



Development of Competitive Prepreg and Welding Thermoplastic Technologies at IRT Saint-Exupéry

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6th International Carbon Composites Conference (IC3)
4-6th of June, 2018



- IRT St-Exupéry is a research foundation, 10 founding members (industrials & academics),
- Bridging research (labs) & inventions (SME, start-ups) to accelerate innovations & facilitate transfer to industry

Nouvelle-Aquitaine



In the Bordeaux-Talence Arts et Métiers campus (July 2016)



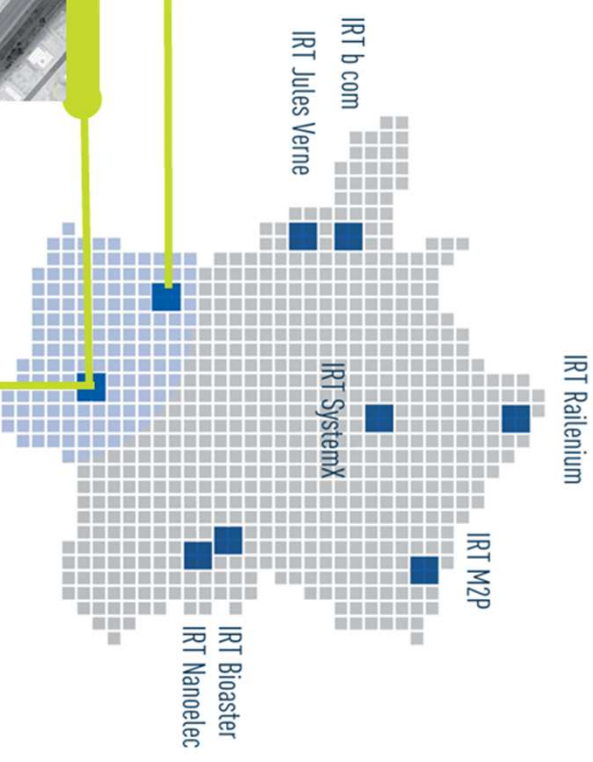
Occitanie



Toulouse Aerospace (beginning of 2018)



Ensemble immobilier :
IRT Saint Exupéry
CEA Tech
Maison de la formation
Espace Clément Ader



Toulouse Rangueil (before 2018)



Industrials

Academics



Laboratories



SMEs

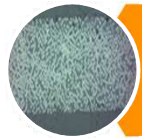


Network



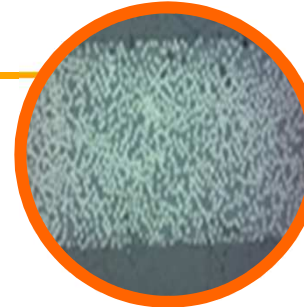
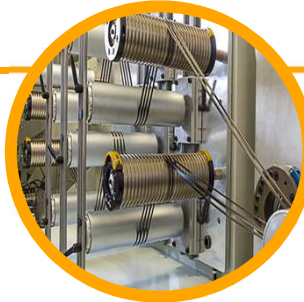
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Materials, Processes & Technologies



Organic Matrix composites

- Thermoplastics, Thermosets
- Functions (electric, damping...)
- HT polymer composites



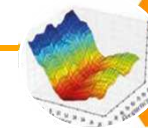
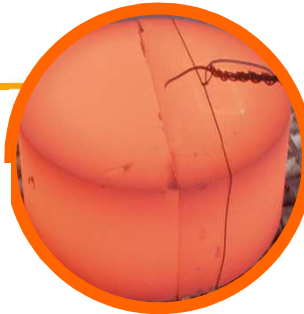
Assembly Technologies

- Surface treatments (Laser/Plasma or traditional)
- Welding for thermoplastics
- Adhesive bonding



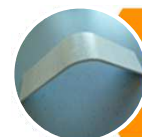
Metallic Materials

- Additive Manufacturing
- Hot Forging
- Ageing & Durability (Ti, Ni, Al Alloys)



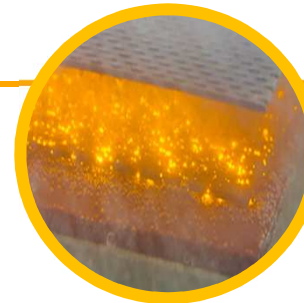
Simulations Technologies

- Database, data reduction
- Material & Process simulation
- Virtual Testing



Ceramic Matrix Composites

- Low cost / Al₂O₃ prepreg
- High-performance resin infused 3D SiC



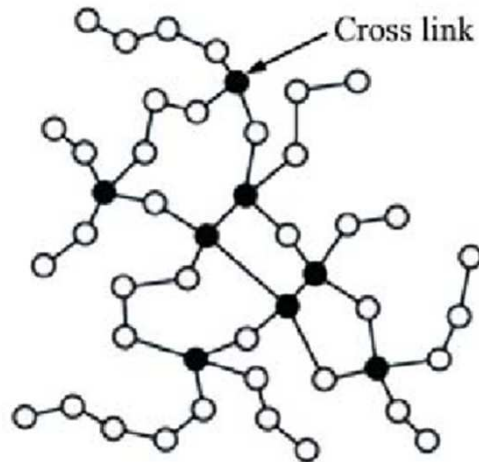
Surface Technologies

- Green(er) Wet processes
- Dry processes (Plasma for painting)
- UV dual-cure Paint / Ink

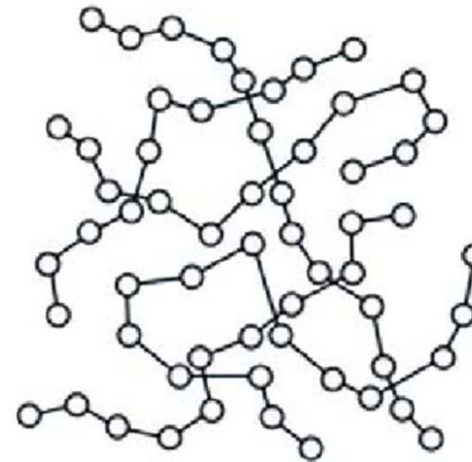
Thermoplastic composite technologies

Material Chemistry determines everything ...

Thermosets



Thermoplastics



Different polymer systems
Different semi-finished products



Different processing conditions
Different composite properties

Motivation for Thermoplastics

Advantages

- Recyclable & of life options
- Novel joining technologies
- Reformable
- High Material Toughness
- No curing chemistry
- Suitable for high volume manufacturing processes

Disadvantages

- High melting temperatures & viscosity
- Control of crystallinity
- Could require semi-finished products
- Adhesives do not work as well
- Lack of suitable ancillary materials
- Industry lacks know-how - New Capital investments required

Growth in a wide variety of markets

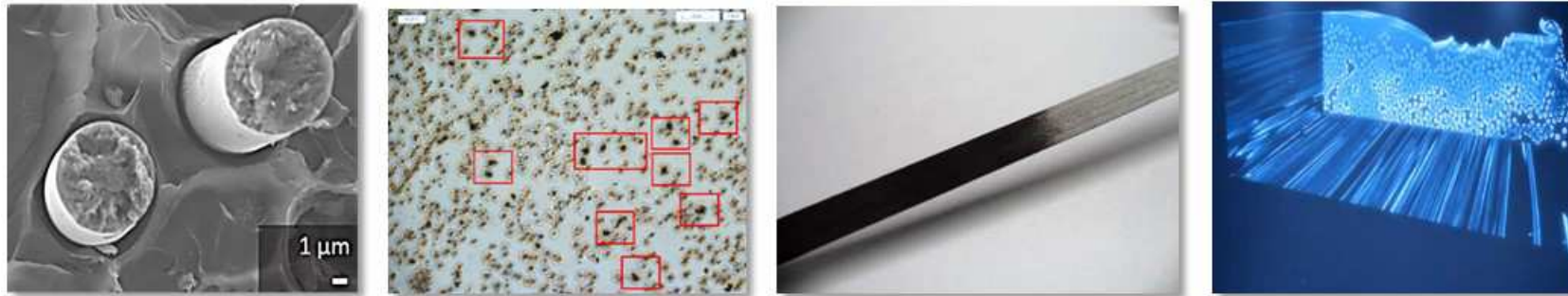
- Medical , Oil & Gas, Automotive, Aerospace ...

Processing technologies becoming more robust ...

- Automated Fiber Placement / Tape Laying
- Continuous Compression Molding
- Thermo / Stamp Forming
- Composite Overmolding

Please, Get out autoclave !

How to optimize robust thermoplastic prepreg for several part manufacturing route ?
How to simplify assemblies ?



Structure-Property Relationship

- **Understand:** Material characteristics (KC) & Process Parameters (KPP)

Route to Industrialisation

- **Define:** Effect of constituents & manufacturing on the long-term performance (eg, fatigue, corrosion), Effect of Defects

Design-to-X

- **Develop:** Material database-Simulations allowing for rapid insertion of new technologies (eg, screening for damage tolerance) & right-1st-time



ARCHITECTURE

- TP prepreg industrial line
- TP prepreg laboratory line
- Positioning for special reinforcement
- Online defect control



RESIN

- Twin-screw extruder line
- Calendar equipment
- High Shear Mixers, Stability analyses, Viscosimeter
- ATG, DSC, Thermomicroscopy

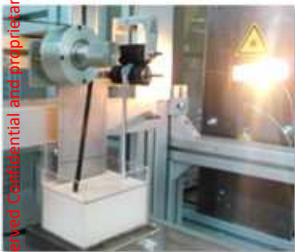
OOA PROCESSES

- Heated hydraulic press
- Induction welding platform
- AFP laboratory consolidation
- Oven consolidation



FIBRES

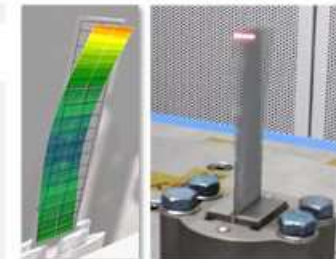
- TP Sizing line
- Surface treatment equipments
- Pull out / Tensile tester
- Microscopy analyses



**STRUCTURE PROPERTIES
RELATIONSHIP
DESIGN TO X – COST
BALANCED**

PERFORMANCE

- Testing machine
- Thermal & Electrical benches
- Electrodynamic shaker (ICA)
- Virtual testing platform



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**INPUTS FROM END-USERS,
CUSTOMERS, TEAMS**

SIZING / DESIGN – INDUSTRIAL
PROCESS – COST OBJECTIVE

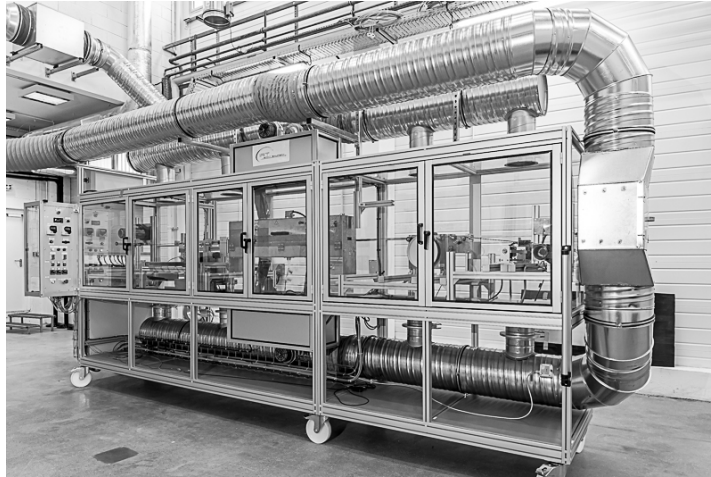
HIGH FIDELITY TRADE OFFS & UNDERSTANDING

ROUTE TO INDUSTRIALISATION

**THERMOPLASTIC SUPPLY
CHAIN**

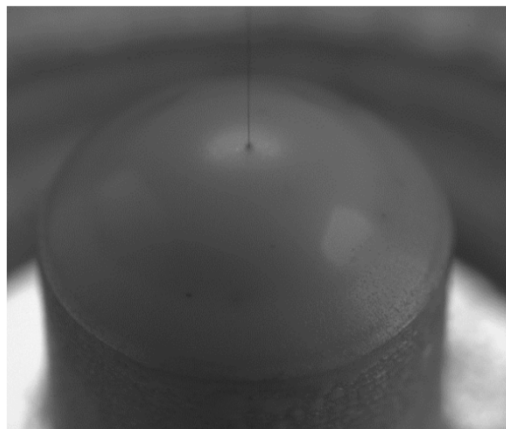
FEEDBACK

**DELIVER INNOVATIVE MATERIALS SOLUTIONS IN
MONTH RATHER THAN IN YEAR**

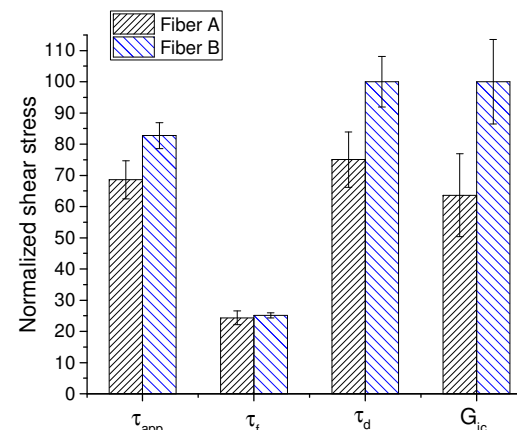


IRT sizing pilot line

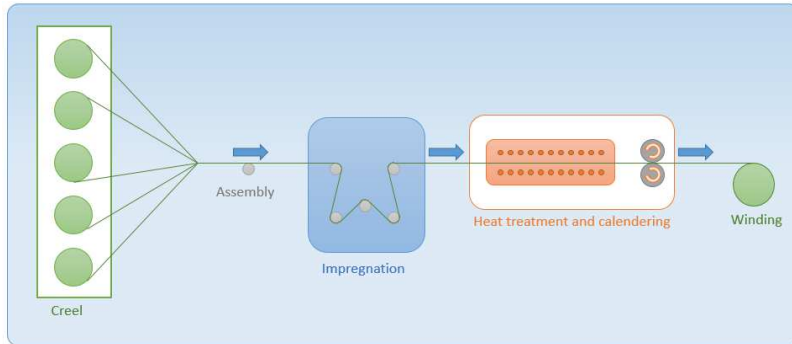
- > Sizing pilot line available
- > PAEK Compatible sizing
- > Multiscale Fiber / Matrix interface analysis



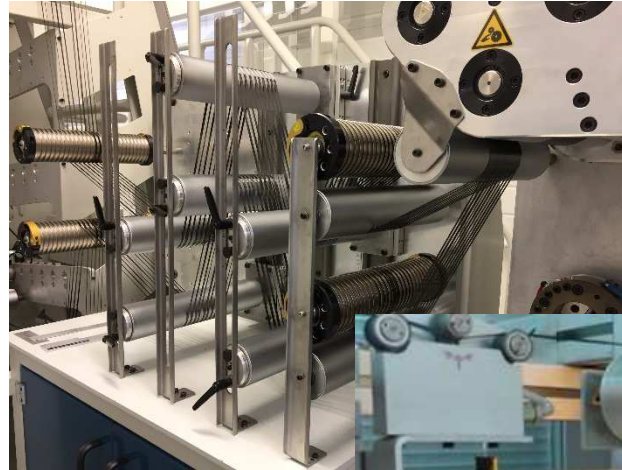
Pull out test – Unsized HR C-Fibre vs TP sizing HR C-Fibre – PAEK



> TP Impregnation pilot line



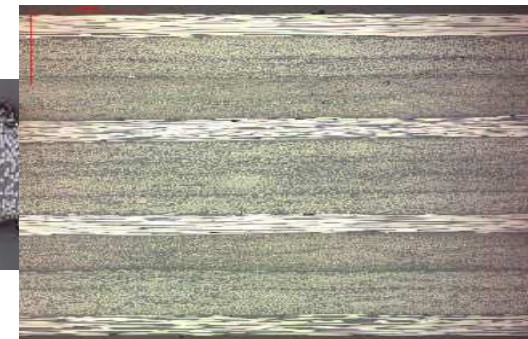
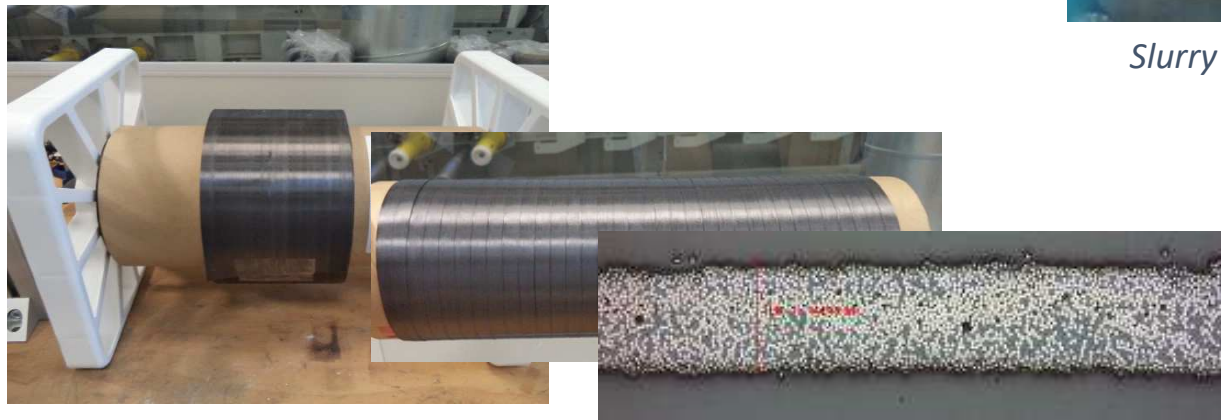
- Plug & Play
- Speed up to 10 m/min
- Sized or unsized fibres (HR,IM, HM)
- Control of process parameters
- Modular



Width max 300mm (creel or unwinding station)



Slurry powder impregnation technology



IRT SE TP UD HR 12K unsized / PAEK matrix 60 %vol TVF

> UD-Tape : a complex process

Polymer Matrix
 Molecular weight
 Polymer structure
 Polymer purity

C-Fibre
 Surface composition
 Surface morphology
 Weight fibre dispersion
 Sizing or Unsized

Impregnation route
 Particle size distribution
 Particle morphology distribution
 Formulation aid (surfactant)

Process Parameters
 Tension @ different process steps
 Particle dispersion homogeneity
 Drying temperature vs time
 Melting temperature vs time
 Calendering temperature vs time
 Compaction pressure vs time

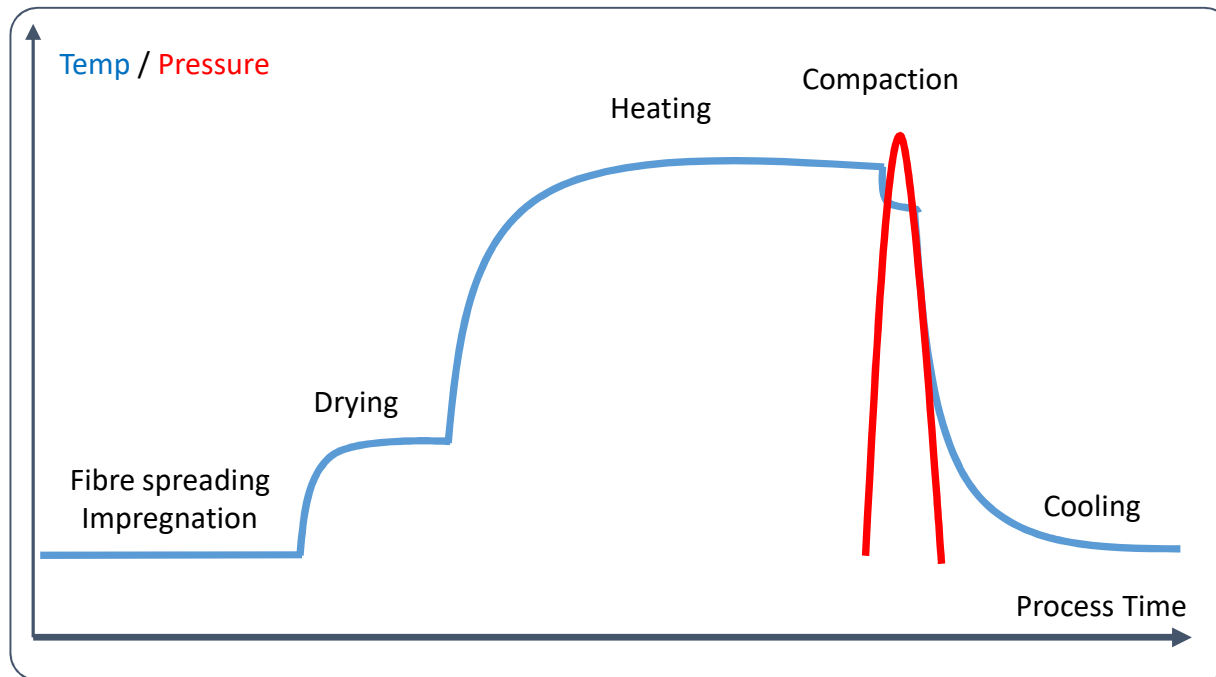


Diagram representing UD-TAPE process (slurry aqueous powder)

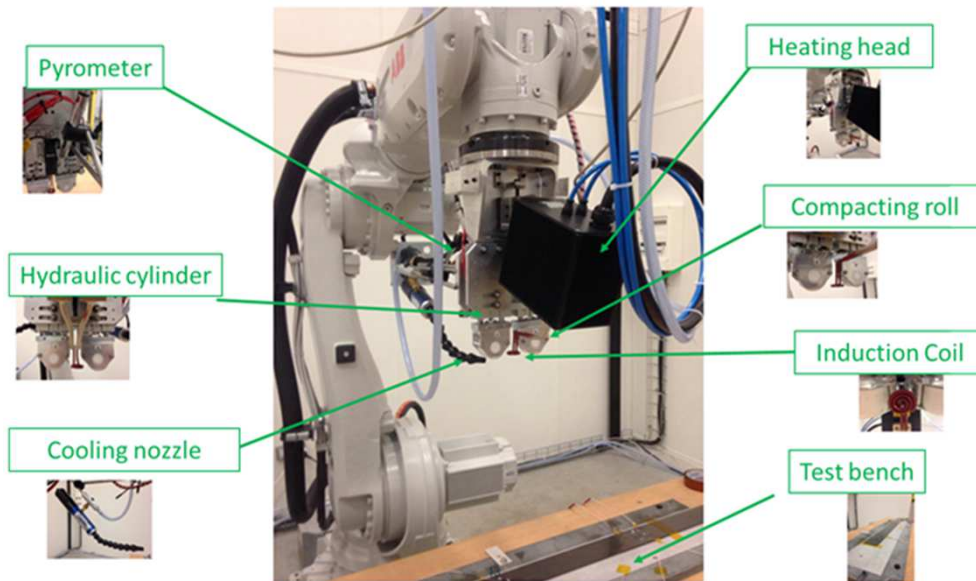
Models & KC Analyses

Ability to predict & quantify

Cost efficient route
 Identify process window
 limitation for manufacturing
 (AFP, ATL, VBO, In-situ,
 CCM,....

Technology portofolio

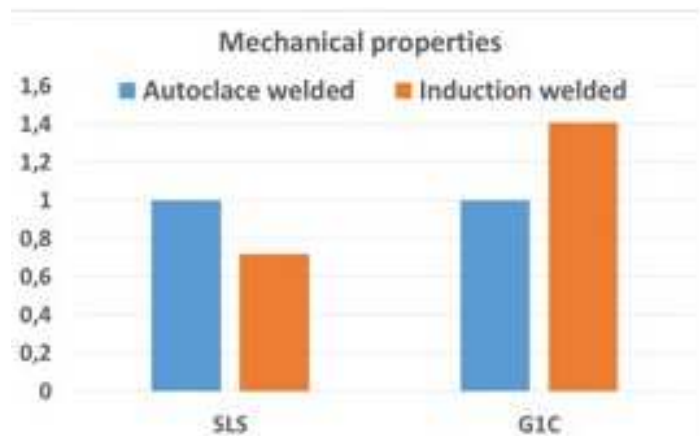
Thermoplastic Welding Technologies



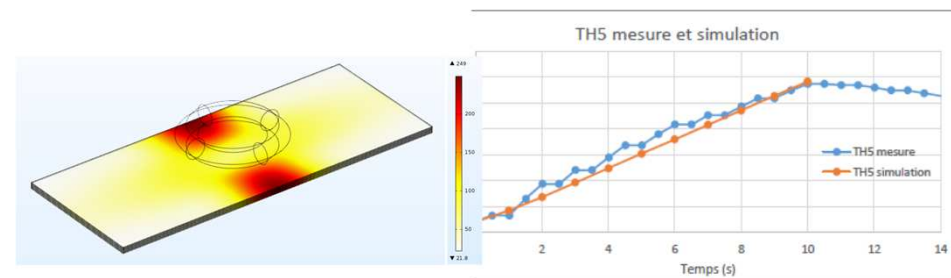
- > Induction welding cellule
- > Susceptorless
- > Mechanical evaluation of welded joints
- > Induction heating simulation



Optical micrography : cross section of a perfectly welded joint



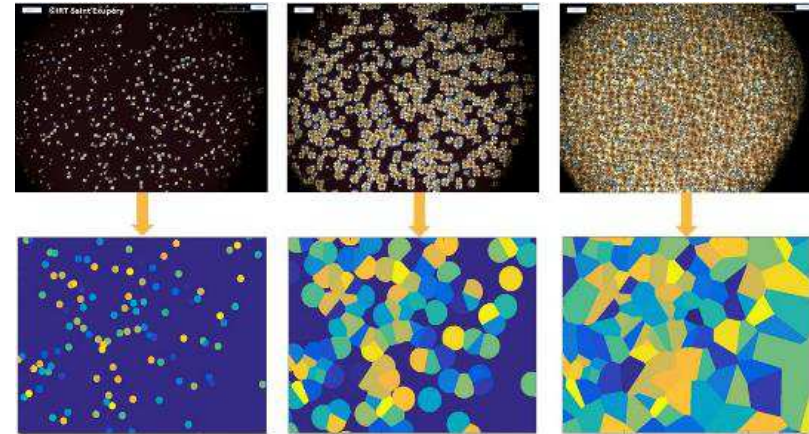
Comparison between welded coupons and autoclave co-consolidation (SLS and G1C)



Electromagnetic and thermal coupling simulation

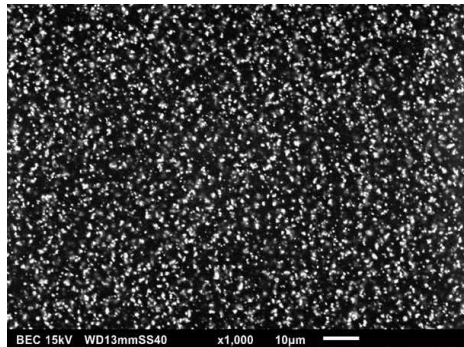
Mechanical & Electrical optimization

- > Crystallization kinetic models available for PEKK
- > Realistic RVE for thermo-kinetic coupling, mechanical, electrical simulation

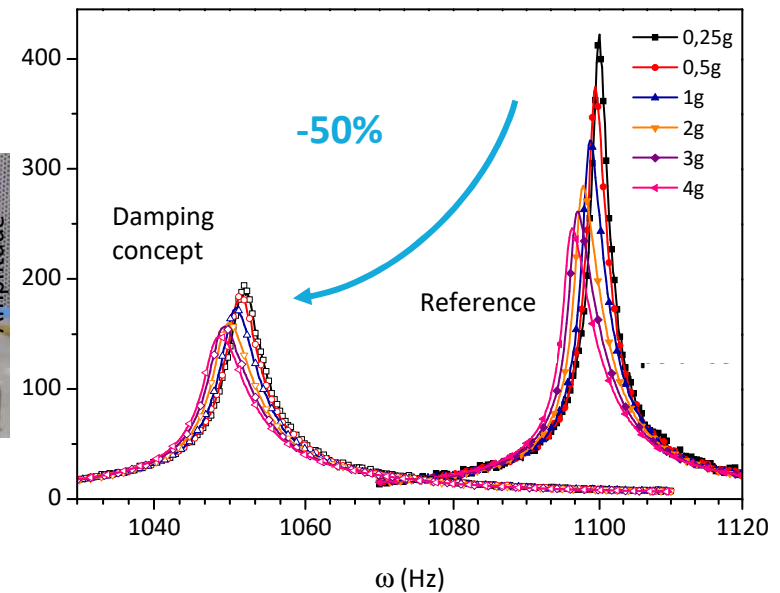


Functionality

- > Enhancement of Electrical conductivity
- > Passive vibration damping
- > Thermal conductivity



Functional polymer PAEK polymer



Damping Functional TP composite
Decrease of bending resonance mode amplitude



Thank you for your attention

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