RESEARCH GROUP

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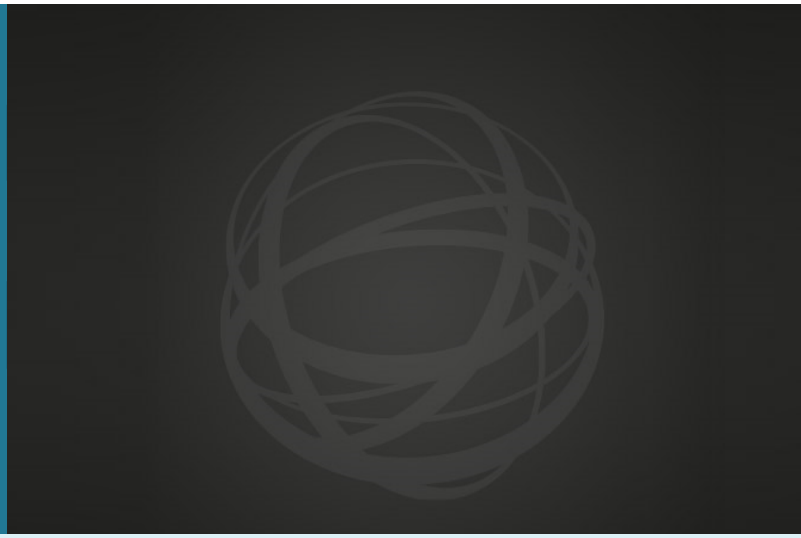
Fibre-based Composites & Interfaces

The main research expertise of this research group is on the development of functional interfaces that will incorporate new generations of multifunctional and ultrahigh-performance composites.



The Fibre-based Composites & Interfaces (FCI) group addresses the development of lightweight composites materials. Our aim is to develop these new materials by focusing both on their sustainability and recycling and an unparalleled performance in terms of weight/mechanical properties while optimizing the core aspect of composite materials: fibre / matrix interfaces. The entire development chain is taken into consideration, from the engineering of materials to their manufacture via design stage optimization and functional tests. Materials classes of interest include reinforcing synthetic and natural fibres, high-performance thermoplastics and thermosets materials and functional hybrid organic thin coatings/sizing to tailor the interface performances.

Main expertise fields

Our activities encompass the characterization, design and development of sustainable fibre-reinforced polymer composites with special focus on performance tailoring of interfaces / interphases and natural fibres.
Sustainable fibres reinforced composites materials:

- Natural fibres reinforced composites
- Hierarchical fibres
- Bioinspired composites materials

Functional interfaces (surface and interface engineering):

- Adhesion (fibre-matrix adhesion and compatibilization of composite constituents, fibre/filament/tape surface activation and chemical treatment, adhesion promotion, nanostructured interphases) and deadhesion (debonding on demand)
- Interface durability
- Thermal & electrical management
- Responsive interfaces
- Self-healing coatings

Composites characterization and analysis:

- In-situ characterization of constituents & interfaces
- Surface characterization
- Filament/tape/coupon testing
- Full-field strain measurement (Digital Image Correlation)
- Microstructural analysis and fractography (SEM, Computed Microtomography)

Research and innovation challenges

- Development of innovative interfacial layers in high performances FRP composites
- Development of bioinspired composites materials by mimicking the structure found in the Nature
- Development of fully bio-based fibers reinforced polymer composites materials including surface treatment approaches to promote adhesion, integrity and functionality of fibre-matrix interfaces.
- Development of structural disassembly and debonding on-demand, as well as recycling routes for composites.
- Development of experimental techniques to characterize interfaces/interphases of composites and connect the nano/micro information to the macro behaviour of composites

Application areas

Automotive, aeronautics, aerospace, building and textile sectors

- Replacement of synthetic fibres by natural fibres for high performance composites applications
- Interfacial layers in high performance CFRP composites
- Interphases with (coupled) mechanical, thermal, electrical, debonding capabilities
- Reuse/repair/recycling of composites materials
- Innovative joining of hybrid systems / dissimilar materials

Main assets

- NFRP composites materials
- Eco-friendly coatings dedicated to fibre-matrix compatibilization of thermoplastic/thermosets with carbon/glass/natural fibres (thermal resistance, moisture absorption)
- Adhesion promoters for metal/polymer assembling
- Antistatic thermoplastic composite
- Thermal dissipative thermoplastic composite
- Functional barrier Coatings (fire, gas, bacteria, water)
- Debonding-on demand solutions
- Self-healable polymer composites
- Advanced multi-scale and multi technique characterization methodologies

Equipment

- Enabling surface treatment technologies: wet and dry processes

Selected publications

- Pitch-based carbon fibre-reinforced PEEK composites: optimization of interphase properties by water-based treatments and self-assembly, A Martin, F Addiego, G Mertz, J Bardon, D Ruch, P Dubois, J. Mater. Sci. Eng, 2016, (5)
- 4D printing of multicomponent shape-memory polymer formulations, Muhammad Yasar Razzaq, Joamin Gonzalez-Gutierrez, Gregory Mertz, David Ruch, Daniel F Schmidt, Stephan Westerman, Applied Science, 2022, 12, 15
- Self-assembly of tetramers of 5, 6-dihydroxyindole explains the primary physical properties of eumelanin: Experiment, simulation, and design, CT Chen, V Ball, JJ de Almeida Gracio, MK Singh, V Toniazzo, D Ruch, M. Buehler. ACS nano 7 (2), 1524-1532
- N. Burger, A. Laachachi, M. Ferriol, M. Lutz, V. Toniazzo, D. Ruch, Review of thermal conductivity in composites: Mechanisms, parameters and theory, Progress in Polymer Science 61, 1-28
- Oussema Kachouri, Julien Bardon, David Ruch, Abdelghani Laachachi, Use of intumescent flame-retardant systems in epoxy adhesives for debonding purpose, Helyion, Volume 10, Issue 3, 15 February 2024, e25240.
- Sebastien Depalfve, David Ruch, Sophie Hermans, Abdelghani Laachachi, Nitrene functionalization as a new approach for reducing the interfacial thermal resistance in graphene nanoplatelets/epoxy nanocomposites. Carbon, 2020.
- C. Mugemana, P. Grysan, R. Dieden, D. Ruch, N. Bruns, P. Dubois, *Macromolecular Chemistry and Physics* 2020, 221, 1900432. Self-healing *metallo*-supramolecular amphiphilic polymer conetworks
- P. Hirchenhahn, A. Al-Sayyad, J. Bardon, A. Felten, P. Plapper, L. Houssiau, Highlighting chemical bonding between nylon-6,6 and the native oxide from an aluminum sheet assembled by laser welding, Accepted in ACS Applied Polym. Mater. (2020)
- Bardon J, Martin A, Fioux P, Amari T, Mertz G, Delmée M, Ruch D, Roucoules V, 2018, Reinforcement of a dodecylacrylate plasma polymer by admixture of a diacrylate or a dimethacrylate cross-linker, Plasma Processes and Polymers, 15(11), p.1800031.
- G. Mertz, M. Delmée, J. Bardon, A. Martin, D. Ruch, T. Fouquet, V. Roucoules, "Atmospheric pressure plasma co-polymerization of two acrylate precursors: Toward the control of wetting properties" Plasma Processes and Polymers (2018), 15(10), 1800073
- G. Mertz et al., Correlation between (nano)-mechanical and chemical changes occurring during photo-oxidation of filled vulcanised Styrene Butadiene Rubber (SBR), polymer Degradation and Stability, 2012 10.1016/j.polymdegradstab.2012.08.008
- B. Brüster, F. Addiego, F. Hassoun, D. Ruch, J.-M. Raquez, Thermo-mechanical degradation of plasticized poly(lactide) after multiple reprocessing to simulate recycling: Multi-scale analysis and underlying mechanisms, polymer degradation and stability

Partenaires

Goodyear Technical Centre, Thales Alenia Space , e-Xstream Engineering, Anisoprint , SOCOMORE

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