Powder Metallurgy & Mining

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Powder Metallurgy Based Porous Metal Biomaterials

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Powder metallurgy (P/M) as a fabrication technique involves the compaction of metallic powders, followed by a heat treatment to produce a denser piece. The technique makes it possible to produce a virtually non-porous and shaped piece with very close dimensional tolerance, which has the properties almost equivalent to the fully dense parent material. Usually diffusional processes through heat treatment are employed to achieve these properties; it is thus particularly suitable for producing materials with low ductility, since only little plastic deformation among compacted particles occurs. For metallic powders with high melting temperatures, they are difficult to be melted or casted. With the intended use of multiple binders, P/M on the binders-mixed powders, followed by a heat treatment is competent to produce shaped pieces with required properties. Furthermore the metal injection molding (MIM) technique can be applied for fast production on the pieces with multifaceted designs.

On the other hand, P/M sintered porous metal material can be made of metallic powders with the inclusion of binders and spacers and produced through pressing, additives removal, and high-temperature sintering processes. With the expected properties such as high strength, rigid structure, good and uniform permeability, and high thermal and corrosion resistance, P/M sintered porous metal products are possibly utilized in various fields such as petrochemical, chemical, metallurgical, power and electrical, environmental, pharmaceutical, and aeronautical industries.

There is a developing and highly-demanding field in favor of P/M sintered porous metal materials for biomedical applications. For example, the development of artificial organs and implants for the replacement of injured and diseased hard tissues such as bones, teeth, and joints is highly required for orthopedic surgery. Subsequent acute wound healing and host responses mostly require appropriate metallic surface/cells interactions, e.g., cells that are capable of forming bones/teeth; bioactive factors that can attract such cells and initiate bones/teeth formation; a matrix that guides the bones/teeth formation; adequate vascularization; initial mechanical support to the surrounding bones/teeth. Therefore, it is pertinent for P/M bioengineers to set out new approaches to restore the normal function of impaired hard tissues. Their challenge is to develop a bones/teeth substitute (preferably porous) that enhances healing (biocompatible) but also offers adequate strength (preferably metallic support). The P/M sintered porous metal biomaterial may thus provide a solution.

Porous ceramic and polymer biomaterials are usually not suitable for load-bearing sites, but can be used for filling lost cavities or regenerating soft tissues. Porous titanium-based scaffolds, for example, are interesting, since they may provide superior mechanical properties with high strength/weight ratios. Some alloying elements, e.g., Zr, Nb, Ta, Sn, Mo, Si, may lead to superior improvement in properties of the materials. Although the potential of porous metal biomaterials has been recognized for years, the development of open porous structures has been hampered by limitations in production techniques. With the intended use of plasma spraying as a coating technique or common P/M containing space holder or sintered titanium-based fibers, it is still difficult to produce a desired porous structure with an architecture that meets both osteoconductive and mechanical requirements.

To have the effect of so-called "osteoconduction", an "open interconnected" porous structure with pores in the range of 200~500 μm is estimated, though there is no exact agreement between scientists about the perfect size of pores to stimulate cells proliferation. From a mechanical point of view, the porous structure should be stiff enough to sustain physiological loads, but should not drastically exceed the stiffness of the bone being replaced to avoid stress shielding. As a consequence, to develop P/M sintered porous metal biomaterials for biomedical applications, it is required to compromise both properties and adjust their structural stability as a function of long-term implantation time. In view of perspective, it is promising to focus upon porous metal biomaterials using P/M sintering or MIM technique, in particular for orthopedic and dental applications.

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