MINISTRY OF EDUCATION AND RESEARCH
TECHNICAL UNIVERSITY
OF CLUJ-NAPOCA, ROMANIA

Fundamental field: Engineering Sciences
Specialisation: Materials Engineering

# HABILITATION THESIS

## – ABSTRACT –

**Advanced Soft Magnetic Materials for Efficient Energy Conversion**

**Assoc. Prof. Eng. Bogdan Viorel NEAMȚU, PhD**

**Faculty of Materials and Environmental Engineering**
**Technical University of Cluj-Napoca**

**– Cluj-Napoca –**
**2025**

# TABLE OF CONTENTS

## Abstract

This habilitation thesis, entitled *Advanced Soft Magnetic Materials for Efficient Energy Conversion*, synthesizes the research and academic activities I have carried out since the defense of my PhD thesis in October 2010 and the awarding of the doctoral degree in June 2011. The manuscript describes both the scientific achievements and the career development plan of the author, reflecting a consistent trajectory in the field of materials engineering.

The manuscript is organized into two main sections. The first, *Scientific Achievements*, opens with a brief overview of the historical development of soft magnetic materials, highlighting the need for continued progress in this field. Building on this context, the section then presents my original research contributions to the advancement of soft magnetic materials.

The first part of the Scientific Achievements section is cantered on the study of Fe-based and Co-based amorphous alloys obtained mainly through mechanical alloying. Mechanical alloying is a non-equilibrium processing route that was systematically explored to identify the conditions favouring amorphization and the optimization of magnetic properties. Detailed comparisons between wet and dry milling, as well as between mechanical alloying and rapid quenching, have provided valuable insight into the role of processing routes on structural evolution. A particularly significant finding was that the uptake of carbon originating from the decomposition of the process control agent plays a critical role in amorphization of the alloys. At the same time, partial substitutions with elements such as Zr, Ti, or Ta proved effective in tailoring the thermal stability, crystallization kinetics, and magnetic behaviour of both Fe-based and Co-based alloys.

Another original contribution consists of the design and development of fibre-based soft magnetic composites, a completely new class of materials introduced for the first time by the author. The concept was validated through an extensive program of experimental investigations, which began with comparisons of fibre- and powder-based composites and continued with systematic studies on the effect of fibre diameter, orientation, coating type and thickness, and compaction route. The integration of amorphous fibres and cold sintering techniques further enhanced the performance of these composites, which were shown to hold significant potential for use in inductors, transformers, and high-efficiency electric motors. In this way, the technological relevance of the achievements in the field of soft magnetic materials is ensured by combining fundamental knowledge with innovative technological solutions.

The professional trajectory began with doctoral training within a joint program between Joseph Fourier University in Grenoble, France, and the Technical University of Cluj-Napoca, Romania. The PhD thesis, defended in October 2010, focused nanocrystalline soft magnetic compacts obtained from Ni-Fe-X alloy powders synthesized by mechanosynthesis and provided solid expertise in non-equilibrium processing and advanced characterization methods. Following the completion of the doctorate, the author made continuous efforts to establish an independent research profile. The first major step was securing in 2013 a national research grant "Amorphous soft magnetic Fe-based and Co-based powders and cores prepared by mechanical alloying and spark plasma sintering" (PN-II-RU-TE-2012-3-0367). This project offered the opportunity to develop a new route to amorphous soft magnetic materials, combining mechanical alloying with spark plasma sintering to obtain dense compacts that preserved superior properties such as high saturation magnetization, low coercivity, and good thermal stability. Beyond the scientific outcomes, which included seven ISI-indexed papers and three proceedings papers, the project contributed to strengthening

collaborations with CNRS–Institut Néel in France and the National Institute of Research and Development for Technical Physics in Romania, while also consolidating experience in project management and research supervision.

A second national project, awarded in 2018, "Fibres-Based Soft Magnetic Composites Prepared by Cold Pressing and Spark Plasma Sintering" – FSMC (PN-III-P1-1.1-TE-2016-0649) (https://neamtubogdan.wixsite.com/fsmc), represented a turning point in my career. Focused on the development of fibre-based soft magnetic composites obtained by cold pressing and spark plasma sintering, this project enabled the introduction of an entirely new type of soft magnetic of composites. The results confirmed the superior magnetic behaviour of fibre-based systems compared to conventional powder-based ones. Extensive investigations covered variables such as dielectric type and proportion, compaction parameters, annealing treatments, fibre geometry, and degree of orientation. The project led to five ISI-indexed publications and the initiation of new international collaborations with Imperial College London, Brose Fahrzeugteile in Germany, and RWTH Aachen University. The recognition of these results at international level significantly increased the visibility of the research.

Building on this foundation, a third national grant was secured in 2021, "Cold Sintered Soft Magnetic Composites Based on Amorphous Ferromagnetic Fibres" – CS-FSMC (PN-III-P4-ID-PCE-2020-0175) (https://neamtubogdan.wixsite.com/cs-fsmc). This project further innovated by employing amorphous fibres instead of crystalline ones, thereby pushing the performance limits of fibre-based composites. Advances in coating technologies reduced eddy-current losses and improved overall magnetic performance, while the adoption of cold sintering techniques opened new perspectives for the processing of magnetic composites. Leadership of a multidisciplinary team of twelve members, among them young researchers and students, not only reinforced research capacity but also ensured knowledge transfer to the next generation of specialists.

The scientific directions pursued are strongly aligned with global priorities in energy efficiency, e-mobility, and renewable energy integration. International collaborations and research stages have provided access to advanced characterization facilities and strengthened the international visibility of Romanian research in this field. At the same time, the teaching activity carried out at the Technical University of Cluj-Napoca complements the research component. Advancing through all academic stages to the current position of Associate Professor in the Department of Materials Science and Engineering, the author has taught courses ranging from general materials science and engineering to advanced functional materials, magnetic materials and nanomaterials. I have supervised about 30 bachelor's theses and 20 master's theses, and I have been actively involved in doctoral training as advisory committee member for 9 PhD students.

Taken together, these achievements reflect a coherent trajectory of scientific development, ranging from early studies on Fe- and Co-based amorphous powders to the introduction of fibre-based soft magnetic composites and, more recently, advances involving amorphous fibres and cold sintering. The results highlight the capacity to integrate fundamental research with technological innovation and to translate laboratory findings into potential applications. Building on this trajectory, the career development plan aims to further advance the field of soft magnetic materials while ensuring continuous improvement in teaching. This integrated approach, combining research work with educational commitment, defines the author's contribution to the scientific community and outlines a clear perspective for future growth.