Fraunhofer
IGCV

Fraunhofer Research Institution for
Casting, Composite and Processing Technology IGCV

reTHINK: „CFRP – Recycling and Sustainability“
Characterization of recycled carbon fibre materials

Singapur

JEC asia
International Composites Event
Singapore · November 15 · 16 · 17 · 2016

16.11.2016 @ JEC Asia
SUNTEC International Convention & Exhibition Centre,
1 Raffles Boulevard, Suntec City,
Singapur 039593

Bangkok

18.11.2016 @ KMITL
King Mongkut's Institute of Technology Ladkrabang,
Central Library 5th floor, Chalongkrung Road,
Ladkrabang District, Bangkok 10520

Kuala Lumpur

UCSI University

21.11.2016 @ UCSI
UCSI University, North Wing Campus, Taman
Taynton View Cheras, Lot 12734 Jalan Choo Lip
Kung, 56000 Kuala Lumpur

Dipl. Ing. Frank Manis

16.-21.11.2016

ELG Carbon Fibre Ltd. RECYCLED CARBON FIBRE
Textechno textile testing technology
Internationales Büro
Composite Cluster Singapore
BONORA
CARBON COMPOSITES
Fraunhofer IFF
SEACUS Southeast Asian Center for Urban Sustainability
CPC CLUSTER FOR POLYMER COMPOSITES UNIVERSITI SAINS MALAYSIA

Why do we need characterization technics?

Pyrolysed (550 °C, 30 minutes dwell time)
CFRP-Woven out of epoxy resin

Mechanical	Optical	Chemical
Durability	Impact	Electrical
Price	Sustainability	Etc.

Climate Change	Toxicity	Ozon Layer Depletion

Why do we need characterization technics?

Composition overview

Compositional summary

Epoxy + Carbon fiber reinforcement

Material family	Plastic (thermoset)			
Base material	EP (Epoxy resin)			
% filler (by weight)	65	-	70	%
Filler/reinforcement	Carbon			
Filler/reinforcement form	Quasi-isotropic lay-up			
Polymer code	EP-CF70			

Composition detail (polymers and natural materials)

Polymer	30	-	35	%
Carbon (fiber)	65	-	70	%

Price

Price	* 33,6	-	37,3	EUR/kg

Physical properties

Density	1,55e3	-	1,58e3	kg/m^3

Mechanical properties

Young's modulus	* 49,7	-	60,1	GPa
Yield strength (elastic limit)	* 603	-	738	MPa
Tensile strength	603	-	738	MPa
Elongation	* 0,32	-	0,35	% strain
Compressive modulus	* 49,7	-	60,1	GPa
Compressive strength	* 542	-	657	MPa
Flexural modulus	91	-	110	GPa
Flexural strength (modulus of rupture)	* 249	-	356	MPa
Shear modulus	* 19	-	23	GPa
Bulk modulus	* 9,09	-	12,2	GPa
Poisson's ratio	* 0,305	-	0,307	
Shape factor	7,7			
Hardness - Vickers	* 10,8	-	21,5	HV
Hardness - Rockwell M	* 80	-	110	
Hardness - Rockwell R	* 117	-	129	
Fatigue strength at 10^7 cycles	* 137	-	231	MPa
Mechanical loss coefficient (tan delta)	* 0,0014	-	0,0033	

Impact & fracture properties

Fracture toughness	* 12,1	-	19,8	MPa.m^0.5
Ductility index	0,41	-	0,61	
Impact strength, notched 23 °C	* 40	-	63	kJ/m^2

Thermal properties

Glass temperature	100	-	180	°C
Heat deflection temperature 0.45MPa	* 279	-	337	°C
Heat deflection temperature 1.8MPa	* 250	-	305	°C
Maximum service temperature	* 140	-	220	°C
Minimum service temperature	* -123	-	-73	°C
Thermal conductivity	* 1,28	-	2,6	W/m.°C
Specific heat capacity	* 902	-	1,04e3	J/kg.°C
Thermal expansion coefficient	* 0,36	-	4,02	µstrain/°C

Electrical properties

Electrical resistivity	* 1,65e5	-	9,46e5	µohm.cm
Galvanic potential	0,14	-	0,22	V

Magnetic properties

Magnetic type	Non-magnetic

Optical properties

Transparency	Opaque

Bio-data

RoHS (EU) compliant grades?	✓

Absorption & permeability

Water absorption @ 24 hrs	* 0,036	-	0,0525	%

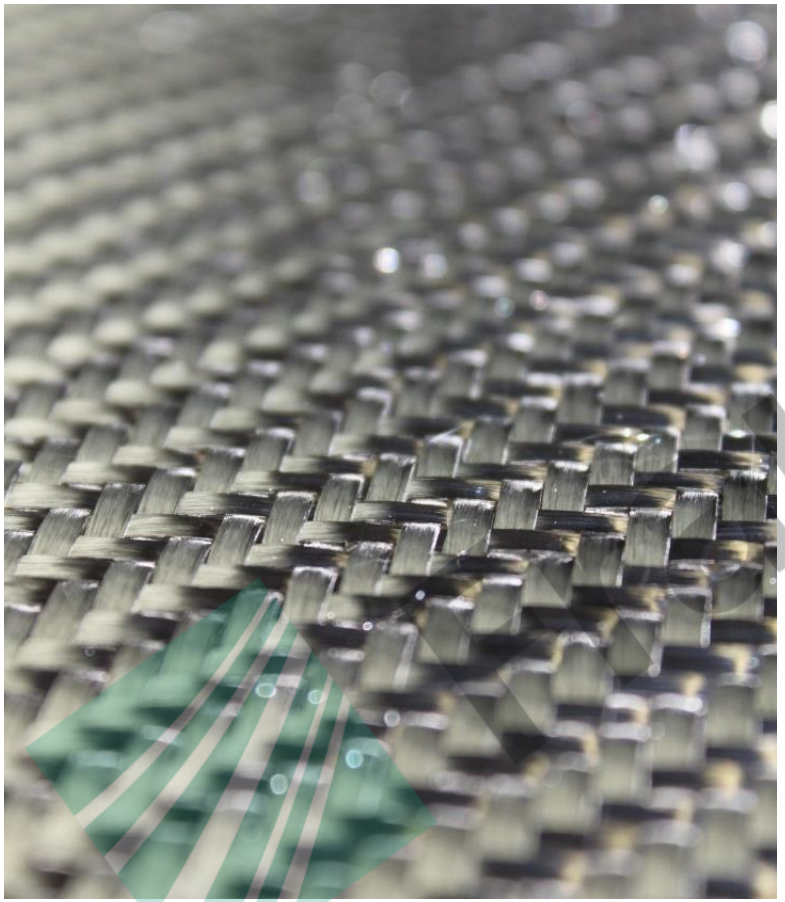
Durability

Water (fresh)	Excellent
Water (salt)	Excellent
Weak acids	Acceptable
Strong acids	Unacceptable
Weak alkalis	Limited use
Strong alkalis	Excellent
Organic solvents	Limited use
Oxidation at 500C	Unacceptable
UV radiation (sunlight)	Good
Flammability	Slow-burning
Flammability - typical UL 94 rating	HB
Oxygen index	* 24 - 26 %

[CES Selector by Granta Design]

Virgin vs. Recycled carbon fibres

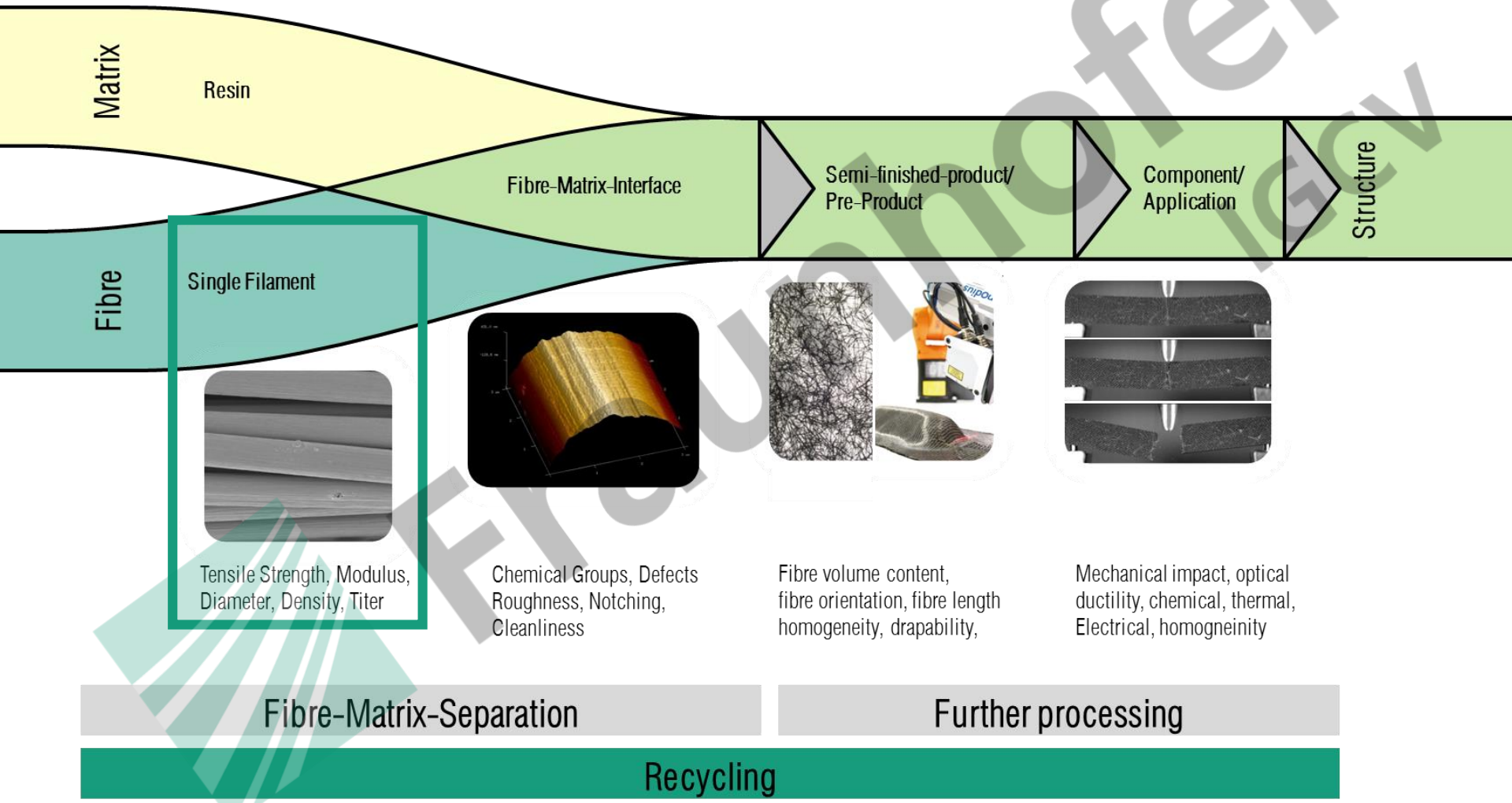
What is the difference?



- Fibre orientation
- Fibre length
- Fibre volume content
- Filament
- Adhesion

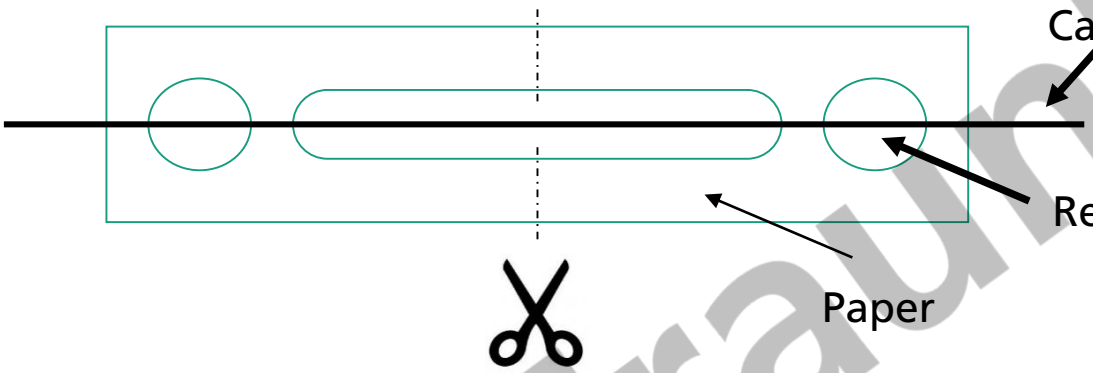
Why do we need characterization technics?

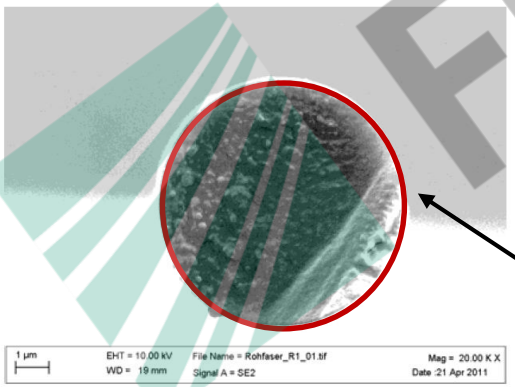
Influences on properties by recycling



Possibilities of characterization
Single filament testing

- ASTM 3379-75: *Method for Tensile Strength and Young Modulus for High-Modulus Single-Filament Materials*





$$\sigma_{xx} = \frac{F_{xx}}{A} = \frac{F_{xx}}{\pi R^2}$$

Favimat-Single fibre tensile test

Possibilities of characterization

Single filament testing

Statistic

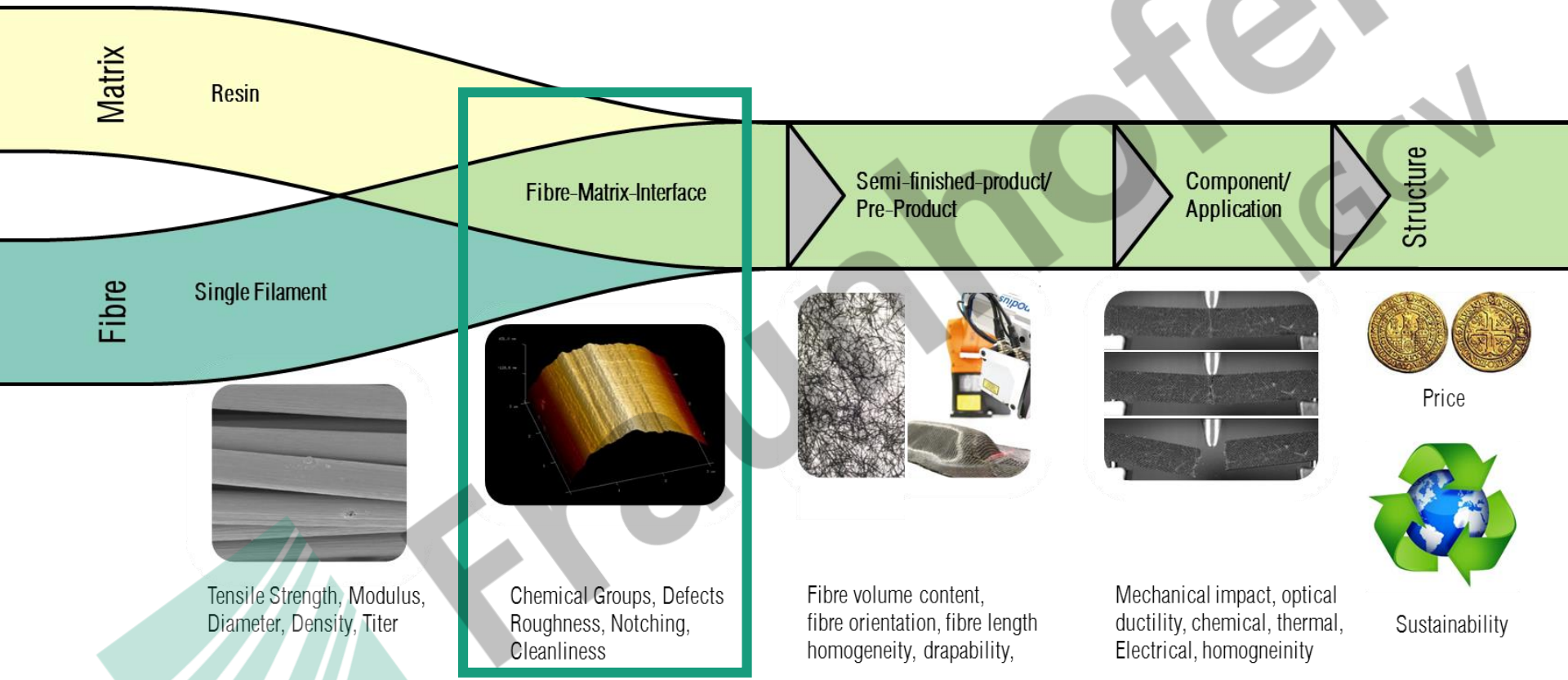
Diameter

Fibre-manufacturer

Testing Parameters

Possibilities of characterization

Influences on properties by recycling



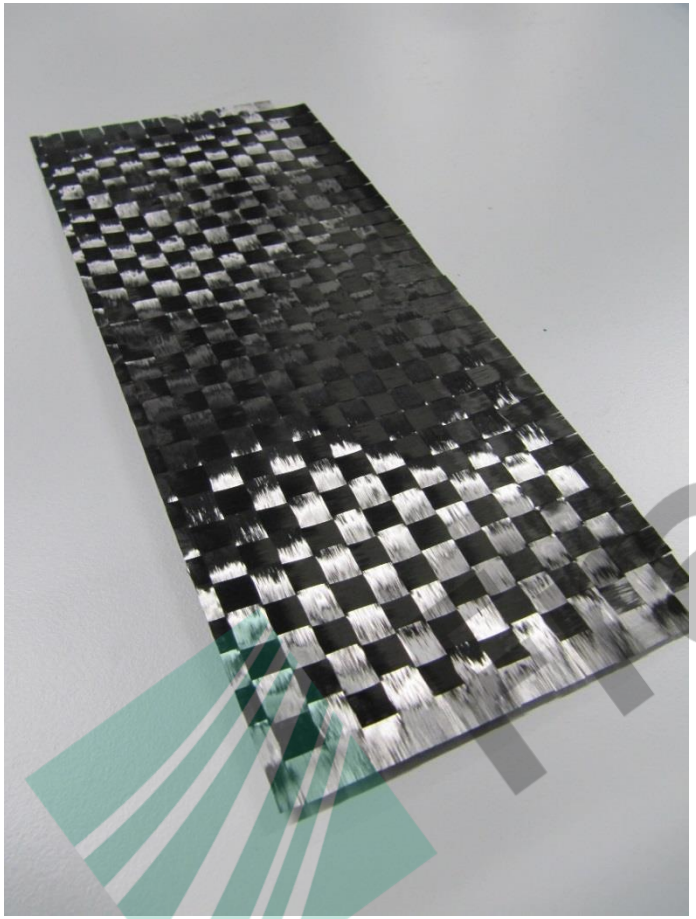
Fibre-Matrix-Separation

Further processing

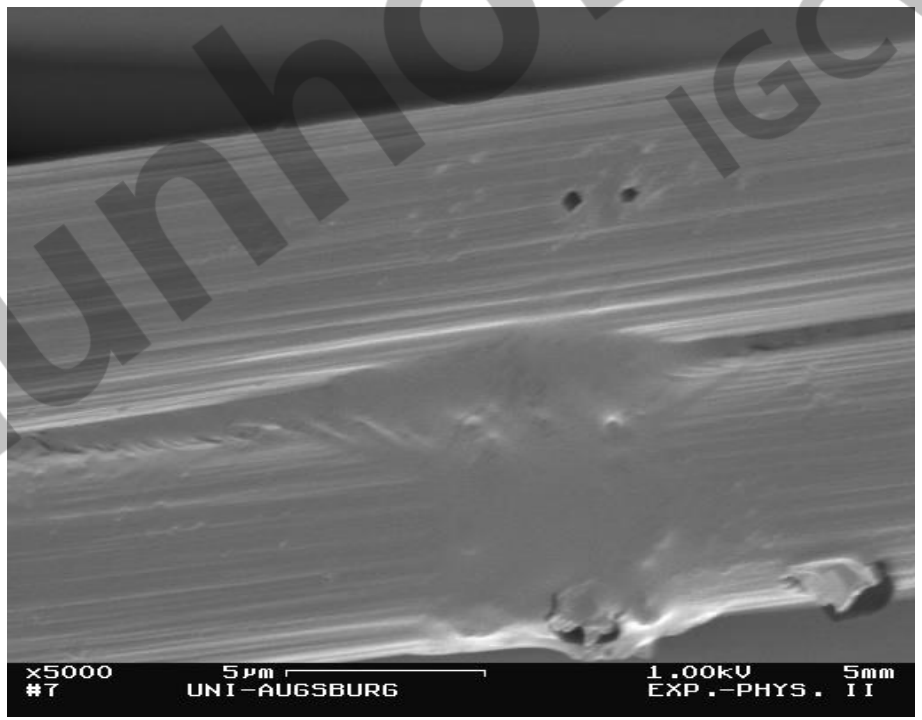
Recycling

Possibilities of characterization

Interface – Defects and Cleanliness

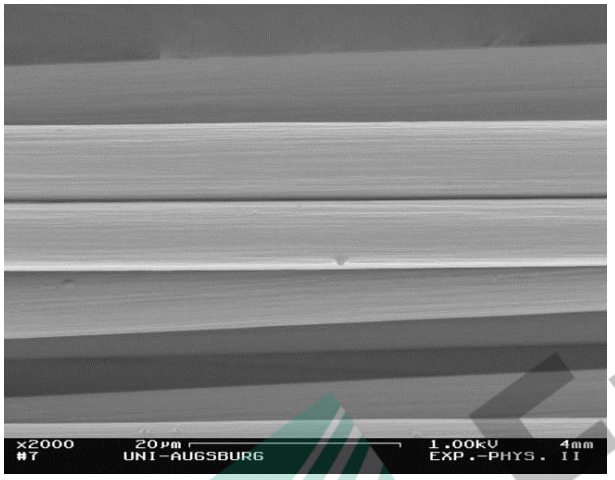


Pyrolysed (550 °C, 30 minutes dwell time)
CFRP-Woven out of epoxy resin

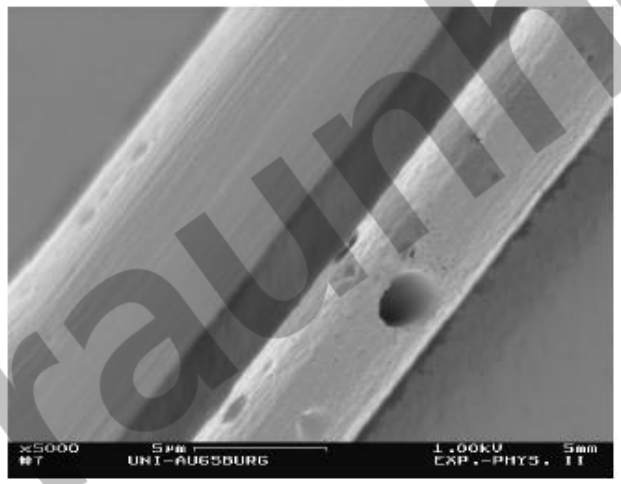


Possibilities of characterization

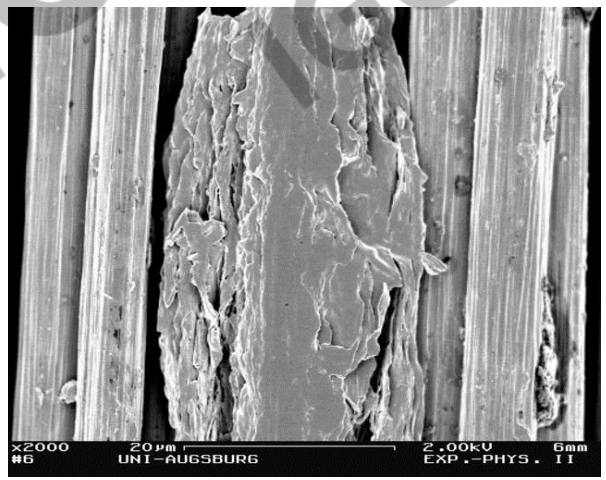
Interface – Defects and Cleanliness



Virgin Fibers



600 °C 30 minutes oxidised
20,9 % O_2

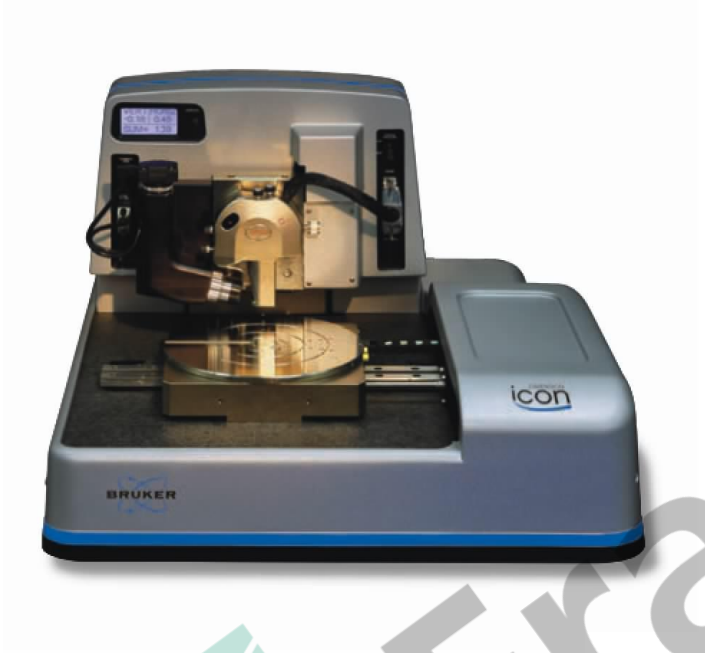


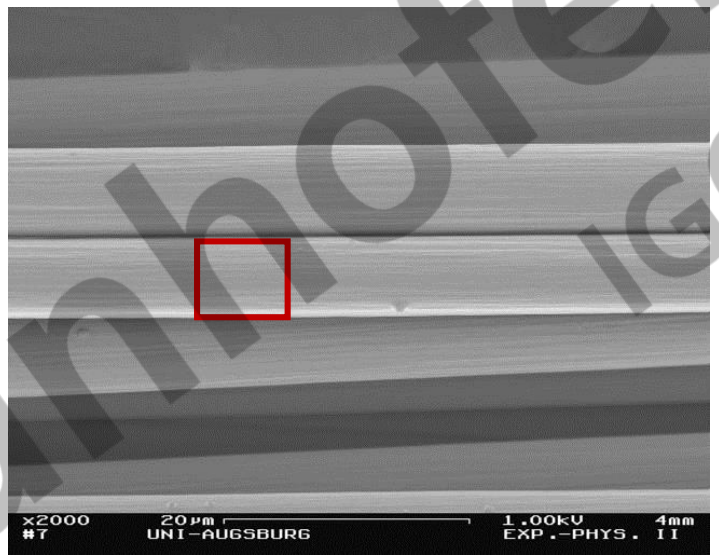
600 °C 30 minutes pyrolysed
100 % N_2

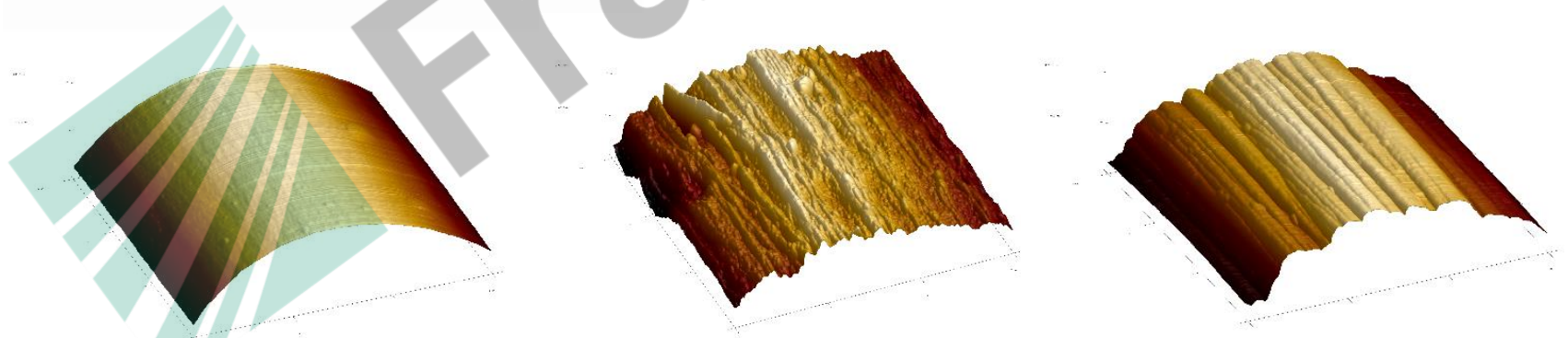
Fraunhofer IGCV

Possibilities of characterization

Interface – Defects and Roughness



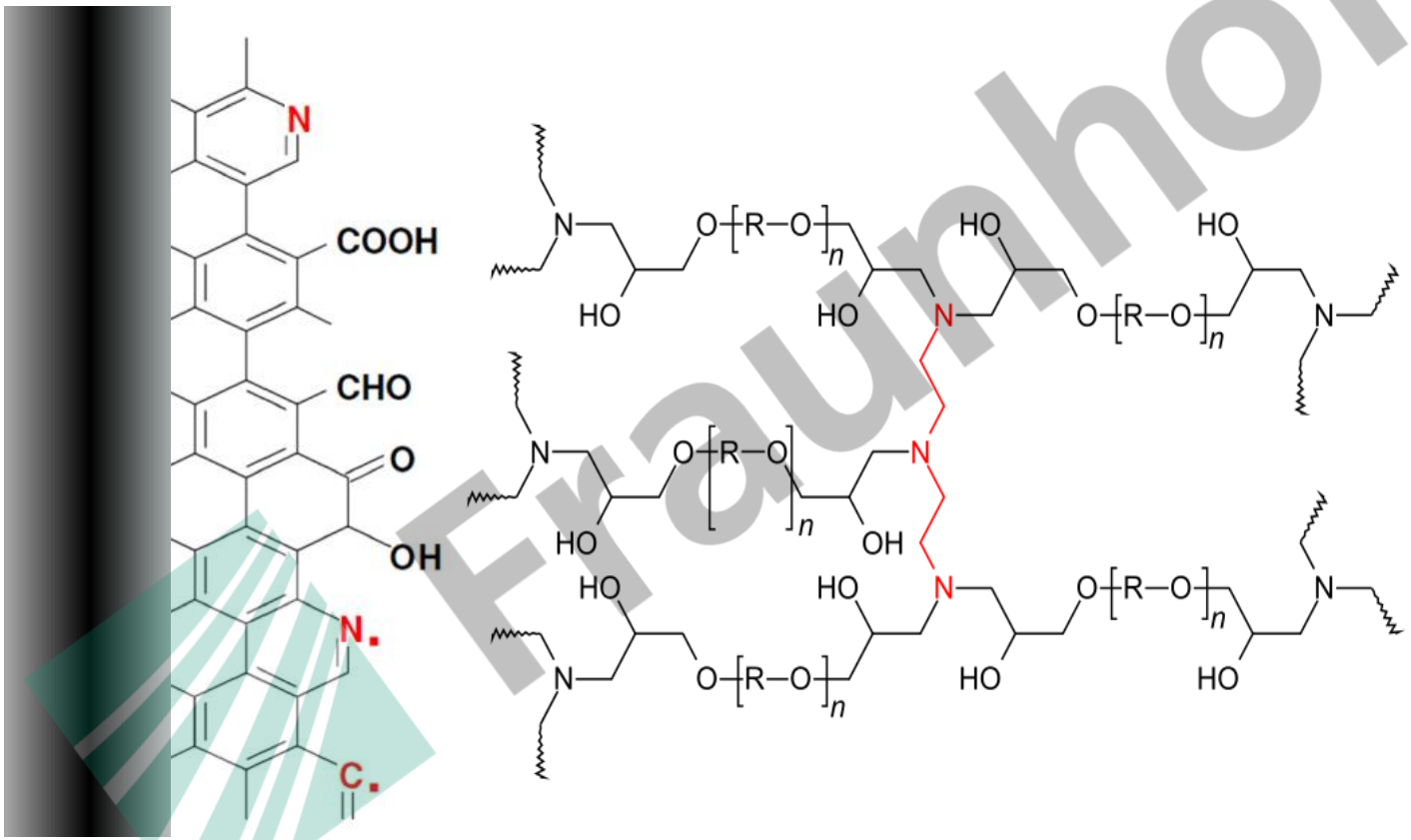


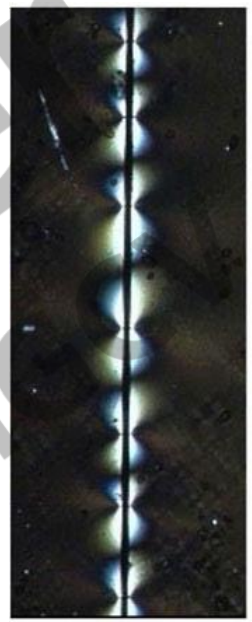


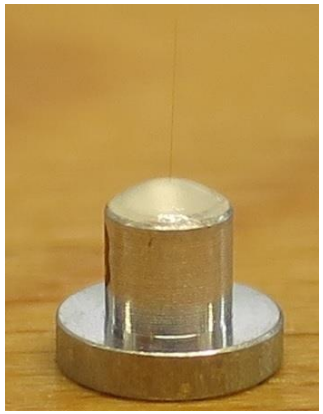
Possibilities of characterization

Interface – Surface Groups

Fibre | Interphase | Matrix



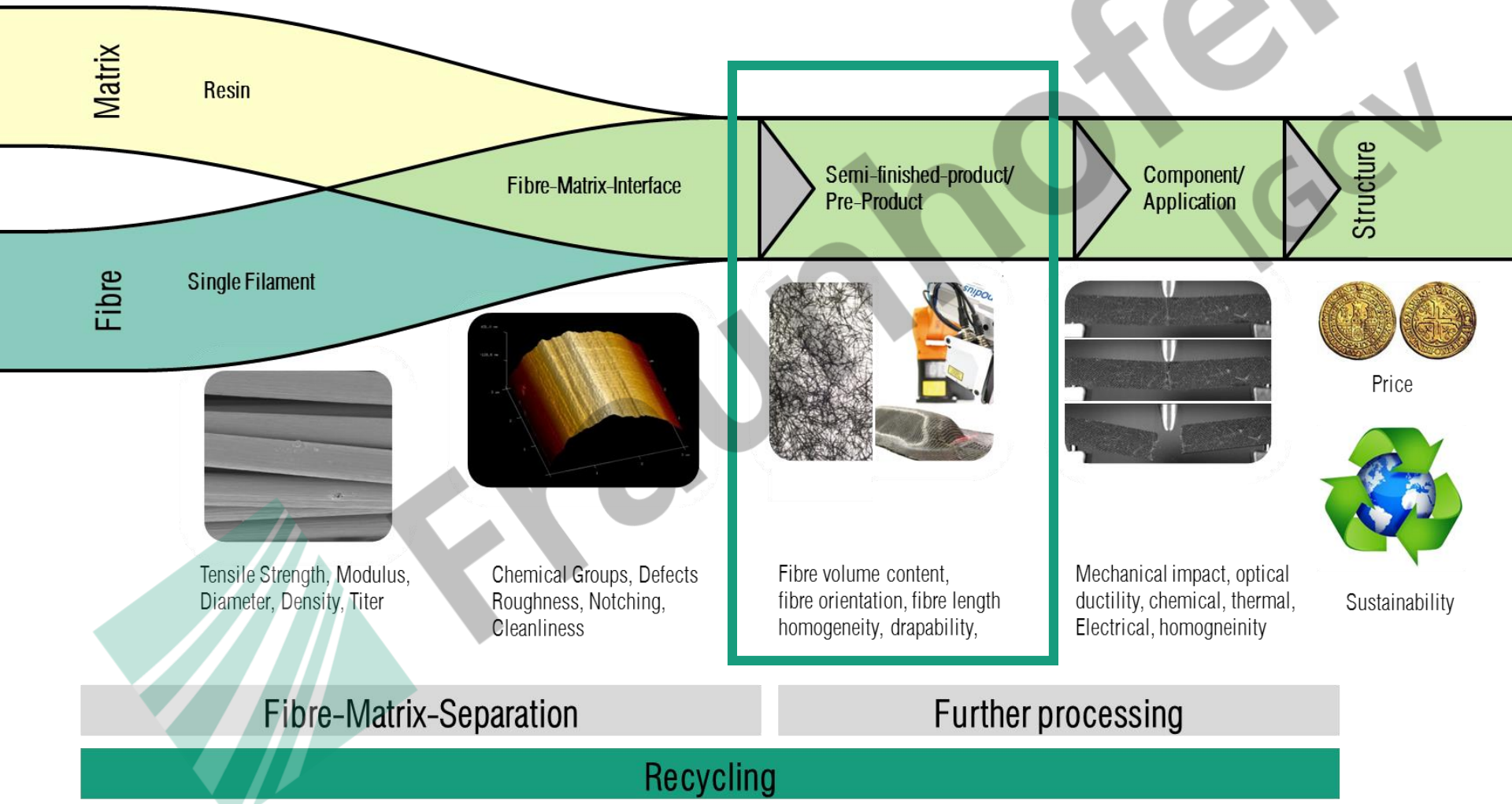




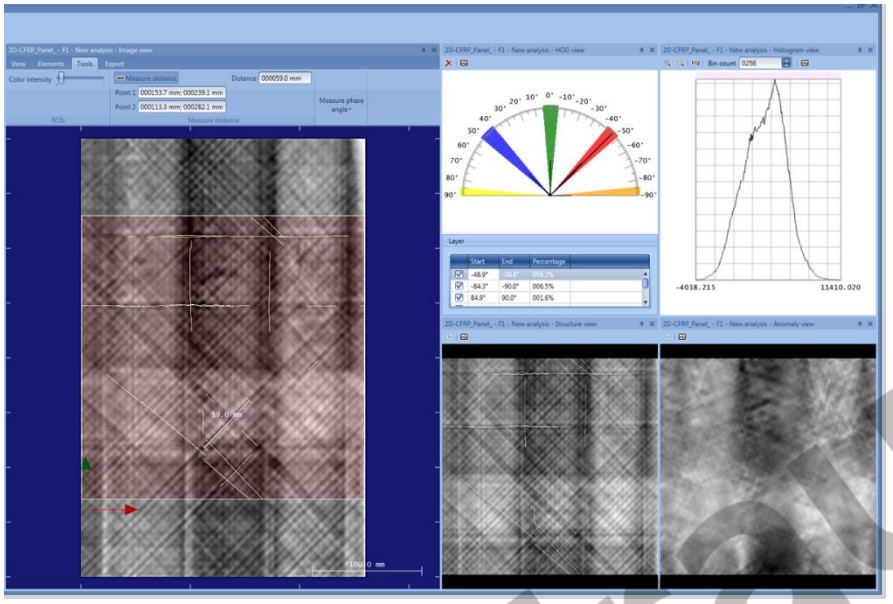
https://www.weizmann.ac.il/materials/Wagner/research
https://en.wikipedia.org/wiki/Epoxy

Possibilities of characterization

Influences on properties by recycling

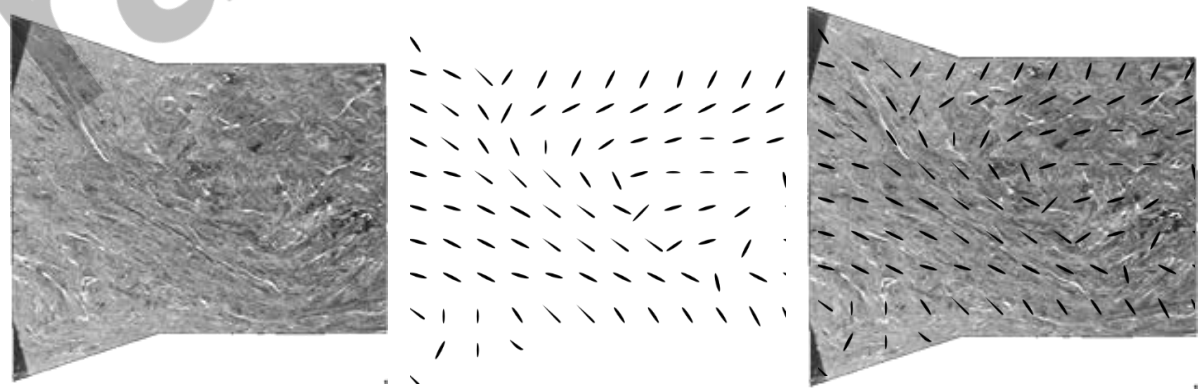


Possibilities of characterization
Semi-Finished-Product



Measurement of:

- Fibre-orientation
- Fibre-volume content
- Homogeneity / defects

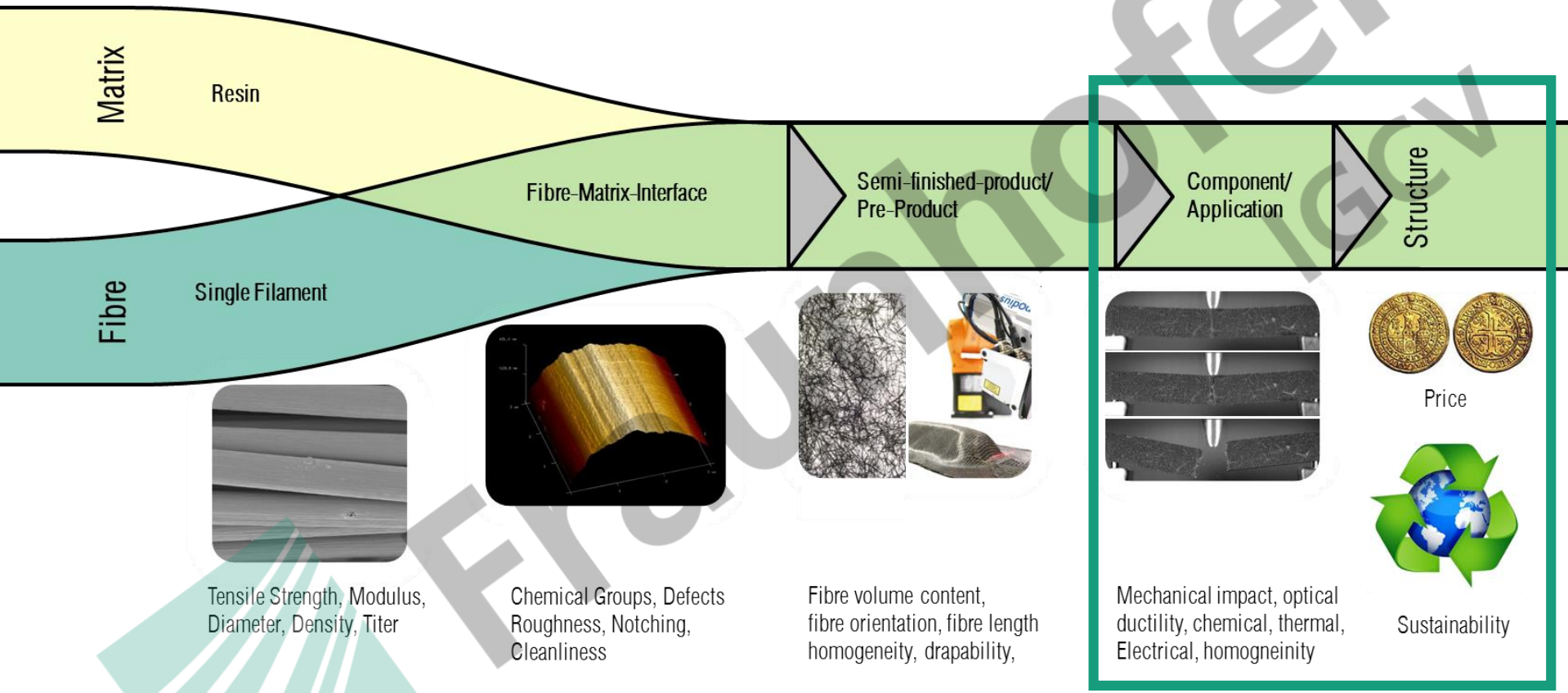


URAGUS Sensors & Instruments

Fraunhofer IGCV

Possibilities of characterization

Influences on properties by recycling



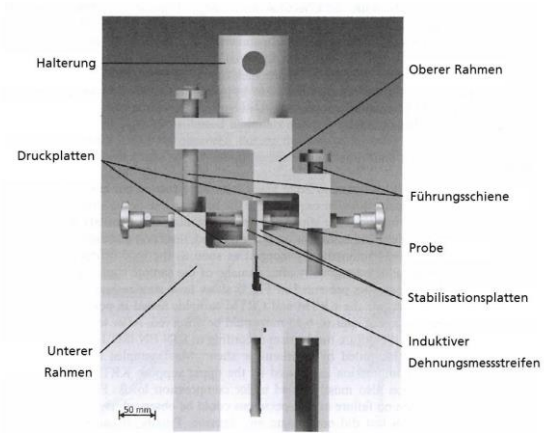
Fibre-Matrix-Separation

Further processing

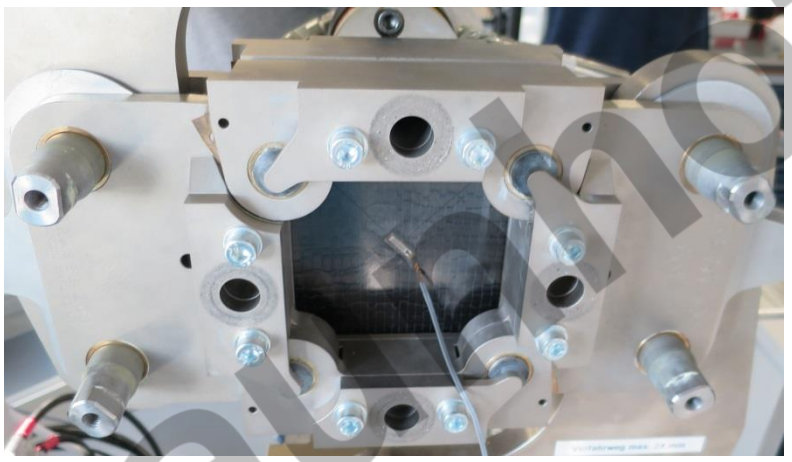
Recycling

Possibilities of characterization
CFRP testing

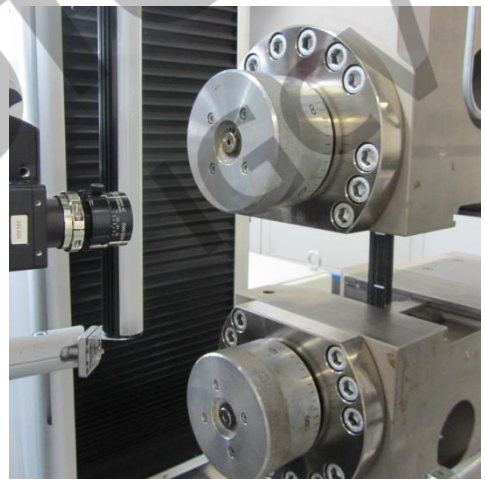
Edge-Shear-Test



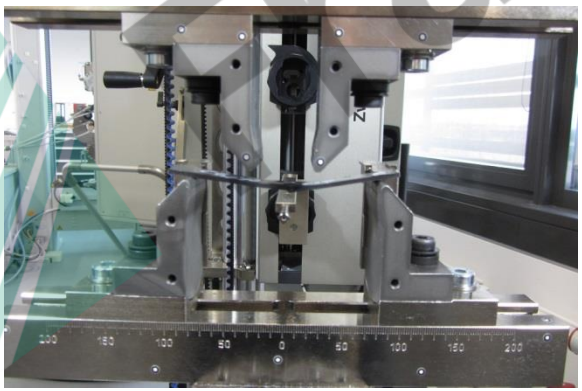
Shear-Frame-Test

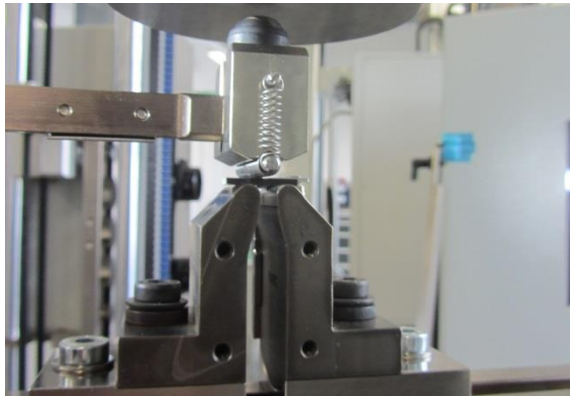


Tensile-Test



3-point-Bending-Test

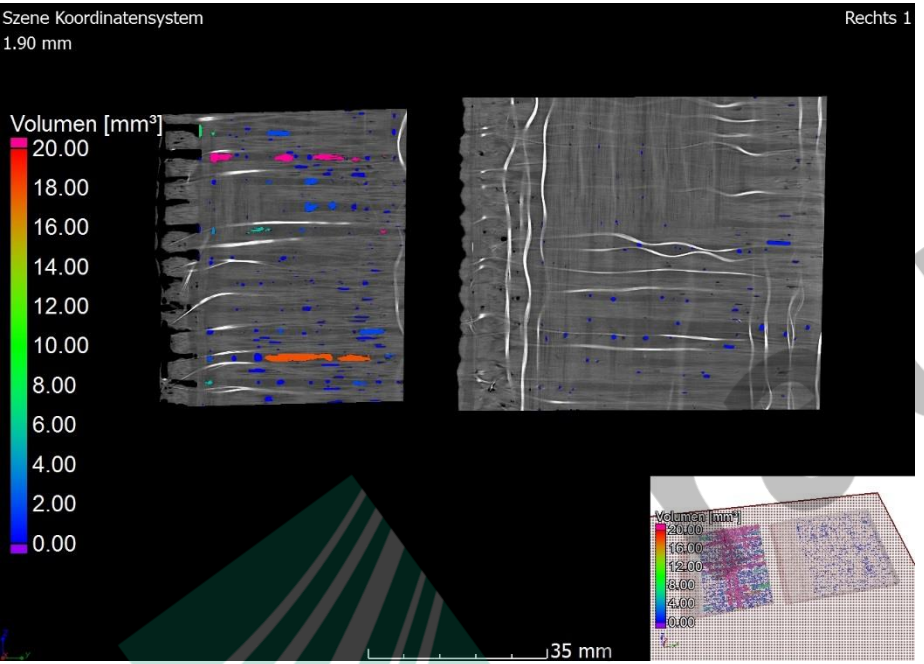


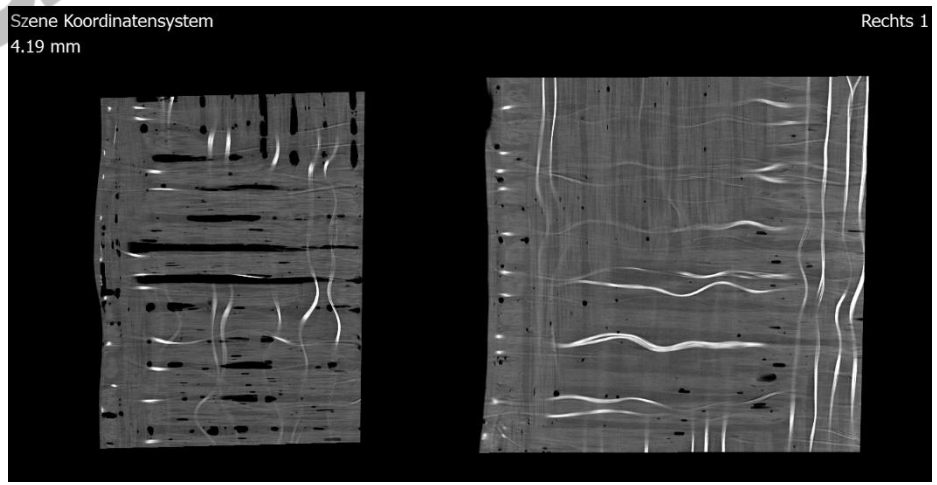


ILSS-Test

Possibilities of characterization

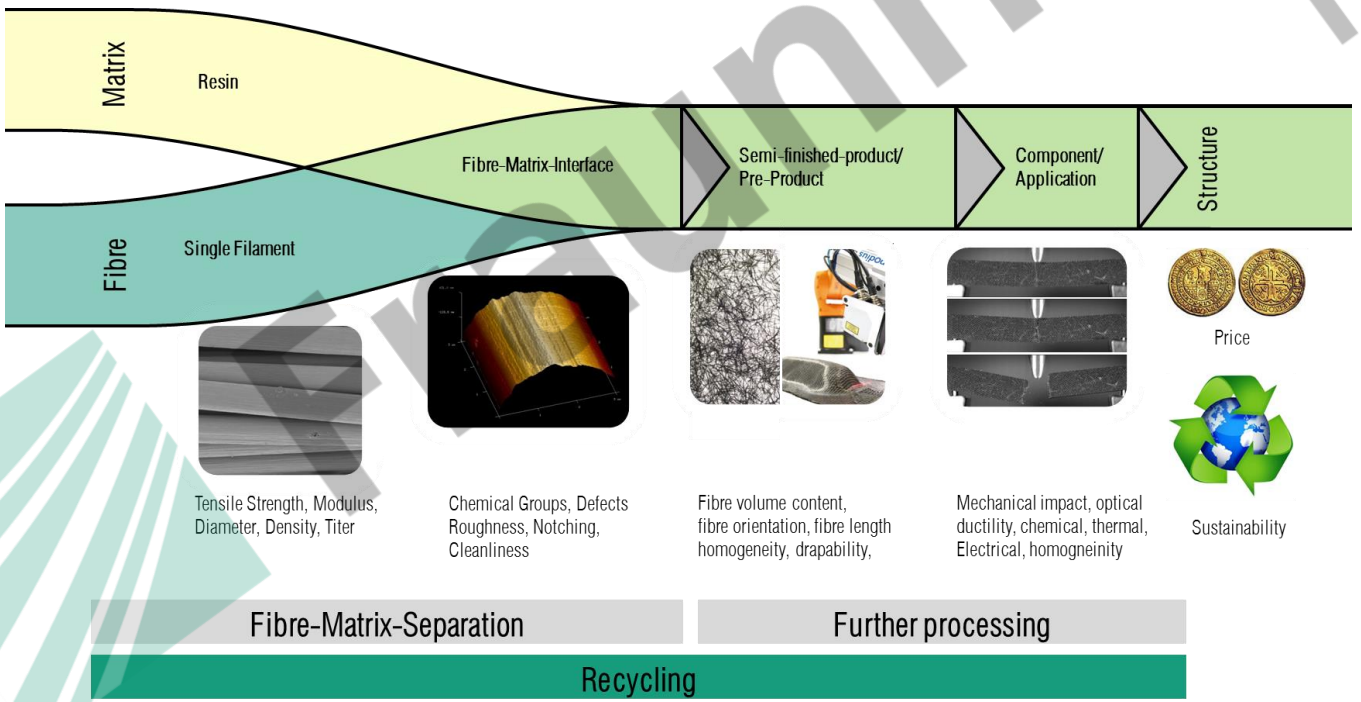
CFRP testing – Computer tomography





Further challenges and developments
What is the future science?

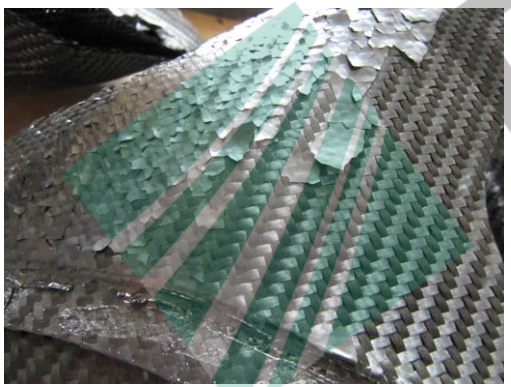
- Online- and Inline-measurement methods have to be invented
- Industry 4.0 and „Big-Data“ - management

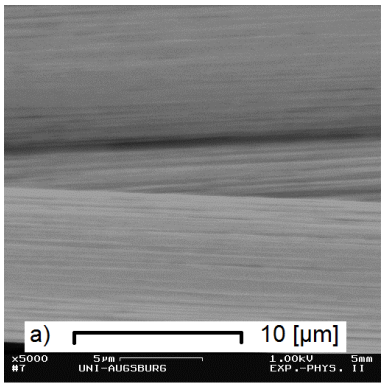


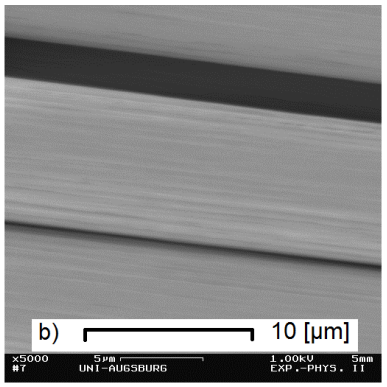
SUMMARY

WHY DO WE NEED CHARACTERIZATION TECHNICS?

- We need characterization technics to describe the properties of rCF materials
- We need characterization technics to ensure a steady and good quality of rCF-(Production)
- We need characterization technics to determine process relevant data (permeability, drapeability, simulation tool)







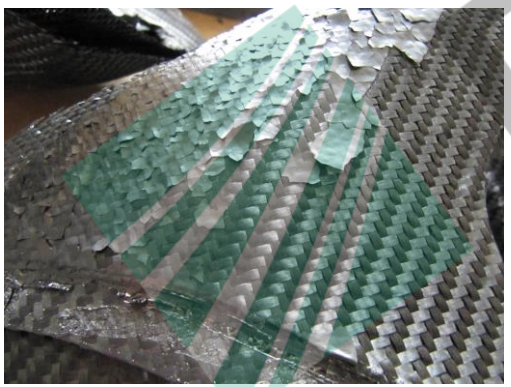
Fraunhofer IGCV

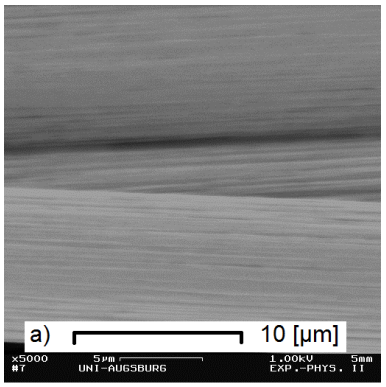
SUMMARY

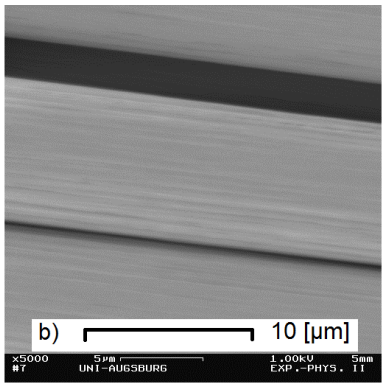
CURRENT STATUS AND PERSPECTIVE

- Some characterization methods are capable for recycled carbon fibres
- Some methods have to be adapted
- Others have to be invented

➢ Further research necessary to insure the quality of rCF-Products and to evaluate new markets







Recycling of CFRP – Characterisation and properties

Contact us

Fraunhofer IGCV
Am Technologiezentrum 2
86159 Augsburg, Germany

Dipl.-Ing. Frank Manis

Phone +49 821 / 90678-229
frank.manis@igcv.fraunhofer.de