The ReCoVeR Project

Regeneration Of Thermally Recycled Glass Fibre For Cost-Effective, Closed-Loop, Composite Recycling in Automotive

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AMRL Advanced Materials Research Laboratory

EPSRC Engineering and Physical Sciences Research Council

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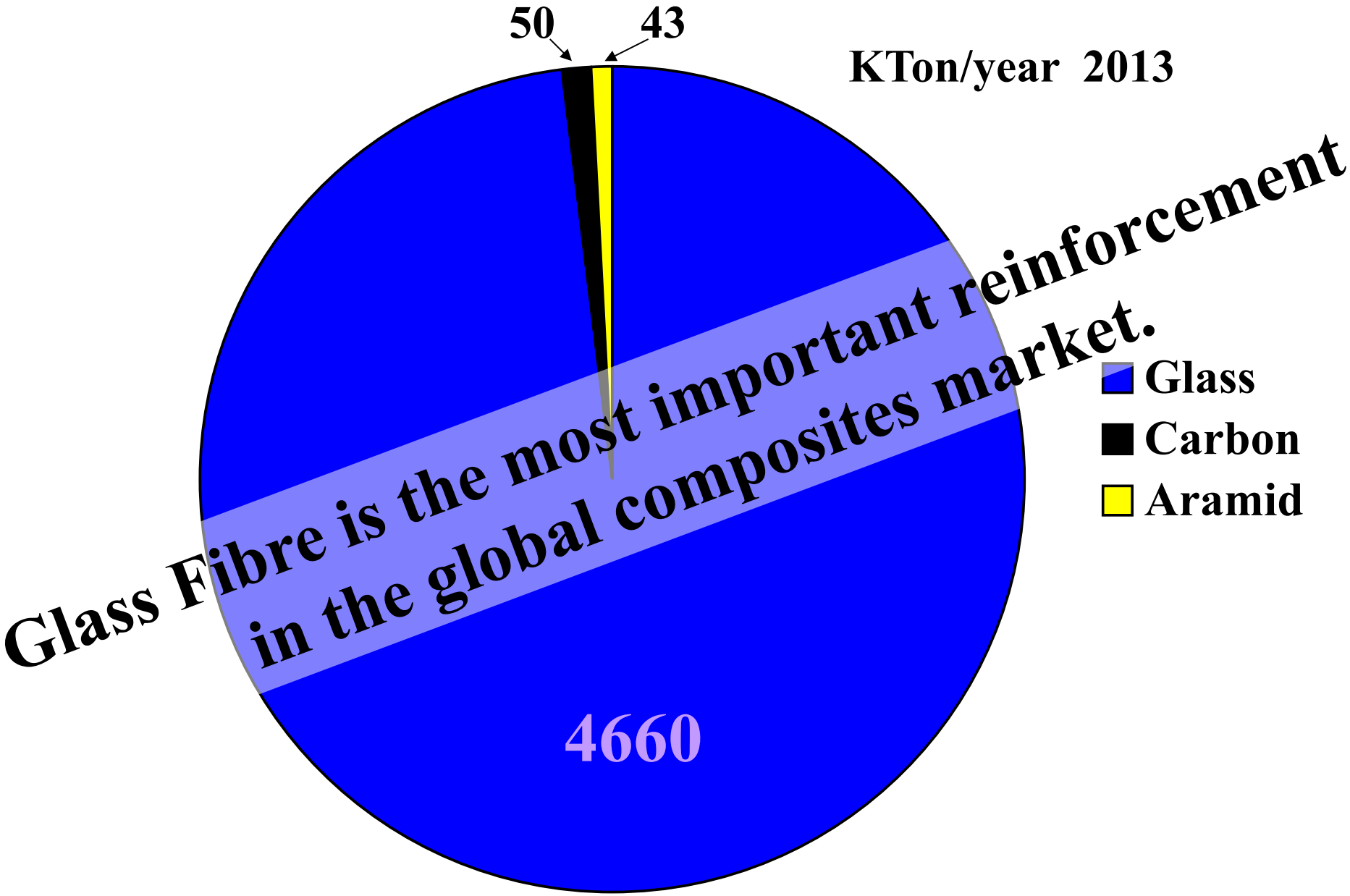
ReCoVeR

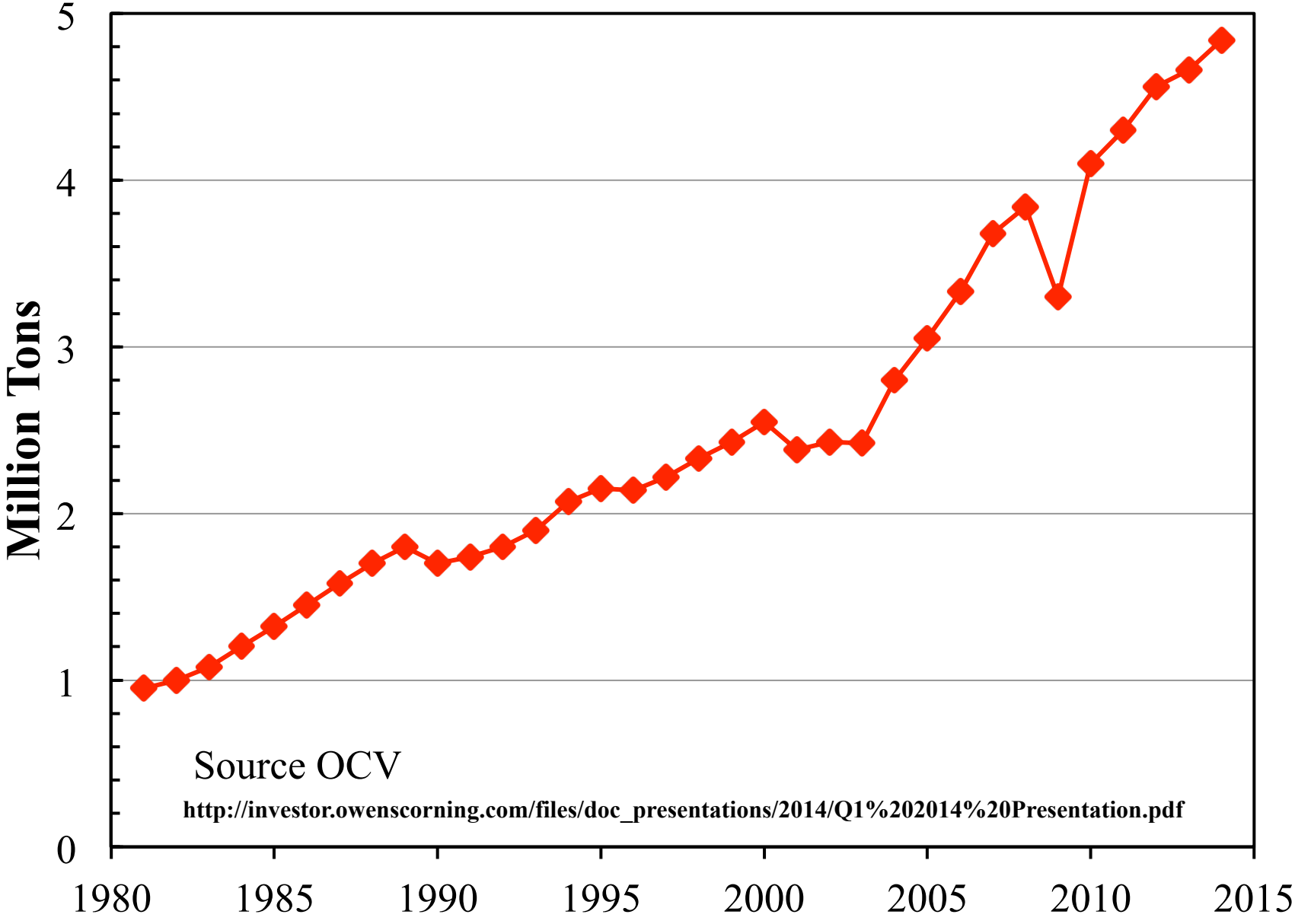
University of Strathclyde Engineering

- Introduction
- ACG Recycling Projects Overview
- Some Initial Results
  - Fundamentals of Glass Fibre Strength Loss
  - ReCoVeRed Glass Fibres
  - Composite Performance
- Conclusions

Global Reinforcement Fibre Usage



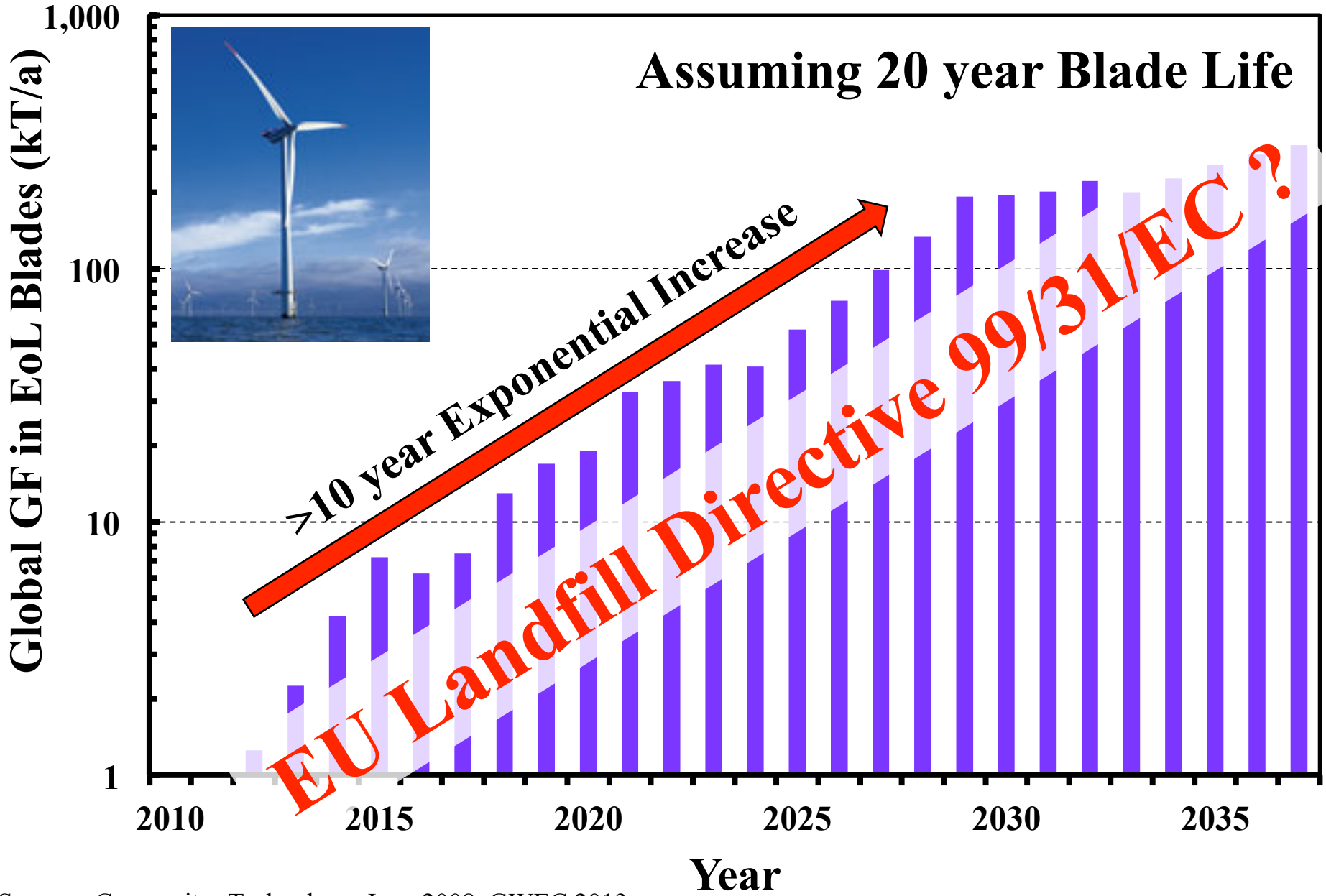
Global Glass Fibre Demand



Composites in Automotive

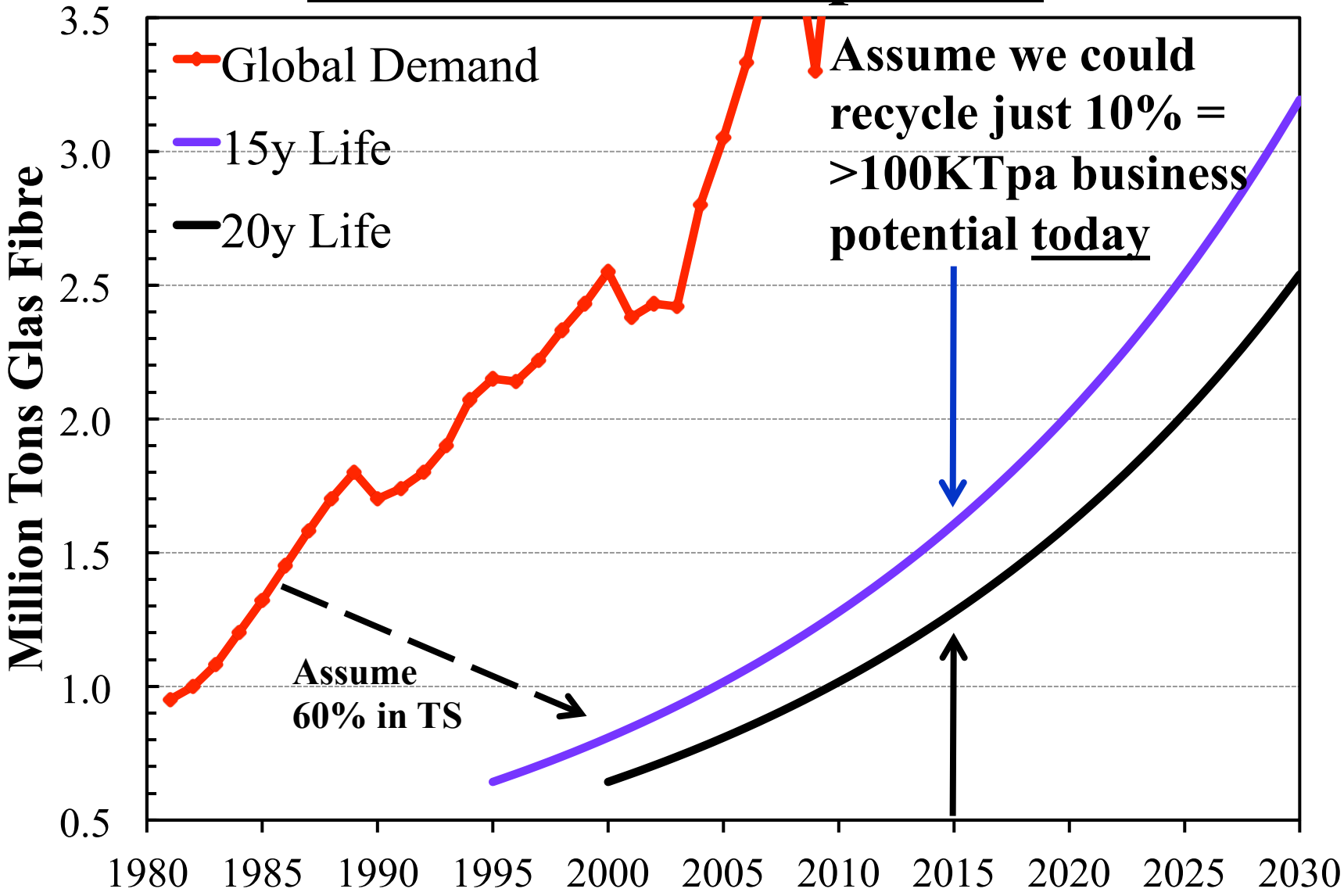
BMW photo as shown in Modern Plastics Magazine

GF in End-of-Life Wind Turbine Blades



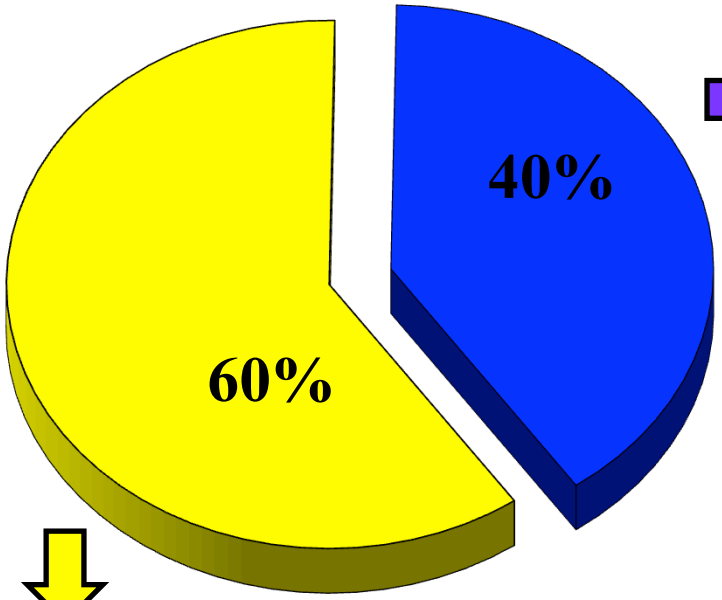
Source - Composites Technology, June 2008, GWEC 2013

Available End-of-Life Glass Fibre in Thermoset Composites



ReCoVeR Glass Fibres: End-of-Life Scenario

4.8 MegaTons Glass Fibre



Mainly into chopped fibre* <u>thermoplastic</u> *composites. Intrinsically recyclable

<u>ReCoVeR and reuse as valuable chopped fibre ?</u>

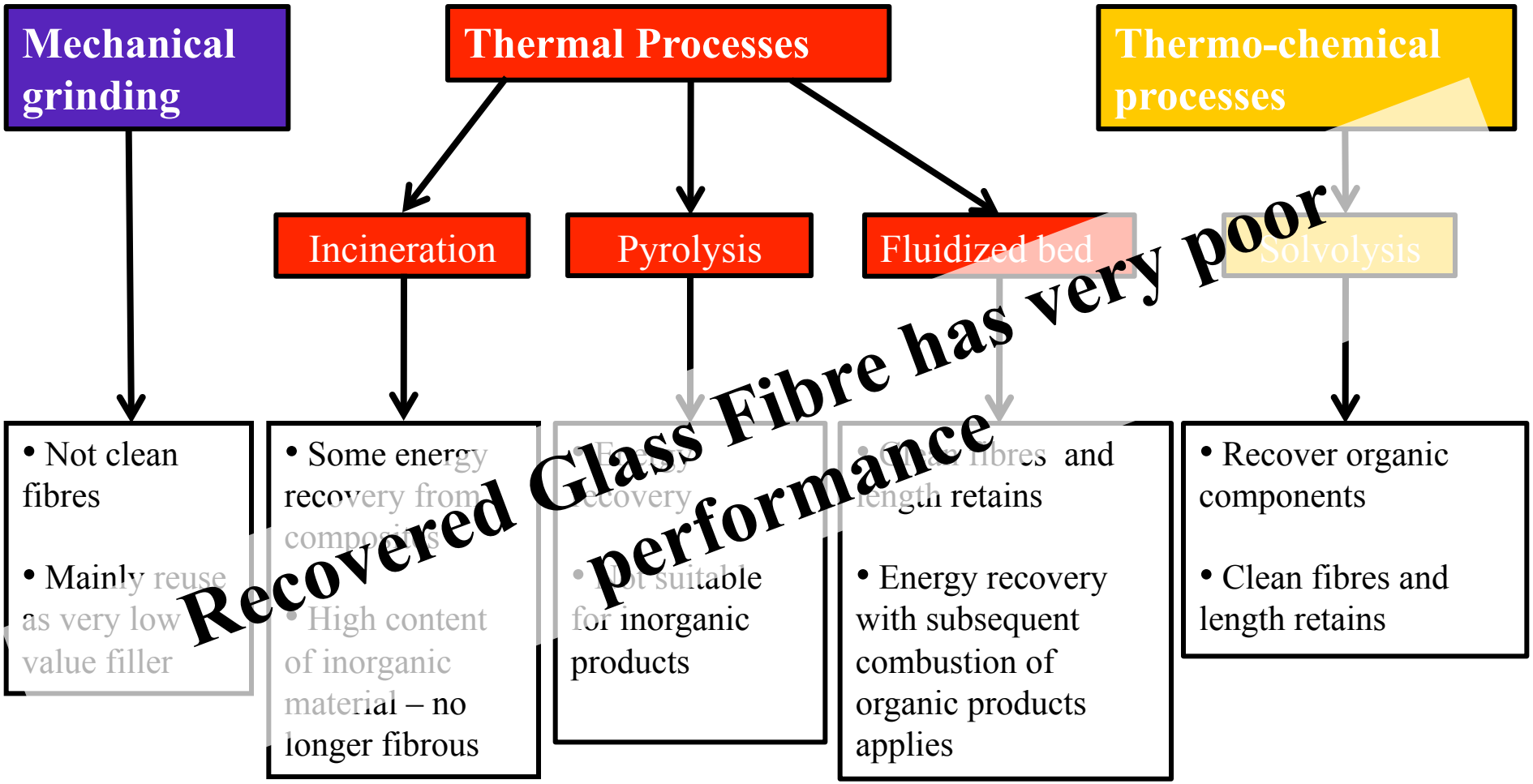
Mainly into continuous fibre* <u>thermoset</u> *composites

Challenging to recycle - so end-of-life = <u>landfill</u> ?

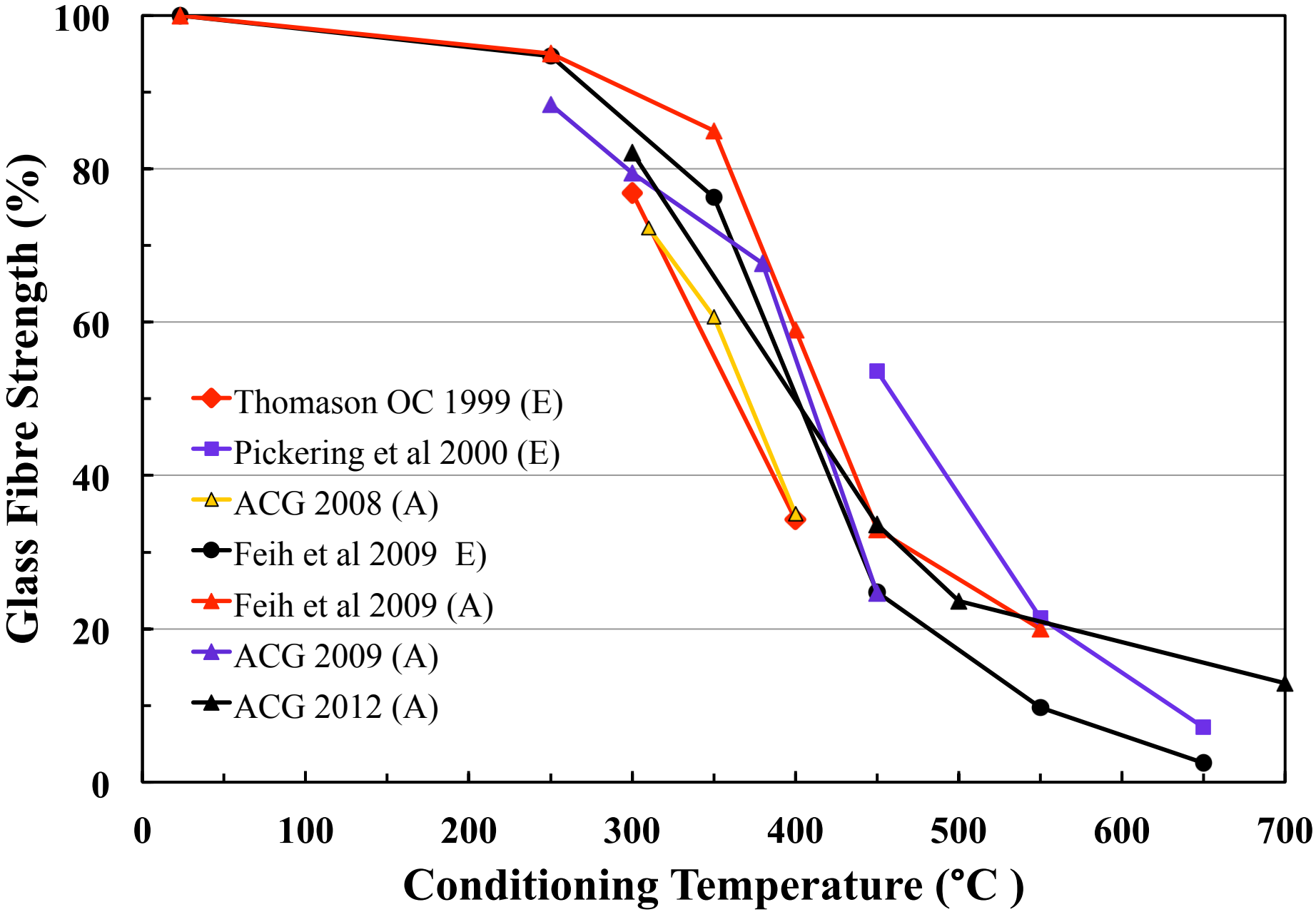
Landfill no longer acceptable – but very difficult to recover continuous fibre

(*or zero value filler*)

GRP Recycling Techniques



GF Strength (*Value*) after Thermal Recycling



Regenerated Composite Value Reinforcement

– *£1M EPSRC funding, 8 Researchers in ACG team*

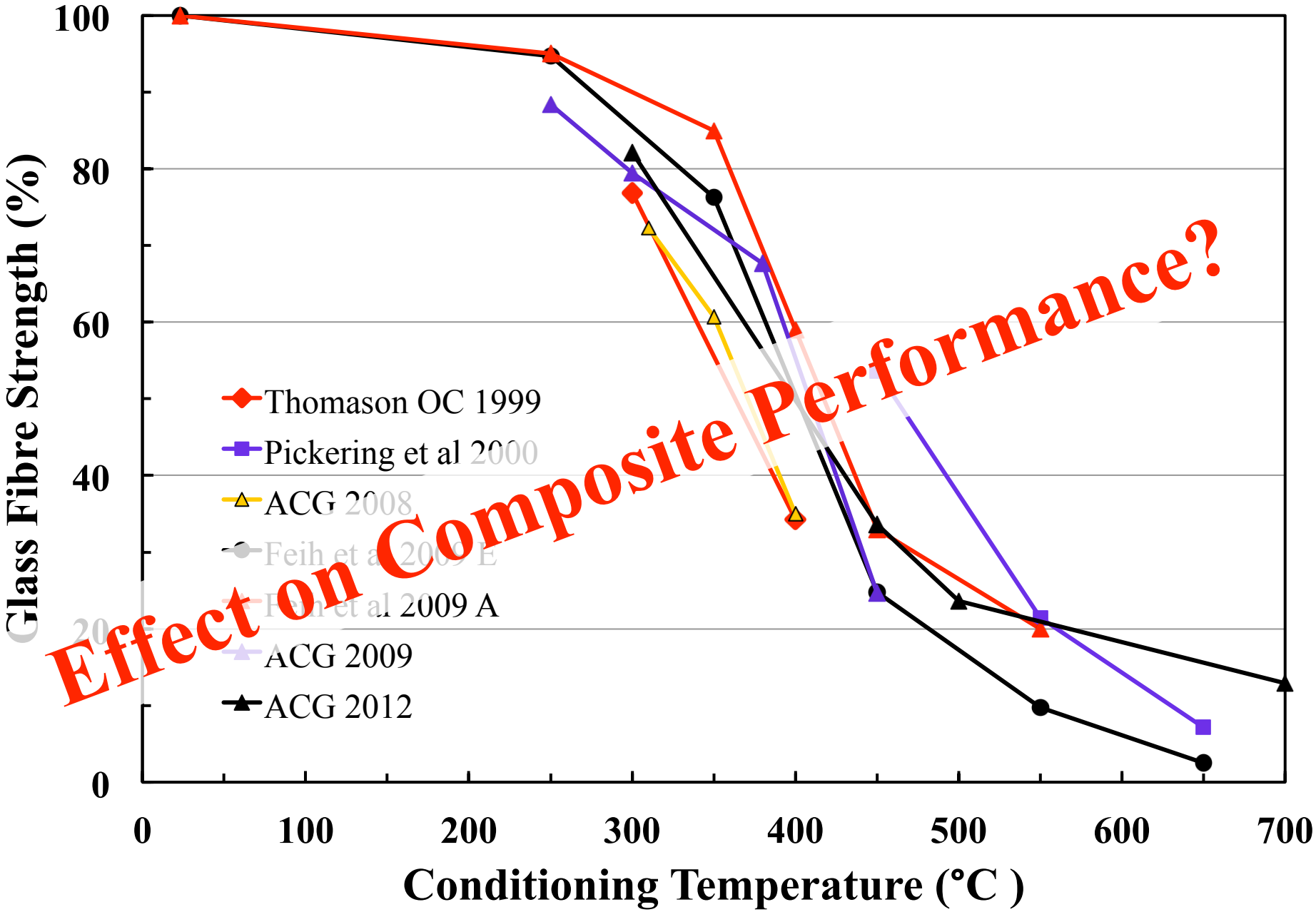
The ReCoVeR Mission

Enable the development of cost-effective, *drop-in*, glass fibre and composite products based on recycled glass fibres with regenerated mechanical performance

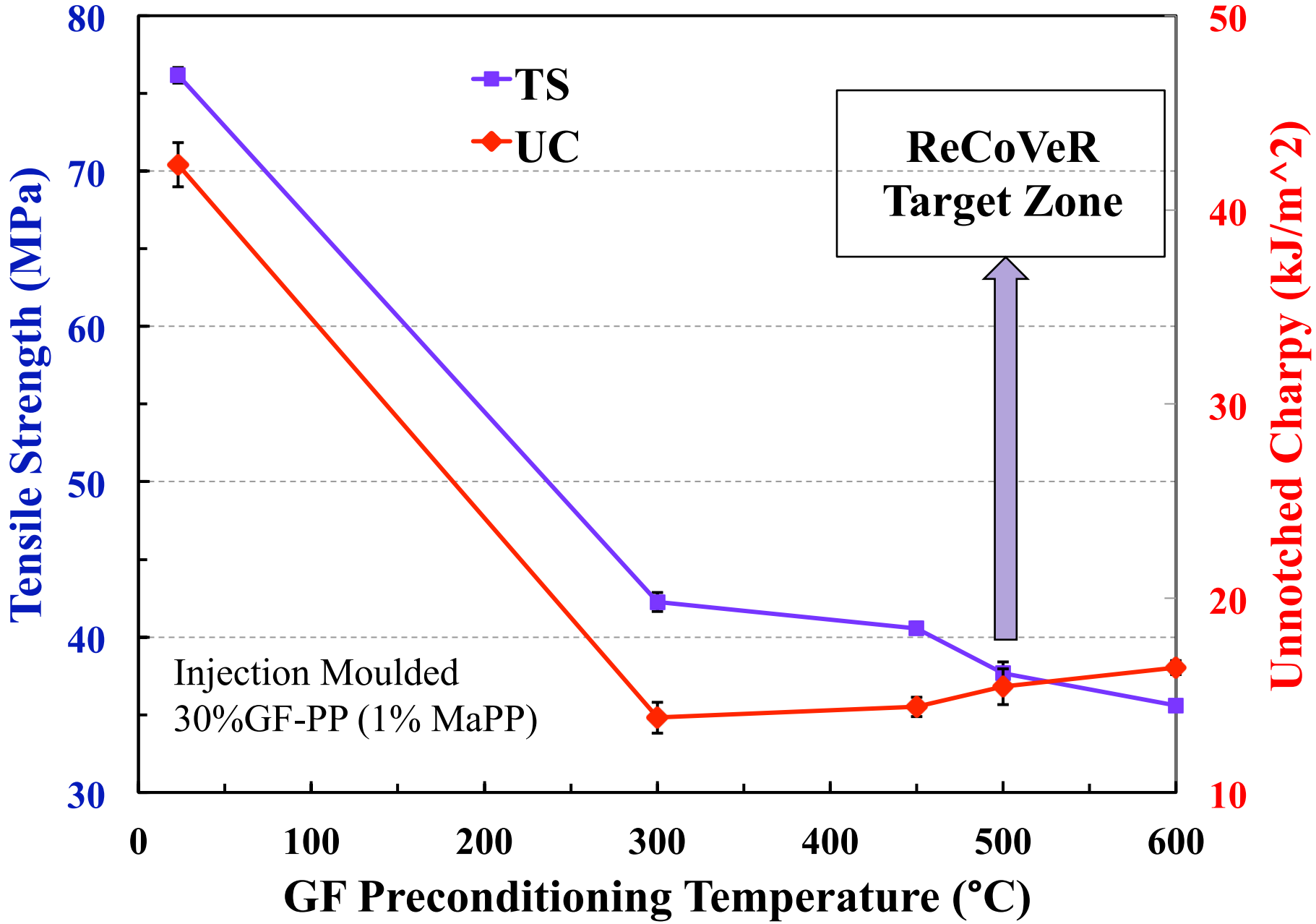
The Research Goals

- *Generate fundamental understanding of the changes in glass fibres caused by thermo-mechanical conditioning (300-600°C)*
- *Develop cost effective treatments to regenerate the performance of thermo-mechanically treated glass fibres*
- *Produce examples of glass fibre and composite products using regenerated glass fibres*

Strength after Thermo-Mechanical Treatment



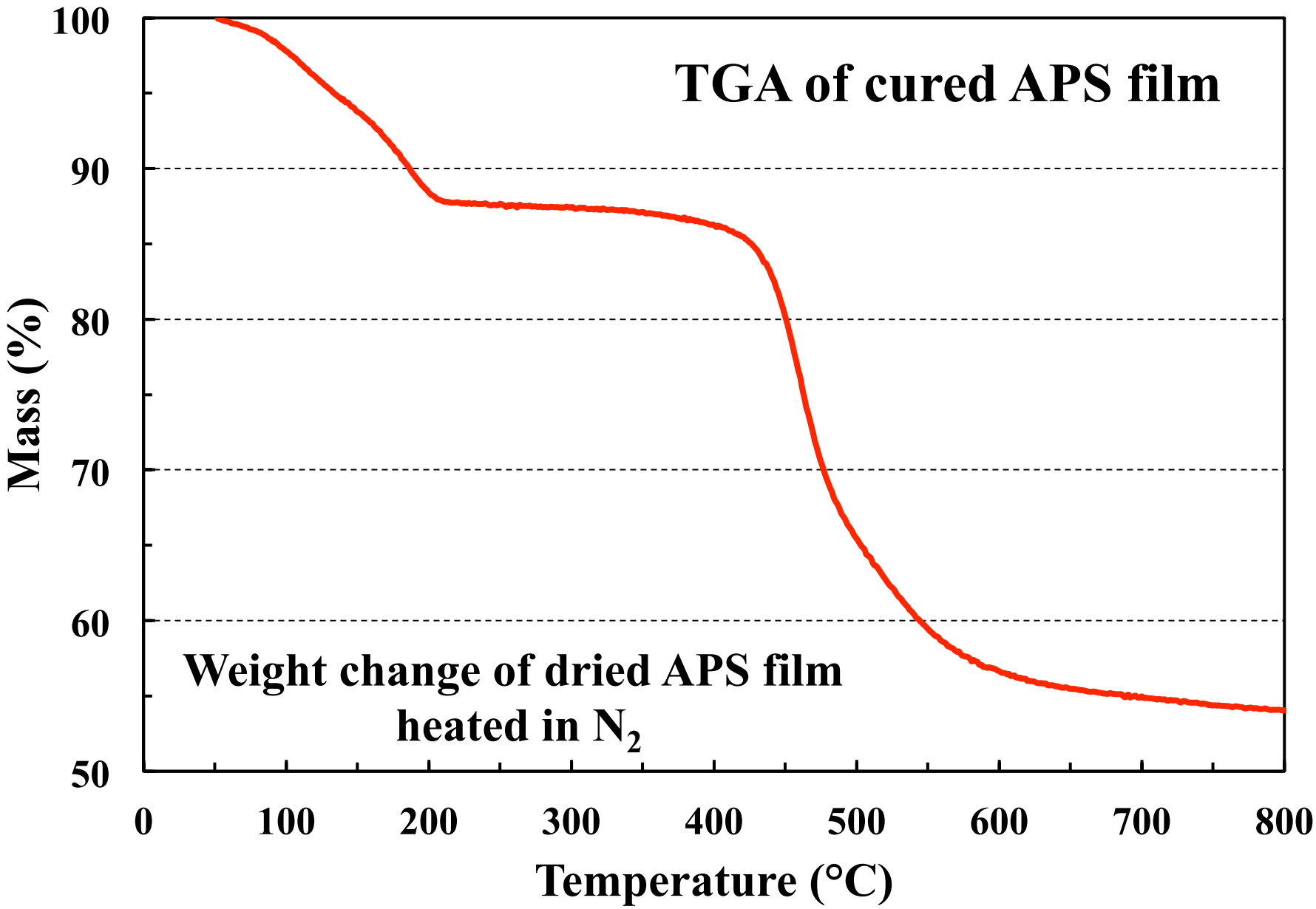
GF Heat Treatment & Composite Performance



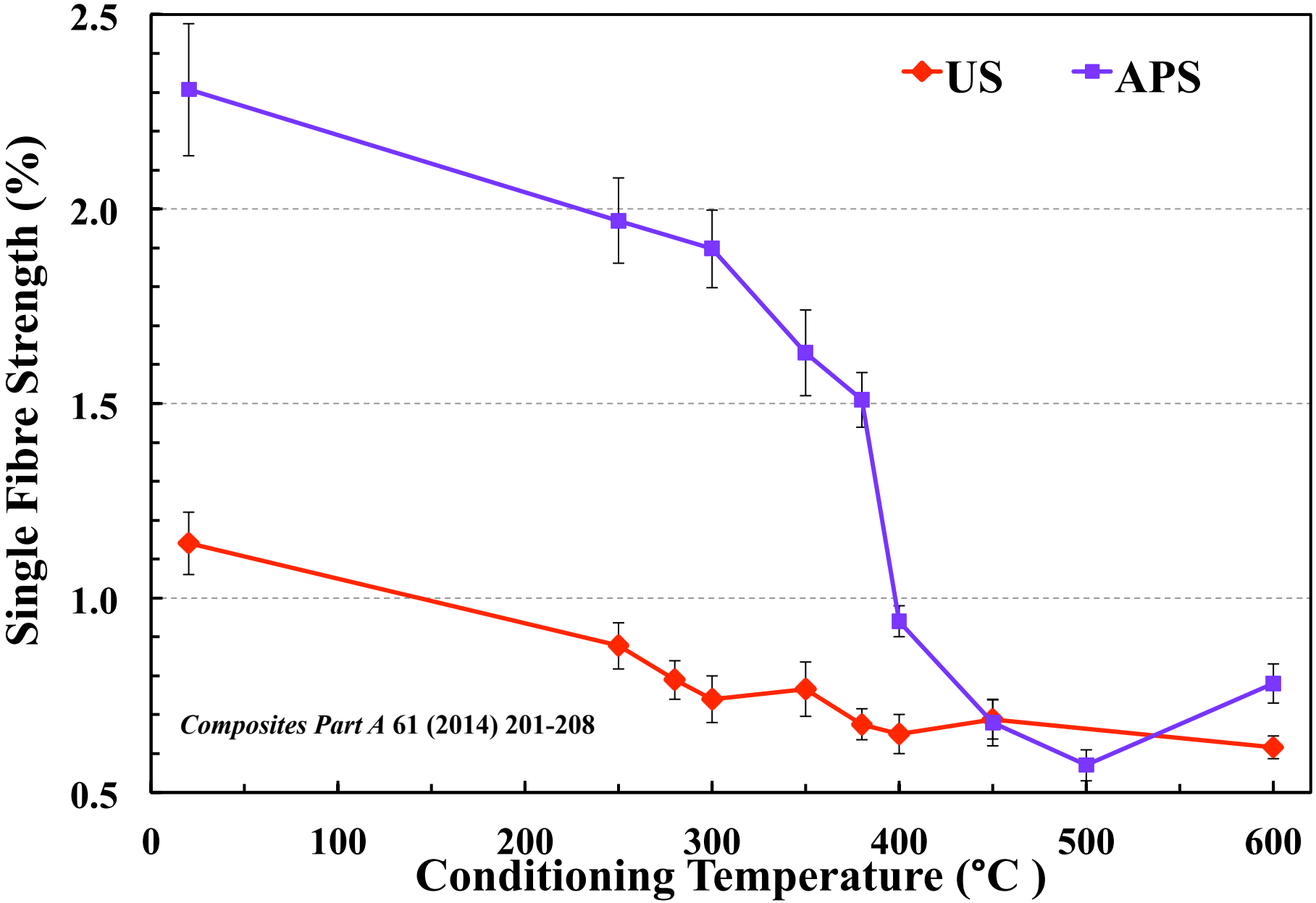
Strength Loss Mechanisms Investigation

- **Fibre strength after heating (or composite recycling)**
- **TGA of silane film degradation**
- **TMA for single fibre modulus and dimension changes during conditioning**
- **AFM/SEM analysis of surface morphology changes**
- **IR analysis of silane NH_2 group on fibre**
- **XPS surface analysis of %N on fibre**
- **TVA of water evolution and dehydroxylisation**
- ***XRD for crystal growth – nothing found up to 800°C***

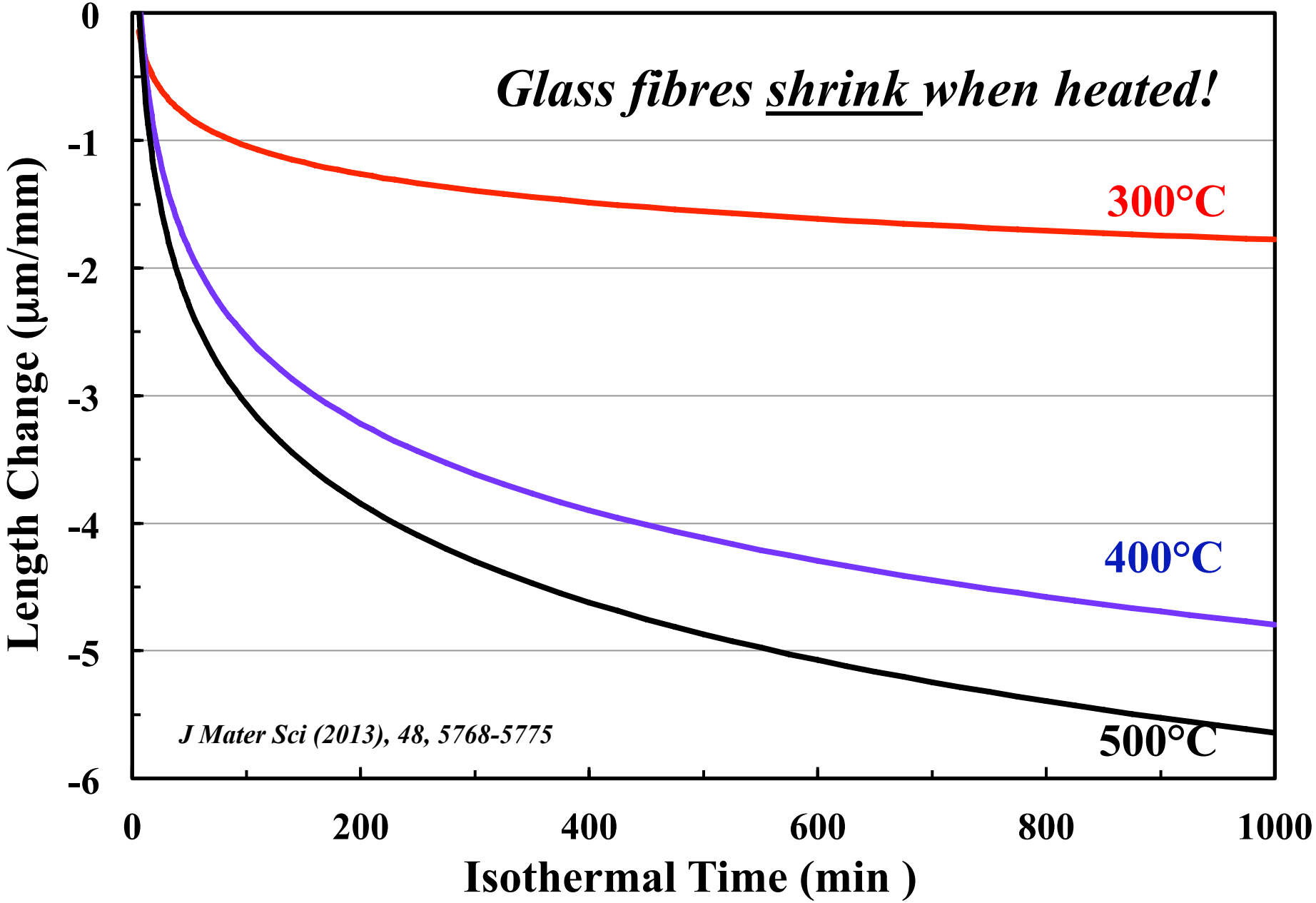
Strength Loss Mechanisms?



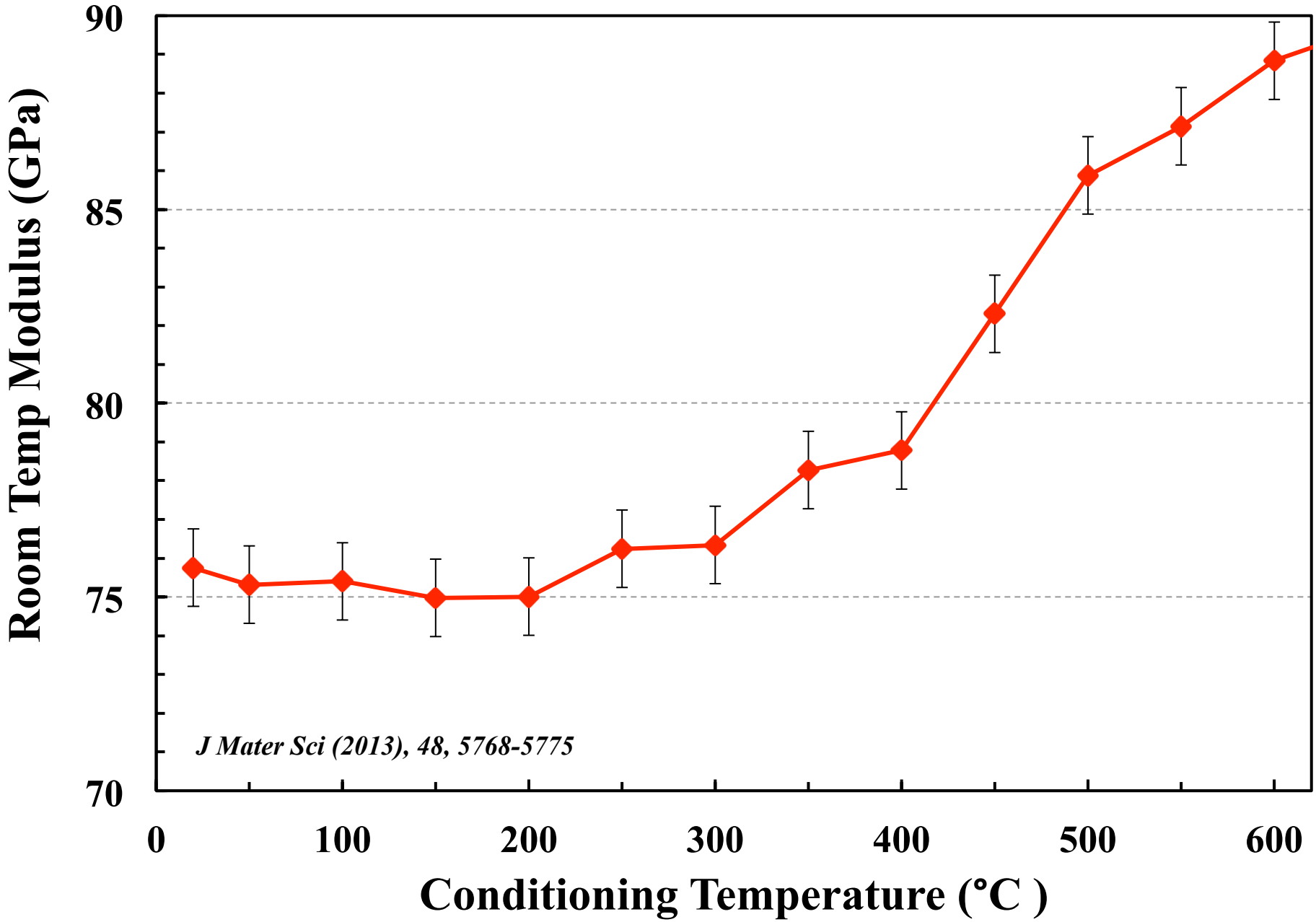
Single Fibre Tensile Testing



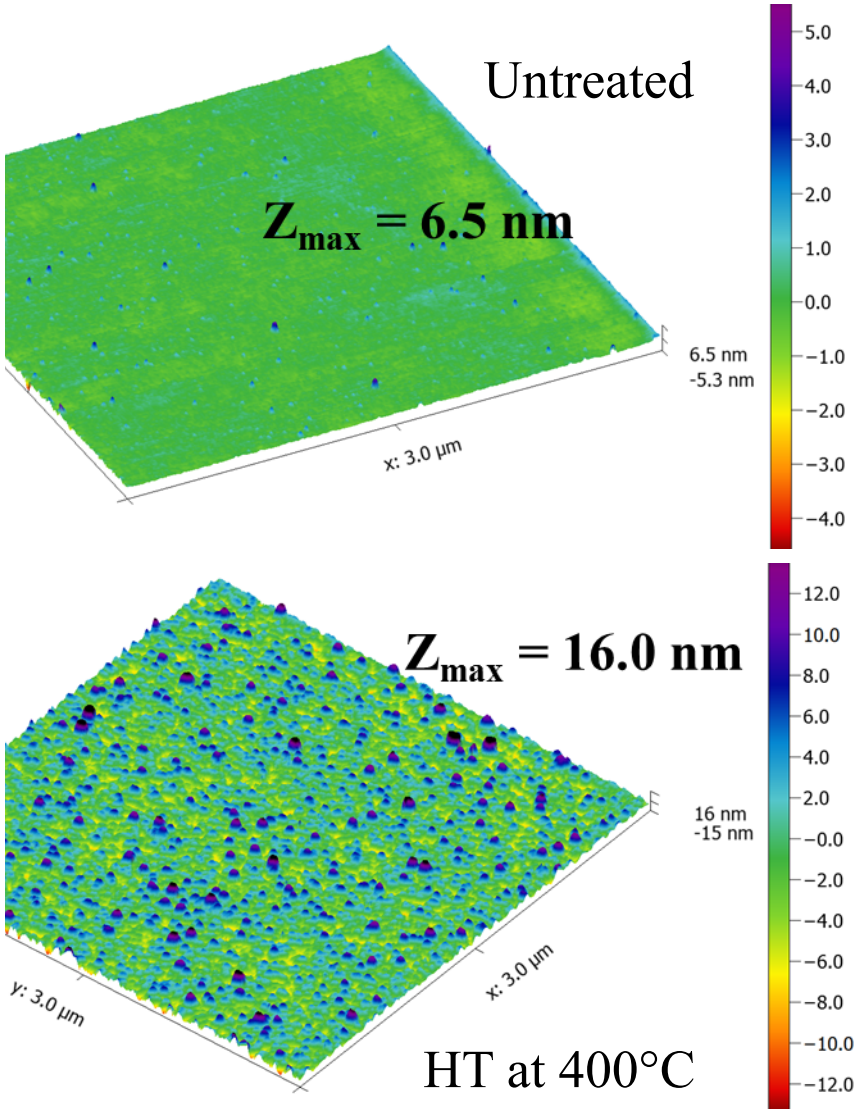
TMA Single Fibre Length Contraction



Strength Loss Mechanisms?

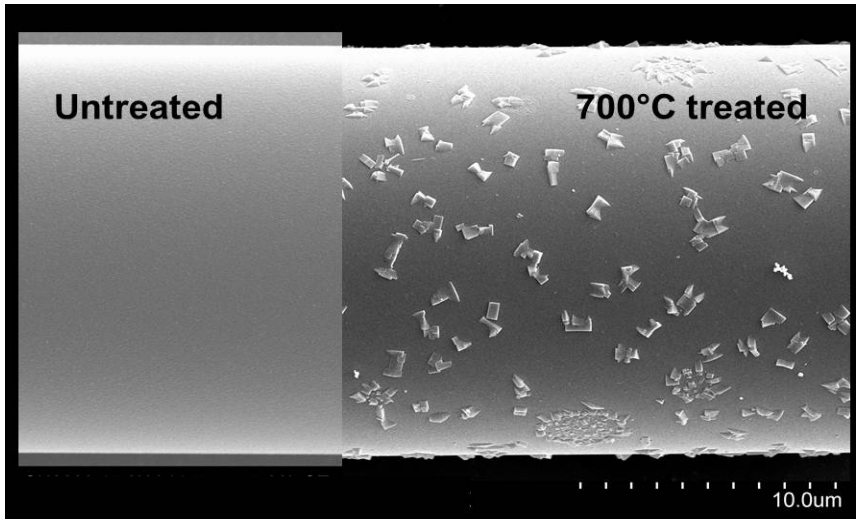


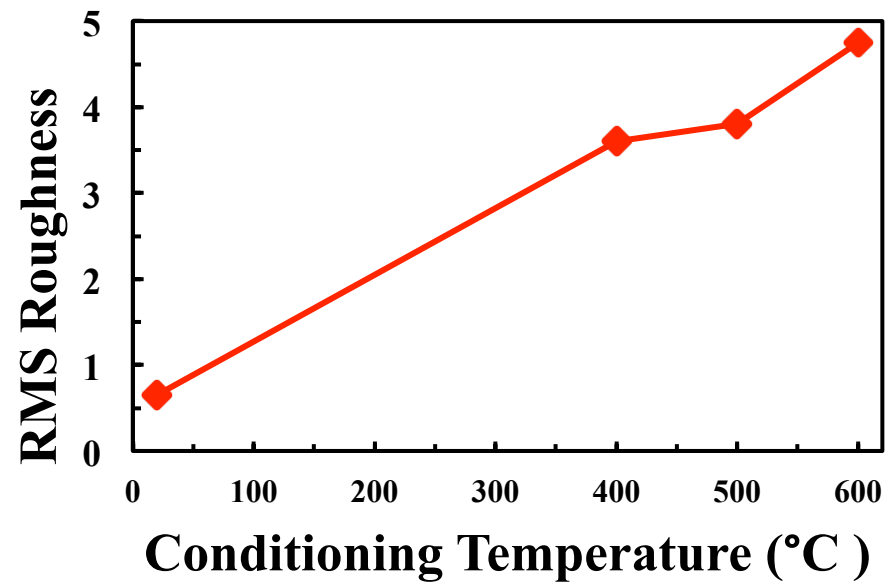
Strength Loss Mechanisms?



AFM

FE-SEM





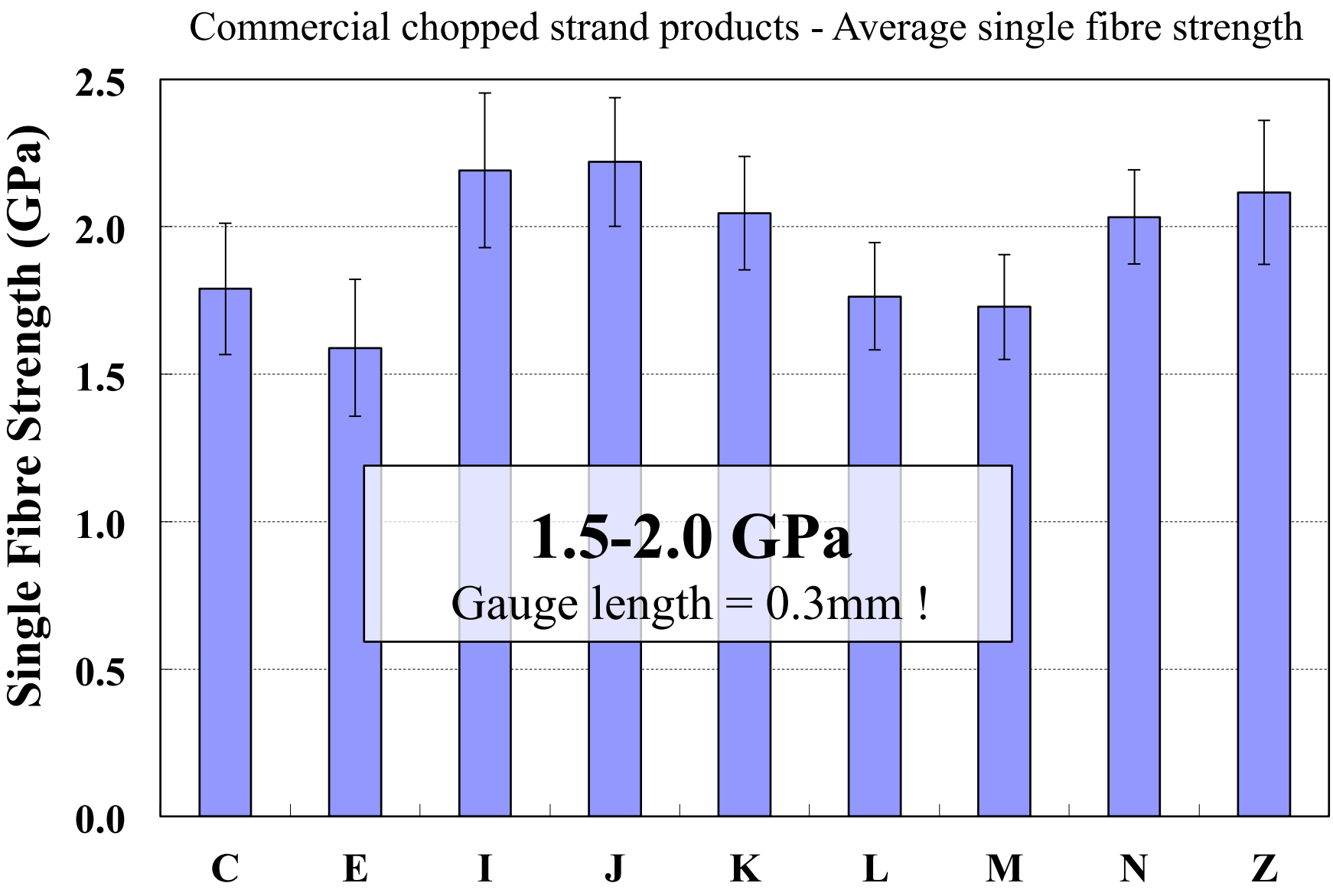
Current State of Strength Loss Mechanisms Investigation

Strength loss probably involves

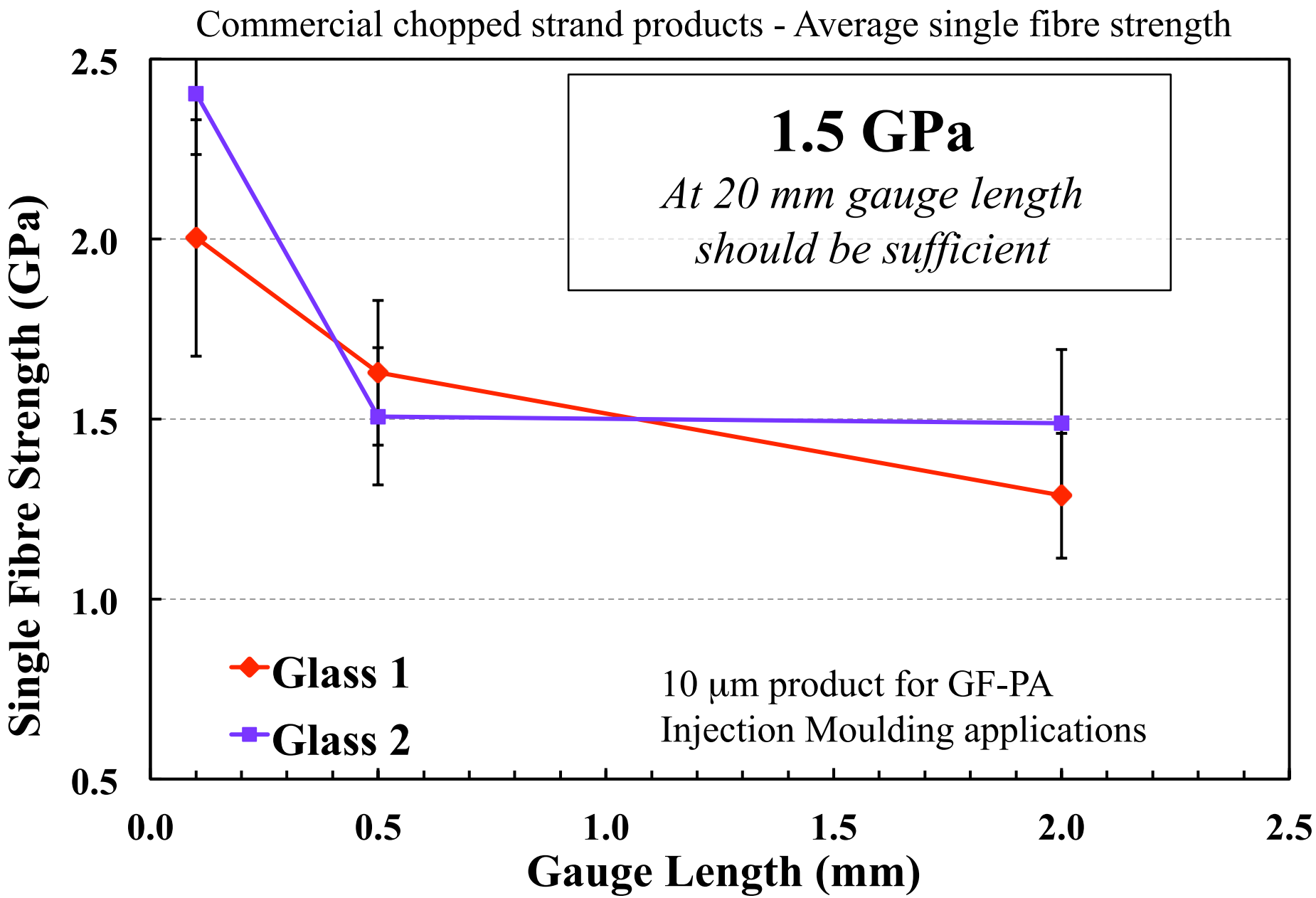
- ***sizing degradation***
- ***surface flaws (number/severity increase)***
- ***change/relaxation in glass structure***
- ***removal of water/dehydroxylization***

More work required for full understanding

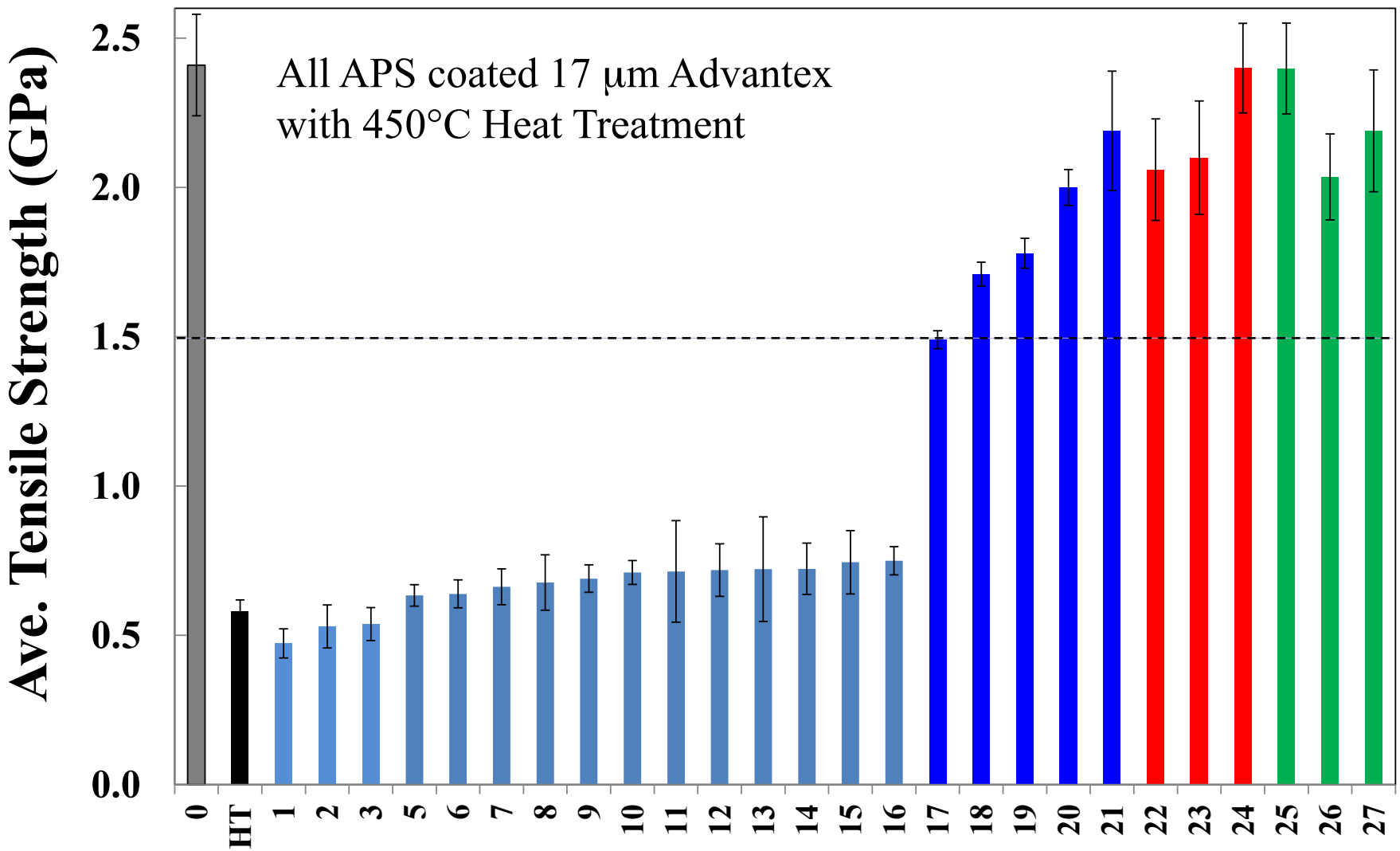
Target Strength for ReCoVeRed Fibre ?



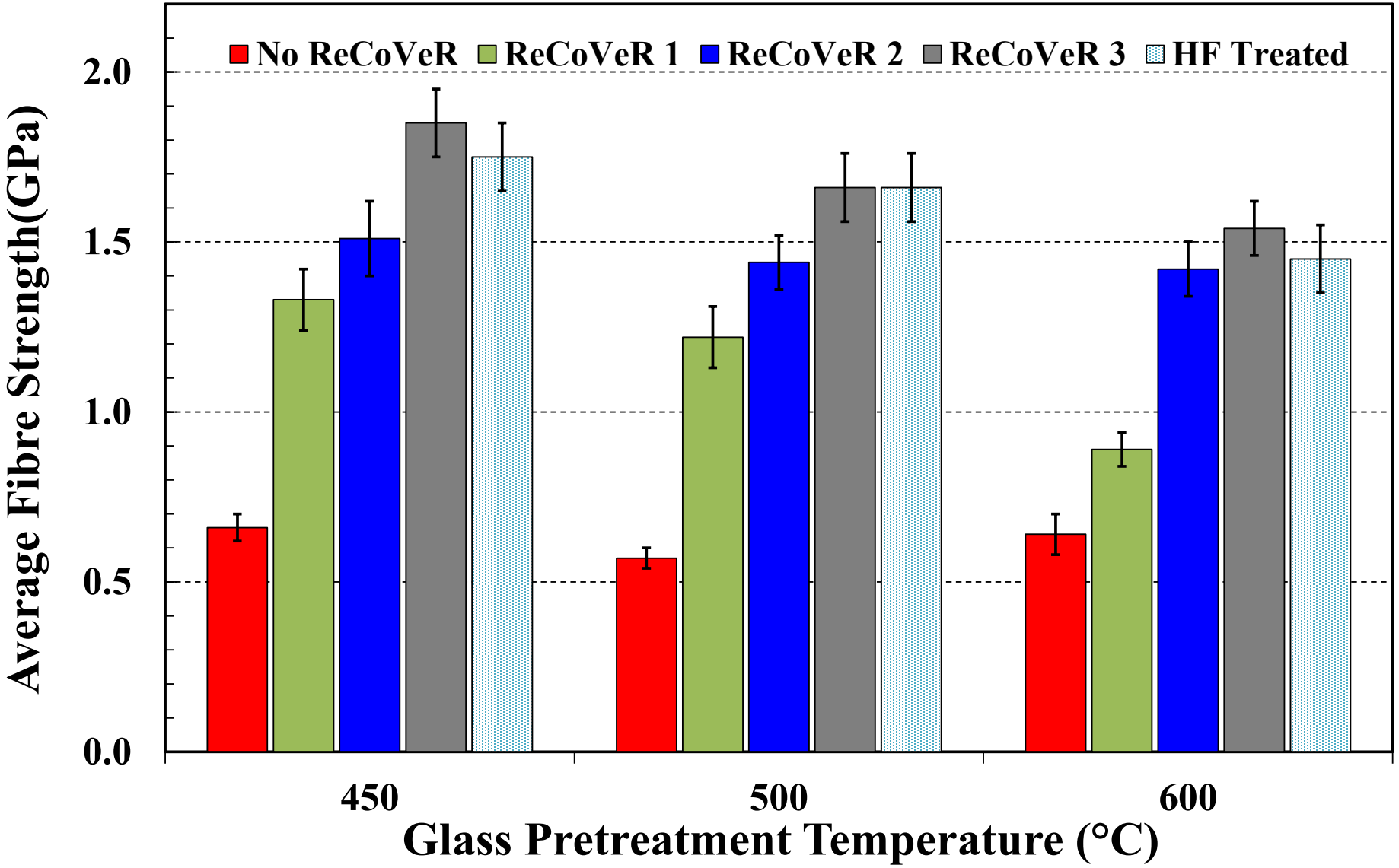
Target Strength for ReCoVeRed Fibre ?



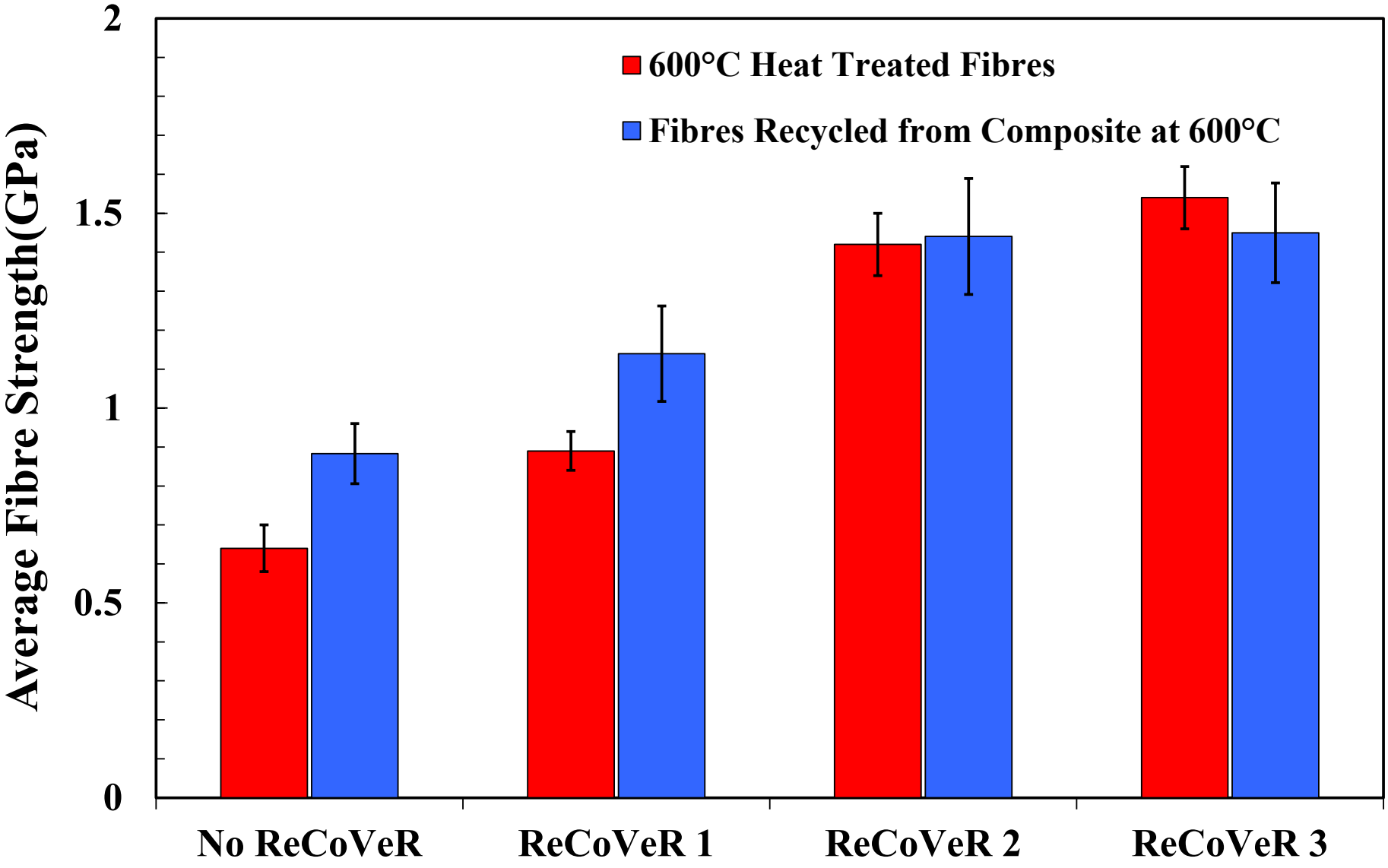
Glass Fibre Strength ReCoVeRy



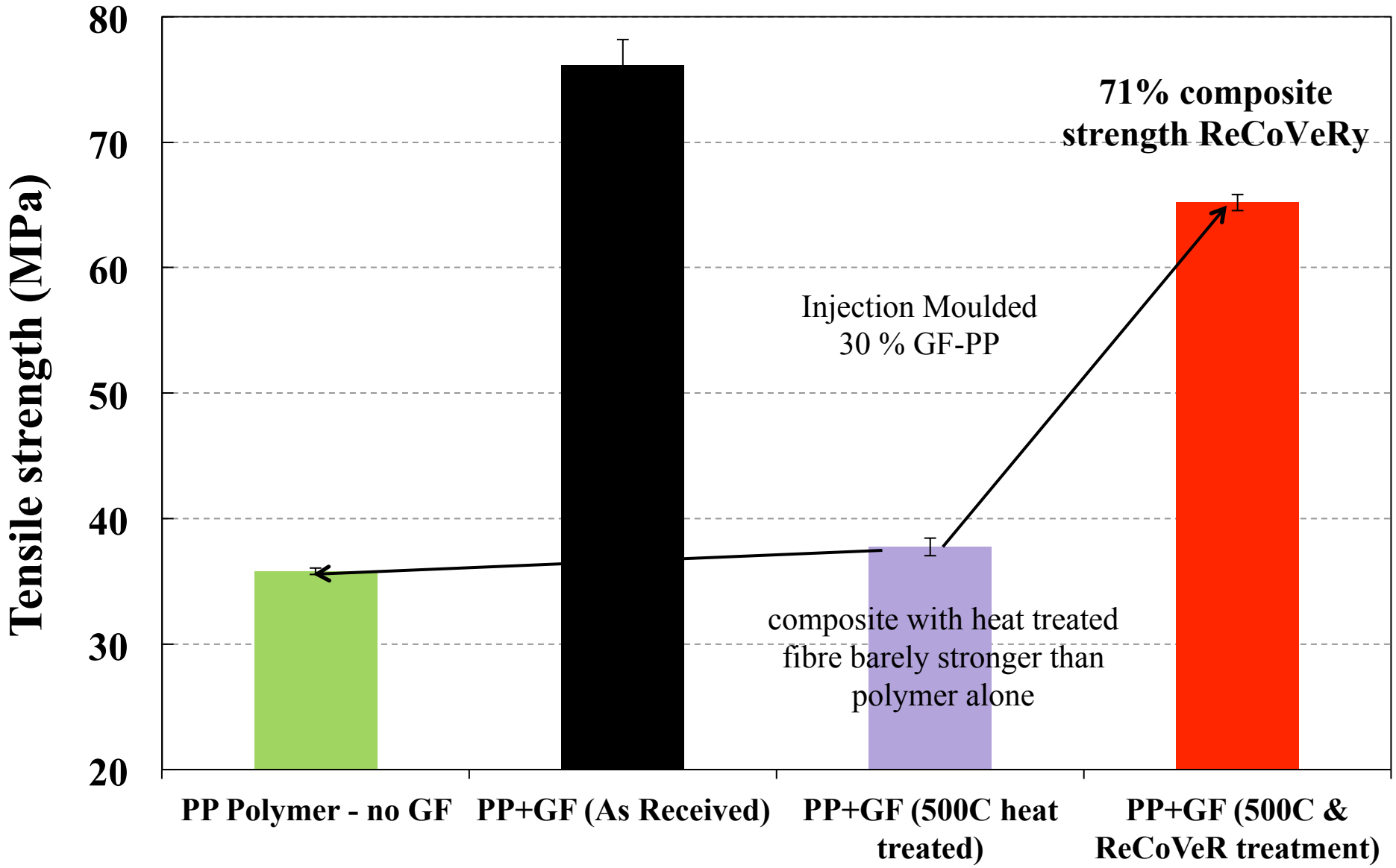
Glass Fibre Strength ReCoVeRy



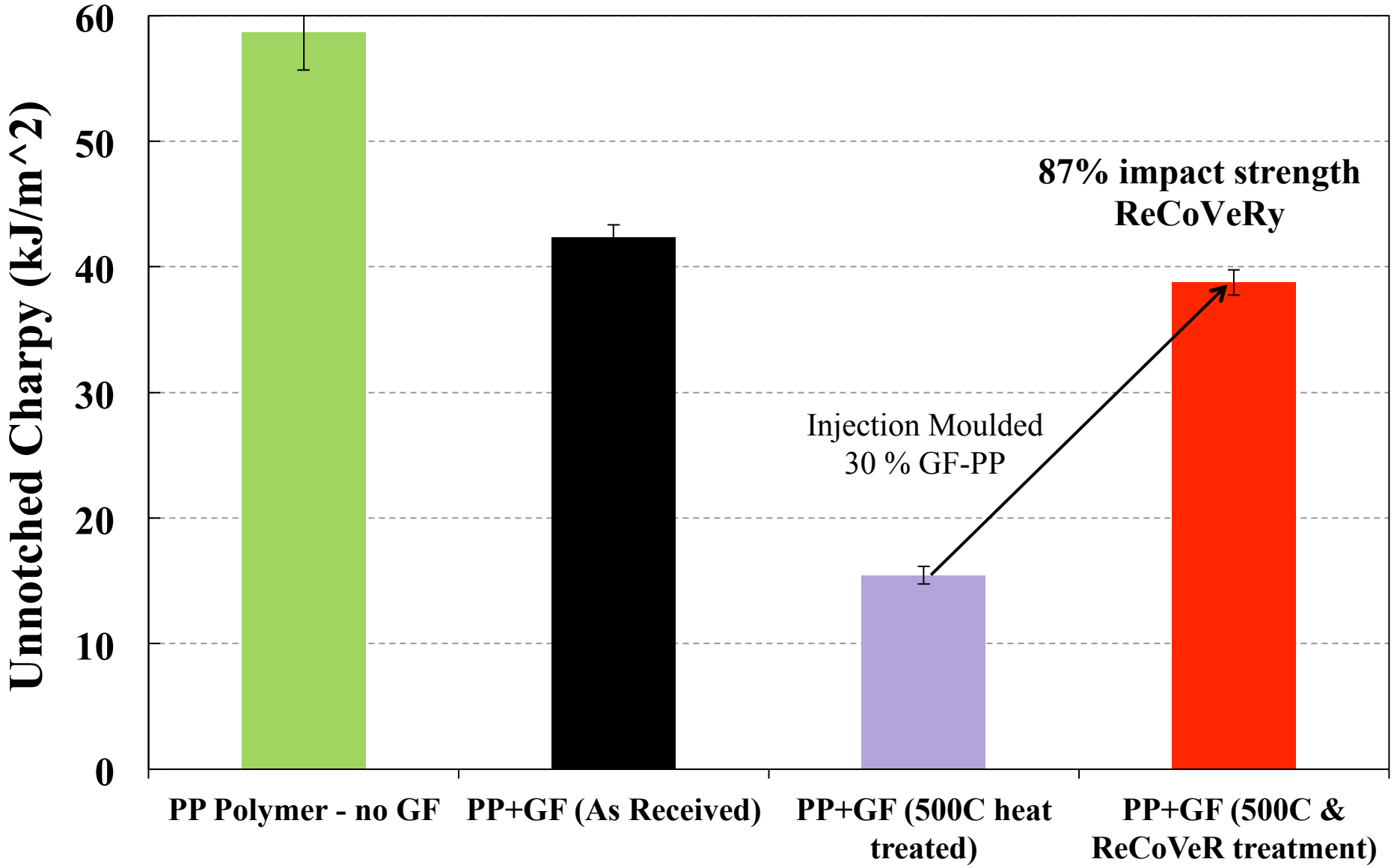
Glass Fibre Strength ReCoVeRy



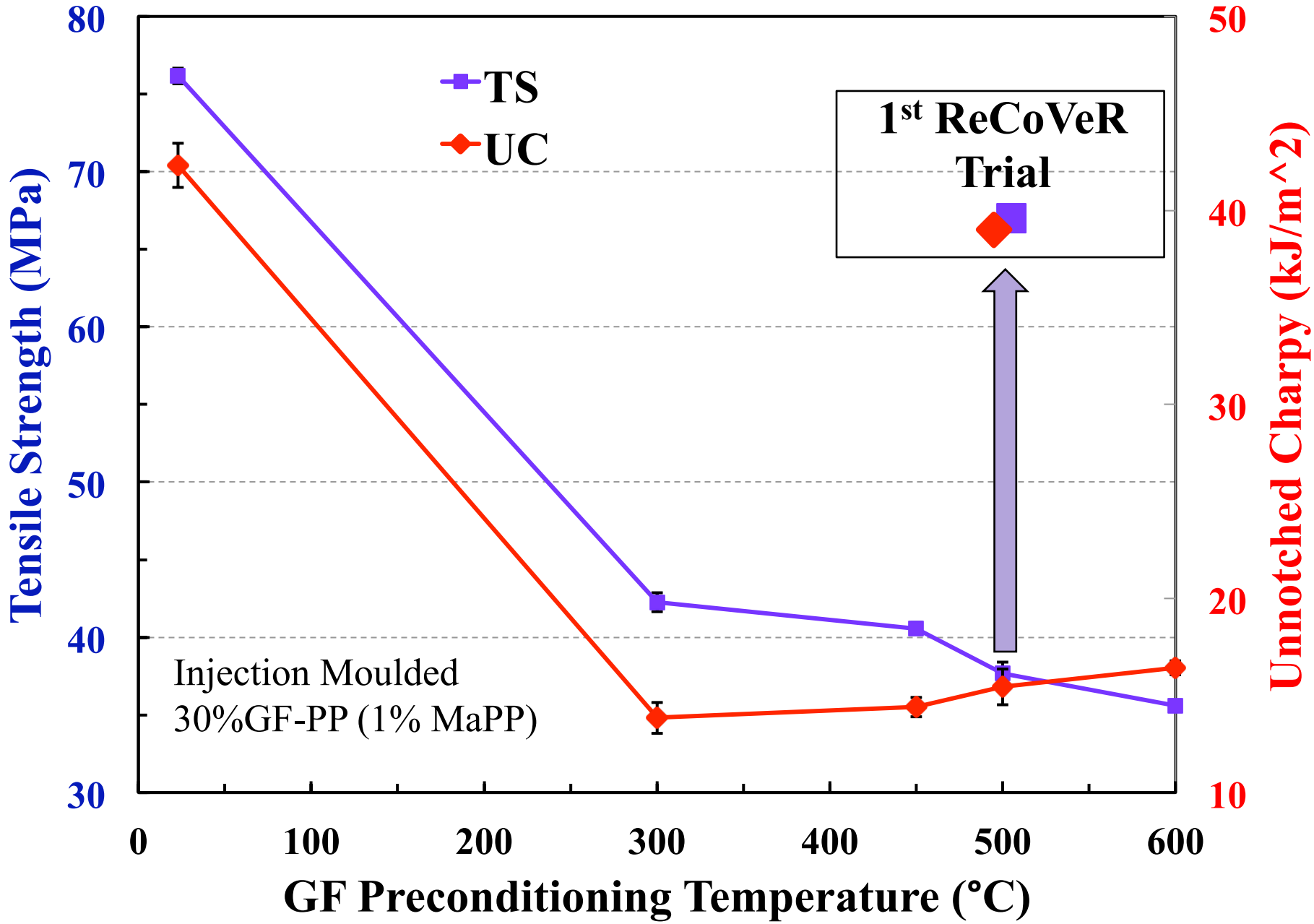
ReCoVeR Composite Performance



ReCoVeR Composite Performance



ReCoVeR Composite Performance



Initial Results on ReCoVeR Glass Fibres in PP Composites

72% ReCoVeRy of Composite Tensile Strength

87% ReCoVeRy of Unnotched Charpy Impact

- Non-optimized sizing on ReCoVeR fibres
- Higher potential ReCoVeRy performance to come
- Patent Application submitted

Conclusions

- **The development of a cost-effective technology to regenerate the properties of thermally recycled glass fibres will have major environmental benefits**
- **Glass fibres lose most of their strength after a short heat treatment above 400°C**
- **Mechanism of strength loss involves both sizing degradation and changes in glass fibre structure**
- **Thermal conditioning of fibres also drastically reduces end-use composite performance**
- **The ACG is developing treatments to ReCoVeR the strength of thermally recycled glass fibres**

New Glass Fibre Sizing Book

This book contains analysis of more than 500 examples of patented size formulations many of which are probably still in use in commercial glass fibre production.

Possibly the most critical component involved in the manufacture of glass fibres and their composites is the fibre surface coating (or size). Yet because of the intense level of industrial secrecy around size formulations there are very few people in the vast chain of composite materials suppliers, processors and end users who have more than a superficial understanding of these coatings. Many questions are raised about glass fibre size by this large and growing composite community. But the most frequently asked is "what is actually in the size on this glass fibre product?"

There is only one source of openly available information on commercial size formulations and that is the patents of the glass fibre manufacturers. This book contains analysis of more than 500 examples of patented size formulations many of which are probably still in use in commercial glass fibre production. The information is tabulated to allow readers to easily identify the similarities and differences between the sizes and their glass fibre products developed for different composite end-use applications, different composite processing techniques, and compatibility with different polymers. Also included is a chapter discussing how patents and their associated information can be used to gain insight into which size formulations may actually be in use in glass fibre production.

Glass Fibre Sizing

James L. Thomason

Glass Fibre Sizing

A Review of Size Formulation Patents

James L. Thomason

Available later this month