CHEMICAL ENGINEERING

AMMIN/DISAT - Design and engineering of materials and devices for hemodialysis

Funded By	Dipartimento DISAT Politecnico di TORINO [P.iva/CF:00518460019]

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Context of the research activity	The project develops high-performance hollow-fiber membranes for hemodialysis and continuous renal replacement therapy (CRRT) by integrating nanomaterials, advanced characterization, and AI. Led by Profs. Cauda and Ferri with Dr. Carofiglio and Dr. Marcato, it focuses on functionalizing membranes to improve biocompatibility and reduce fouling. By combining experimental data (SEM, XPS) with CFD simulations and Machine Learning, the PhD thesis aims to optimize mass transport and create a rational design for next-generation clinical filters.

Objectives	The experimental activity is structured into two complementary lines. The first (led by Prof. Cauda) concerns the design and functionalization of membranes using nanomaterials, leveraging the TNHLab group's expertise in the synthesis and characterization of nanostructures for biomedical applications. Surface treatments of polyarylethersulfone (PAES) membranes will be explored to improve biocompatibility, reduce protein fouling, and modulate selectivity toward solutes of clinical interest. Experiments will be conducted using hemodialysis machines on filters with fibers in clinical use, supported by Dr. Marco Carofiglio. The second line (led by Prof. Ferri) focuses on the advanced characterization of hollow fibers and the microstructural properties of membranes. This utilizes the Comfort Lab's expertise in analyzing fibrous materials for biomedical applications through scanning electron microscopy (SEM), thermal analysis (TGA, DSC), and spectroscopic techniques (FT-IR, XPS) to correlate membrane microstructure with transport performance. The modeling and computational activity, led by Dr. Agnese Marcato as the third proponent, involves CFD (Computational Fluid Dynamics) simulations and the development of surrogate models using machine learning for the optimization of hemodialysis systems. The originality of the project lies in the systematic integration of nanostructured materials design, advanced experimental characterization, and predictive modeling applied to renal replacement therapy devices. The

	expected impact is significant both on a scientific level—advancing knowledge of transmembrane transport phenomena in hollow-fiber filters—and on an applicative level, opening concrete perspectives for the rational design of enhanced-performance filters in clinical settings.

Skills and competencies for the development of the activity	The candidate must be familiar with transport phenomena in filtration processes and in porous/heterogeneous media. Knowledge of multiscale upscaling techniques for the governing equations and, in general, the modeling of the chemical and physical phenomena involved using computational fluid dynamics codes is also required. Previous knowledge of machine learning is appreciated but not required.