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FURIOUS: Versatile FUran-based polymeRs for strIct and high value applicatiOns in packaging, aUtomotive and underwater environmentS

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Introduction

Plastics are part and parcel of our current everyday life, used to produce both common objects and sophisticated devices, thanks to their exceptional properties including lightweight, durability, versatility and low costs. The European economy is, indeed, still heavily dependent on fossil-based raw materials as a source of plastic production. In this frame, the substitution of fossil-derived monomers with renewable source deriving ones has been targeted as a key issue to be addressed, posing however a difficult challenge in terms of demanding properties that must be achieved by the bio-based polymers. Renewable resources, such as biomass feedstock turned out to be potential sustainable alternatives to produce green chemicals. Polysaccharide feedstocks, abundant in nature and available from agricultural wastes, can be converted into C5- and C6-sugars that can be then transformed into sustainable building blocks for the synthesis of bio-based polymers. In particular, the aromatic 2,5-furandicarboxylic acid (FDCA), considered one of the 12 top value-added chemicals from biomass, can be obtained from sugars like xylose, glucose and fructose, by the catalytic oxidation of 5-hydroxymethyl furfural (5-HMF), which is one of the most investigated routes. Up to now, the intriguing physical/mechanical, oxygen and vapour barrier properties of furan-based polyesters make them the most credible alternative to conventional plastics. However, the best studied furan-based polyester, Polyethylene Furanoate (PEF), is basically stiff and fragile, which strongly limits its applications in sectors far from the rigid packaging. Additionally, limited information is available on the processability of this new class of polymers with respect to conventional polymer processing techniques.

FURIOUS project aims to exploit all the established polymer synthetic strategies to obtain a new class of versatile 2,5-FDCA-based biopolymers (PXF), in terms of *ad hoc* designed chemical structure, processability and recyclability, mandatory features for a real entry of these bio-based polymers as sustainable alternatives to traditional petroleum-based plastics in strict use conditions, as demanded by automotive, packaging and underwater sectors.

Objectives and ambition

FURIOUS will significantly advance in the chemical processes of furan-based biopolymers, by assessing and implementing innovative possibilities, by focusing the *ad hoc* chemical design and

the synthesis on stringent and demanding applications. The result will be the achievement of sustainable processes and products for a variety of applications, opening new opportunities for the exploration of new niche markets and products. The project will enable the use of the proposed synthesis procedures to obtain high quality and high demanding products to be applied under severe conditions. Furthermore, through a circular approach in terms of End of Life (EoL) options, it will contribute to progress in terms of circular economy with zero waste perspectives (Figure 2). This approach will lead to *a)* an advancement in the synthesis of new polymers from 2,5-FDCA with distinct and versatile structures, by generating at the same time valorised products to be applied in demanding sectors, such as *b)* biomedical and electronic packaging. where resistance to sterilization and high barrier properties are required, coupled to tuneable processability to cover both rigid and flexible films, as well as *c)* automotive sector where resistance to UV weathering and intrinsic antibacterial properties are the key objectives, obtainable by selecting electrospinning and injection moulding as reference applicable processes, and *d)* the extreme underwater environment (where the photoreactivity and the biodegradability in seawater of the new polymers will advance in parallel with mouldability of these polymers by 3D printing technologies). FURIOUS not only intends to advance in terms of materials as bio-based alternatives to high performance benchmark products, but aims to investigate the processability of this new versatile family in terms of standard and less conventional processing routes, by making these polymers competitive on the market against conventional ones, in terms of performance, processability and sustainability. On this basis, FURIOUS proposes a highly innovative science-based framework to develop a wide number of sustainable and versatile furan-based materials. In this context, the project will focus on the development and validation of three relevant application contexts: Biomedical and Electronic Packaging, Automotive and Underwater Devices.

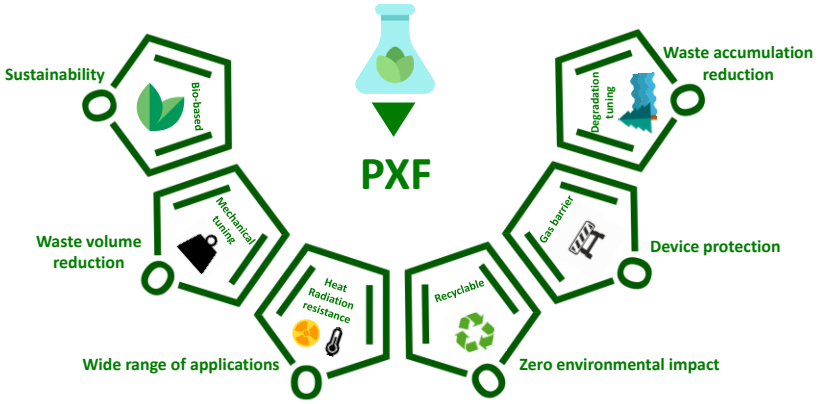

***Figure 2**: FURIOUS general objectives*

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Biography

Mario Milazzo is an Assistant Professor at University of Pisa where he graduated in 2010 in Mechanical Engineering. He received his PhD in BioRobotics in 2016 at Scuola Superiore Sant'Anna. His research interests cover a large number of fields including computational materials science and engineering, mechanics, (bio)materials, mechatronics, and industrial robotics.