TPMS porous structures: From multi-scale design and precise additive manufacturing to multidisciplinary applications

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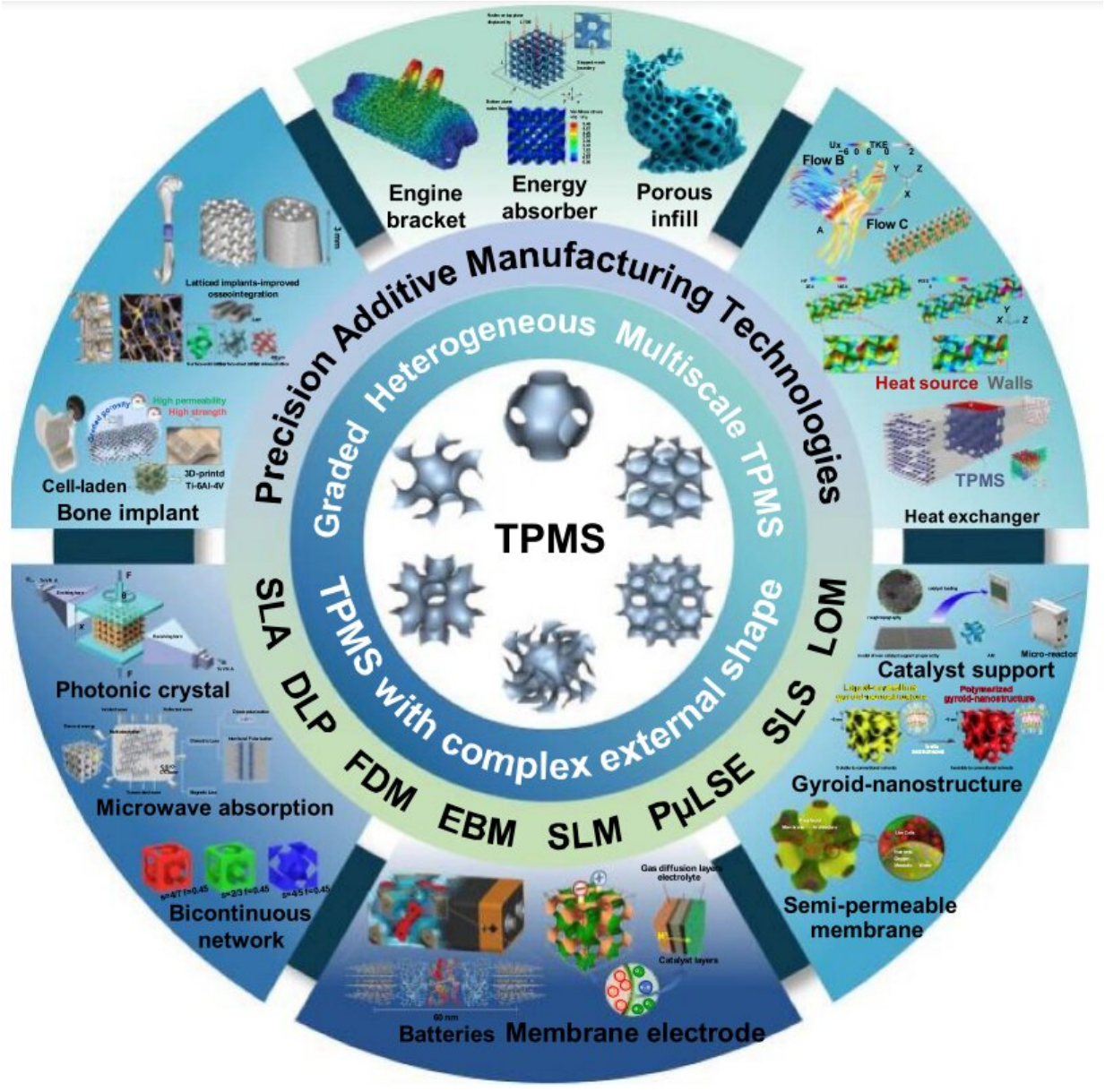

Overview of this review of TPMS porous structures. Credit: By Jiawei Feng, Jianzhong Fu, Xinhua Yao, Yong He.

With the rapid development of material science and manufacturing science, a large number of complex structures have been designed, manufactured and applied in the industrial field.

Most of the current industrial applications belong to solid structures without holes. Some internal holes are even regarded as structural manufacturing defects. However, there are a large number of intricate porous structures in nature, such as skeletons, honeycombs, corals, sponges, and cork. The special properties of natural porous structures attract researchers to try to design various biomimetic porous structures. Biomimetic porous structures represented by honeycombs, foams and lattices have achieved excellent application results in previous studies.

In recent years, more and more researchers have tried to use TPMS to design and fabricate porous structures. TPMS is a periodic smooth implicit surface with zero mean curvature. Compared with other types of porous structures, the TPMS porous structure has two obvious advantages: (1) The overall TPMS porous structure can be accurately described by mathematical expressions. The basic properties such as porosity and volume specific surface area can be directly controlled by the function expression parameters; (2) The surface of TPMS is very smooth. There are no sharp turns or connection points of the lattice porous structure. And the overall structure is highly interconnected. In some biological tissues in nature, structures very similar to TPMS have been found.

At present, the research on the porous structure of TPMS is blooming, but there are still many problems in the key steps of design, manufacture and application that need to be solved.

Recently, postdoctoral fellow Feng Jiawei, Professor Fu Jianzhong, Associate Professor Yao Xinhua, and Professor He Yong from the School of Mechanical Engineering, Zhejiang University published "Triply periodic minimal surface (TPMS) porous structures: From multi-scale design, precise additive manufacturing to multidisciplinary applications" in *International Journal of Extreme Manufacturing*, which systematically summarized the research progress of triply periodic minimal surface porous structures in recent years.

The article summarized the current geometric design algorithms and performance control strategies for TPMS porous structures. Based on that, various precision additive manufacturing methods for manufacturing TPMS porous structures were discussed. The performance advantages of TPMS porous structure and broad application prospects in the future were also illustrated.

Most of the natural porous structures have non-uniform and irregular pores. Based on the implicit surface features of TPMS, by controlling the distribution of periodic parameters and curvature parameters, biomimetic structures similar to natural porous structures can be generated.

In terms of internal pores, a variety of non-uniform (gradient), non-homogeneous, multi-scale TPMS porous structure design algorithms have been proposed. In terms of the shape of the porous structures, by combining various computational geometry algorithms, the free-form surface shape TPMS porous structure can be generated.

The performance analysis of TPMS porous structure has been a research

hotspot in recent years. From the perspective of different disciplines, researchers have analyzed the multidisciplinary application performance of TPMS porous structure, such as mechanics, thermals, and acoustics.

Compared with the traditional topological porous structure, TPMS has unique advantages. The smooth geometry has a significant effect on the actual performance improvement. On the basis of the structural properties, a large number of current researches focus on how to further optimize and improve the structural properties of TPMS to meet the increasingly complex industrial application requirements.

Additive manufacturing technology is an ideal solution for the fabrication of intricate TPMS porous structures. Various processes have been attempted to manufacture TPMS porous structures, including selective laser melting (SLM), selective laser sintering (SLS), Stereo Lithography Apparatus (SLA), digital light processing (DLP), fused deposition modeling (FDM), etc.

By selecting appropriate materials and processing techniques, various types of high-precision TPMS porous structures can be fabricated. However, in the process of path planning, there is still a lack of efficient and accurate process planning methods for TPMS porous structures. And there is still a lot of room for improvement in manufacturing quality.

With the continuous improvement of the level of design and manufacturing, combined with excellent structural properties, TPMS porous structures have been successfully applied in many disciplines. The internal pores of TPMS can enter the platform stage under compressive load to continuously absorb energy.

At present, there have been a large number of reports on the application of TPMS porous structure energy buffer devices. The smooth pores of TPMS are very suitable for cell adsorption and growth. And pores are

more suitable for nutrients and nutrients.

At present, the research on the design, manufacture and application of TPMS porous structure is still a hot topic. Around the uniqueness of TPMS porous structure, researchers have carried out a series of interesting attempts. But there are still many problems that need further discussion and research.

The current research on the design, manufacture and application of TPMS porous structures is relatively isolated. In order to ensure good manufacturing quality, some manufacturing process issues should be added as constraints to the design process to improve the manufacturability of TPMS porous structures. Most of the TPMS porous structures currently used in practical applications are uniform porous structures with regular pore distribution.

In the future, the influence mechanism of pore distribution on the actual performance should be further explored, so as to further optimize and improve the performance of TPMS porous structures. Especially in the complex environment of industrial applications, how to realize the multi-physics performance analysis and multidisciplinary application performance combination optimization of TPMS porous structure is an important basis for promoting the wider application of TPMS porous structure.

More information: Jiawei Feng et al, Triply periodic minimal surface (TPMS) porous structures: from multi-scale design, precise additive manufacturing to multidisciplinary applications, *International Journal of Extreme Manufacturing* (2022). DOI: 10.1088/2631-7990/ac5be6

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