

Polyhydroxyalkanoates (PHAs) are well-known polymers in today's medical world. They're valued for their compatibility with our bodies, customizability, and natural biodegradability, standing out as suitable candidates for in-vivo implants, regenerative devices, and medical applications. However, there's a challenge: they're not perfect in terms of strength and mechanical performance. In this project, one of the most important issues connected with these polymers with huge biomedical applications will be addressed and settled. This polymer, in biomedical applications, experiences tensions that could cause mechanical malfunctions. To solve the problem, we need to address the microstructure under the tensions; this microstructure, in polymers, regards crystalline and amorphous phases. Imagine these materials as a tiny, invisible city. In this microscopic city, the crystalline phase is like the sturdy buildings that provide strength and structure, while the amorphous phase is akin to the flexible, adaptable infrastructure connecting everything. Our goal is to explore this microscopic world and unveil the secrets of how the elements of this world transform under stress, akin to unlocking a treasure chest of knowledge about these incredible semicrystalline polymers!

Here our mission steps in – we're blending PHAs with different chemical structures and chain lengths to elevate their capabilities. So, why are we doing this? By understanding their adventures on various length scales (e.g., crystal phase transitions, crystal morphology alterations, initiation of damaging mechanisms like cavity formation, etc.) under external tensile/compression stress fields, we'll succeed in modifying, redesigning, and transforming these blends into leading improved biomedical materials. This could be achieved by shedding light on both microscopic and macroscopic features, governed by the complex hierarchical structures inherent in their semicrystalline nature. In our tiny city, these changes represent the enhancements and modifications we make to the solid structured buildings (the crystalline Phase) and flexible connecting pathways (the amorphous phase), ensuring to re-design of a robust and adaptable material.

This project adopts a multi-scale, multi-stage approach to differentiate the crystalline morphology and amorphous phase structure, topology, and actual state through variations in the molecular structure of PHAs (e.g., different chain length, presence and distribution of comonomer units, etc.) and conditions of crystallization (e.g., modification by blending with copolymers with longer side chains, introducing nucleating agents to improve crystallization kinetics, and removal of inhomogeneities and foreign particles, as well as already present residual nuclei of PHA which act as inherent nucleating agents in the melt).

Subsequently, we will explore the impact of these alterations on several physicochemical parameters (morphological changes, mechanical properties, structure, and evolutions of crystalline and amorphous phases), as well as on the active micromechanisms of deformation and related process instabilities of PHA blends. Experimental studies will be complemented by computer modeling, simulating the deformation of polyhydroxyalkanoates with various structures and crystallinity.

The expected results of this project will bring about a paradigm shift in our understanding of PHA blends, paving the way for advanced, strain-inspired biomedical PHAs. In addition, we are convinced that the outcome of the project will be one more step toward fulfilling Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on legal frameworks for medical devices, especially ANNEX I/ chapter II, requirements regarding design and manufacture.