Transilvania
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HABILITATION THESIS

SUMMARY

Title: Functional polymeric materials obtained with ionic liquids auxiliaries and additives

Domain: Materials Engineering

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BRAŞOV, 2021

Abstract

The habilitation thesis *Functional polymeric materials obtained with ionic liquids auxiliaries and additives* presents my research results after obtaining of the Ph.D. in materials engineering in 2010, related to obtaining, processing, and additivating different synthetic and natural polymer materials with ionic liquids. Ionic liquids are a class of organic compounds with negligible vapor pressure, trending in many fields such as materials engineering, energy materials, electrochemistry, synthesis, and so forth.

Throughout the material presented in the habilitation thesis, I have demonstrated the usefulness of different types of *ionic liquids* as antistatic agents, ionizing and UV radiation stabilizers, cleaning agents, solvents, carriers for various polymers. The results also extend to obtaining polymer matrix composites, materials with hydrogen storage capacity, or polymeric gels with increased adsorption capacity towards heavy metal ions or dyes. What makes these ionic liquids unique is their highly tunable character. They can be obtained through synthesis to match practically any desired property value in terms of polarity, thermal and radiation stability, electrochemical window, hydrophilicity/hydrophobicity.

My multidisciplinary scientific achievements (B2 section) are structured into four chapters: 1. *Ionic liquids for the development of polymeric materials*; 2. *Ionic liquids as additives and auxiliaries for polymeric materials*; 3. *Polymer matrix composite materials via ionic liquids,* and 4. *Polymeric gel materials via with ionic liquids.* The thesis also presents discussions regarding the *Evolution and development plans for career development* (B3 section).

Chapter one presents an overview of the main types of ionic liquids, their importance to polymeric materials science, their advantages, and limitations they possess. This chapter also reviews these compounds' primary uses in obtaining and processing synthetic and natural polymer materials.

Chapter two presents my original research results indicating that ionic liquids could tune the properties of polymeric materials to a great extent. This chapter demonstrates ionic liquids' usefulness as UV and ionizing radiation stabilizers for cellulosic materials (cellulose fibers and wood). The polymeric materials present a high uptake affinity for ionic liquids. Their radiation-protecting effect is directly proportional to their ability to be retained on the material's surface (which depends on their hydrophobic character and molecular mass). Ionizing radiation (such as high-energy electron beams) can generate active radical species in ionic liquids, which is useful because it can promote grafts on the polymeric material's surface. Due to their ionic character, ionic liquids can serve as antistatic agents for polymer materials determining an increase in the material's surface electrical conductivity.

The results of my research have indicated that ionic liquids can also serve as plasticizers for cellulosic materials. As opposed to conventional plasticizers, ionic liquids determine a remarkable increase in the strain at the breaking point of cellulose and wood and an increase in the tensile strength due to the macromolecular rearrangements they can promote in polymers.

An application of the ionic liquids was also exemplified in this chapter, as auxiliaries -solvents for different biopolymers and natural resins –, and carriers -dispersing agents for particulate inorganic compounds- for impregnation and coating of wood. A useful feature of ionic liquids is that they are both a vehicle for the impregnant while also having the ability to swell the polymer matrix.

Due to their high solvation ability for cellulose and small-molecular compounds, ionic liquids have been found useful as cleaning restoration agents for old paper artifacts by merely washing the material with an aqueous or alcohol solution of the ionic liquid. The degraded compounds from the paper artifact, which are the cause of yellowing or staining, are washed out, and the brittleness and toughness of the cellulose can be restored.

Chapter three presents a few case studies where ionic liquids can act as multipurpose additives to obtain multifunctional composite materials. Usually, multiple additives need to be compounded in a typical polymeric

composite material for each required function (compatibilization, stabilization, etc.), but by using ionic liquids, multiple functions can be served by one the same compound. Ionic liquids act as good compatibilizers between thermoplastic polymer matrices and organic (wood, cellulose fibers) or inorganic reinforcing agents and fillers. At the same time, they provide water action resistance, UV stability, and function as biocides (i.e., fungicides).

Ionic liquids can serve as laser ablation media for graphite to obtain nanomaterials, such as multi-walled carbon nanotubes. They also improve nanomaterials' dispersibility and compatibility (e.g., multi-walled carbon nanotubes) with thermoplastic polymer matrices.

By exploiting ionic liquids' high solvation ability, composites comprised entirely of biopolymers can be obtained, resembling agglomerated wood panels without thermosetting polymers in the composition. A final application of ionic liquids presented in this chapter is related to obtaining composite aerogels comprised of a cellulose/palladium-on-carbon/ionic liquids structure. The composite materials show high hydrogen storage capacities at room temperature, making them viable candidates for energy storage applications.

Chapter four presents my research using ionic liquids as solvents and porogens for obtaining biopolymer hydrogels by a physical crosslinking method, namely the application of repeating alternate freezing and thawing cycles (cryogelation). The obtained hydrogels present good water stability and show a high sorption ability for heavy metals ions and dyes. Ionic liquids enable extending the cryogelation method to biopolymers, challenging to be dissolved otherwise in conventional solvent systems. Also, this chapter describes and models the behavior of poly (vinyl alcohol) hydrogels in an ionic liquid solution with various concentrations.

Future development of my (didactical) academic career is presented in **section *B3*,** alongside future research directions. The latter includes:

- synthesis of custom-made ionic liquids from "green" natural sources;
- assessment of the environmental and health impact of ionic liquids;
- extending ionic liquids' application to the obtaining of composites with other types of synthetic polymers besides polyolefins;
- application of ionic liquids in the valorization of polymer wastes, and
- synthesis of hybrid metal/ceramic coatings and films for photocatalytic applications.

My research activity has materialized in the publication of 38 papers with impact factor (indexed by Clarivate Analytics Web of Science) and 15 ISI-proceedings articles. I was project director for 3 research projects, and the visibility of my research is reflected by my h-index of 10 (Clarivate and Scopus). I am a full editor of the Journal of Materials Science (Springer, impact factor 3.553), and I am a reviewer of national projects financed by UEFISCDI.