metals

*Editorial*

# Diversity of Nanoporous Metals

**Takeshi Fujita**

School of Environmental Science and Engineering, Kochi University of Technology, 185 Miyanokuchi, Tosayamada, Kami City, Kochi 782-8502, Japan; fujita.takeshi@kochi-tech.ac.jp; Tel.: +81-887-57-2508

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## 1. Introduction and Scope

Nanoporous metals have been attracting considerable research and industrial attention because of the structural uniqueness of their bicontinuous metallic structure. This structural uniqueness facilitates their application as gas-conversion catalysts and battery/supercapacitor electrodes and as an ideal substrate for surface-enhanced Raman spectroscopy, nanoporous graphene synthesis, the formation of hierarchical porous structures, and others. Nanoporous metals have been established as a novel class of materials and have led to the creation of cross-interdisciplinary research fields. The understanding of the atomistic description of surface roughening and nanopore formation is also important for maximizing the functionality of nanoporous metals.

This Special Issue is focused on the recent advances in nanoporous metals, ranging from fundamental aspects to various applications as well as on the computational modeling and theory of structure formation in this research field.

## 2. Contributions

Eight research contributions (five articles and three communications) are discussed in this Special Issue. Six contributions report various nanoporous metals from different precursor materials. One is related to in situ transmission electron microscopy (TEM) observation under a catalytic reaction, and the rest deals with the 3D structural modeling of nanoporous structure by computations.

Considering various interesting nanoporous metals, Kumar et al. [1] reported a nanoporous Au–Fe alloy synthesized via a wet chemistry route using ordered nanoporous silica as a hard template. The nanoporous Au–Fe consisted of aligned arrays of nanopores that were uniform in composition. Moreover, Hu et al. [2] established a bottom-up synthesis of a porous NiMo alloy reduced by $NiMoO_4$ nanofibers to fabricate non-noble metal porous electrodes suitable for hydrogen production. The porous NiMo alloy was realized as an excellent cathode in electrical water splitting and demonstrated catalytic activity almost identical to that of commercial Pt/C in a 1.0 M KOH solution with excellent electrochemical stability. Wang et al. [3] synthesized a self-assembled CuS nanostructure by dealloying a TiCu precursor alloy and sulfurating the leftover products using highly concentrated $H_2SO_4$ solutions. Vargas-Martínez et al. [4] systematically investigated the selective dissolution of the Al phase from a precursor Al–Cu alloy. The samples of eutectic composition presented a high uniformity and small ligament sizes after the selective dissolution. Mbarek et al. [5] reported the chemical dealloying of Cu–Mg–Ca alloys under free corrosion conditions for different alloy compositions and leaching solutions. This alloy system was a good precursor candidate for the preparation of nanoporous copper because of the easy dissolution of Mg and Ca. Yang et al. [6] developed a new route to fabricate nanoporous high-entropy alloy (HEA) with a high specific surface area. The as-obtained nanoporous $Cu_{30}Au_{23}Pt_{22}Pd_{25}$ quasi-HEA microspheres displayed a hierarchical porous structure with a high specific surface area of 69.5 $m^2$/g.

Fujita et al. [7] performed in situ TEM of a dealloyed nanoporous NiCo catalyst prepared by the dry reforming of methane (DRM) to investigate the origin of the catalytic activity and structural durability. DRM induced chemical demixing of Ni and Co accompanied by grain refinement, thereby implying possible "synergic effects" in a typical bimetallic NiCo catalyst.

Finally, Richert and Huber [8] presented a computationally efficient and versatile finite element method (FEM) beam model that is based on skeletonization and diameter information of nanoporous gold. The comparisons between the mechanical response of this skeleton beam model and a solid FEM model implied that improved algorithms for image processing are needed to provide accurate diameter information.

## 3. Conclusions and Outlook

The contributions of this Special Issue involve a wide range of topics on nanoporous metals. Indeed, nanoporous metals are developing and growing rapidly in cross-interdisciplinary research fields. However, there are many issues that must be resolved for the industrial application of nanoporous metals. As Guest Editor, I hope this Special Issue will inspire new ideas and open new avenues for the development of "new materials" in order to realize a more sustainable society.

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## References

1. Kumar, P.S.M.; Sivakumar, T.; Fujita, T.; Jayavel, R.; Abe, H. Synthesis of Metastable Au–Fe Alloy Using Ordered Nanoporous Silica as a Hard Template. *Metals* **2018**, *8*, 17. [CrossRef]
2. Hu, K.; Jeong, S.; Wakisaka, M.; Fujita, J.; Ito, Y. Bottom-Up Synthesis of Porous NiMo Alloy for Hydrogen Evolution Reaction. *Metals* **2018**, *8*, 83. [CrossRef]
3. Wang, Z.; Zhang, X.; Zhang, Y.; Li, M.; Qin, C.; Bakenov, Z. Chemical Dealloying Synthesis of CuS Nanowire-On-Nanoplate Network as Anode Materials for Li-Ion Batteries. *Metals* **2018**, *8*, 252. [CrossRef]
4. Vargas-Martínez, J.; Estela-García, J.E.; Suárez, O.M.; Vega, C.A. Fabrication of a Porous Metal via Selective Phase Dissolution in Al–Cu Alloys. *Metals* **2018**, *8*, 378. [CrossRef]
5. Mbarek, B.W.; Pineda, E.; Escoda, L.; Suñol, J.J.; Khitouni, M. Dealloying of Cu–Mg–Ca Alloys. *Metals* **2019**, *8*, 919. [CrossRef]
6. Yang, L.; Li, Y.; Wang, Z.; Zhao, W.; Qin, C. Nanoporous Quasi-High-Entropy Alloy Microspheres. *Metals* **2019**, *9*, 345. [CrossRef]
7. Fujita, T.; Higuchi, K.; Yamamoto, Y.; Tokunaga, T.; Arai, S.; Abe, H. In-Situ TEM Study of a Nanoporous Ni–Co Catalyst Used for the Dry Reforming of Methane. *Metals* **2017**, *7*, 406. [CrossRef]
8. Richert, C.; Huber, N. Skeletonization, Geometrical Analysis, and Finite Element Modeling of Nanoporous Gold Based on 3D Tomography Data. *Metals* **2018**, *8*, 282. [CrossRef]