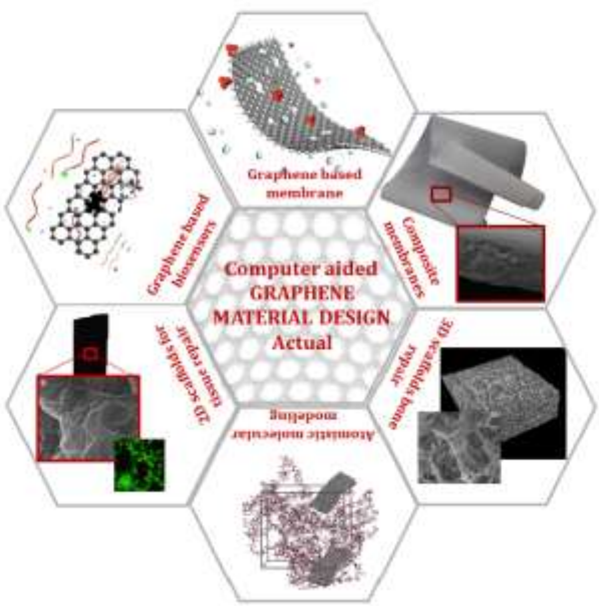
Abstract

The habilitation thesis titled **Graphene based biomaterials: opportunities, perspectives, and challenges** address scientific contribution to the recent advance in graphene biomaterials research, a topic that has significantly influenced the landscape of tissue and membrane engineering.The first section is grounded to the context and recent advancement in graphene biomaterials research for tissue and membrane engineering and brief overview of my research track within the framework aforementioned topics. Scientific achievements concerning a very complex applicative research which aimed at an improved understanding and the knowledge-based design of high performance biopolymer-graphene biomaterials for bone regeneration which provide a much improved effectiveness and economically feasible alternative for current treatment options in the restoration of non-healing bone defects are presented. 2D and 3D biomaterials potentially attractive for bone repair based on biopolymers (sodium alginate, chitosan, and gelatin), synthetic poly (vinyl alcohol) and graphene derivatives were proposed and investigated under the complex condition envisaged by real-life bone repair application. The obtainment of effective bone graft substitutes was possible by an attentive choice of key parameters, i.e. the nature and amount of the selected scaffold material, processing methods and conditions used in the fabrication of the two and three-dimensional material. Interdisciplinary assessment of graphene based biomaterials features by coupling medical science, biology, materials science, chemistry, and *in silico* techniques were performed. Good GO dispersion within the polymer host and alterations of the structure and morphology of the scaffolds materials were observed. Thermal and mechanical stability of the composites was improved, by adding GO within the polymer matrix. Analysis concerning swelling behavior and enzymatic biodegradation of the GO based composites indicated that both are governed by GO amount. Conversely, the ability of scaffolds materials to form apatite like crystals were also investigated and formation of mineral deposits it appears not to be a function of GO presence / content. In vitro assessment in terms of biocompatibility and osteogenic properties ensured that the GO-polymer bone graft substitute material sustains bone cell attachment, proliferation and differentiation. The in vivo performance of the biopolymer-graphene biomaterial in mice model displayed a much improved effectiveness and seems a feasible alternative for current treatment options in the restoration of non-healing bone.

Another accomplishment of my research activity was to design relevant graphene / polymer composites which endorse a much improved trade-off between permeability and selectivity with various other properties needed to ensure processability and durability considering the complex milieu of real life application. The aim is pursued by combing the low cost and ease of membrane formation / fabrication associated with conventional polymers with outstanding graphene properties and ultrasound treatment (US). US treatment effectiveness on graphene dispersion and modulating the US treatment in order to get best performance material membrane is described. High-performance composite membranes based on graphene /graphene derivatives and aromatic polymers i.e. polysulfone or cellulose acetate were successfully fabricated. The effect of graphene and graphene derivatives on membrane materials structure, morphology, topography, hydrophilic-hydrophobic character as well as thermal,

mechanical and biological behavior was thoroughly evaluated. Furthermore water and ethanol permeation, bovine serum albumin rejection assay and in vitro cells viability, proliferation and adhesion on nanocomposite membranes were evaluated. The combined results indicated that a suitable amount of graphene oxide added to polymer matrix not only improves the membrane performance in terms of flow and stability but also increases the bovine serum albumin rejection degree. Another focus was investigating the effects of carbon nanotubes (CNTs) and GO incorporation in cellulose acetate (CA). Synergic positive effects of GO and CNT incorporation on the structure, mechanical and biological properties suggesting CA/CNT/GO composite material most promising for biomedical applications. The results presented in the current chapter clearly establish a solid foundation towards more efficient biomedical separation process and contribute to the exploration of the frontiers of knowledge and will support long-term innovation in the field.

The Professional Development Plan presented in the last chapter of the current work seeks to express ambitious and visionary goals but has a realistic plan with achievable indicators against which me /us as a team and third parties can measure our progress. The aspirational objective reflects my highest hopes i.e. help millions of people with cost efficient and improved treatments for wide variety of diseases and make Romania the place where the promise of artificial organs becomes a reality. The commitment objective envisages basic scientific research which provides the groundwork for therapy development and preclinical research dedicated to graphene based biosensor for testing osteogenic stem cell potency, multi-scale computer-aided molecular design and engineering of super carbonaceous materials for selective separation, knowledge-based design of polymer-graphene bone graft substitutes and Bioactive nano-engineered implants.



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Graphical abstract