RECYCLING APPROACH OF T700S-TUFF-ELIUM 188 O COMPOSITES

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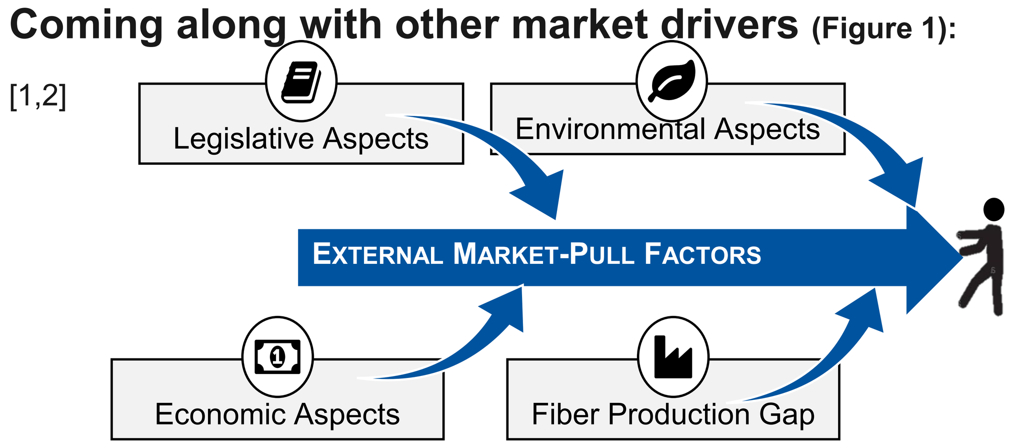
Introduction

Increasing production and End-of-Life waste flows [3]:

- Production gap of up to 60 % forecasted for 2025 [1]
- Production flow increase forecasted and subsequently increasing production waste flows [2]

Coming along with other market drivers (Figure 1):

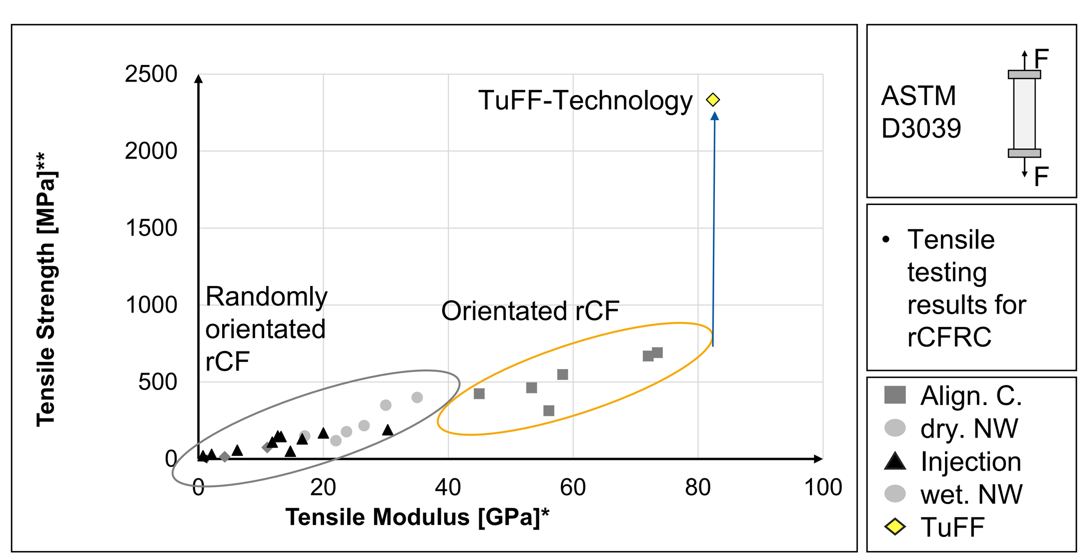


Current main applications of re-use [2,4]:

- Nonwovens
- Sheet Molding Composites

➡ Non-use of remaining fiber properties

Figure 2: **SOA Possibilities**



[5,6,7,8,9,10,11]

* Tensile modulus normalized to 30 % FVF
** Tensile strength normalized to fiber strength of 4900 MPa

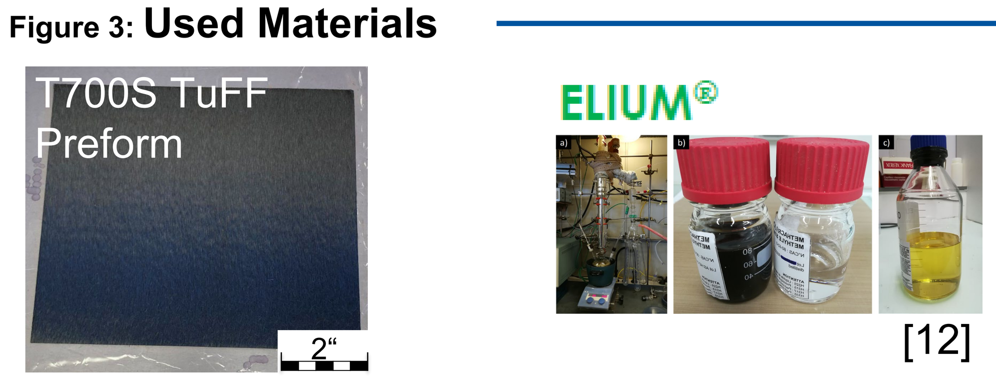
Overall Goal:

Demonstration of a closed-loop recycling while maintaining material properties throughout multiple iterations

Used Materials

- T700S 3 mm short fibers with 50C sizing, standard modulus, Toray Inc., Tacoma (WA)
- Elium 188 O as thermoplastic acrylic resin system activated with the peroxide LUPEROX AFR 40, Arkema Inc., King of Prussia (PA)

Figure 3: **Used Materials**



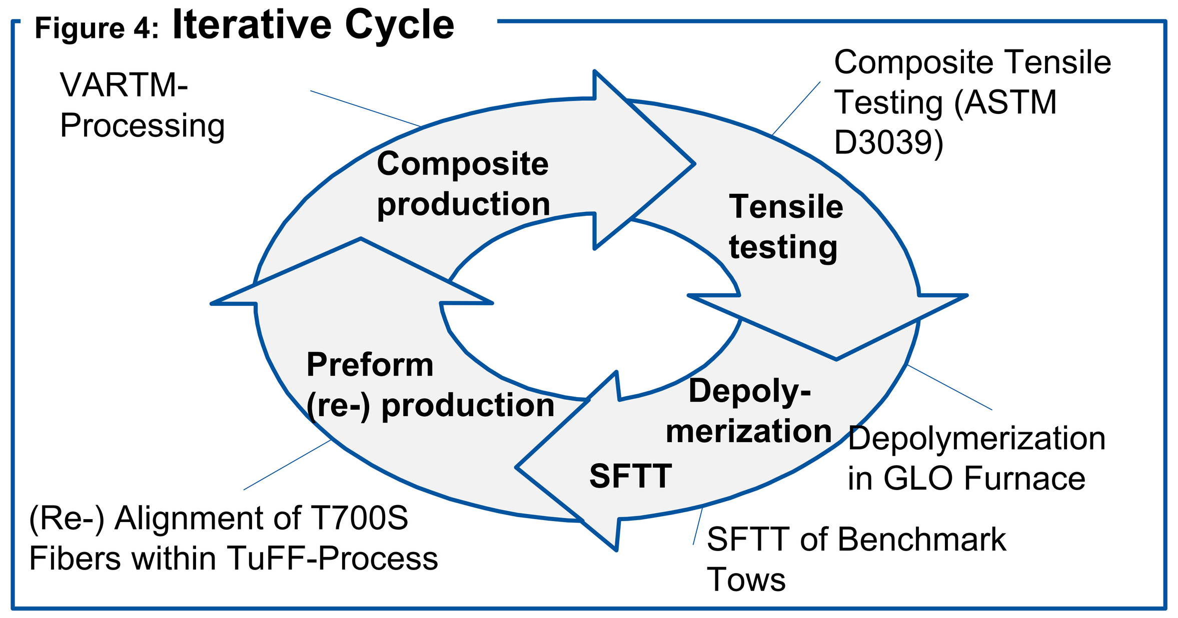
[12]

Preliminary Tests

- Investigation of virgin T700S fibers (SFTT)
- Investigation of polymerization and depolymerization cycles of Elium 188 O
- Definition of temperature cycle for depolymerization using Thermogravimetric Analysis (TGA)
- Surface and dispersion investigation after depolymerization

Iterative Approach

Figure 4: **Iterative Cycle**



- T700S-TuFF preforms are infused with the activated resin using a vacuum assisted resin molding process.
- After a 48 h polymerization cycle at two different temperatures, the part is demolded, prepared and tensile tested according to ASTM D3039.
- Non-tested parts are depolymerized using a GLO Carbolite Furnace.
- After the first attempt, using the temperature cycle defined within the preliminary tests, the recovered material is not dispersible. Residues are found under SEM investigation. The Cycle is reconsidered, and the iteration repeated with the recovered T700S fibers. (Figure 5)
- The reconsidered depolymerization cycle was developed using TGA experiments and successfully performed in the GLO Carbolite furnace.
- Single Fiber Tensile Tests (SFTT) are performed on benchmark tows. Recovered fibers are tested on dispersibility and the fiber surface is investigated (c). Dispersion results mostly in single fibers (a) and few fiber accumulations (b). (Figure 6)

Figure 5: **TuFF Material after the first depolymerization attempt**
a) With fiber direction, b) in fiber direction

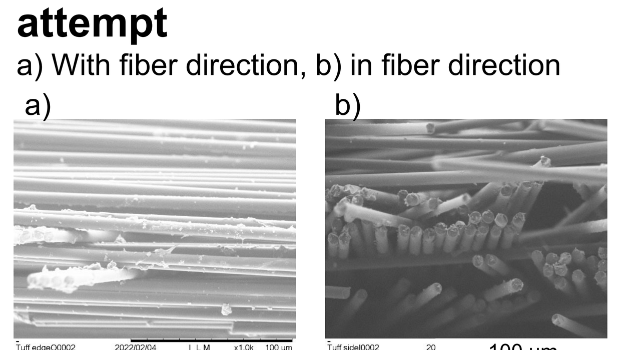
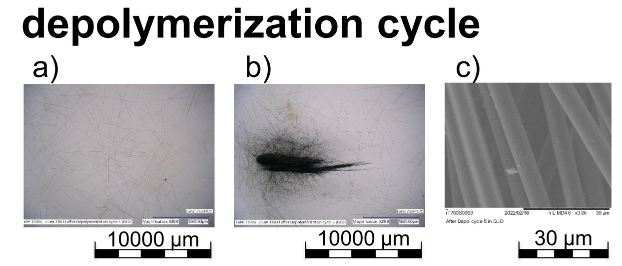


Figure 6: **Dispersion results (a), b)) and fiber surface (c) after reconsidered depolymerization cycle**



Results

- Single fiber tensile strength retention between virgin and recycled fibers of 75 % achieved. 69 % after the second depolymerization.
- Even structured composite's cross-section area achieved (Figure 8). Linear stress-strain curves for all tested sets of samples (Figure 7). Composite tensile strength retention of 55 % and tensile modulus retention of 100 %. (Table 1)
- Main determined failure mode fiber pull-out and matrix failure. (Figure 9)

Figure 7: **Tensile Strength Result Examples** (virgin and recycled)

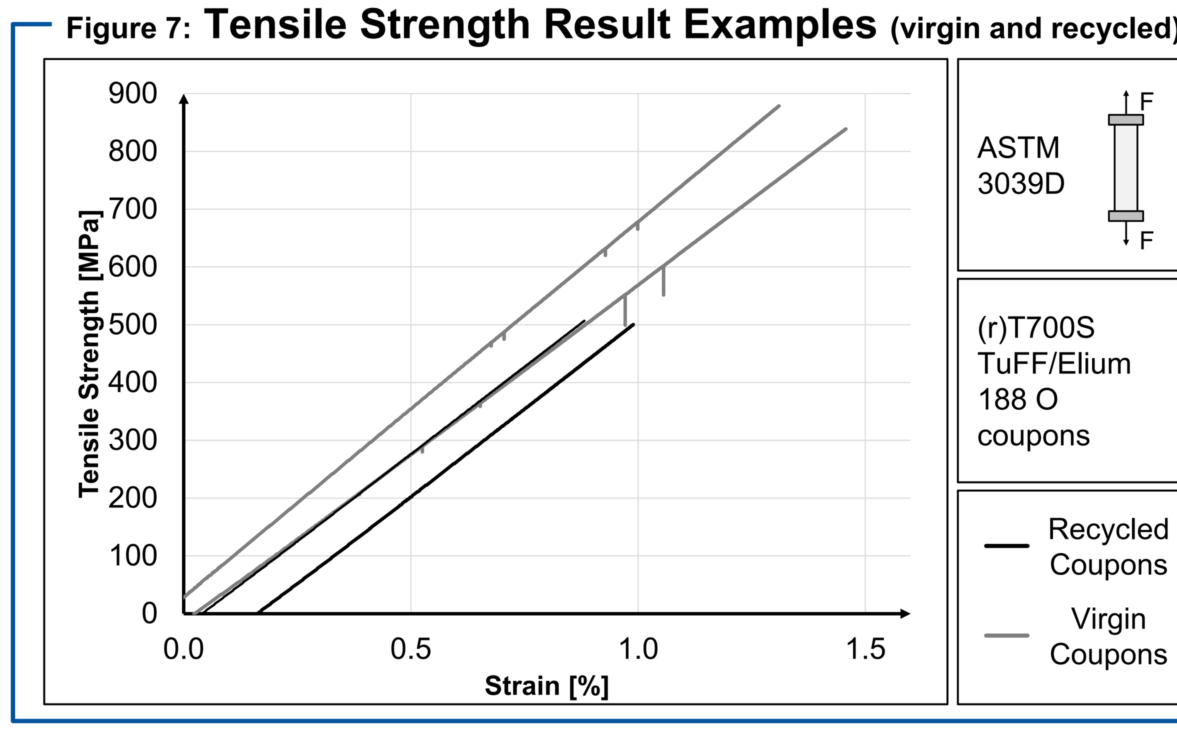


Table 1: **Summary of T700S/Elium 188 O composites (virgin and recycled)**

	FVF [%]	ø Tensile Strength [MPa]	ø Modulus of elasticity [GPa]	ø Strain to failure [%]
vT700S	27	814 ± 51	60.91 ± 3.13	1.34 ± 0.06
rT700S	24	484 ± 12	60.71 ± 0.93	0.93 ± 0.05

Figure 8: **Cross section area of tested composites**

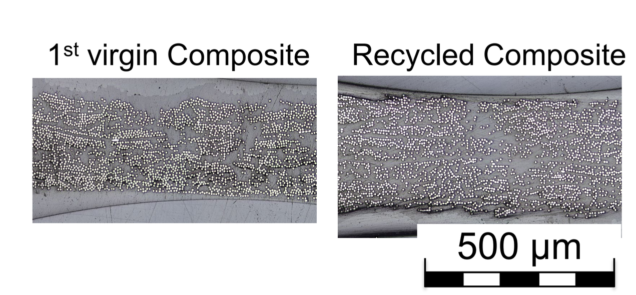


Figure 9: **Failure modes of recycled fiber composites**

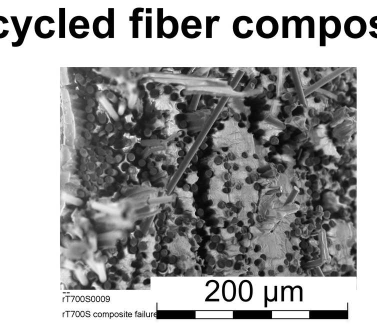
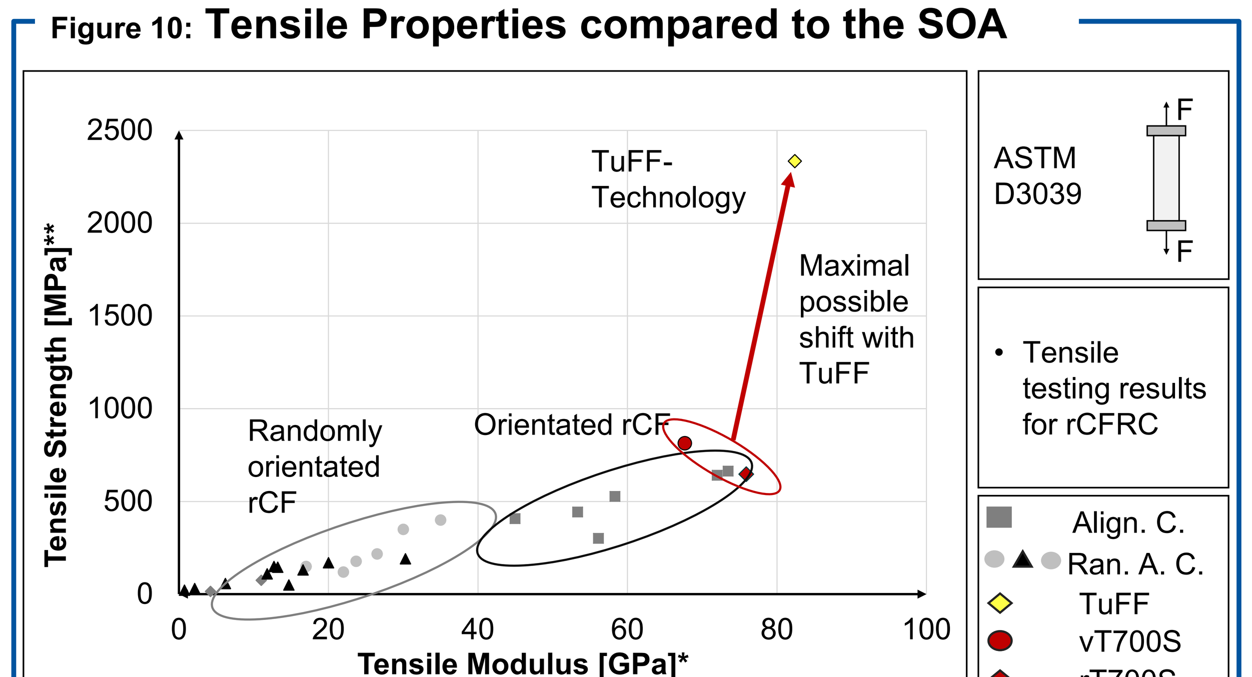


Figure 10: **Tensile Properties compared to the SOA**



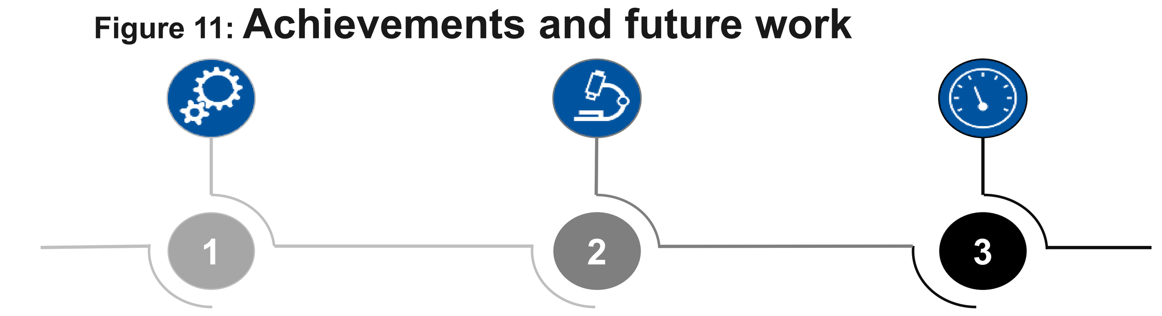
[5,6,7,8,9,10,11]

* Tensile modulus normalized to 30 % FVF
** Tensile strength normalized to fiber strength of 4700 MPa

Discussion and Outlook

- Working recycling process demonstrated for one iteration, with retention values higher than most of the reported values in literature. (Figure 10)
- Recovered fibers mostly dispersible in single fibers and reusable in TuFF process ensuring even properties allover the produced part.
- TuFF-process as enabling technology for even higher property translations from fiber to composite properties. Future work has to focus on these topics to achieve 100 % of property retention. (Figure 11)

Figure 11: **Achievements and future work**



Composite Production
✓ Working process determined

Future work:
- Shorter polymerization process
- Achieve higher FVF

Composite Properties
✓ Medium mechanical properties achieved

Future work:
- Fiber-Matrix adhesion of virgin fibers and after recovery

Depoly-merization
✓ Clean fiber surface achieved
✓ Dispersible material recovered

Future work:
- Reduce fiber property degradation
- Minimize duration and flow rates

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Acknowledgements

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