

ABSTRACT

The habilitation thesis entitled *“Contributions to the development of nano- and biomaterials with electrotechnical applications”* synthesizes an extensive research activity structured into three major directions, reflecting a natural progression from sustainable materials derived from recycled resources to nanocomposites with controlled architecture and nanostructured materials activable in electromagnetic fields. The general aim of the thesis is the development of advanced functional materials with optimized dielectric, electromagnetic, thermal, and structural properties, capable of meeting the current requirements of modern electrotechnics and materials engineering.

The first research direction focuses on **sustainable biocomposites for electrotechnical applications**, starting from the integration of natural materials (sawdust, cellulosic fibers, feather flour) and recycled polyolefins (PP, PE, PET) into functional composite systems. Efficient polymer–organic phase compatibilization methods were demonstrated, biocomposites with improved mechanical and dielectric behavior were produced, and their potential for replacing conventional materials in electrical insulation, lightweight construction, and technical panels was validated. By implementing combined recycling processes, including microwave sterilization, extrusion, and injection, a sustainable technological strategy was established, supported by ecological impact indicators (DOC, TDS, heavy metals). The biocomposites developed within this direction contribute to defining the concept of eco-electrotechnical materials and integrating circular economy principles in materials engineering.

The second research direction addresses **anisotropic nanocomposites with architecture oriented in electromagnetic fields**, representing an advanced stage of the scientific program. Through electric or magnetic field-induced orientation (BN, BaTiO₃, carbon fibers; Fe₃O₄, Fe₂O₃, Ni–Zn ferrites), materials with directional thermal conductivity, enhanced dielectric permittivity, and controllable piezoelectric response were obtained. The research demonstrated that field-driven particle organization generates preferential pathways for thermal and electrical transport, relevant for thermal management, electromagnetic shielding, flexible sensors, and energy harvesting. This direction is complemented by the development of 3D directed architectures, such as core–shell filaments, ceramic nanotubes, and piezoelectric nanofibrous networks, obtained via techniques such as 3D printing, electrospinning, and field-assisted sintering. Numerical modeling (CST, COMSOL) and optical-algorithmic analysis enabled the quantification of anisotropy and optimization of filler distribution, building a predictive framework for designing intelligent materials.

The third direction focuses on **nanostructured materials activable and thermoformable in electromagnetic fields**, oriented toward modern industrial applications. Thermoplastic composites and reversible adhesives incorporating metallic nanoparticles were developed, capable of converting electromagnetic energy into localized heat, enabling rapid and energy-efficient bonding–debonding processes. Functional paints and coatings with EMI/ESD properties and enhanced resistance to UV radiation, moisture, temperature, sali

environments and biological factors were developed. Furthermore, magnetodielectric composites and selectively recycled electronic waste were integrated into materials with advanced electromagnetic shielding capabilities. Life cycle assessment (LCA) and multi-factor durability analyses highlight the ecological relevance and technological feasibility of the proposed systems.

Together, the three research directions define a coherent scientific trajectory, progressing from sustainability and recycling to electromagnetic control and intelligent activation of materials. The results are supported by a substantial scientific output (Q1–Q2 journal papers, IEEE conference proceedings, and international collaborations), confirming the maturity, originality and relevance of the research.

Building upon these findings, a **future research direction** is proposed: the development of **nanostructured materials for electrochemical sensor applications**. Leveraging previous achievements in oriented architectures, ceramic nanotubes, functional thin films and 3D-printed composites, this direction aims to create high-sensitivity sensing platforms with controlled geometries, enhanced electrochemical stability and integration potential in flexible and miniaturized electrotechnical systems. Combining electromagnetic activation capabilities with tailored nanostructures may enable innovative, sustainable and efficient electrochemical sensors for environmental monitoring, biomedical diagnostics and micro-analytical technologies.

Overall, the habilitation thesis demonstrates an integrated, interdisciplinary and application-oriented approach to the design and validation of advanced composite and nanostructured materials, confirming the author's ability to independently coordinate and develop complex research directions in the field of electrotechnical materials science.

In the second part of the thesis, the author presents her career trajectory over recent years, highlighting the most significant achievements in both teaching and research, thereby demonstrating the fulfilment of the national minimum standards required and mandatory for the public defense of the habilitation thesis.