# ABSTRACT

## Habilitation thesis

# Multifunctional nanostructured materials obtained by the Thermionic Vacuum Arc (TVA) method and by plasma-laser interaction (LTVA) method

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This habilitation thesis presents an extensive investigation into the synthesis and characterization of thin films and nanostructured materials produced through the Thermionic Vacuum Arc (TVA) and Laser-Induced Thermionic Vacuum Arc (LTVA) deposition methods. These techniques represent powerful tools for producing high-purity, dense, and adherent coatings with well-controlled microstructures and are distinguished by their capability to generate highly ionized, ultra-pure plasmas, which enable the controlled growth of dense, adherent, and contamination-free thin films. The study aims to elucidate the fundamental mechanisms of these deposition techniques, optimize their operational parameters, and explore their applicability in developing multifunctional nanostructured materials for industrial and technological applications.

**Chapter 1** provides a detailed presentation of the Thermionic Vacuum Arc (TVA) method, describing its physical principles, plasma generation processes, and material transport mechanisms. The chapter also details several electrode configurations—ranging from TVA systems with two movable anodes to configurations with multiple electron guns and variable numbers of anodes—each adapted for specific material requirements and deposition geometries. —highlighting the flexibility of TVA in tailoring deposition geometries and plasma characteristics. Particular emphasis is focused on the unique properties of TVA plasma, characterized by its stability, high degree of ionization, and extremely low contamination levels. The chapter concludes with a discussion of the main scientific and industrial domains in which TVA has demonstrated significant advantages over conventional deposition techniques.

**Chapter 2** focuses on the deposition of carbon-based thin films and nanostructures. Different approaches are explored, including the deposition of nanostructures in vacuum and under controlled gas flows (G-TVA), which enable the tuning of film morphology, chemical composition, and functional characteristics. The chapter investigates binary systems based on carbon—specifically C–Ag, C–Mg, and C–Si— for which comparative studies are conducted to assess their structural, optical, and electrical properties. These results reveal strong correlations between plasma parameters, film composition, and the resulting physical characteristics. The chapter also presents examples of binary and ternary composite films designed for industrial applications, emphasizing the versatility of TVA in producing complex multifunctional materials.

**Chapter 3** extends the research toward magnesium-based nanostructures and the development of functional coatings obtained via the TVA and LTVA methods. The chapter introduces the Laser-Induced Thermionic Vacuum Arc (LTVA) technique, which combines laser beam with thermionic plasma generation. The experimental configuration, operational parameters, and laser–plasma interaction mechanisms are thoroughly described. This hybrid method allows for precise control of the plasma characteristics and material transfer process and, also for enhanced control over film composition, microstructure, and deposition rate. Comparative studies between TVA- and LTVA-deposited layers reveal distinct differences in crystallinity, morphology, and adhesion, demonstrating the potential of LTVA for producing complex nanostructures with superior functional properties.

**Chapter 4** investigates multifunctional magnesium-based materials obtained through LTVA, focusing on binary systems. Particular attention is given to binary combinations Mg:X (where X = Ag, Zn, C), which exhibit enhanced optical, mechanical, and chemical properties due to synergistic effects between magnesium and the secondary elements. The synergistic effects resulting from the combination of magnesium with other metallic or nonmetallic elements are analyzed in terms of microstructural evolution and functional behavior. The chapter discusses the influence of deposition parameters on film composition and performance, emphasizing the potential of these materials for applications in corrosion protection, catalysis, and energy systems. The results demonstrate the potential of such films for advanced applications in corrosion resistance, catalysis, and biomedical technologies, where material purity and controlled nanostructuring are critical.

**Chapter 5** presents the author's professional development plan and academic perspectives, emphasizing achievements in research, education, and scientific leadership. The discussion includes contributions to university education, mentorship of students and young researchers, and the scientific relevance and impact of the results obtained. It highlights the capacity to conduct and coordinate complex research projects, mentor young researchers, and transfer scientific knowledge and technological innovations to both academic and socio-economic environments. All of these activities will continue in the future, combined with the perspective to apply for research and innovation projects, the ability to transfer knowledge and technological results to the academic and socio-economic environments being part of the author's academic career development plan.

In conclusion, the thesis demonstrates that the TVA and LTVA deposition techniques represent highly efficient and versatile methods for the fabrication of advanced nanostructured materials with tunable physical and chemical properties. Through the systematic study of plasma behavior, material synthesis, and thin film characterization, the research provides valuable contributions to the field of plasma-assisted thin film technologies and opens new directions for the design of multifunctional materials for next-generation applications.