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Editorial

Electromagnetic Preparation of Materials: From Fundamentals to Applications

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1. Introduction

Magnetic phenomena are amazing and mysterious topics. Thousands of years ago, ancient people discovered applications of magnetic phenomena, a well-known example being the compass, which is one of the four great inventions of ancient China. The appearance of the compass had a far-reaching impact on the development of ancient militaries and navigation technologies. Up to modern times, numerous great findings and theories relating to magnetic phenomena have been reported and 19 Nobel prizes have been awarded in this field. Currently, the application of magnetic phenomena plays an increasingly important role and has come to pervade every corner of our lives.

In principle, magnetic phenomena stem from the interaction between a magnetic field and a substance. The magnetic field, as one of the most important physical fields, can interact with any substance on a micro/macro scale. In consideration of obvious advantages such as the contactless interaction and novel magnetic effects, materialists and metallurgists are always attempting to utilize magnetic fields to control flow fields, macro/microstructures, and properties. Over the past century, the application of magnetic fields in material processing has enabled great achievements and considerable progress from fundamental theories to industrial applications [1]. In consequence, on the one hand, a new interdiscipline, i.e., Electromagnetic Processing of Materials (EPM), came into being in combination with multiple disciplines such as electromagnetics, fluid mechanics, material science, etc. [2]. On the other hand, many electromagnetic processing techniques have been maturely applied to industrial production, such as induction heating, electromagnetic forming, electromagnetic stirring, and levitation melting. As EPM grows by leaps and bounds, more and more new phenomena, new laws, and new techniques are being explored.

To present state-of-art studies on advances in terms of EPM, the Special Issue "Electromagnetic Preparation of Materials: From Fundamentals to Applications" has been organized.

2. Contributions

The Special Issue is composed of one review article and five research articles.

The review article by Hou et al. [3] focused on the application of a static magnetic field (SMF) to the solidification processing of metallic materials. This review first introduced the magnetohydrodynamic effects and magnetization effects. Then, recent studies were summarized regarding the SMF-regulated metal solidification, including undercooling, interfacial tension, grain coarsening and refinement, segregation and porosity, and crystal orientation. Finally, this article prospected efforts to be addressed in the future, including low-cost and large-bore strong magnets, in-situ SMF testing devices for high temperatures, and fundamentals of magnetic effects.

Of the five research articles, three of which focused on SMF-regulated metal solidification. Wang et al. [4] prepared a directionally solidified MnCuNiFe alloy under a high magnetic field (HMF) of 1~3 T, aiming to improve the damping performance of a Mn-Cu-based alloy. They reported that the dendrite microstructure was refined, the Ni element

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was enriched, and the martensitic transformation and the twin boundary relaxation occurred under HMF, ensuring the high-damping capacity in a wide temperature range from 200 K to 320 K. Li et al. [5] investigated the effect of a 5 T HMF in combination with high-temperature tempering on the microstructure and mechanical properties of GCr15 bearing steel. They pointed out that the increase in the dislocation density and the refinement of carbides led to a higher Vickers hardness with the application of the HMF at the stage of high-temperature tempering. Zhou et al. [6] investigated the effect of vertical HMF of 0~5 T on the morphology evolution of the solid–liquid interface and the solidified microstructure during the directional solidification of Zn-2wt.%Bi immiscible alloy. They established a relationship between the morphology of the solid–liquid interface and the evolution of the solidified microstructure under various magnetic flux densities and discussed the multiple control capabilities of solute transportation by vertical HMF. These works can provide new insights into controlling microstructures by an HMF.

One article devoted attention to the utilization of magnetohydrodynamic effects to control melt flow. Xiao et al. [7] proposed a new efficient and convenient electromagnetic dross removal technology applied in a zinc pot of hot-dip galvanizing line. Their study focused on the numerical simulation of the electromagnetic force acting on molten zinc and the flow situation of molten zinc on account of industrial application conditions. They found that an electromagnetic field could effectively act on the top surface of molten zinc, affect the flow of molten zinc, and yield optimal application parameters. This work offers new ideas for the cleaning of zinc dross.

One article focused on electroslag remelting (ESR). Zhang et al. [8] investigated the slag weight gain in humid air using four machine-learning models during the ESR process. They found that the slag weight gain increased with the increase in air humidity, experimental time, slag particle size, and CaO content in the slag. Two slags were selected to produce H13 steel ESR ingots in the winter and summer, respectively. This work helps to promote the application of machine learning techniques in the steel industry's management.

3. Conclusions and Outlook

This Special Issue was made possible thanks to the joint efforts of the authors, the reviewers, and the editorial staff, to all of whom we offer our thanks. It is expected that the Special Issue will provide enlightenment for researchers in this field. Additionally, we must bear in mind that some important scientific questions remain to be clarified in the field of EPM. The mechanism of magnetic effects during material processing should be investigated further. We expect that additional interesting and novel research work following this Special Issue will be reported and further promote the development of EPM.

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

References

1. Yamaguchi, M.; Tanimoto, Y. Magneto science: Magnetic field effects on materials, fundamentals and applications. In *Materials Science*, 1st ed.; Hull, R., Osgood, R.M., Jr., Eds.; Springer: Berlin/Heidelberg, Germany, 2006; Volume 89, pp. 1–354.
2. Asai, S. *Electromagnetic Processing of Materials*, 1st ed.; Springer: Dordrecht, The Netherlands, 2012; pp. 113–150.
3. Hou, Y.; Gao, Z.; Li, C. Solidification Processing of Metallic Materials in Static Magnetic Field: A Review. *Metals* **2022**, *12*, 1778. [CrossRef]
4. Wang, D.; Niu, H.; Zhang, S.; Xuan, W.; Ren, Z.; Tian, Q. Enhancement of Damping Capbility of MnCu Alloy by High Magnetic Field. *Metals* **2022**, *13*, 6. [CrossRef]
5. Li, Y.; Chen, S.; Zhu, F.; Huang, C.; Zhang, Z.; Xuan, W.; Wang, J.; Ren, Z. Effect of High Magnetic Field in Combination with High-Temperature Tempering on Microstructures and Mechanical Properties of GCr15 Bearing Steel. *Metals* **2022**, *12*, 1293. [CrossRef]
6. Zhou, B.; Guo, X.; Lin, W.; Liu, Y.; Guo, Y.; Zheng, T.; Zhong, Y.; Wang, H.; Wang, Q. Effect of Vertical High Magnetic Field on the Morphology of Solid-Liquid Interface during the Directional Solidification of Zn-2wt.% Bi Immiscible Alloy. *Metals* **2022**, *12*, 875. [CrossRef]

7. Xiao, Y.; Guo, Q.; Liu, T.; Wang, Q.; Chai, M.; Zhang, K.; Li, Y.; Pan, D. Numerical Simulation of the Electromagnetic Dross Removal Technology Applied in Zinc Pot of Hot-Dip Galvanizing Line. *Metals* **2022**, *12*, 1714. [CrossRef]
8. Zhang, G.; Hu, Y.; Hou, D.; Yang, D.; Zhang, Q.; Hu, Y.; Liu, X. Assessment of Porosity Defects in Ingot Using Machine Learning Methods during Electro Slag Remelting Process. *Metals* **2022**, *12*, 958. [CrossRef]