metals

Editorial

Special Issue: "Processing and Treatment of Hexagonal Metals"

Jaroslav Čapek

FZU—Institute of Physics of the Czech Academy of Sciences, Na Slovance 1999/2, 182 21 Prague 8, Czech Republic; capekj@fzu.cz; Tel.: +420-266-05-2604

Citation: Čapek, J. Special Issue: "Processing and Treatment of Hexagonal Metals". *Metals* **2021**, *11*, 1753. https://doi.org/10.3390/met11111753

Received: 6 September 2021
Accepted: 28 October 2021
Published: 31 October 2021

1. Introduction and Scope

There is currently an increasing demand for metals with a hexagonal close-packed structure (HCP). Particularly, titanium and its alloys are widely used in aerospace, aircraft and the medical industry [1,2]; zirconium is used in the nuclear industry [1] and Mg-based alloys in the automotive and aircraft industry [1]. Besides, Mg-based materials are also considered for fabrication of absorbable implants [3]. Zn-based alloys are used in the automotive or construction industries [4] and are also studied as absorbable material for implantology [5]. The aforementioned applications put high demands on the quality of the components, because their failure would have critical consequences.

The HCP metals show anisotropy in their mechanical behavior. This is because of the large differences between the values of the critical resolved shear stress (CRSS) belonging to various slip systems. The lowest CRSS is observed for basal or prismatic slip systems. Basal slip dominates in Mg and Zn, while prismatic is the main one in Ti and Zr [1]. Both those slip systems accommodate deformation only in the $\langle 11\bar{2}0 \rangle$ directions [1]. This means that the deformation in the direction of the **c** axis must be accommodated by another deformation mechanism. In this case, twining is often activated, especially at larger grain sizes and deformation rates [6,7]. From the aforementioned, it is clear that the mechanical behavior of metals and alloys with a HCP structure is very sensitive to the microstructure and texture of the material. Those characteristics are strongly influenced by processing and thermomechanical treatment. Therefore, the understanding of the relationships between the processing conditions and material microstructure is necessary to predict the behavior of the material. As follows from the aforementioned, many HCP materials are also exposed to a relatively aggressive corrosion environment (body fluids, etc.) or to fatigue stress during their service. Moreover, enhanced biocompatibility (cell adhesion, etc.) is desired for medical implants. For such applications, the quality of the surface plays a very important role for material behavior. The surface characteristics (roughness, topography, chemical composition, etc.) can be changed and adjusted by various methods, such as chemical and electrochemical polishing, laser shock peening, etc. [8–10]. A proper finishing of the surface often plays a crucial role on the material lifespan; therefore, the development of suitable surface treatments for HCP metals can further enhance the great application potential of those materials.

2. Contribution

The papers written by Roudnická et al. [11] and Fojt et al. [12] deal with biomaterials prepared by additive manufacturing, particularly by selective laser melting (SLM). Both these papers clearly demonstrate that the materials processed by SLM can behave significantly differently compared to the materials prepared by conventional methods. Roudnická et al. [11] investigated the influence of the processing route (SLM vs. investment casting) on the response of the material to heat treatment. The hardness response to the annealing of both materials followed the same trend, but the SLM-processed material possessed higher absolute values of hardness. The hardness evolution, however, was explained by various changes of the microstructure. The SLM-processed material mainly underwent an isothermal transformation of the FCC phase in the HCP phase. In the case of the casted material the hardness increase was ascribed to the precipitation of fine carbides.

Fojt et al. [12] dealt with the corrosion behavior of a SLM-processed Ti alloy. They found that the raw SLM material was susceptible to localized forms of corrosion attacks. This was ascribed to partially melted powder particles stuck to the material's surface. Even just mechanical machining of the surface, which brings the surface properties closer to the conventionally fabricated materials, significantly improved the corrosion resistance of the material. In addition, etching in an acidic mixture was found to be an effective instrument to decrease the susceptibility of the material to the localized corrosion attack, especially in the case of the cellular/trabecular samples. Another increase in the corrosion resistance was achieved by electrochemical anodization in a solution of sulfuric acid.

Pinc et al. investigated the influence of the size and amount of ceramic particles on mechanical and corrosion behavior of the Zn-HA/MO composites [13]. Such materials are considered for fabrication of absorbable scaffolds for healing of bone defects. It was found that increasing the amount of ceramic particles decreased material strength and ductility. This was ascribed to the insufficient attachment between the zinc matrix and ceramic particles, which was caused by the large difference between their melting points and low reactivity. A better mechanical performance was achieved when finer ceramic particles were used. Higher degradation rates were achieved if monetite (MO) particles were used.

In the paper from Capek et al., the influence of the initial microstructure of pure zinc on the microstructure and mechanical behavior of thin zinc wires prepared by direct extrusion with a huge extrusion ratio was investigated. The extrusion did not lead to the basal texture which is common for the extruded zinc. As could be expected, the increasing extrusion temperature led to the increasing grain size. The wires extruded at 100 °C showed significant differences in their microstructure. The wires prepared from billets with a very coarse-grained structure displayed bimodal grain size with the mean grain size significantly smaller compared to the wires prepared from the billets with medium grain size. This was most likely caused by the formation of twins and shear bands during the extrusion process. The twins and shear bands could enhance the recrystallization and result in the bimodal microstructure with finer grains. It was also observed that the bimodal grain size led to strain-assisted grain growth during the tensile test, resulting in a decrease in strength. The obtained results clearly demonstrate that the behavior of zinc is influenced not only by the conditions of the thermomechanical treatment, but also by the microstructure of the initial material. This means that it is necessary to know the whole history of the material to predict its behavior after the thermomechanical treatment.

Dvorsky et al. [14] investigated the influence of the processing route on the behavior of the WE43 magnesium alloy. In their detailed and extensive study, they compare microstructure, mechanical and corrosion behavior, as well as ignition temperature of the WE43 alloy prepared by casting, extrusion, T4 heat treatment and two kinds of powder metallurgical routes. They found that the processing route influences the grain size and distribution of intermetallic particles. The tensile yield strength of the prepared materials could be correlated very well using the Hall–Petch relationship. The dissolution of the alloying elements into solid solution by the T4 heat treatment led to lower corrosion rates and a more uniform corrosion attack. It also increased the ignition temperature of the material. The high ignition temperature was ascribed to the formation of the Y_2O_3-based oxides.

Funding: This research received no external funding.

Acknowledgments: As a guest editor, I would like to thank to Marina Tian, the section managing editor, for her helpfulness. I also would like to thank the editorial board of the Metals journal. Special thanks belong to all authors and reviewers, because without their excellent work we could not have prepared this special issue.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Wang, Y.; Huang, J.C.C. Texture analysis in hexagonal materials. *Mater. Chem. Phys.* **2003**, *81*, 11–26. [CrossRef]
2. Jackson, M.J.; Ahmed, W. (Eds.) Titanium and Titanium Alloy Applications in Medicine. In *Surface Engineered Surgical Tools and Medical Devices*; Springer: Boston, MA, USA, 2007; pp. 533–576. [CrossRef]
3. Banerjee, P.C.; Al-Saadi, S.; Choudhary, L.; Harandi, S.E.; Singh, R. Magnesium Implants: Prospects and Challenges. *Materials* **2019**, *12*, 136. [CrossRef] [PubMed]
4. Pola, A.; Tocci, M.; Goodwin, F.E. Review of Microstructures and Properties of Zinc Alloys. *Metals* **2020**, *10*, 253. [CrossRef]
5. Hernández-Escobar, D.; Champagne, S.; Yilmazer, H.; Dikici, B.; Boehlert, C.J.; Hermawan, H. Current status and perspectives of zinc-based absorbable alloys for biomedical applications. *Acta Biomater.* **2019**, *97*, 1–22. [CrossRef] [PubMed]
6. Yoo, M.H. Slip, twinning, and fracture in hexagonal close-packed metals. *Met. Mater. Trans. A* **1981**, *12*, 409–418. [CrossRef]
7. Chmelík, F.; Trojanová, Z.; Lukáč, P.; Převorovský, Z. Acoustic emission from zinc deformed at room temperature Part II The influence of grain size on deformation behaviour and acoustic emission of pure zinc. *J. Mater. Sci. Lett.* **1993**, *12*, 1166–1168. [CrossRef]
8. Mohammed, M.T.; Khan, Z.A.; Siddiquee, A. Surface Modifications of Titanium Materials for developing Corrosion Behavior in Human Body Environment: A Review. *Procedia Mater. Sci.* **2014**, *6*, 1610–1618. [CrossRef]
9. Maawad, E.; Sano, Y.; Wagner, L.; Brokmeier, H.-G.; Genzel, C. Investigation of laser shock peening effects on residual stress state and fatigue performance of titanium alloys. *Mater. Sci. Eng. A* **2012**, *536*, 82–91. [CrossRef]
10. Asri, R.I.M.; Harun, W.; Samykano, M.; Lah, N.A.C.; Ghani, S.A.C.; Tarlochan, F.; Raza, M. Corrosion and surface modification on biocompatible metals: A review. *Mater. Sci. Eng. C* **2017**, *77*, 1261–1274. [CrossRef] [PubMed]
11. Roudnicka, M.; Bigas, J.; Molnarova, O.; Palousek, D.; Vojtech, D. Different Response of Cast and 3D-Printed Co-Cr-Mo Alloy to Heat Treatment: A Thorough Microstructure Characterization. *Metals* **2021**, *11*, 687. [CrossRef]
12. Fojt, J.; Hybášek, V.; Kačenka, Z.; Průchová, E. Influence of Surface Finishing on Corrosion Behaviour of 3D Printed TiAlV Alloy. *Metals* **2020**, *10*, 1547. [CrossRef]
13. Hosová, K.; Pinc, J.; Školáková, A.; Bartůněk, V.; Veřtát, P.; Školáková, T.; Průša, F.; Vojtěch, D.; Čapek, J. Influence of Ceramic Particles Character on Resulted Properties of Zinc-Hydroxyapatite/Monetite Composites. *Metals* **2021**, *11*, 499. [CrossRef]
14. Dvorský, D.; Kubásek, J.; Hosová, K.; Čavojský, M.; Vojtěch, D. Microstructure, Mechanical, Corrosion, and Ignition Properties of WE43 Alloy Prepared by Different Processes. *Metals* **2021**, *11*, 728. [CrossRef]