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*Editorial*

# Crystallography and Applications of Metallic Materials

**Joan-Josep Suñol**

Physics Department, Universitat de Girona, Campus Montilivi, 17071 Girona, Spain; joanjosep.sunyol@udg.edu

## 1. Introduction and Scope

Scientific and technological interest in metals, metallic alloys and compounds is related to the wide range of applications in fields such as mobility, biomedicine, heat transfer, energy and sustainability. Depending on the application, there are different properties to be optimized, including those that are mechanical, optical, electrical, magnetic, corrosion resistance, etc. Likewise, one of the objectives of this Special Issue is to remark on the high influence of the microstructure in its functional response. Thus, reinforcing that crystallographic analysis and characterization of metallic alloys is of scientific and technological interest. The control of the microstructure allows for designing new advanced materials for specific applications. Although review articles were also invited for submission, most of the published papers discuss use of crystallography as an element of analysis of the structure of the compounds produced and characterized.

Therefore, the aim of this Special Issue is to present the current knowledge and trends of metallic materials based on the crystallography development and analysis by outlining the relationships between the microstructure, properties and applications.

## 2. Contributions

Among the published manuscripts, there are two in which the main contribution is in the field of crystallography. It is well known that dislocations and dislocation slips have a significant and direct effect on crystal orientation Contribution (1). In this work, various aspects were considered, such as dislocations, their motion, the influence of sub-grain boundaries, crystalline misorientations in polycrystalline materials and the crystallographic texture. The second work analyzed the reorientation mechanisms of a specific material (graphene coated copper) on {001} surfaces Contribution (2). In this case, a melting–solidification mechanism was proposed to understand the formation mechanism of the surface reconstruction. It was found that controlled processing temperature was needed to produce the desired thickness. One of the aspects we wanted to highlight in this Special Issue was the relationship between the processing and production conditions of metal alloys, and the control and optimization of its microstructure.

Among the different families of metal alloys, the one that has probably been the most studied over the years is steels. There are three manuscripts in which the structure and properties of various steels are discussed. One of the works takes into account one a common topic in this field: the analysis of phase transformations from the aspect of crystallography Contribution (3), specifically, in a pipeline high-strength–low-alloy (HSLA) steel. Several models were applied and it was concluded that a secondary austenite (not retained) was formed, precipitating at the grain boundaries. Another field is that of stainless steels. The analysis of their applicability involves the study of their resistance to corrosion. The effect of barnacles on the corrosion behavior of 304 stainless steels was analyzed employing electrochemical tests Contribution (4). Depending on the growth stage of the barnacles, the corrosion mechanism varied. In the third work, the formation of austenite in the oxidized layer of an ultra-high-strength 13Ni15Co10Mo maraging steel was analyzed Contribution (5). Maraging steels are based on the Fe-Ni-Co-Mo system. Their high mechanical strength is due to the precipitation of intermetallic compounds



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within a low-carbon martensitic BCC matrix. To improve toughness, the prevention of crack initiation and propagation was discussed.

Of the rest of the published articles, five discuss well-differentiated alloys: Ti, Al, Ni, Cu and Fe. Each metal has several family sets of metal materials associated with it. All five articles are good examples of specific alloys. Ti-based alloys have applications in sectors such as biomedicine and mobility. However, there are also other applications, as in addition to their relatively low density, mechanical response to high temperatures and resistance to corrosion, they are also characterized by their resistance to radiation. In the published article, the influence of neutron irradiation on the microstructure and functional response of coarse and ultrafine-grained titanium (grade 2) was analyzed Contribution (6). The high radiation resistance was attributed to the high density of dislocations and the dense lattice of high-angle grain boundaries. On the other hand, irradiation increases strength and reduces ductility. This is a good example of the applicability of ultrafine-grained materials. The following work also concerns with ultrafine-grained materials, specifically, an Al-Mg-Zr-Ni-based alloy. The influence of Ni addition (during multidirectional forging) on nucleation was analyzed Contribution (7). Therefore, it was concluded that nucleation and precipitate formation were favored by the addition of an element (Ni). The precipitates were of the intermetallic compound $Al_3$(Sc, Zr), which align with the fact that one of the main pathways of study in the field of materials is the controlled addition of a minority element to modify the microstructure of the compound.

With regard to the production and synthesis techniques, those likely being developed to a greater extent in recent years are ones including additive manufacturing. They are a set of techniques that constitute an alternative to conventional synthesis methods. In the following study, a Ni-based alloy was produced Contribution (8) via laser powder bed fusion. Precipitation-hardened nickel–chromium grade 718 was the high-strength superalloy used at temperatures up to 648 °C. The study focused on the influence of powder particle size distributions on the mechanical response. In renewable energies, one of the fields in continuous development is the generation of new materials that allow for the increase in the overall efficiency of solar cells. We do not just have to think about conventional materials that optimize energy conversion, there are other issues, such as improving adhesion strength and reducing the residual stress of electroplated copper films Contribution (9). The main conclusion was that the high adhesion strength was due to the low density of voids and residual stress at the interface. It is an application of Cu within heterojunction technology.

Likewise, traditional metallic alloys are Fe-based, mainly due to their high presence on the Earth's surface and the wide variety of applications based on the possibility of obtaining Fe-based compounds with well-differentiated structures and microstructures. One of the typical structures is amorphous. Regarding crystallography, there are many scientific studies that analyze the crystallization process (including nucleation) of these alloys. In the published work, the influence of a protective coating on the crystallization of a Fe-Si-B alloy was analyzed Contribution (10). It was a Ta coating that prevents the release of the free volume to the surface during heat treatment. The kinetics of the crystallization process were also analyzed.

It has been said that with respect to materials, the 21st century may be the century of magnetism. There are hard, semi-hard or soft magnetic materials. Magnetically hard magnets are usually applied as permanent magnets. Magnetically soft ones have traditionally been applied in high-frequency processes due to their low hysteretic loss. One of the fields of development in the field of soft magnetic material energy is that of magnetic cooling. This application is based on the high magnetocaloric effect when an external magnetic field is applied. Other interesting properties are the shape memory effect, the large magnetoresistance or the presence of exchange bias (usually at low temperatures). The two relevant published works discuss Heusler alloys. Its applicability is based on the usual coexistence of the magnetic (Curie temperature transformation) and structural transitions (martensitic). The first manuscript analyzed the influence of the addition of a fourth element (Ga, Fe or Al) to a Ni-Mn-In Heusler alloy on the microstructure and on the magnetic and magnetocaloric properties Contribution (11). The best functional response was obtained with the addition of aluminum. The latest work is that of a Heusler Co-Mn-Si alloy produced in the shape of a microwire using the Taylor–Ulitovsky technique Contribution (12). The effect of heat treatment on magnetic response was analyzed. It was found that heat treatments at higher temperatures (1023 K, 2 h) cause greater changes in the microstructure and magnetic response.

In short, despite only encompassing twelve works, as a whole, this Special Issue covers a wide spectrum of materials, properties and applications.

## 3. Conclusions and Outlook

The processing–microstructure–property relationships introduced in this Special Issue are valuable in assisting the development, improvement and design of new metallic materials for specific applications. This issue provides new directions for alloy and process design, taking into account crystallography analysis (crystallographic structure, defects, texture, anisotropy).

As the Guest Editor, I would first like to thank the authors of these papers for providing excellent articles for this Special Issue. Second, I would like to extend my gratitude to all the reviewers for their timely work and efforts to improve the quality of the articles. Third, I also thank all the editors and other staff of *Metals* for their trust and assistance, and for the efforts that have made the publication of this Special Issue possible. As the Guest Editor, I hope that the data, observations and methodology presented in these Special Issue papers can greatly promote the development of crystallography analysis in metallic materials.

**Conflicts of Interest:** The author declares no conflicts of interest.

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