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Editorial

Metals Powders: Synthesis and Processing

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1. Introduction and Scope

Metallic parts can be obtained by a wide variety of techniques. One of these techniques, traditionally known as powder metallurgy, uses powders as starting materials, which must be processed to obtain the final products. The European annual production and use of metal powders can alone be estimated to be more than one million tonnes. Powder synthesis through mechanical alloying, atomization, evaporation–condensation, electrochemical reduction processes, phase separation, etc., leads to a wide range of purities, alloys compositions, particle sizes and shapes, and microstructures; some of these properties are only possible to achieve through the techniques used for powders production. The demand for advanced material compositions and microstructures in transportation, aeronautics, medicine, energy production and several other fields, makes the use of metal powders an interesting technique for the production of metallic pieces. The extensive variety of metal powders, not only regarding compositions but also microstructures, makes the production and use of powders a continuously increasing market.

These powders can then be processed through traditional powder metallurgy cold-press and sinter techniques, hot isostatic pressing, injection moulding, field-assisted electrical sintering techniques or additive manufacturing techniques, among others. Under appropriate processing conditions, these techniques lead to materials with tailored properties that would be impossible to attain with other procedures. Near net shape components, with complex shapes and good dimensional precision make further processes unnecessary.

In this frame, this Book of Metals covers research works on recent advancements in some of the techniques used for the synthesis and processing of metals powders.

2. Contributions

The Book gathers works from academic researchers with new results. It consists of ten research papers focused on different materials and processes. The studied materials cover pure Ti [1,2] and Ta [3], and alloys with compositions Fe-Co-Cu [4], Al-Ti [5], Al-Mg-Si [6], Co-Cr-W-V [7], Mn-Bi [8], Fe-Si-B [9] and Fe-WC [10].

Some of these paper focus on the synthesis of metallic powders. Thus, Hwang at al. [3] studied the extraction of Ta powder, and Choi et al. [2] the extraction of Ti. Ball milling is the technique used by Xiang et al. [8] to obtain Mn-Bi powders with outstanding magnetic properties. Other manuscripts deal with the processing of metallic powders. Guerra et al. [4] studied the sintering of Fe-Co-Cu powder mixtures for their use as diamond impregnated tools for cutting granite stones. Urban et al. [5] studied the consolidation by electrical resistance sintering of mechanically alloyed amorphous Al-Ti powders. Magnetic properties are studied by Sun et al. [9] in cold pressed Fe-Si-B alloys. Kim et al. [6] studied the fabrication of functionally graded Al-based materials by hot extrusion. Civantos et al. [1] processed Ti by the space holder technique to be used as medical implants. Hard Co-based material processed by sintering was studied by Niannian et al. [7], and Fe-WC hardmetals processed by electrical resistance sintering by Cintas et al. [10].

Manuscripts can also be grouped according to the microstructure of the studied powders. Several manuscripts [1–4,6,10] deal with crystalline materials, whereas other works [5,7–9] use amorphous powders. According to the country of the corresponding author, three papers come from China [7–9], another three from Korea [2,3,6], two from Spain [5,10], one from USA-Spain [1], and one from Portugal [4]. In addition, authors from the United Kingdom, Germany, Mexico and Romania have contributed to the different papers.

Regarding powders synthesis, the production of Ti from TiO_2 by self-propagating high-temperature synthesis using Mg powder as reducing agent is studied in [2]. This process, avoiding the use of $TiCl_4$, produces magnesium and magnesium oxide by-products that need being removed. Different HCl acid leaching conditions are studied, finally obtaining a total oxygen content of the Ti powder of about 1 wt.%. On the other hand, Ta is obtained via reduction of tantalum pentoxide (Ta_2O_5) with Mg gas [3]. The powder obtained again contains MgO, also dissolved and removed in a water-based HCl solution. The final oxygen content was this time about 1.3 wt.%.

The production of Mn-Bi alloyed powders is studied in [8]. These are promising rare-earth-free permanent magnetic materials. The selected way to avoid Mn segregation in low-temperature phase MnBi is through melt spinning. Ribbons are annealed and then transformed into powders both with and without surfactant assisted ball milling processes. Surfactant assisted milled Mn_{55}-Bi_{45} powders have a higher size reduction during milling, but higher decomposition of low-temperature MnBi phase and lower saturation magnetization. Powders milled without surfactant show improved coercivity (18.2 kOe at room temperature and 23.5 kOe at 380 K), and in general better magnetic properties.

Powders processing studies include a wider range of techniques. The simpler technique consisted in pressing Fe-Si-B amorphous powders to prepare amorphous magnetic powder cores [9]. Particle size distribution, moulding pressure, and coating agent content were studied, with better results for intermediate particles size, moulding pressure about 2.40 GPa and addition of 1.5 wt.% sodium silicate.

The traditional powder metallurgy technique of press and sinter is used in [4] in the form of hot pressing to produce Fe-Co-Cu discs, which after adding 2.5 wt.% of diamond pieces, are used to cut granite stones. The composition 72wt.% Fe–25wt.% Co–3 wt.% Cu showed the best results in terms of toughness, diamond retention capacity and lower wear rate. Hot press sintering is also used in [7] to prepare a hard and tough Co-based alloy. Powders of Co, C, W, Ni, V and C were mechanically alloyed up to reach the amorphous state. After consolidation, the Co matrix and different carbides allow reaching hardness of 960 HV and fracture toughness of 10.5 $MPa{\cdot}m^{1/2}$.

This same traditional PM technique is used in [1] to produce Ti implants. However, the use of 50 vol % NH_4HCO_3 space-holder allows producing porous samples resembling the bones structure. Produced materials achieved suitable cell biocompatibility, with the best mechanical behaviour to replace cortical bone tissues when fabricated with 100–200 μm space-holders.

Hot extrusion process is studied in [6] to fabricate functionally graded Al-base materials. Functionally graded materials improve the interfaces to prevent cracks coming from residual stresses in a heterogeneous material. Experiments to improve the interfacial properties were carried out by using Al3003 powder and bulk Al6063 alloys. After extruding at 468 °C with a ratio of 100, the interface between the two materials showed almost no cracks, resulting a final product with high strength and adequate elongation.

A different sintering technique, electrical resistance sintering, is used in [5] with previously mechanically alloyed amorphous Al-Ti powders. This work studies the possibility of retaining such unstable structure after sintering with a very quick process. The amorphous structure is at least partially retained after sintering for 1.2 s, attaining a remarkable final hardness in the sintered compacts. In addition, electrical resistance sintering is used in [10] to produce WC-6 wt.% Co hardmetals. The initial powders with WC particle size of about 260 nm are processed by a sintering process lasting about 2 s, resulting hardness values higher than 1900 HV, and maintaining the ultrafine WC grain size in the order of the 300 nm, all without the need for using a protective atmosphere.

Thus, this book includes interdisciplinary research works that address different synthesis and processing techniques applied to metal powders. I hope this small compendium of works among the vast options for powder synthesis and processing serves the researcher starting in the powders world, providing a vision of the different possible techniques, and enables those working for a long time in this area to stimulate future scientific ideas and works.

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Conflicts of Interest: The authors declare no conflict of interest.

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