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Editorial

Microstructure and Mechanical Behavior of Structural Materials

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Metallic materials continue to attract significant interest for structural applications globally, ranging from high-performance sectors like aerospace and automotive industries to everyday household items. The mechanical performance of these structural metallic materials is predominantly governed by their microstructure, which directly influences their mechanical properties. Consequently, understanding the microstructure–property relationship is crucial for predicting and optimizing the performance of structural components in various applications.

This Special Issue, titled "Microstructure and Mechanical Behavior of Structural Materials", presents a collection of 13 original research articles and 2 comprehensive review papers, each contributing to the understanding of diverse structural materials and their microstructure–property correlations. Several studies focus on Fe-based alloys, exploring the microstructural and mechanical behavior of both low-carbon and stainless steels. For instance, Shekhawat et al. [1] examined the influence of initial grain orientation on grain rotation in low-carbon steel, revealing that grains aligned with the γ-fiber (ND//<111>) orientation remained stable, while grains in other orientations experienced notable rotation. Pompeo et al. [2] investigated 17-4PH stainless steel fabricated via bound metal deposition, demonstrating that a 45° infill angle reduced δ-ferrite content and resulted in enhanced hardness.

This Special Issue further includes findings on lightweight (Ti- and Al-based) alloys highlighting how processing techniques and microstructural evolution influence the mechanical properties. Kim et al. [3] investigated the intermetallic compound layer thickness and morphology in Al-Si-Mg/STS420 joints, demonstrating a significant effect of reaction time and temperature on IMC layer thickness and hardness gradients. Hulka et al. [4] examined Ti-20Zr alloy as a potential biomaterial, revealing a lamellar α and β structure post-heat treatment and air cooling. The softer α phase, approximately 30% softer than the β phase, along with a stable corrosion-resistant oxide layer formed in simulated body fluid, promotes bone integration, supporting its biocompatibility. Krawczyk et al. [5] showed that aging Ti-3Al-8V-6Cr-4Zr-4Mo alloys at 550 °C significantly enhances texture strength, whereas aging at lower temperatures leads to reduced texture intensity and lower mechanical performance. Kayani et al. [6] analyzed the impact of powder size on pore density and IMC formation in porous TiAl alloys, concluding that finer powders (325 mesh) increase porosity and facilitate faster diffusion during sintering, facilitating the formation of IMCs, especially at lower temperatures. Rawles et al. [7] optimized the rolling process of Mg-Al and Ti-6Al-4V alloys, achieving significant improvements in strength and hardness after cold working. Korchef and Souid [8] demonstrated that optimized equal-channel angular pressing processing refines the grain size in Al alloys, increasing hardness and yield strength. Kušter et al. [9] studied polymer composites containing Al-Cu-Fe quasicrystals and found that adding more than 20% of quasicrystals improved impact strength and wear resistance, while an excess of 30% compromised mechanical performance. Newport et al. [10] focused on the post-processing heat treatment of Al-Mg-Sc composites

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produced via direct energy deposition (DED), showing that a 300 °C heat treatment forms Al_3(Sc,Zr) phases, optimizing tensile strength without significant grain coarsening.

Several studies in this Special Issue provide valuable insights into the fracture and damage mechanisms in specialized materials. Deng et al. [11] investigate the three-point bending fracture process of Yellow River ice, emphasizing the role of grain size and crack depth ratio in influencing fracture resistance. Wang et al. [12] employ multiscale simulations to study the spallation characteristics of Ta under high-strain-rate impacts, revealing the evolution of damage mechanisms and the effects of strain rate on spallation strength. Liu et al. [13] examine the impact of secondary orientation on the deformation behavior of Ni-based single-crystal superalloys at room temperature (RT) and 850 °C. Their findings indicate that the secondary orientation has a negligible influence on mechanical properties at RT but plays a significant role at elevated temperatures, contributing to the enhanced ductility of superalloys.

Lastly, two review articles provide additional insights into the relationship between microstructure evolution and mechanical properties. Zarinejad et al. [14] focus on additive manufacturing techniques for W alloys, addressing persistent issues like thermal stress-induced cracking and oxide formation. The review discusses innovative methods, including laser-based DED and binder jetting, that enhance W-based material performance. Thool et al. [15] reviewed the microstructural and textural evolution in HCP metals such as Zr, Mg, and Ti, emphasizing the impact of twinning and dislocation movements on anisotropic behavior. Both studies offer a comprehensive view of emerging trends and future directions in advanced structural materials research. Overall, the studies in this Special Issue provide valuable insights into how microstructural modifications impact the mechanical properties of structural materials, supporting advancements in material design and process optimization.

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