WEST UNIVERSITY OF TIMIȘOARA
PHYSICS DOMAIN

Research on the Physics and Technology of Crystalline Materials, Magnetorheological Suspensions and Elastomers

SUMMARY OF THE HABILITATION THESIS

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Summary

My research interests, after defending my PhD thesis in September 2003, have included and continue to include current topics in various fields such as the study of single crystals (Al_2O_3, CaF_2, BaF_2, doped fluorides, silicon), the study of composite materials (elastomers and their derivatives, ferrofluids), as well as interdisciplinary directions such as archaeology, medical physics, and educational physics. Due to this and given the number and significance of my publications in the aforementioned fields, I considered it appropriate for the title of my habilitation thesis to be: *"Research on the Physics and Technology of Crystalline Materials, Suspensions and Magnetorheological Elastomers."*

After an extensive research period focused on the study of crystalline materials—starting during my undergraduate years (1993/1994 under the coordination of Prof. Dr. Irina Nicoară), continuing with my bachelor's thesis (1996), master's thesis (1997), and culminating in my doctoral studies (1999–2003)—I transitioned from studying crystalline materials / single crystals to investigating materials based on the assembly of magnetizable nano- and microparticles in liquid matrices and elastomers. This shift was driven by several factors, such as the easy and low-cost production of nano/microparticles through plasma treatment of metallic and non-metallic materials, their incorporation into liquid and viscoelastic matrices, and the vast development potential of this field, especially due to the wide range of applications and their integration into a „circular economy" system.

The habilitation thesis follows the structure recommended by IOSUD – UVT, consisting of five chapters, along with an introduction, conclusions, and bibliography. It includes the author's main contributions to the research of these materials, as well as the key directions for professional development in the context of current achievements and trends in the author's field of specialization [UVT, 2024].

In the *Introduction*, I found it appropriate to address the current stage of development and interest in the field of new materials, with explicit reference to composite materials (hybrid magnetorheological elastomers, magnetically active fabrics, materials based on magnetorheological suspensions), ferrofluids (water- or kerosene-based with magnetic nanoparticles), and studied monocrystals (Si, Al_2O_3, CaF_2, BaF_2, doped fluorides). This section also includes a synthesis of my postdoctoral research activity.

Chapter 1, titled *Synthesis and Study of Monocrystalline Materials*, presents results obtained during postdoctoral research activities focused on the synthesis and characterization of crystalline materials - Al_2O_3, CaF_2, BaF_2, doped fluorides, and Si. The three subchapters explore the process of crystal growth and characterization, focusing on the use of advanced numerical modelling techniques and experiments to optimize crystal quality.

Chapter 2, titled *Contributions to the Study and Mathematical Modelling of Nanoparticle Behaviour in Fluid Media Under Nonuniform Electric Fields*, focuses on a relatively new research direction at UVT. It analyses the behaviour of nanoparticles in fluid media under the influence of nonuniform electric fields through the phenomenon of dielectrophoresis (DEP). This technique allows contactless manipulation and separation of nanoparticles and is applicable in biotechnology and biomedical engineering. The chapter highlights both the potential of DEP technology and the need for continued research to minimize the risks associated with nanoparticles.

Chapter 3 is the most substantial in the habilitation thesis and is based on a significant number of my own articles. It is titled *Magnetically Active Materials Based on Suspensions and Magnetorheological Elastomers: Production, Processes, and Physical Mechanisms*. This chapter describes and analyses in detail aspects related to the production, properties, and applications of advanced materials that respond to external magnetic fields. These materials include magnetorheological suspensions and elastomers that can change their mechanical and electrical properties in the presence of a magnetic field, making them useful in applications such as sensors, actuators, and vibration dampers. The content highlights the importance of smart materials in the transition to a circular economy, emphasizing the innovations brought by magneto-active materials in improving efficiency and sustainability in various industries.

Chapter 4, titled *Contributions to the Investigation of Thermal and Electromagnetic Properties of Ferrofluids in Low- and High-Frequency Fields*, is closely related to both Chapter 2 and especially Chapter 3. It offers complex studies on the thermal and electromagnetic properties of ferrofluids, viewed as composite systems of nanoparticles, focusing on their behaviour in magnetic fields and under varying electrical frequencies. The chapter addresses thermal conductivity, electrical conductivity, and the applicability of ferrofluids in magnetically controlled heat transfer and magnetic hyperthermia for cancer treatment. The study provides significant contributions to understanding the mechanisms of heat transfer and electrical conduction, as well as the use of ferrofluids in biomedical and technological applications. Additionally, my original results on the behaviour of a ferrofluid in a microwave field may be applicable to any composite system of superparamagnetic particles embedded in a solid dielectric matrix, proving very useful in the use of these materials as electromagnetic absorbers or in other microwave applications.

Chapter 5, titled *Directions for Professional Development in the Context of the Author's Achievements and Current Trends in the Field of Specialization*, outlines my objectives regarding future research directions to be pursued after obtaining habilitation, particularly in terms of topics for future PhD theses. This chapter covers elements from my work so far, such as: a) electromagnetic phenomena in nanocomposite materials; b) technical and biomedical applications of these materials; c) physics in an interdisciplinary context – chemistry, archaeology, medical physics, and educational physics & science popularization.

The habilitation thesis concludes with *Conclusions* and a *Bibliography* section, a rich collection that includes both reference or up-to-date books and articles in the field, as well as my own contributions, thereby emphasizing the relevance of the research topics presented.