ABSTRACT
of the
Habilitation Thesis: “Toward New Frontiers for Composite Materials”

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Fundamental domain: ENGINEERING SCIENCES

Domain of academic studies Domeniul de studii universitare: INGINERIA MATERIALELOR

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The present habitation thesis represents a synthesis of scientific and academic activity in the field of materials science and engineering for the period between 1999 and 2016, after the public defense in March 12, 1999 of the Ph.D. thesis with title “*Contributions to the study of metal matrix composites reinforced with ceramic particles regarding fabrication and changes of structure and properties by mean of heat treatments*”.

Scientific contributions that are presented follow the latest evolutions from the classic concept of composite material with light metallic matrix (Ti, Al etc.) discontinuously reinforced with micron-sized ceramic particles, produced by mean of conventional casting or powder metallurgy techniques, toward new scientific frontiers.

In this respect, the *1st Chapter* of the thesis syntheses the scientific contributions for development of Ti-based composites with amorphous matrix and crystalline secondary phases for biomedical applications. Two main directions of researches have been so far concretized in this field. The first direction is represented by the development of a new Ni-free titanium alloy with composite amorphous/crystalline structure, which was achieved by replacement of Ni, which is notorious for its harmful effects to human body, with minor addition of Ga. The new $Ti_{41.5}Zr_{2.5}Hf_5Cu_{37.5}Ga_{7.5}Si_1Sn_5$ alloy fabricated as 2 and 3 mm rods by mean of suction casting method has a very complex structure of an amorphous/nano-crystalline composite, the amorphous matrix embedding several crystalline phases, ranging from relatively large-sized dendrites to very fine nano-crystals of about 10 nm. The second direction that was followed was represented by development of new Ti-based composites without any Cu-content, for applications as orthopedic implants, considering the well-established cytotoxic effect of this element, which was replaced with Ag. The newly designed alloy $Ti_{42}Zr_{10}Pd_{14}Ag_{26}Sn_8$ fabricated by ultra-rapid melt cooling shows a complex microcrystalline structure, with residual amorphous matrix. The new alloy has some promising features for use as biomaterial, considering the bactericidal effect of metallic Ag and the composite amorphous – crystalline character with potential for high mechanical properties, including an ameliorated ductility in comparison with the BMGs.

The *2nd Chapter* presents the scientific contributions that resulted in development of new porous materials, which are considered to be also composite materials by some leading opinions. A new biomaterial with Ti-based amorphous matrix was fabricated using an advanced technique that combines melt-spinning of amorphous ribbons followed by powder metallurgy processing. Resulting $Ti_{42}Zr_{40}Ta_3Si_{15}$ amorphous material has some outstanding properties such as 14 vol% porosity, the rigidity around 52 GPa, close to the Young’s modulus of cortical bone, which is between 4 and 30 GPa, a compressive strength higher that 337 GPa and good biocompatibility in simulated body fluid. To our knowledge

this is the first biocompatible Ti-based bulk glassy alloy having mechanical properties close to human bone, as underlined by the reviewers of *Acta Biomaterialia*, where the results were published.

New processing frontiers for fabrication of Al-based composites reinforced with ceramic particles are summarized in the *3rd Chapter*. Researches in this field have been focused mainly on new hybrid Al-based composites produced by mean of an innovative fabrication method. The new composites have two types of reinforcements, the first one is alumina introduced by embedment, using classical powder metallurgy techniques, and the second fraction of alumina particles is produced by *in-situ* methods, particularly reactive sintering treatments.

The 4th Chapter illustrates with examples the application of computerized image processing to the analysis of reinforcement distribution for some discontinuously reinforced aluminum matrix composites. This advanced investigation technique allows objective interpretation of microstructural images obtain by light or electronic microscopy, as well the use of statistical methods for characterization and optimization of particle distribution, which is responsible for some critical properties of the composites, especially ductility and toughness. The analysis was performed to evaluate morphological changes in reinforcement distribution for a composite with Al-matrix reinforced with SiC particles, produced by powder metallurgy, during secondary processing by mean of high-ratio plastic deformations.

Fabrication of experimental materials for the researches presented in this thesis was accomplished using some advanced or innovative processing techniques, such as arc-melting, ultra-rapid cooling by mean of suction or pressure casting, melt spinning, as well as powder metallurgy techniques like cryo-milling, hot pressing, and reactive sintering. Materials characterization was performed with some advanced investigation methods like differential scanning calorimetry (DSC), X-ray diffractions (XRD), both conventional and using synchrotron radiation, scanning electron microscopy (SEM), high resolution transmission electron microscopy (HR-TEM). Special software programs were used for computerized image processing of microstructural images (light microscopy, SEM), processing of DSC curves, XRD spectra, alloy design, material testing, statistics, graphic representation, etc.

The scientific achievements in the field of materials science and engineering were published in prestigious journals with large impact on the research community, such as *Intermetallics*, *Acta Biomaterialia*, *Acta Materialia*, *Materials, Journal of Thermal Analysis and Calorimetry*, *Metall*, *Journal of Magnetism and Magnetic Materials*, or included in the proceedings of international conferences.

The research directions that are presented in the thesis are envisioned to be continued in the context of future career evolution, for development of new Ti-based composites for biomedical applications, which should be also comprehensively characterized, regarding biocompatibility and appropriate mechanical properties. Special attention will also be given to Al-based composites for structural applications that require high mechanical properties associated with low specific weight. Collaborations with industrial companies within applicative research contracts will be also continued.

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