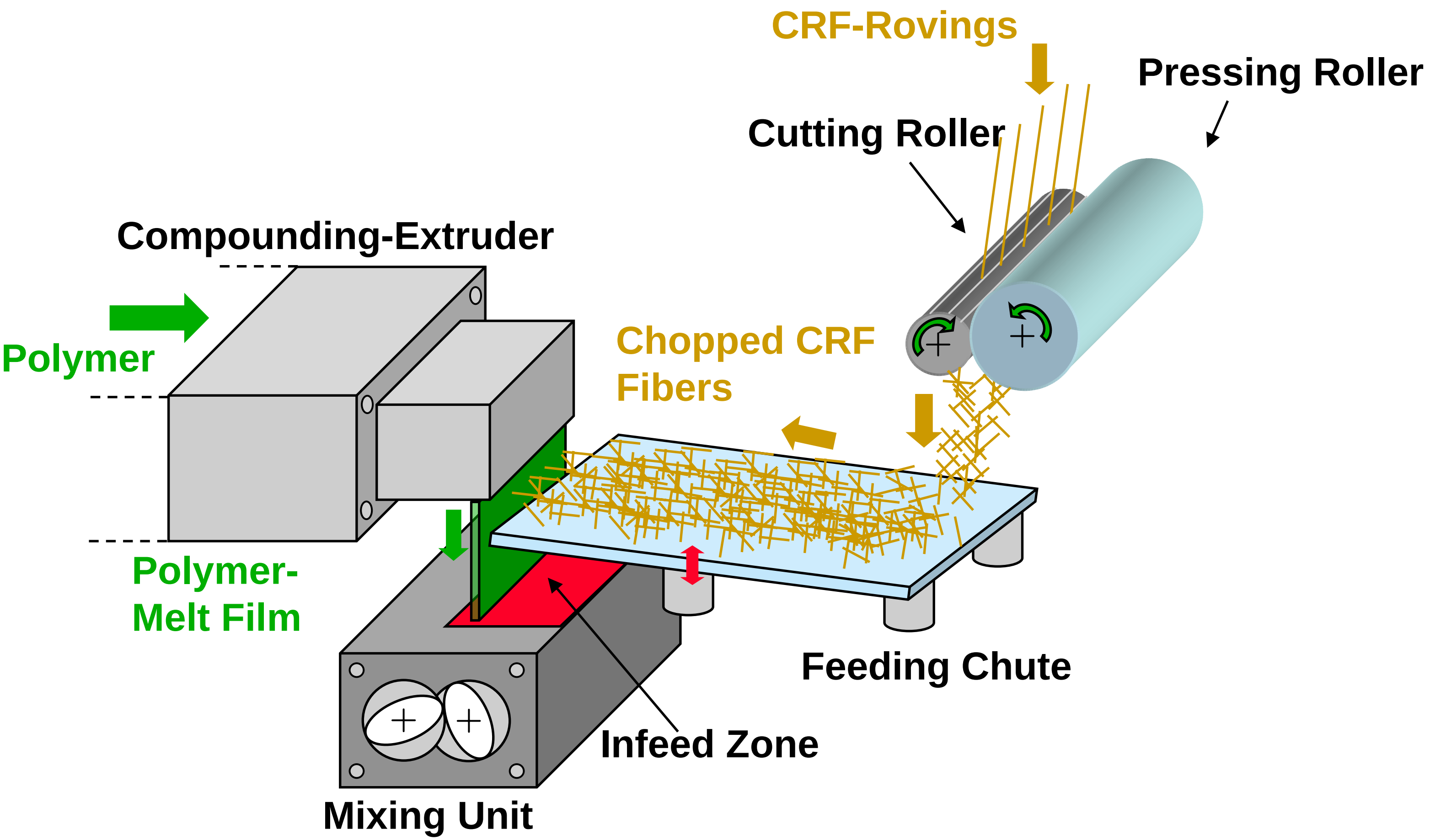
Properties	Procedure	Unit	Norm	measured value
Matrix resin				PP
Fiber content		wt.%		25
Tensile modulus	2mm/min	GPa	ISO527	2,7
Tensile strength	**50mm/min**	**MPa**	**ISO527**	**72**
Strain at break (tensile)	50mm/min	%	ISO527	12
Flexural modulus	2mm/min	GPa	ISO178	2,1
Flexural strength	2mm/min	MPa	ISO178	60
Flexural tension at 3,5%	2mm/min	MPa	ISO178	52
Charpy Impact (un-notched)	**23°C, 4J**	**kJ/m^2**	**ISO179**	**85**
	-18°C, 4J	**kJ/m^2**	**ISO180**	**83**
Charpy Impact (notched)	23°C, 4J	kJ/m^2	ISO179	11
	-18°C, 4J	kJ/m^2	ISO180	7
Hardness Shore D	23°C		DIN53505	70
Heat deflection HDT-A	1,8 MPa	°C	ISO75	80
Density	calculated	g/cm^3		0,998

Source: http://www2.iap.fhg.de/verbundwerkstoffe/de/index.html

Direct Processing of CRF Composites - Challenges

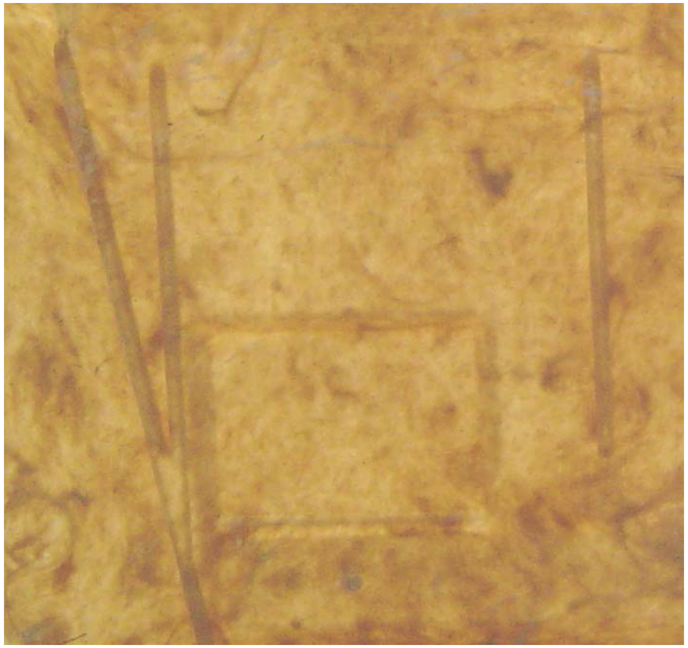
- Chopping of CRF – high elongation
- Homogenisation of chopped fibers in matrix polymer by mixing unit
- Cutting of CRF-LFT plastificates into strands for compression molding
- Compatibility of fibers and polymer – fiber-matrix adhesion
- Optimization of flow capability of CRF reinforced polymer

Direct Processing of CRF Composites – Process Modifications

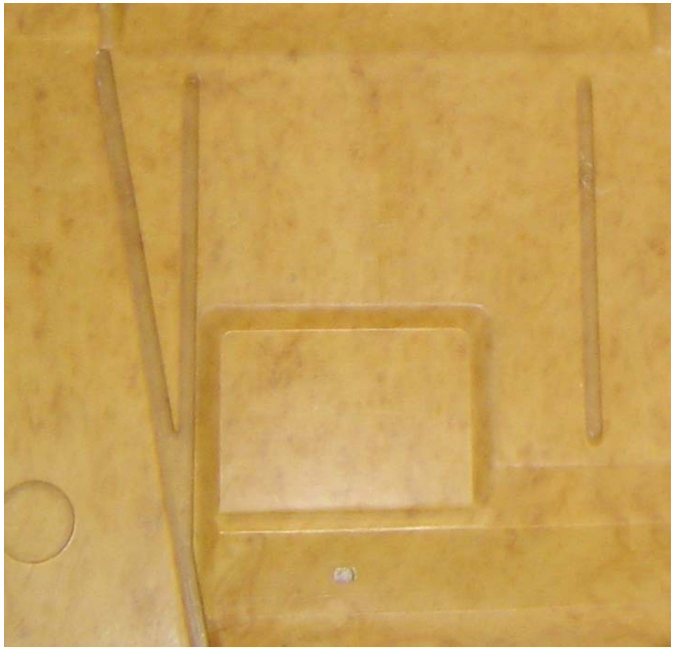


Direct Processing of CRF Composites – Material Homogeneity

- Significant improvement of material homogeneity by process optimization



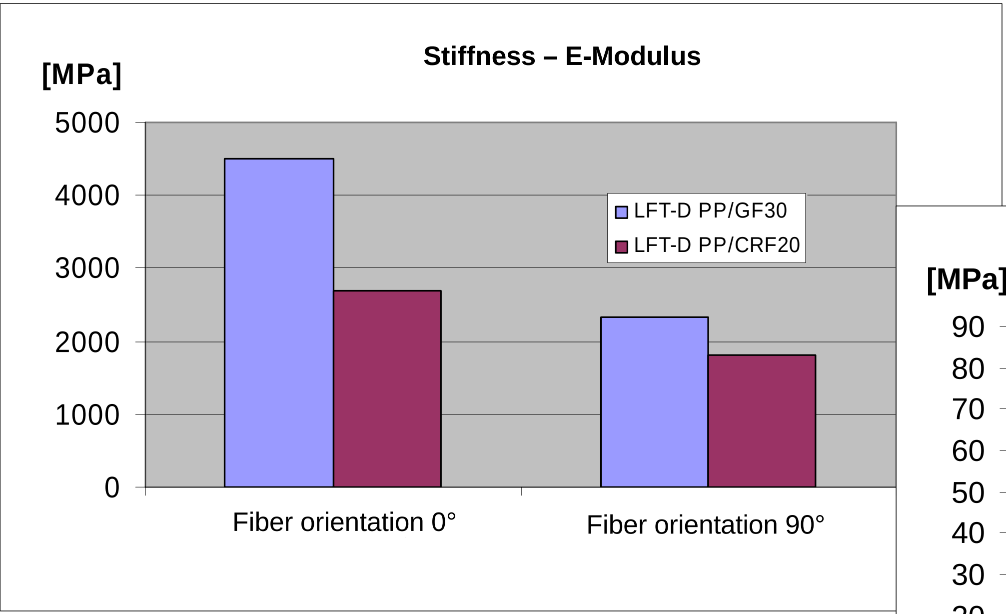
LFT-D Technology – not optimized
(25 weight-% fiber content)

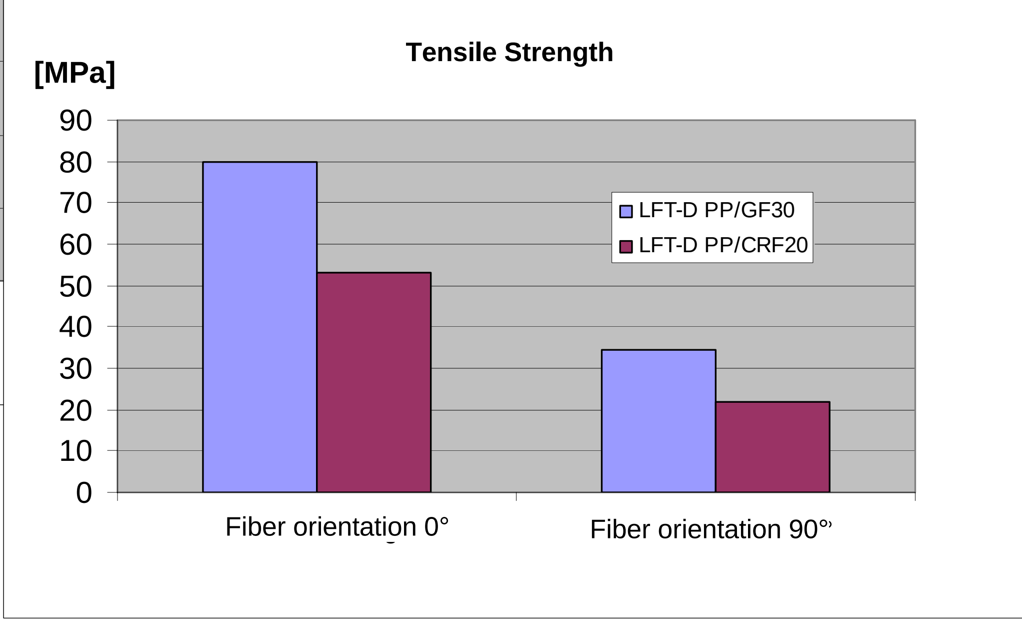


Optimized LFT-D Technology
(25 Gew.-% fiber content)

Material Properties of Extrusion Compression Molded Parts

Polypropylene with 20 percent by weight RAYON long fiber reinforcement (fiber length 12 mm) compared to long glass fiber reinforced PP





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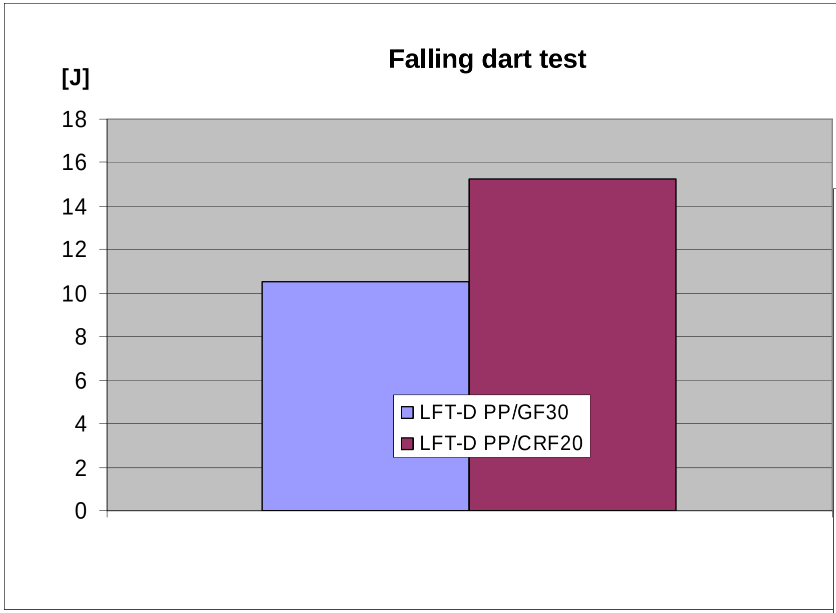
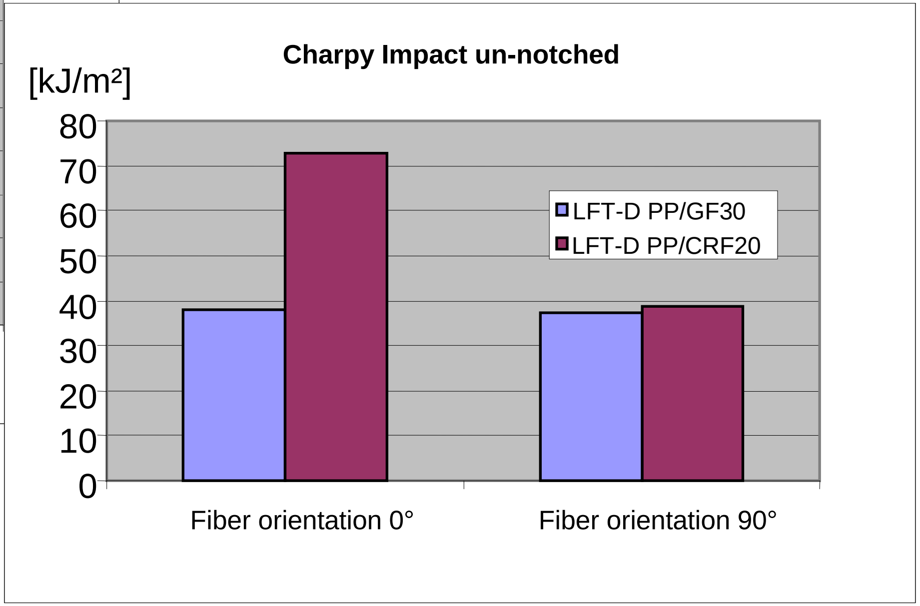
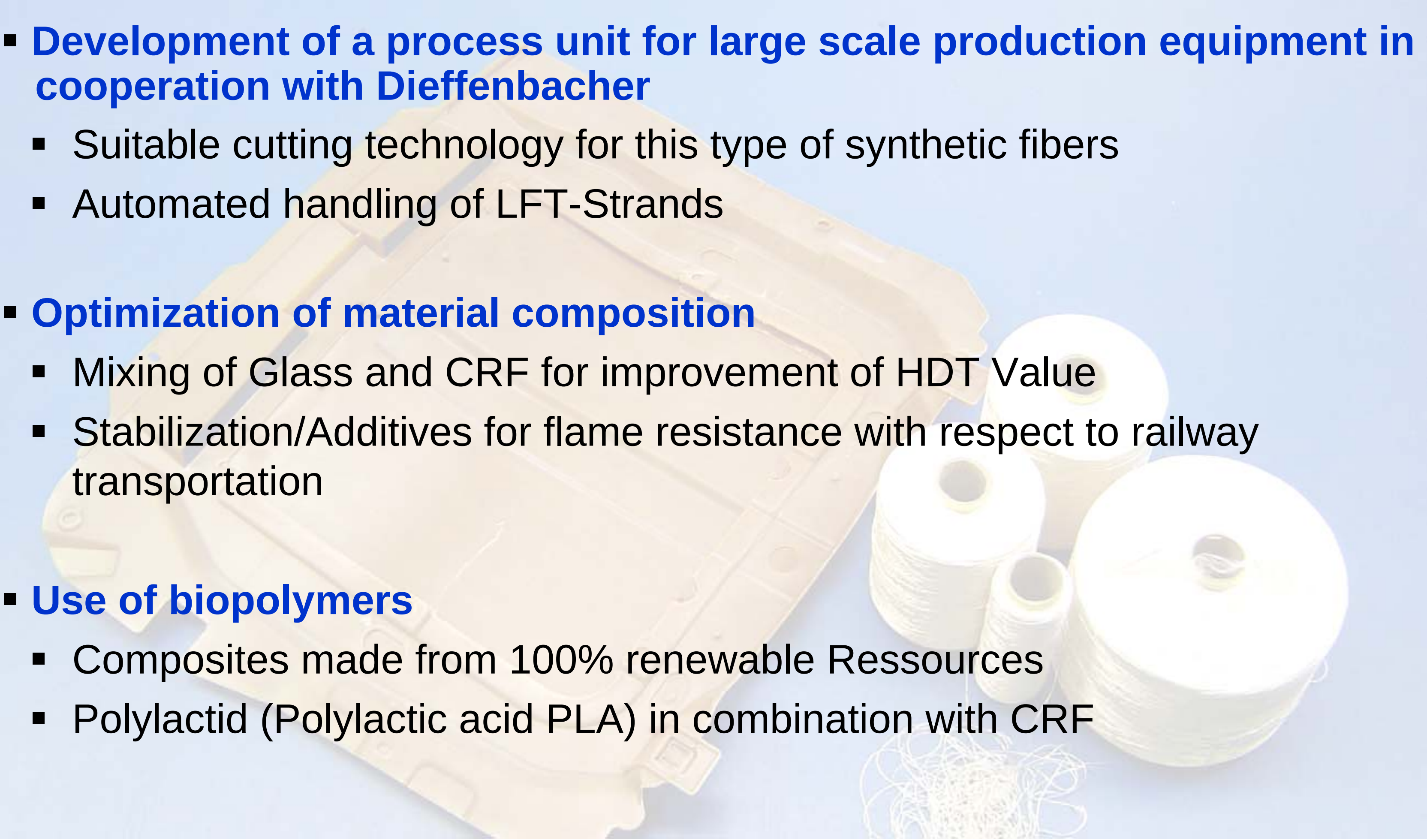




Current Material and Process Developments

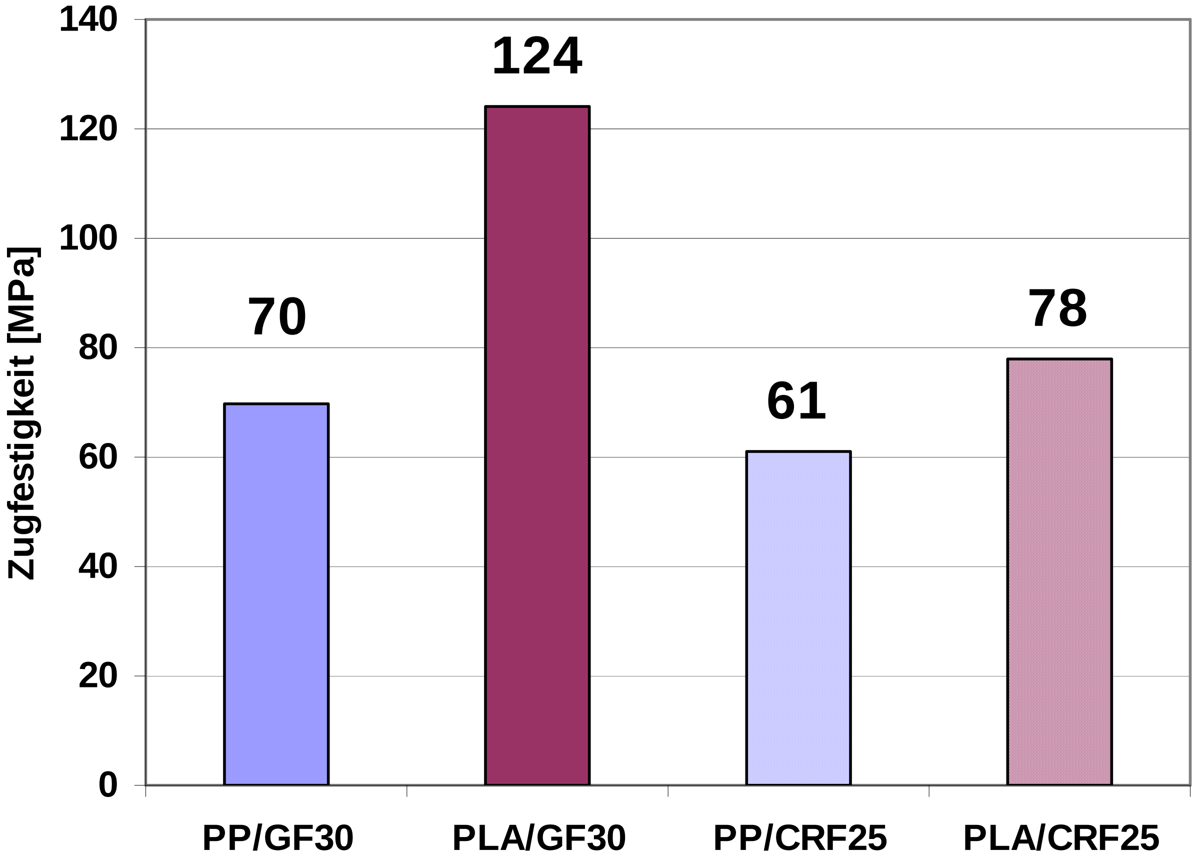


- **Development of a process unit for large scale production equipment in cooperation with Dieffenbacher**
  - Suitable cutting technology for this type of synthetic fibers
  - Automated handling of LFT-Strands

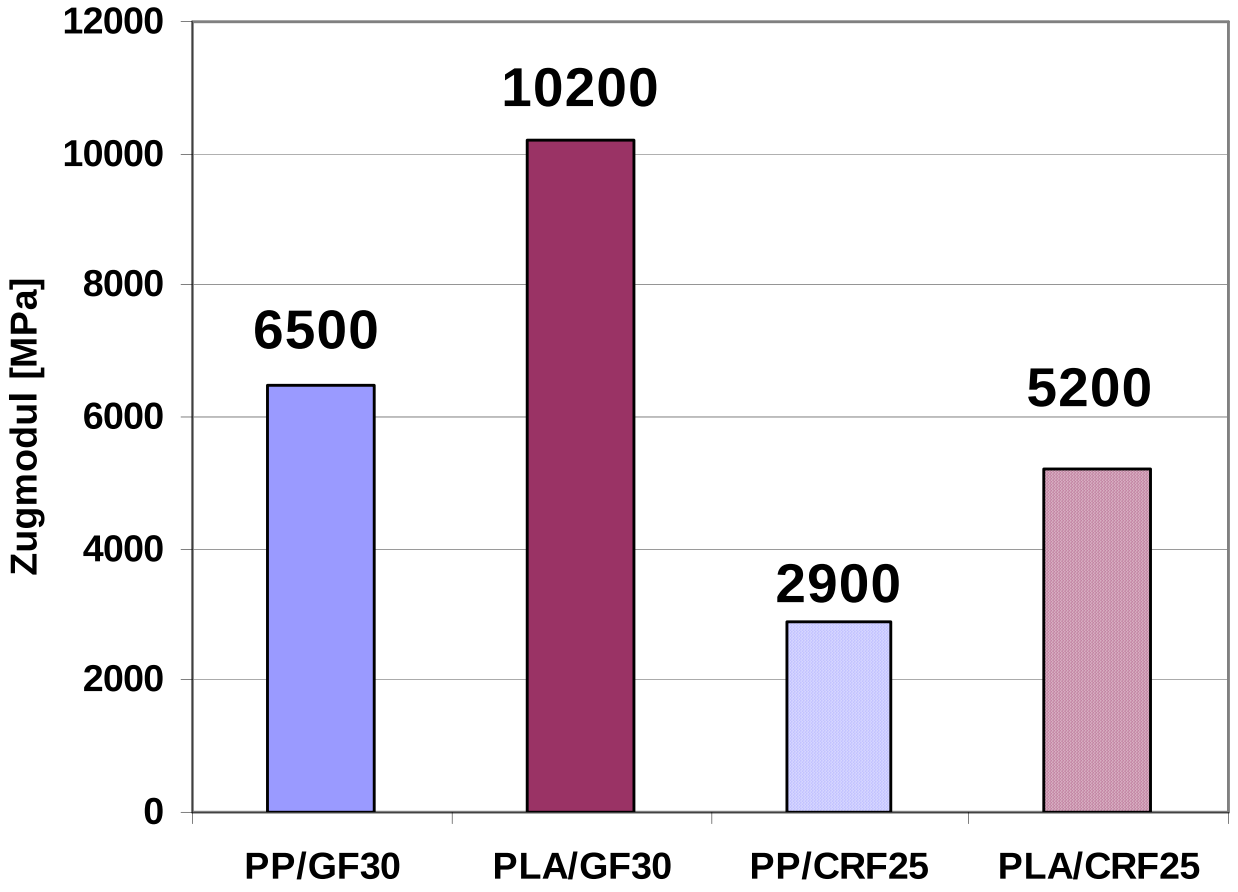
- **Optimization of material composition**
  - Mixing of Glass and CRF for improvement of HDT Value
  - Stabilization/Additives for flame resistance with respect to railway transportation

- **Use of biopolymers**
  - Composites made from 100% renewable Ressources
  - Polylactid (Polylactic acid PLA) in combination with CRF

CRF in Biopolymers – Tensile Strength



CRF in Biopolymers – Tensile Strength



LFT-D Regenerated Cellulotic Fiber Reinforced Polypropylene

VOLVO
Underbody Cover
Made of PP/CRF25,
25 weight-% Fibers

Unterbody Cover
OPEL Corsa made of
PP/CRF20,
20 weight-% Fibers

Flame Retarding Behaviour of CRF Composites

Characterisation of combustion behaviour of different composites

25 weight-% CRF reinforced Polypropylen (IAP granules, short fibers), injection molded

Length of burning time for 100mm 229 s

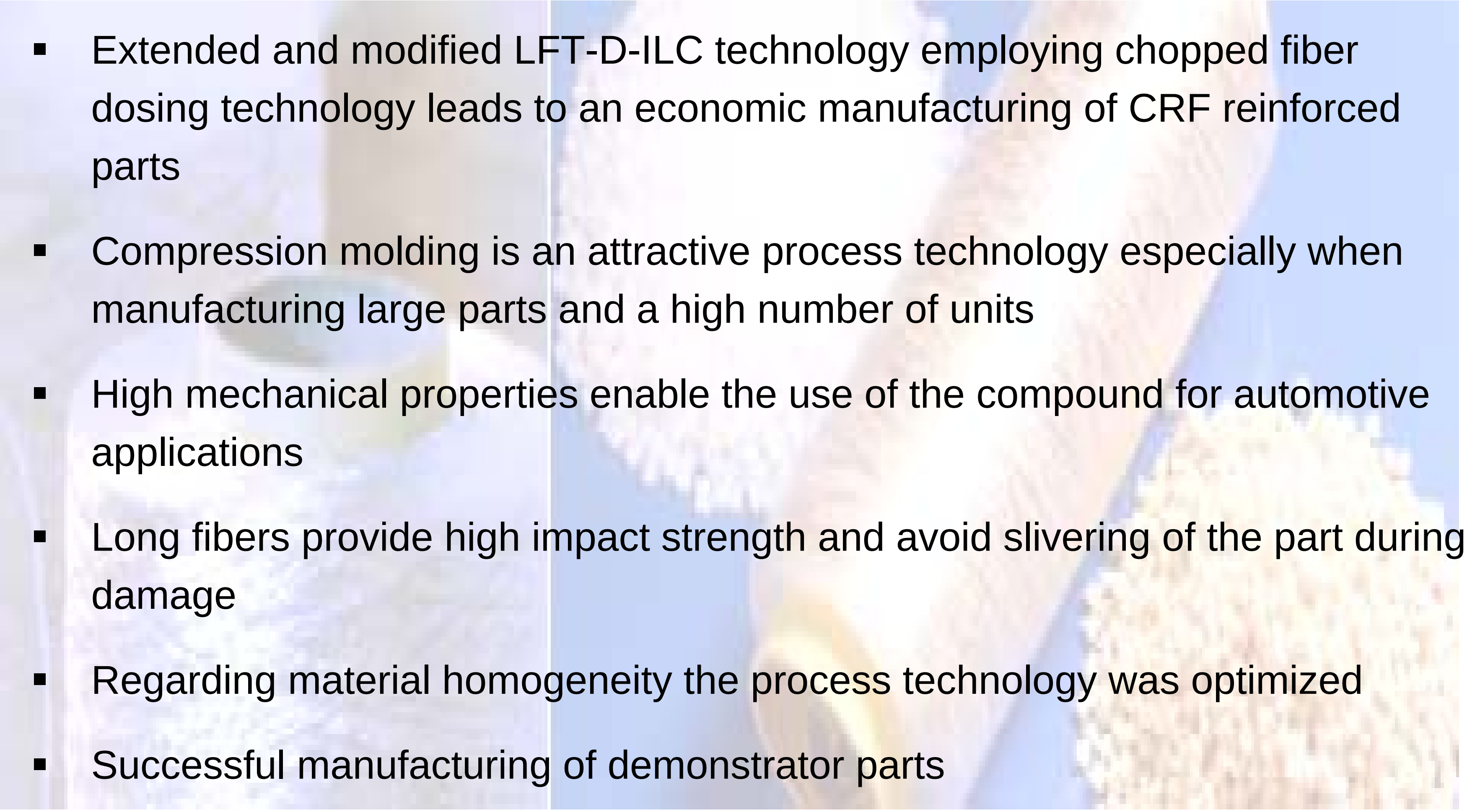
25 weight-% CRF reinforced Polypropylen (ICT, LFT-D), compression molded

Length of burning time for 100mm 327 s

30% glass fiber reinforced Polypropylen (ICT, LFT-D), compression molded

Length of burning time for 100mm 233 s

Summary



- Extended and modified LFT-D-ILC technology employing chopped fiber dosing technology leads to an economic manufacturing of CRF reinforced parts
- Compression molding is an attractive process technology especially when manufacturing large parts and a high number of units
- High mechanical properties enable the use of the compound for automotive applications
- Long fibers provide high impact strength and avoid slivering of the part during damage
- Regarding material homogeneity the process technology was optimized
- Successful manufacturing of demonstrator parts

http://www.neue-verbundwerkstoffe.de

http://www.ict.fraunhofer.de

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