Composite Recycling

making GFRP
recycling
a reality

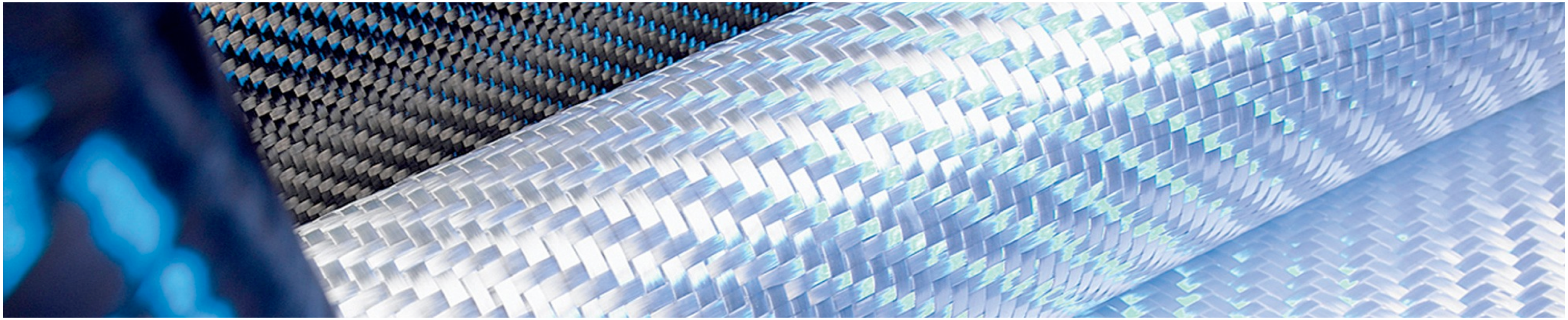
A sustainable future for the composites industry

OST Coffee Lectures
18 June 2024

Composites are extraordinary materials

Outstanding material properties

- **Specific strength 10x higher than metals**
- **Corrosion resistant**
- **Lower thermal conductivity**
- **Better fatigue resistance**

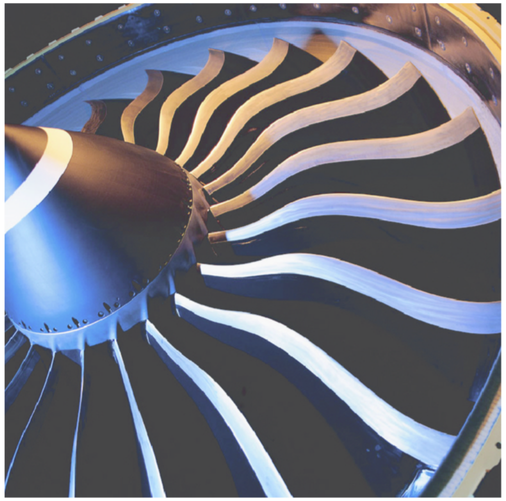


Composites are extraordinary materials

Applications of composites reducing CO_2 emissions

700 bar hydrogen tanks

130m wind turbine blades



Jet engine blades

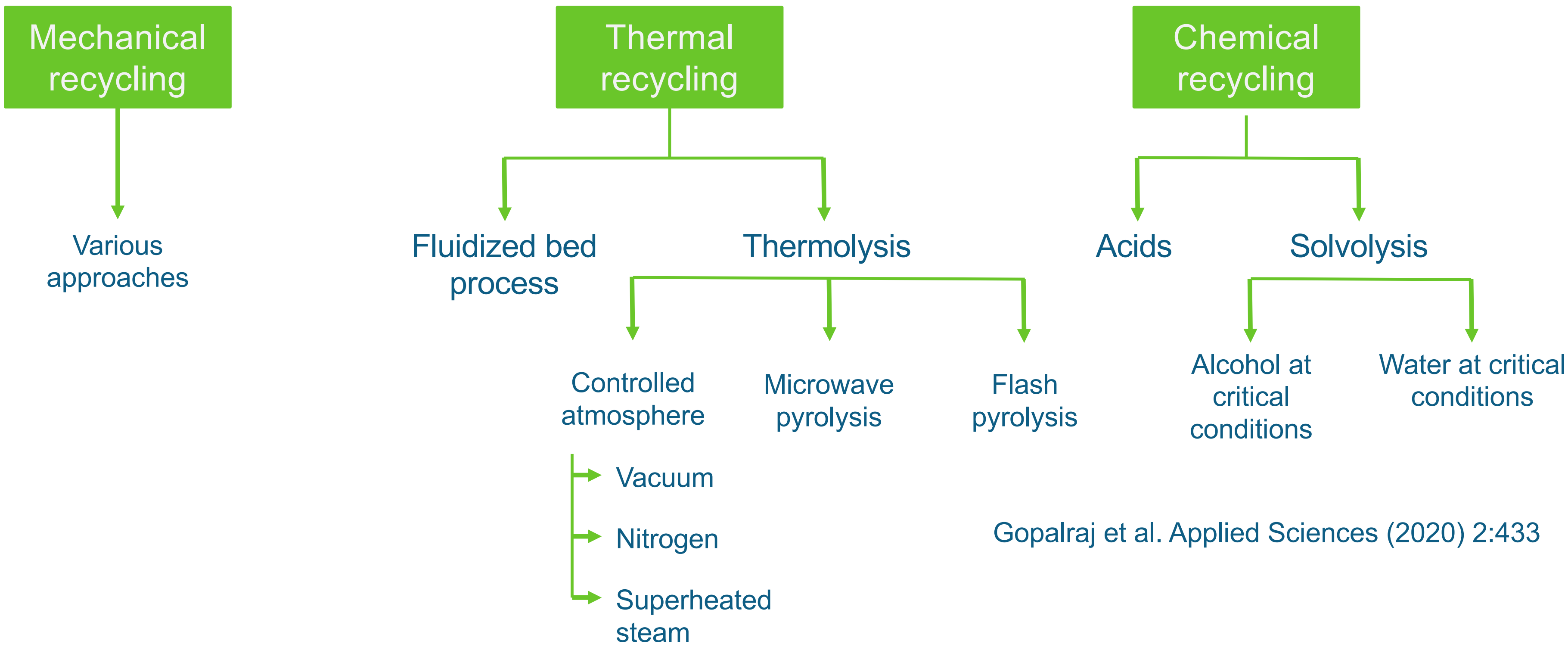
Composites are durable…but not recyclable

Treating end-of-life and production wastes poses a major challenge

- **More than 500’000 tonnes** of composite wastes were produced in 2023 in Europe
- **840’000 tonnes** produced by the aircraft and wind turbines industries worldwide by 2030
- Landfilling is **banned in Austria**, soon this ban will be extended to the rest of Europe

Wind blade deposit in the Permian basin, Texas, USA

Recycling technologies exist



Gopalraj et al. Applied Sciences (2020) 2:433

Recycling technologies : Solvolysis

Advantages

- effective resin/fibre separation
- recovery of high-quality fibres
- low energy consumption

Challenges

- high operating cost
- solvent management
- incomplete depolymerization, residues on the fibres

Recycling technologies : Thermolysis

Advantages

- scalable units
- recovery of high-quality fibres
- versatility of polymers and fibres treatable

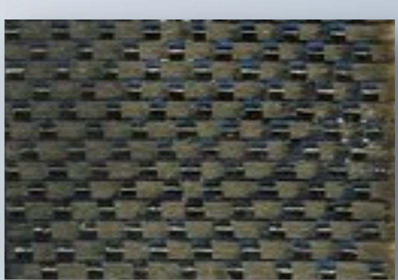
Challenges

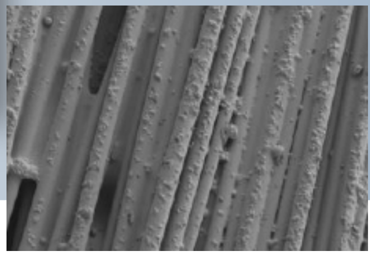
- high initial investment
- energy intensive
- treatment of output gases

Our thermolysis approach

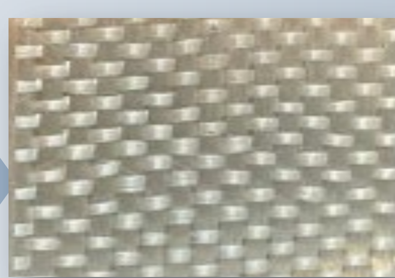
Developed from the start in partnership with industry players and academia

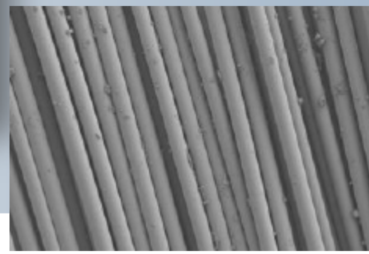
Proprietary Thermolysis Process





Proprietary Post-treatment Process



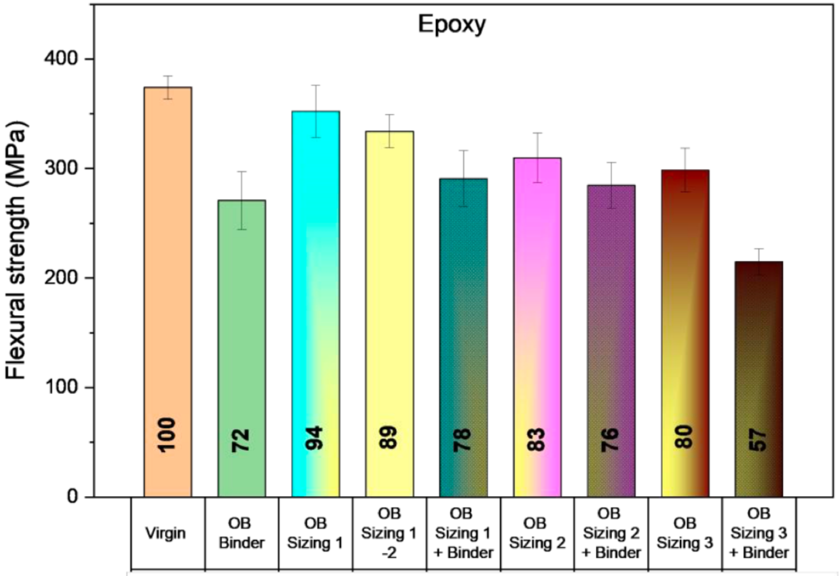


- No fine shredding, process optimized for single waste type (GFRP and CFRP)
- Process parameters and output specs are **adapted to each composite matrix**
- **Cleaning of fibres** is performed during a second calcination step
- Process temperature is kept **below 500°C** to **retain mechanical properties** of the glass fibres

Glass fibre recovery

Keeping the quality of the fibres as high as possible

Innosuisse Project on Fibre treatment



- Two approaches to make new composites with recovered fibres : **mixing** with virgin fibres and **re-sizing**
- **Mixing** leads to 75% recovery of flexural strength mixing 33% of recovered fibres with virgin fibres
- **Re-sizing** allows for up to 94% recovery of flexural strength – Innosuisse project just started

Thermolysis oil recovery

Thermolysis oil has a high recovery potential

Innosuisse Project FullRecycling

Identification	Chemical Formula	Retention time (mn)	Relative area (%)
Toluene	C_7H_8	3.52	16.7
Ethylbenzene	C_8H_{10}	6.19	12.9
Styrene	C_8H_8	6.86	41.7
Cumene	C_9H_{12}	7.35	1.1
A-Methylstyrene	C_9H_{10}	8.2	7.1
Dimethyl terephtalate	$C_{10}H_{10}O_4$	12.51	5.2
Diphenylpropane	$C_{15}H_{16}$	0.5	0.35

- Thermolysis oil contains molecules that can be used in the petrochemical industry to form new plastics
- Mostly **benzene, toluene, styrene, xylene and phenols**
- Strategy is to explore distillation, and steam cracking of the heavier compounds

HUNTSMAN

OST Ostschweizer Fachhochschule

PAUL SCHERRER INSTITUT PSI

Composite Recycling | making GFRP recycling a reality

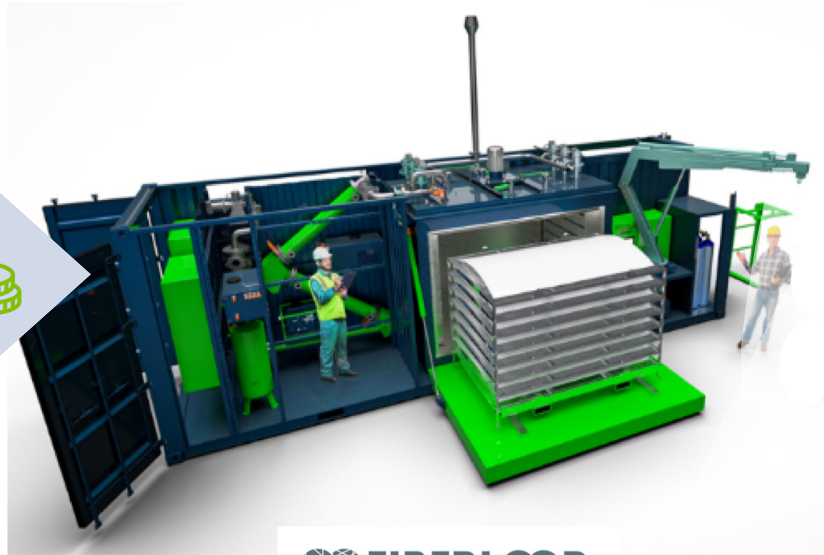
A proven and circular business model

Waste collection → Thermolysis & Post-treatment → Reclaimed outputs → New composites

CR collects recycling fees

CR sells reclaimed outputs

APER LA PLAISANCE ÉCO-RESPONSABLE



FIBERLOOP

Glass fibres

Pyrolysis oil

CHOMARAT

GROUPE BENETEAU

HUNTSMAN

ARKEMA

Composite Recycling | making GFRP recycling a reality

Mobile capability

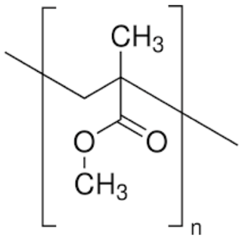
Our mobile recycling units go to the waste

- Optimizes client service – reduced shipping of bulky waste material
- Can be deployed rapidly and easily (ex: hurricane strike zone)
- Much faster operational scale-up than single central facility
- Enables study and mapping of waste streams prior to building of fixed regional facilities

Focus on Elium™ Resin from Arkema

An innovative matrix system

- Thermoplastic resin
- Excellent mechanical properties
- Easy processing
- Lightweight
- Cost effective



Focus on Elium™ Resin from Arkema

A game-changer in the production of wind blade turbines

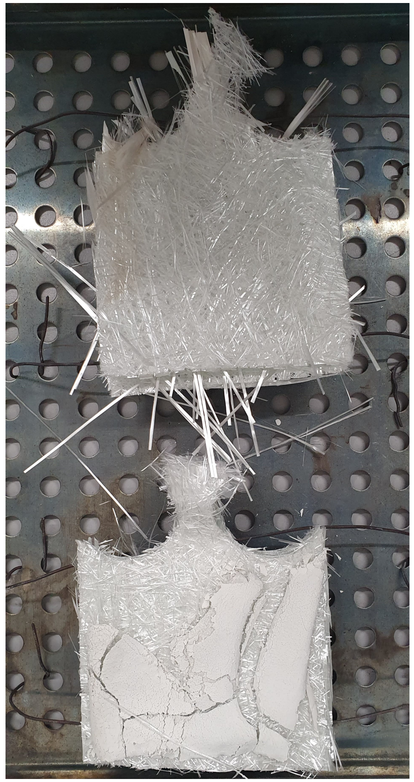
Mechanical data	Units	ELIUM	EPOXY
Density	g/cm3	1.178	1.15
Glass transition temp	°C	97.9	90
Flexural strengh	MPa	84	90
Tensile strengh	MPa	54	70
Elongation break	%	2.5	8
Tensile Modulus	GPa	3	2.9
Water absoption	7d[%]	0.5	0.35

Thermolysis of Elium-based composites

Elium-based composites particularly well-suited for thermolysis recovery

Identification	Area (%)
Methylmetacrylate	**77.2**
Light compounds	**9**
Additives	2
Heavy compounds	9

GC-MS of pyrolysis oil from Elium-based composite



- PMMA (Polymethylmetacrylate) based, thermolysis can be performed at **lower temperature**
- Fibres are **better preserved** during the pyrolysis process, and **less energy** is used
- Pyrolysis oil recovered by CR contains **up to 70% MMA** (methylmetacrylate)

Case study: ZEBRA project

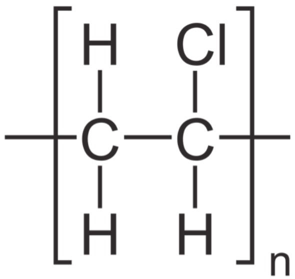
A 62-meter blade was made using Arkema's Elium® resin AND glass Fabrics from Owens Corning

ARKEMA canoe LE CENTRE TECHNOLOGIQUE NOUVELLE AQUITAINE COMPOSITES & MATÉRIAUX AVANCÉS engie LM WIND POWER suez OWENS CORNING®

Future developments

Challenges and possible solutions

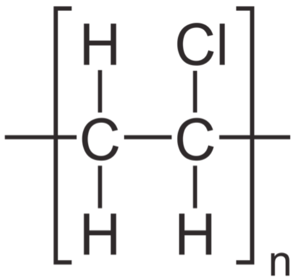
- **Treating composites with problematic composition : halogens**
  - Many former generation composites contain halogens
    - Chlorine : Polyvinyl chloride (PVC), chloroprene – used as filler
    - Fluor : Polytetrafluoroethylene (PTFE) – used to improve chemical resistance
    - Bromine : Polyvinyl bromide (PVB) – used as flame retardant



Future developments

Challenges and possible solutions

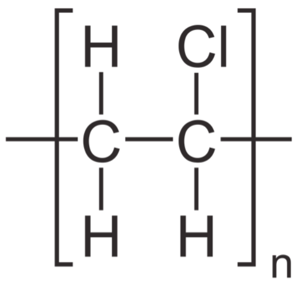
- **Treating composites with problematic composition : halogens**
  - Produce acids through pyrolysis
  - Get into the thermolysis oil, hindering use in refineries
  - Concerns for atmospheric emissions



Future developments

Challenges and possible solutions

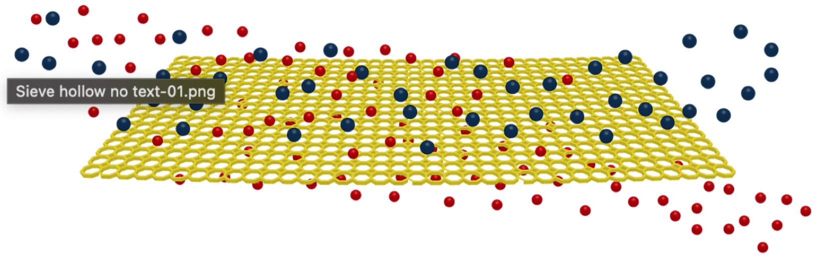
- **Solution to treat halogen-containing composites**
  - Sorting waste
    - Shredding and separating problematic parts
  - Thermolysis process
    - Insert an intermediate step to remove the elements before extracting the oil
  - Chemical or physical treatment of the oil to remove halogens and heavy metals



Future developments

Challenges and possible solutions

- **Thermolysis CO_2 emissions**
  - Run thermolysis reactor on electricity from renewables
    - Our heaters are exchangeable with electric ones
  - Implement a carbon capture solution
    - CO_2 concentration is high at the exhaust
    - Possible recovery with molecular sieving and closed loop adsorption/desorption



UniSieve

Our dynamic & talented team

Co-Founders

Guillaume

- MBA Int'l business
- 10 years Ford Motor Co (EU, Asia Pacific, LatAm)
- 15 yrs independent consultant in biz dev and corporate restructuring
- Extensive network in composites and shipbuilding
- Avid sailor

Pascal

- Postdoctoral studies at EPFL
- 10 years in semi-conductor industry (BeamExpress, Novagan)
- CEO/founder of LakeDiamond, mfr of synthetic diamonds
- Extensive start-up experience
- 90+ papers published

Finance

Smaranda

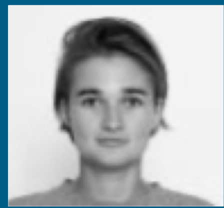
- 15 yrs across i-banking, wealth management, and venture capital
- Deep understanding of markets, financial data and investment valuation
- Excellent interpersonal and communication skills in 5 languages

Comms

Wendy

- Harvard MBA with comms, biz devt, and finance experience at multiple Fortune 100 companies
- 20+ yrs managing marketing for premium global brands across wide range of industries and 3 continents

Ops/Biz Devt



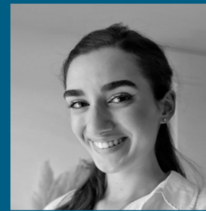
Victoire

- 10 years corporate and operations experience
- Master in energy management and sustainability
- Bachelor degree from EHL
- Avid rower

Lab / Technical Team

Michael

- Bachelor of Arts
- Cleanroom processing
- Thermolysis processing



Daphné

- M.Sc Material science engineer
- Sustainable materials
- Advanced plastic processing
- Composite repair
- Aircraft enthusiast
- Communication in +4 languages

Technology traction

- First mobile containerized unit (2 tonnes/day capacity) to be delivered by Swedish supplier FiberLoop in July 2024
- Three larger reactors (4-tonne daily capacity) to follow in 2025
- Glass fibre output quality validated for industrialization and LOIs signed by industrial partners Chomarat & Bénéteau
- Patent filed on the principle of static thermolysis treatment and on-site processing via mobile container

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Composite Recycling

good fibres only !