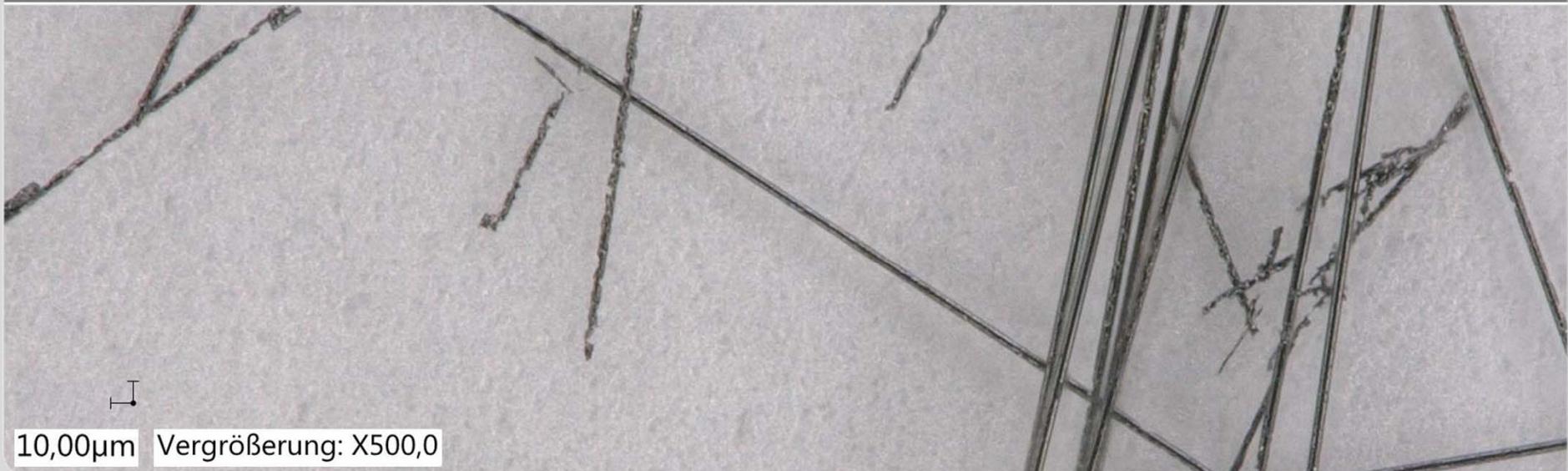


Potentials and Risks in the Recycling and Recovery of Carbon Fibers

Manuela Wexler, Werner Baumann, Günter Beuchle, Hans-Joachim Gehrman, Manuela Hauser, Daniela Merz, Sonja Mülhopt, Carsten Weiss, Dieter Stapf

Advanced Materials – Second Online Conference
September 15, 2020

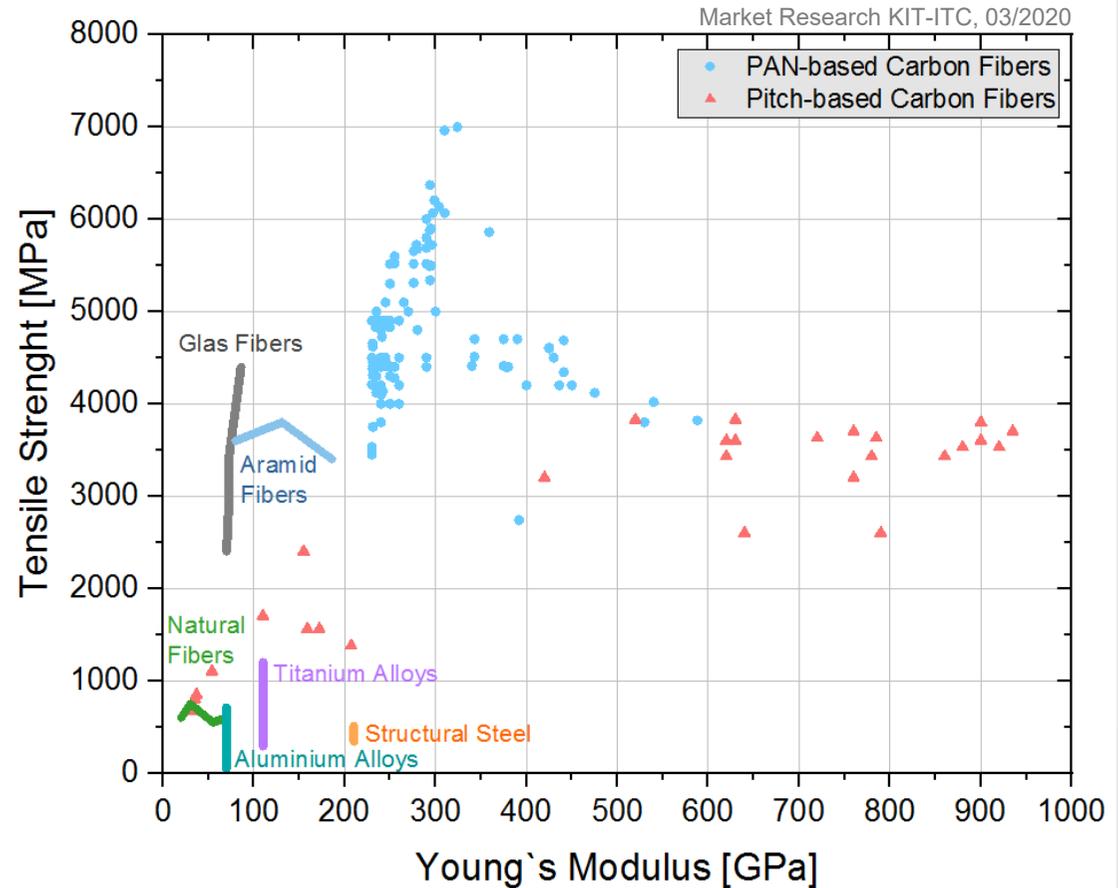
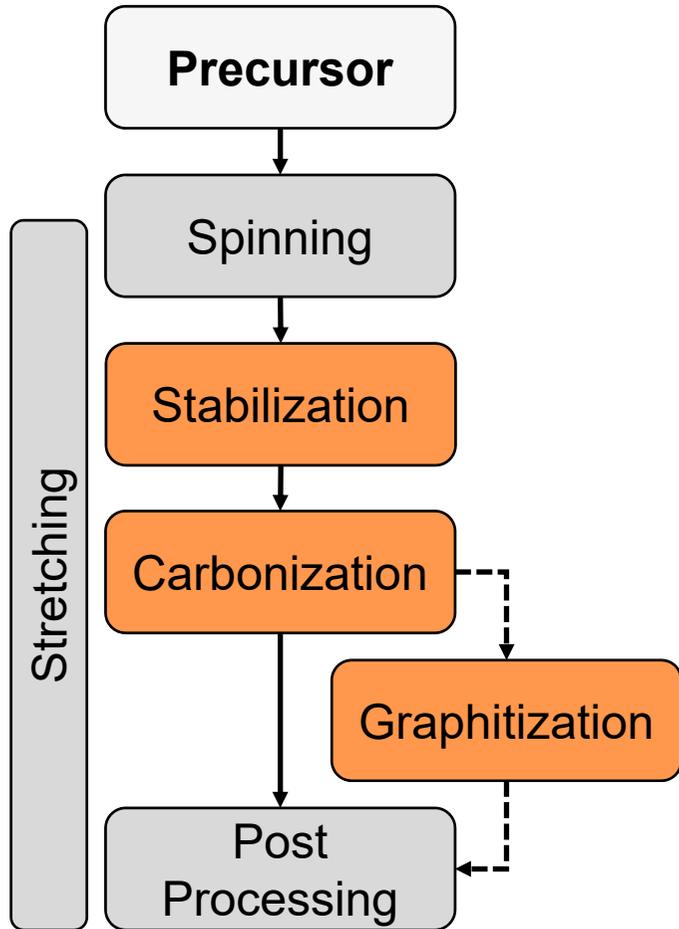
Institute for Technical Chemistry, Institute of Biological and Chemical Systems - Biological Information Processing



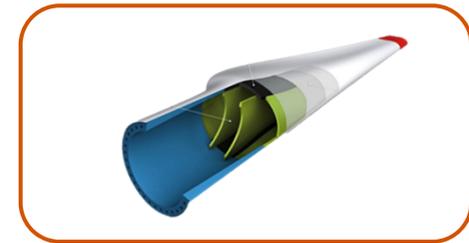
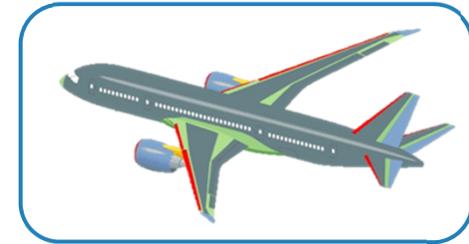
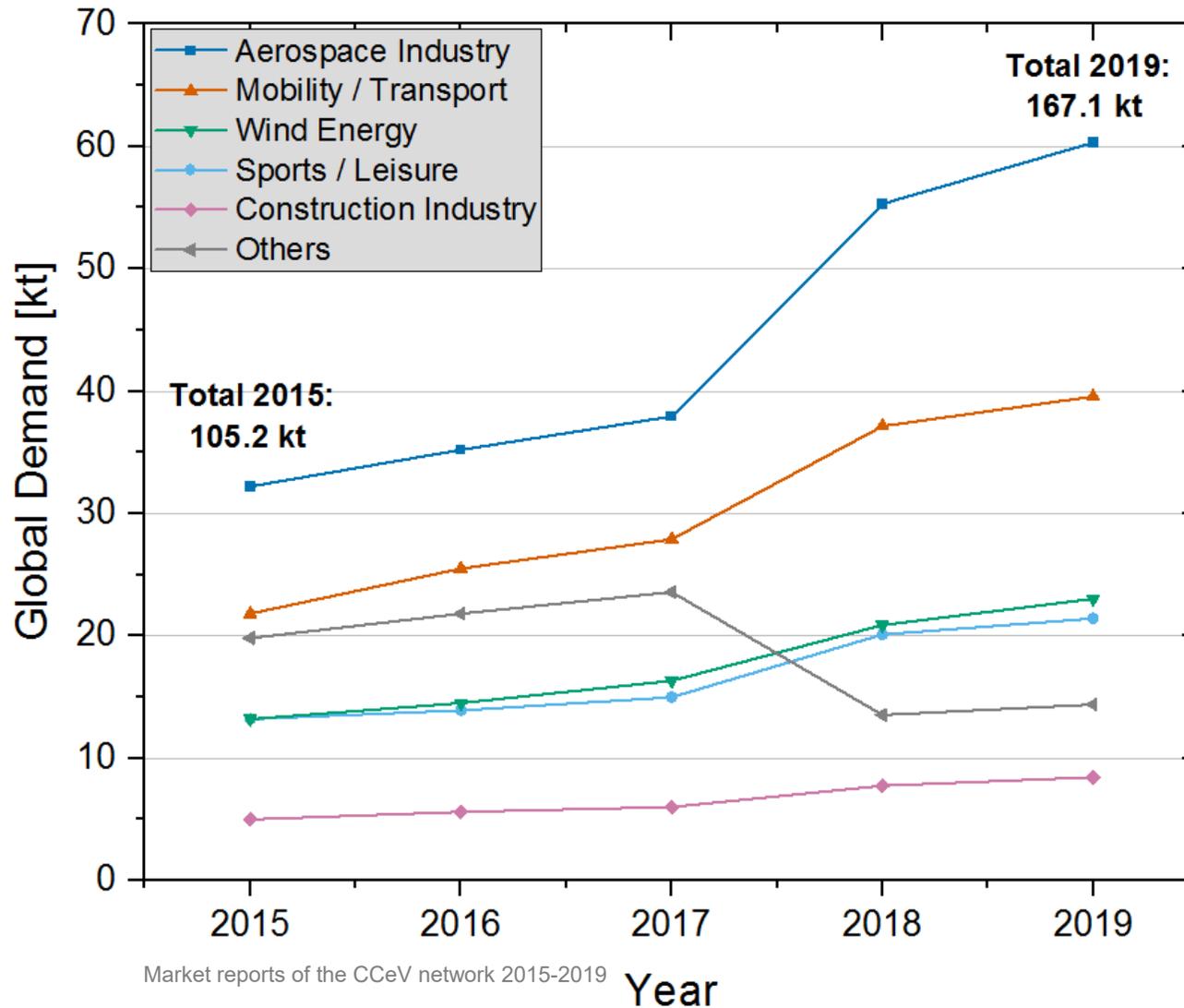
Production & Mechanical Properties of Carbon Fibers

Production of CF

Mechanical Properties

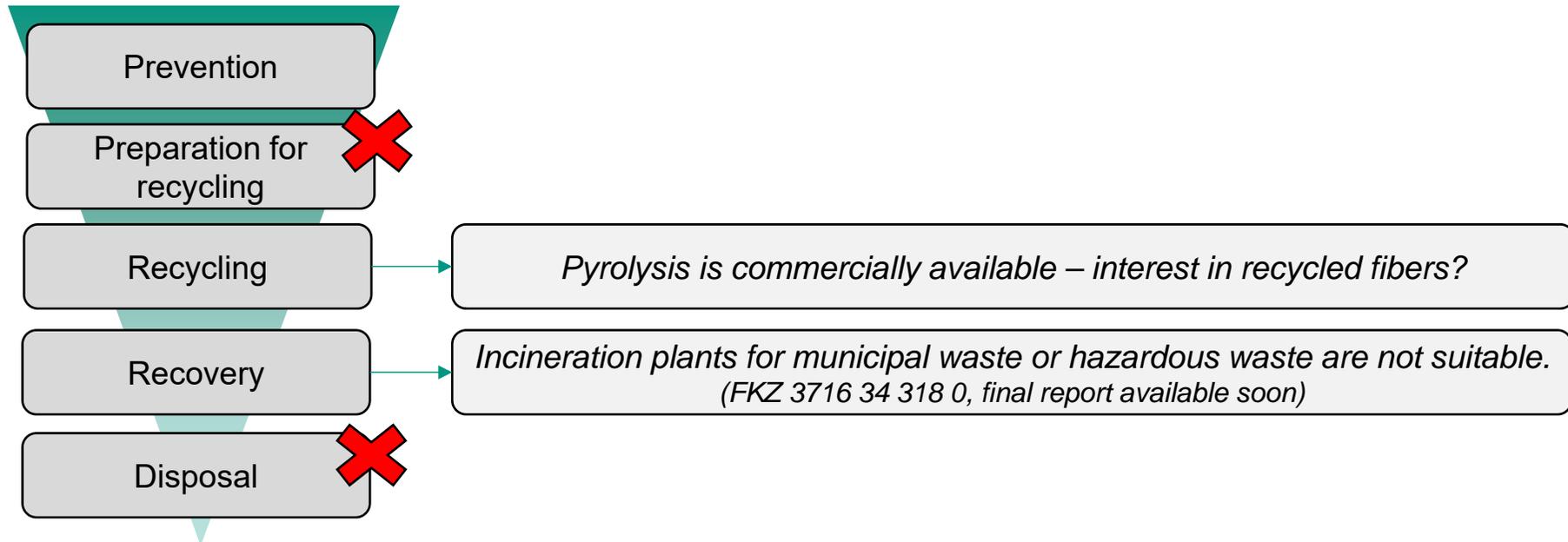


Application of Carbon Fiber Reinforced Composites



Treatment of waste containing Carbon Fibers

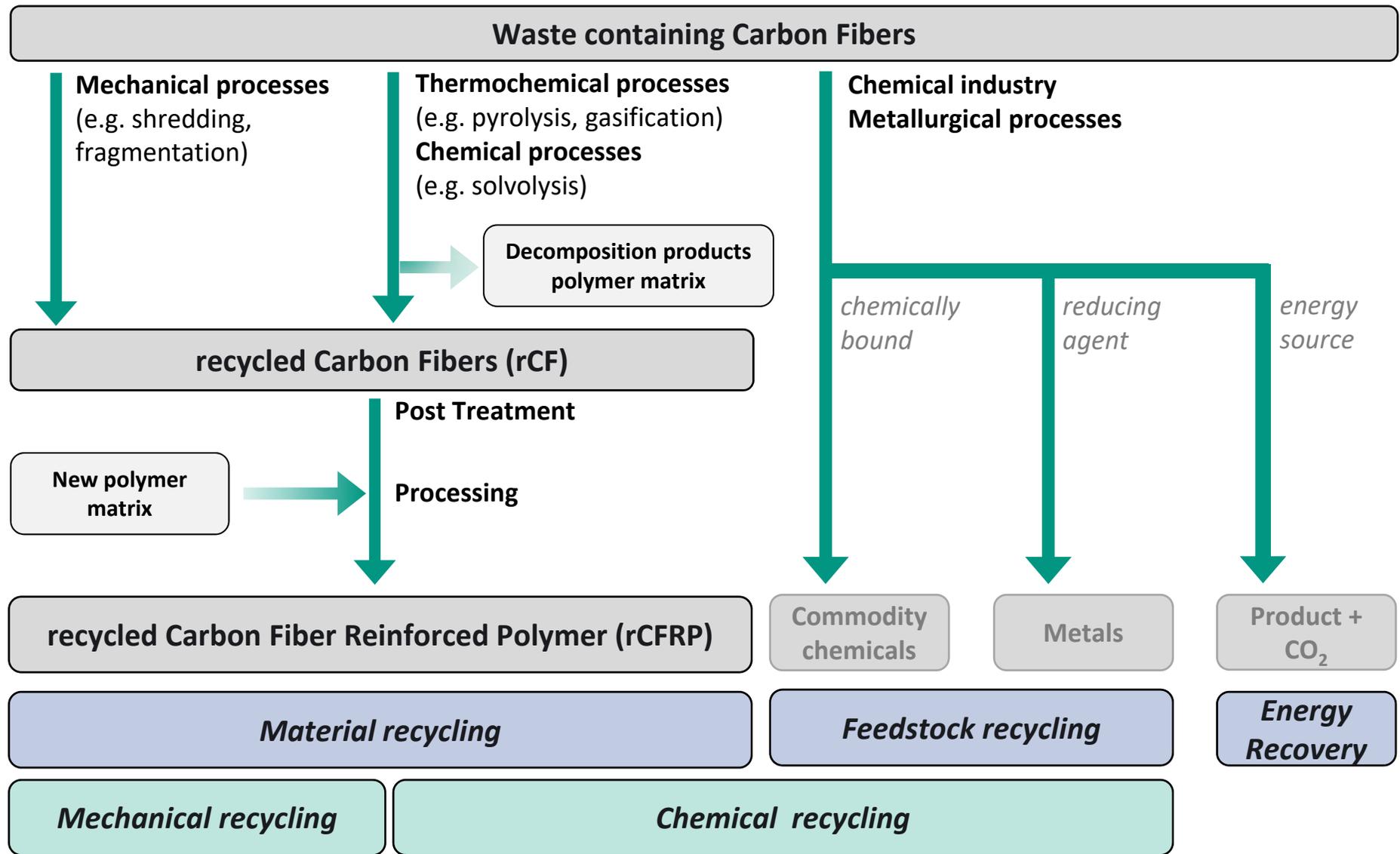
The current status in Germany



- Recommendations on handling waste containing Carbon Fibers include:
 - Storage as an interim solution
 - Marking (e.g. chemical marker)
 - Collection / Collection systems, waste code
 - Research in the fields of safety, environment, technical solutions
 - Handling of fiber dusts

Treatment of waste containing Carbon Fibers

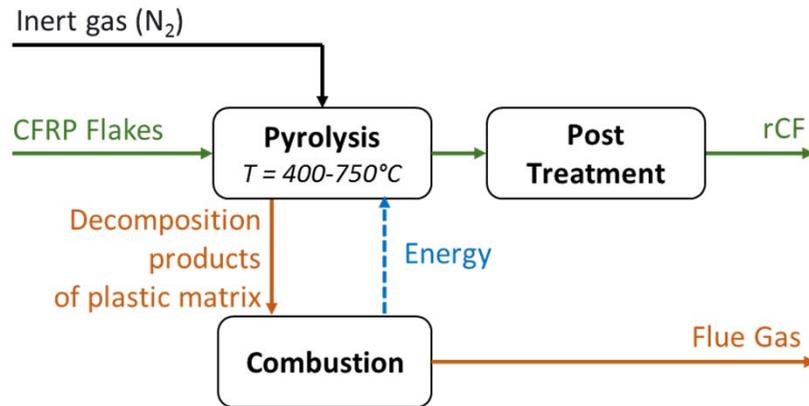
Overview of technical processes



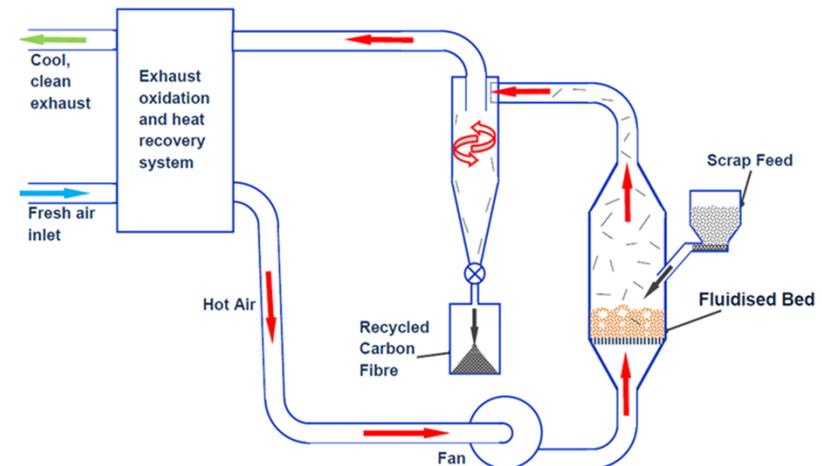
Treatment of waste containing Carbon Fibers

Thermochemical processes

Thermal treatment (Pyrolysis)



Oxidative thermal treatment



Meng (2017), PhD thesis, University of Nottingham.

2 commercial plants in Europe (ELG Carbon Fibre & CFK Valley Stade Recycling)

- Capacity ~ 1000 t/a
- Temperature > 500 °C

Suitable for

- Production waste
- End-of-Life Components

Fluidized Bed Reactor (Pilot plant) (University of Nottingham)

- Pressure ~ 1 bar
- Temperature ~ 500 °C
- bed of quartz sand

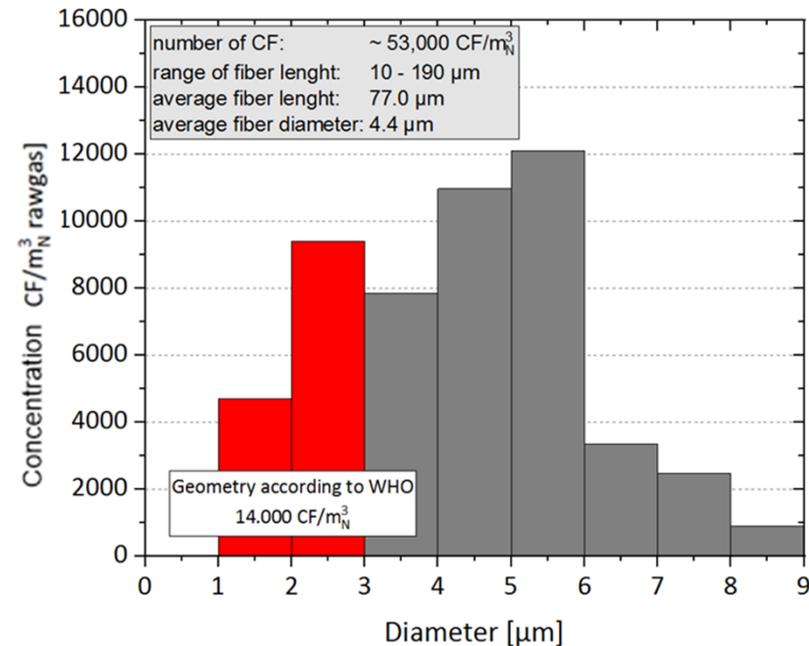
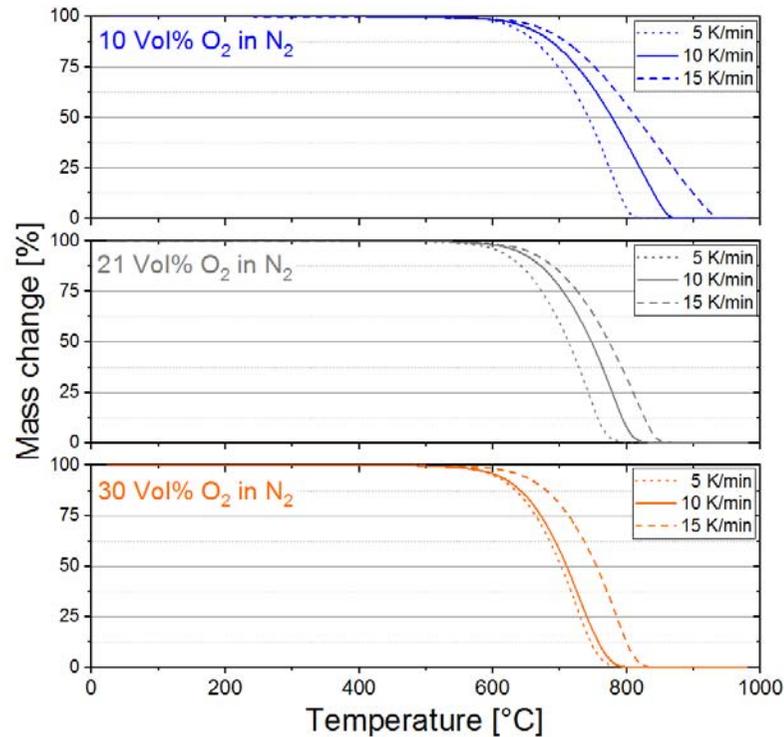
Suitable for

- Production waste
- End-of-Life Components

Treatment of waste containing Carbon Fibers

Energy Recovery – Municipal Waste Incineration Plant

- Possibilities & limits of the Recovery / Recycling of waste containing CFRP in thermal processes
- Focus on possible risks in handling the process-specific residues



CF cannot be utilized in state-of-the-art incineration plants



Description of the Project

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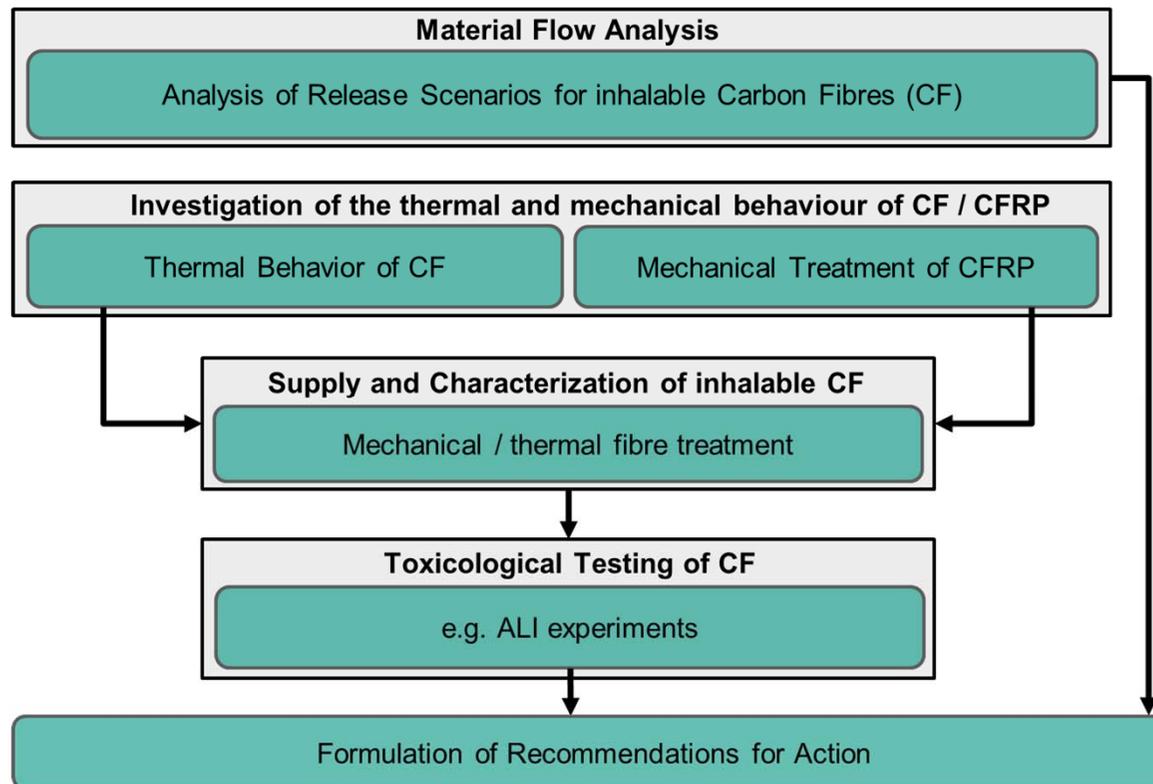


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Carbon Fibers in a Circular Economy – Release Behavior and Toxicity due to thermal and mechanical treatment

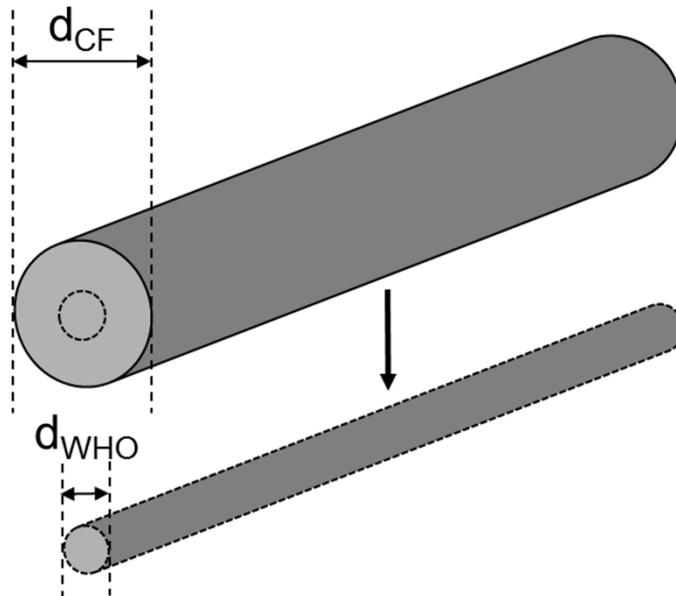
Duration: 01/2019 – 12/2021, FK 03XPO195



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Institute of Applied Biosciences



Model Representation

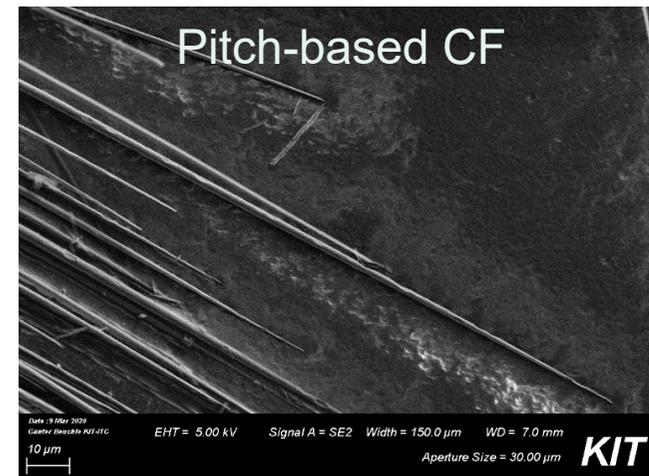
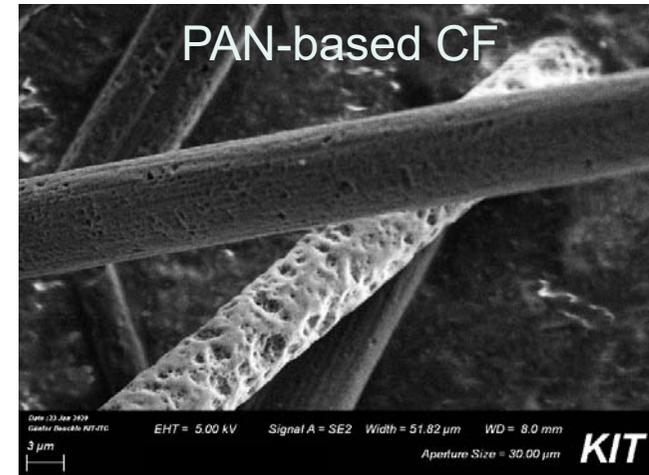


d_{CF} diameter of virgin CF

d_{WHO} max. diameter WHO-Fiber (3 μm)

d_{CF} [μm]	$\Delta(d_{CF} \rightarrow d_{WHO})$ [%]
4.4	54
7	82
11	93

Reality





Generation & Characterization of airborne Carbon Fibers

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Automated Image Analysis



Thermal treatment



Mechanical treatment



Cutting & Generation of aerosol



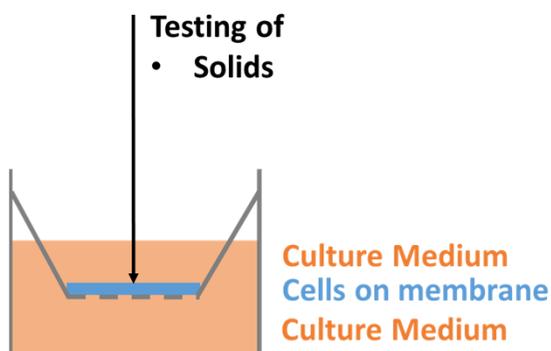
Generation of aerosol

Toxicological Testing



Pictures taken from <https://www.vitrocell.com/>; <https://www.thermconcept.com/>; <https://www.retsch.de/>; <https://www.tsi.com> (all accessed August 26, 2020)

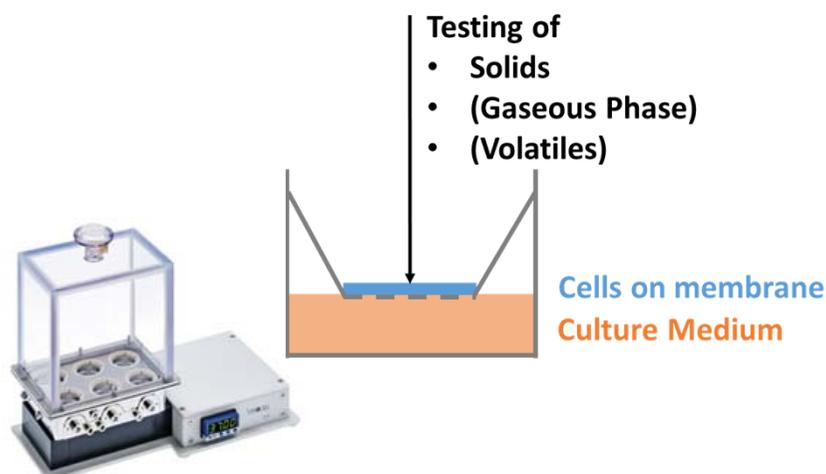
Submerged Exposure



- Easy to handle.
- High throughput methods applicable.

- Liquid on top of cells.
- Undefined dose (Interactions between Particles and Culture Medium).
- Particle dose is applied at once.
- Neglect of gaseous phase.

Air-Liquid-Interphase (ALI)



Cloud System



Automated Exposure System

- realistic imaging of processes in the lungs.
- Precise dose determination.

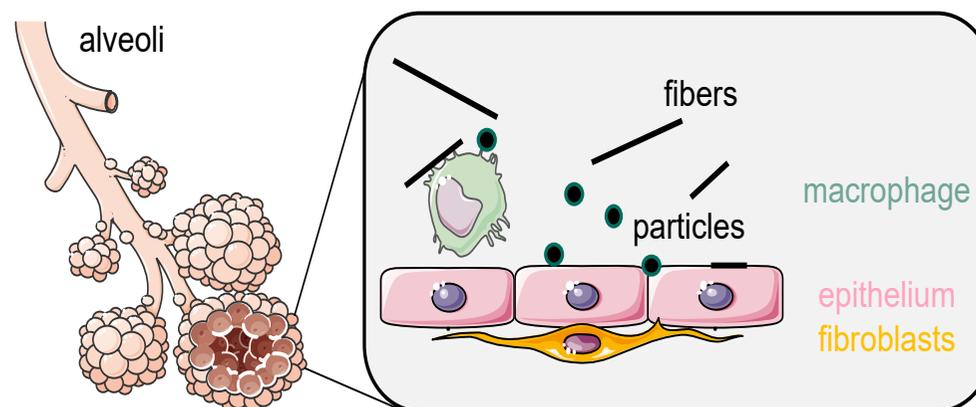
- Testing of bulk material and suspensions.

- Investigation of complex aerosols inc. gaseous phase.

- Technically complex System.

Pictures taken from <https://www.vitrocell.com/> (accessed August 26, 2020)

Determination of biological Endpoints on Lung Cells



Variation of
CF – Types / CF – Concentration / Exposure duration

- Toxicological endpoints:**
1. Phagocytoses
 2. Cytotoxicity
 3. ROS Production
 4. Anti-oxidative / Inflammatory / Fibrotic effect
 5. Genotoxicity

Summary & Outlook

- CFRP demand increases – waste streams will also increase
- Pyrolysis process to recycle Carbon Fibers is established
- CF cannot be utilized in state-of-the-art plants at the end of their life
- Research on further processes is currently being conducted
- Formation of inhalable CF-fragments possible over complete life cycle
→ Release must be safely avoided
- CarbonFibreCycle Project
 - Detailed description of release scenarios
 - Identification of critical CF types
 - Cell Exposure towards critical CF types



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