MATERIALS SCIENCE AND TECHNOLOGY

CRT/DISAT - Towards sustainable Flame-Retardant polymers: processing, microstructure, and performance relationships

Funded By	Dipartimento DISAT FONDAZIONE CRT CASSA DI RISPARMIO DI TORINO [P.iva/CF:06655250014]
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Context of the research activity	The project investigates how processing parameters (extrusion, injection molding...) affect the structure and flame-retardant performance of filled thermoplastics. It aims to develop quantitative correlations and predictive models to optimize processing conditions, enhancing fire safety, mechanical integrity, and sustainability within an Industry 4.0 framework.
Objectives	Context of the Research Activity. The development of flame-retardant (FR) thermoplastic materials is a crucial topic in materials science, driven by fire safety regulations and the growing need for sustainable solutions. Although FR systems are increasingly used, their effectiveness strongly depends on processing parameters such as extrusion and injection molding conditions, which affect filler dispersion, morphology, and thermal–mechanical behavior. Currently, only limited research has systematically investigated the relationship between processing variables and flame retardant performance. Understanding these correlations is essential to define optimized compounding, extrusion and injection molding strategies that ensure consistent FR efficiency and mechanical integrity. This PhD project aims to explore the links between processing conditions, material structure, and flame retardant behavior in filled thermoplastic systems. The work contributes to the broader goals of Industry 4.0, promoting intelligent process control and data-driven materials design for safer and more sustainable polymer technologies. _____ Objectives. The project aims to establish a quantitative relationship between processing parameters and flame retardant performance of thermoplastic compounds. Specific objectives are:

	1. To investigate how extrusion and injection molding variables (temperature, shear rate, residence time, cooling rate) influence filler dispersion, crystallinity, and interfacial properties. 2. To characterize the resulting materials through morphological (SEM), thermal (DSC, TGA), rheological, mechanical (DMA, tensile), and fire performance tests (LOI, UL-94, cone calorimetry). 3. To develop predictive correlations between process parameters and FR efficiency using also statistical and computational tools (DoE, regression, machine learning). 4. To identify optimal processing windows maximizing FR performance while maintaining mechanical and environmental integrity. 5. To provide design guidelines for polymer processors and contribute to the scientific understanding of processing–microstructure-performance relationships in flame-retardant systems.

Skills and competencies for the development of the activity	Candidates should possess: A strong background in polymer science and technology, with knowledge of polymer structure, processing, and characterization and high motivation to learn through advanced research. Understanding of flame retardant systems and basic principles of fire inhibition in polymers and experience with fire testing and thermal analysis, such as LOI, UL-94, cone calorimetry, DSC, and TGA. Familiarity with polymer processing techniques, particularly extrusion and injection molding, and the ability to interpret process–structure relationships. Competence in data analysis and experimental design, ideally including basic statistical or computational modeling skills. Good communication and teamwork skills, enabling collaboration in multidisciplinary research and industrial contexts. Practical attitude for the lab activities and problem-solving skills are also appreciated.