MATERIALS SCIENCE AND TECHNOLOGY

ASI - Vitrimeric composite materials for aerospace industry

Funded By	A.S.I. - AGENZIA SPAZIALE ITALIANA [P.iva/CF:03638121008]
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Context of the research activity	The aerospace industry seeks lighter, stronger, and more efficient materials to improve performance and reduce costs. This research explores advanced vitrimeric composites reinforced with carbon fibers for aerospace applications. Vitrimers offer unique features like self-repairability, recyclability, and high mechanical properties. The project will combine experimental and simulation methods to optimize production and assess performance, aiming to advance aerospace materials and sustainability.
Objectives	The aerospace industry continuously seeks lighter, stronger, and more efficient materials to improve performance and reduce maintenance costs of aircraft structures. Among the available options, composite materials are a promising solution, offering numerous advantages over traditional materials. This research proposal aims to further explore the potential of advanced composites for high-performance aerospace applications. The goal is to develop vitrimeric composites reinforced with carbon fibers, optimizing their manufacturing process and assessing their short- and long-term performance. Vitrimers are a fascinating class of polymers that combine the characteristics of thermoplastics and thermosets. Their distinctive feature lies in their dynamic covalent bonds, which allow for reversible chemical reactions and structural rearrangements under appropriate conditions. Unlike conventional thermosets, which undergo irreversible crosslinking, vitrimers can undergo bond exchanges without losing their shape or overall integrity. Vitrimer composites have unique features such as self-repairability, thanks to reversible chemical bonds; high mechanical properties, due to carbon fibers; adaptability and moldability for creating complex shapes; and eco-sustainability, as they are recyclable through low-impact chemical processes and are made from bio-renewable sources. The research will involve both experimental and simulation activities. The synthesis and reactivity of vitrimer monomers will be studied through nuclear magnetic resonance and Fourier transform infrared spectroscopy. Various composites will be developed using traditional fiber impregnation techniques and innovative 3D molding methods in collaboration with the SpereCube company. The composites' properties will be tested through mechanical and thermal analyses, fatigue tests, impact tests, and self-repairability and recyclability assessments.

	Numerical simulation software will be used to predict material behavior and optimize component design, in collaboration with the group led by Prof. Pastrone from PoliTO's Mechanical and Aerospace Engineering Department. The success of this research could lead to significant advances in composite materials for the aerospace industry. These materials may enable the production of more efficient and durable engine blades and propellers, reducing operational costs and aviation's environmental impact. Additionally, the vitrimer resin within the composite could be used to repair cracks from delamination, delaying catastrophic failure. Moreover, the reversible bonds of the vitrimer resin allow for recycling at the end of the material's life without significant degradation or weight loss. The research findings could also be applied to other industries requiring high-performance materials. In conclusion, this proposal aims to contribute to the development of advanced composite materials for aerospace applications through a multidisciplinary approach integrating design, production, and performance evaluation. The results are expected to have a significant impact on the aerospace industry and the advancement of composite material technology. PoliTO's expertise and experience in various fields (ceramics, glasses, composites, metals, nanostructured materials, polymers for additive manufacturing and energy storage) and its specialized laboratories align perfectly with the proposed research activities.

Skills and competencies for the development of the activity	A candidate for this project should possess competencies in chemistry, polymer chemistry and should have basic knowledge on the EU environmental policy especially concerning the circular economy. Moreover, the ideal candidate should possess a good problem solving ability, high communication skills and should be able to work both independently and in a team. The candidate should be able to communicate both in Italian and in English fluently. Appreciated but not required, experience in numerical simulation.