metals

Editorial

News Trends in Powder Metallurgy: Microstructures, Properties, Durability

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1. Context and Scope of the Special Issue

Compared with traditional casting or plastic deformation processes, powder metallurgy-based methods are versatile routes for producing in-demand microstructures of various types. Centimeter-sized, fully dense, coarse-grained, ultrafine-grained, nanostructured, and heterogeneous-controlled structure (architected) materials can indeed be processed in respect to the bottom-up approach through techniques of fast sintering (SPS, microwave sintering...) and the emerging additive manufacturing such as by powder bed fusion (PBF), leading to an original microstructure design. Consequently, the mechanical and physical properties of the alloys, and their durability, are profoundly modified, thus broadening the application range.

In this Special Issue, we have initially proposed to interested authors to contribute to the following topics:

- Toward new microstructures: analysis, properties, and stability;
- Powder properties, nanostructuration, mechanical alloying, and aging;
- Unconventional sintering processes: SPS, microwave, etc.;
- Additive manufacturing by powder bed melting processes;
- Mechanical properties: fatigue, creep, plasticity mechanisms;
- Physical properties: magnetism, electrical conduction;
- Damage, fracture, and effect of the environment: oxidation, electrochemical corrosion.

Finally, a review of the scientific advances in this field have been carried out through a selection of 13 original research papers (progress reviews and articles) on the impact of the microstructure on the mechanical and functional properties of metallic alloys obtained by sintering (SPS) and additive manufacturing (PBF) routes.

2. Presentation of the Contributions

From the point of view of traditional metallurgy, mechanical resistance and ductility are antagonist properties. Therefore, the quest for methodologies and concepts that are susceptible to make them coexist are of great interest. To this end, and among others, the idea of a harmonic structure, first introduced by Prof. Ameyama, has been proven to be of prime interest for addressing the dual problem of improving both the strength and the ductility and other fatigue properties of metallic materials. Four main contributions to this Special Issue by Bhupendra et al. [1], Guennec et al. [2], Fer et al. [3], and Song et al. [4] illustrate the incredible potential of the concept which can be indeed applied to various metallic materials and alloys.

Nevertheless, the microstructural mechanisms at the origin of the coexistence between ductility and mechanical resistance of heterogeneous structures of harmonic types are not yet well understood, particularly in terms of synergy between the different structural entities (shell and core). This understanding begins with identifying the unique plasticity mechanisms of the coarse grains of the core and the ultra-fine grains of the shell. In this Special Issue, a first answer is provided by Garcia de la Cruz et al. [5]. In their study, the authors discuss the work hardening mechanisms of UFG nickel, interestingly considering samples with grain sizes ranging from 0.82 to 25 µm. While a lower strain hardening capability is observed with decreasing grain size, samples in the submicrometric range display the three distinct stages of strain hardening representative of face-centered cubic metals, with a short second stage and the third stage beginning soon after yielding.

Again, in terms of properties (mechanical or physical), and considering durability issues, metallic structures could not be conceived without optimizing the microstructure, which we know has a colossal influence on the subsequent properties, and therefore on the performances. The review by Monchoux et al. [6] provides an overview of the link between process, microstructures, and properties of metallic alloys elaborated by SPS. In this Special Issue, these aspects are also approached and presented systematically by Moser et al. through two studies that focus on the importance of densification on the mechanical properties of tungsten which are made ductile via nanostructuring and densification after SPS, by Dine et al. [7], as well as on the influence of impurities such as oxygen and carbon on SPS-processed Molybdenum. [8]. Finally, considering sustainability, metal recycling is a hot topic. Ikram et al. [9] demonstrate how SPS can be effective with recycled metal powders for obtaining Nd-Fe-B permanent magnets with magnetic properties equivalent to those elaborated using pristine powder.

If it was still needed to convince of the versatility of the processes for the development of products and parts with great added value, based on powder metallurgy routes (in particular spark plasma sintering and additive manufacturing), the reader would find some essential data in this Special Issue. First, a detailed review on titanium aluminides having the potential of substituting nickel-based superalloys (NBSAs) in the aerospace industries is discussed by Mogale et al. [10]. Then, this article further reviews published works on phase constituents, microstructures, alloy developments, and mechanical properties of TiAl alloys produced by SPS. Finally, an overview of challenges as far as the implementation of TiAl in industries of interest is highlighted.

In the same vein, assembly processes to produce structural or functionalized structural materials (or parts to be functionalized later) can become real challenges. Powder metallurgy and SPS make it possible to meet these challenges. Three studies presented in this Special Issue deal with these aspects. First, Naimi et al. [11] propose to use SPS sintering of ODS steels to overcome the difficulties with joining oxide dispersion-strengthened (ODS) steels using traditional welding routes. Then, in the work of Tellez-Martinez et al. [12], ingeniously, a new processing route is proposed to produce graded porous materials by placing particles of Ti6Al4V with different sizes in different configurations to obtain bilayer samples that can be used as bone implants. It is concluded that the proposed elaboration way can produce materials with specific and graded characteristics, with the radial configuration being the most promising for biomedical applications. Finally, mastering the texturing of surfaces is an important issue, in particular for the chemical or biological functionalization of medical implants, which constitutes a societal issue of great importance for which new material solutions are sought. In this quest, additive manufacturing and, in particular, powder bed processes are of particular interest. In this perspective, Gonzales et al. [13] present an original approach for texturing Ti6Al4V samples obtained by SLM subjected to successive treatments: acid etching, chemical oxidation in hydrogen peroxide solution, and thermochemical processing. The effect of temperature and time of acid etching on the surface roughness, morphology, topography, and chemical and phase composition after the thermochemical treatment was studied. These surfaces are expected to generate greater levels of bioactivity and high biomechanics fixation of implants, as well as better resistance to fatigue.

Acknowledgments: As guest editors of this Special Issue, we hope that the present selected papers will be useful to researchers working in the area of powder metallurgy. We would like to thank the authors for their contributions to this Special Issue, and all of the reviewers for their efforts in ensuring high-quality publications. We would also thanks to the Metals editorial assistants for their support during the preparation of this volume. Finally, we would especially thanks Natalie Sun, managing Editor of Metals, for offering us the opportunity to work on this project, and for guiding us through the editorial set-up.

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