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Editorial

Development of Light Alloys and Their Applications

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1. Introduction

Magnesium, aluminium and titanium are commonly classified as light alloys because of their high strength-to-weight and/or stiffness-to-weight ratios. Owing to these properties, light alloys have attracted considerable commercial and industrial interest. Among them, aluminium alloys are the most widely used, finding extensive applications not only in the automotive and aerospace sectors but also in everyday products such as packaging cans and foils. In recent years, titanium and magnesium alloys have also seen increasing utilisation. Titanium alloys are predominantly employed in the aerospace industry due to their low density combined with excellent mechanical strength, particularly at elevated temperatures. In addition, their outstanding corrosion resistance makes them suitable for demanding environments, including marine and petrochemical applications. Magnesium alloys, on the other hand, are preferred when further weight reduction is critical, such as in aircraft components, material-handling equipment and portable power tools.

Despite the successful application of light alloys across a broad range of industries, several challenges and limitations remain, including issues related to processing efficiency, performance optimisation, cost effectiveness and environmental sustainability. Addressing these challenges will require continued advances in alloy design, processing technologies, modelling and characterisation methods, as well as closer integration between fundamental research and industrial practice. Against this backdrop, this Special Issue "Development of Light Alloys and Their Applications" comprises ten contributions that collectively reflect the breadth and depth of current research on light alloys and their applications.

The published works cover key topics across aluminium, titanium and magnesium alloys, including advanced joining and solid-state processing techniques, microstructure–property relationships, novel alloy systems, additive manufacturing and hybrid manufacturing routes, and surface engineering and corrosion behaviour (contributions 1 and 2). Several papers focus on aluminium and titanium alloys for structural applications, highlighting the critical roles of welding, friction stir processing, cooling behaviour and fatigue performance in tailoring mechanical properties for demanding service conditions (contributions 3–6). Other contributions report the development and characterisation of emerging aluminium-based alloys designed for specialised functions, such as thermal neutron shielding, and assess the performance of complex dissimilar-metal joints intended for harsh industrial environments (contributions 7 and 8).

In addition, two comprehensive review articles (contributions 9 and 10) provide forward-looking perspectives on biodegradable magnesium alloys for biomedical applications. These reviews not only summarise recent advances in alloy design, surface modification and corrosion control, but also critically examine the remaining scientific, technological

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Received: 18 December 2025
Accepted: 20 December 2025
Published: 24 December 2025

and regulatory challenges that must be addressed to enable broader clinical adoption. The insights presented highlight the importance of multidisciplinary approaches that integrate materials science, surface engineering, biomechanics and clinical requirements.

Taken together, the contributions in this Special Issue demonstrate the dynamic and evolving nature of light alloy research. They point towards future directions that emphasise intelligent alloy design, process optimisation, sustainability-driven innovation and application-specific performance tailoring. It is anticipated that the findings and perspectives presented here will stimulate further research efforts, foster collaboration between academia and industry, and contribute to the continued advancement of light alloys as key materials for next-generation structural, functional and biomedical applications.

2. Highlights of Novelty and Impact of the Published Papers

The following section highlights the key novelty and significance of each contribution published in this Special Issue. Ugodchikova et al. (contribution 1) explore the effect of particle incorporation on micro-arc oxidation (MAO) coatings on bioinert titanium alloys. Coatings containing β-tricalcium phosphate (CP), wollastonite (CS), and their combination (SP) were fabricated at 350–500 V. Surface morphology, composition, phase structure, and fine structure were characterised using SEM, EDX, XRD, and TEM. Scratch tests showed SP coatings exhibited the highest adhesion (Lc = 22 N), highlighting their potential for durable, load-bearing biomedical implant applications.

Fernández-Calvo and co-workers (contribution 2) demonstrate a hybrid manufacturing approach combining ablation casting and laser metal deposition (LMwD) for Al-5356 alloy, enabling near-net-shape components with complex geometries. Their work validates the process by showing low porosity (<0.04%) and minimal lack-of-union defects, with LMwD regions exhibiting higher strength than ablation-cast areas. These findings highlight the potential of integrating conventional and additive manufacturing to improve mechanical performance, productivity, and reliability in industrial-scale aluminium alloy fabrication.

Elshaghoul and team (contribution 3) investigate Friction Stir Spot Welding (FSSW) of high-strength AA2024-T4 aluminium, focusing on low rotational speeds (700–1300 rpm) and a short 3 s dwell time. Results reveal the optimal 900 rpm achieves maximum load-carrying capacity and stir zone hardness, demonstrating how grain refinement and thermal softening govern joint strength in demanding automotive and aerospace applications.

El-Eraki and collaborators (contribution 4) provide first-time insights into the isolated effect of friction stir processing (FSP) travel speed on hypoeutectic Al-5 wt.% Si alloys. By refining grain structure, FSP significantly enhances hardness, tensile strength, toughness, and wear resistance, with 26 mm/min achieving optimal performance. Their work underscores travel-speed control as key for tailoring cast alloy properties.

Wang et al. (contribution 5) investigate the fatigue behaviour of TC4/Ti60 dissimilar titanium alloy joints fabricated by electron beam welding. Results reveal that the weld zone, strengthened by martensite, resists failure, while fatigue cracks initiate in the TC4 base material. Findings provide key insights into microstructure–fatigue relationships for high-performance structural applications.

Wang and team (contribution 6) investigate gradient cooling effects on Al-2 at.% Nd alloy microstructure and properties in a vacuum. Slower cooling transforms mixed columnar–equiaxed grains into equiaxed grains and forms discontinuous α-Al and $Al_{11}Nd_3$ eutectic phases, reducing phase and grain boundaries. First-principles calculations confirm these changes, correlating microstructural evolution with a 25.5% decrease in hardness.

Amer's study (contribution 7) reports a novel quaternary intermetallic phase, $Al_{21}GdCrTi$, in an Al-Gd-Cr-Ti alloy, alongside detailed analyses of microstructure evolution, texture, mechanical strengthening, and neutron absorption. Hot–cold rolling enhances hardness, yield, and tensile strength while maintaining ductility. The alloy exhibits ~100× lower neutron scattering than pure aluminium, providing a foundation for advanced neutron-shielding materials.

Marônek and co-workers (contribution 8) evaluate Cu-Al-AlMg3 structural transition joints fabricated via explosion welding for galvanizer hanger renovation. Microstructural analysis reveals wavy interfaces, localised strain hardening, and Al_2Cu intermetallic formation. Bond strength doubles that of AW1050 alloy, with failure at the AW1050–AW5754 interface, demonstrating the effectiveness of welding parameters and potential for industrial structural applications.

The two reviews on biodegradable magnesium alloys complement each other in scope and focus. Aikin et al. (contribution 9) provide a broad, historical perspective, highlighting alloy design, manufacturing, surface engineering, and clinical translation, while addressing challenges such as unpredictable degradation, safety, and regulatory issues. Liu and team (contribution 10) are more technical and solution-oriented, concentrating on alloying and surface treatments to improve corrosion resistance, mechanical performance, and biocompatibility. Together, they offer both a forward-looking clinical roadmap and targeted strategies for overcoming material limitations, underscoring the continued development of Mg-based biomaterials for medical applications.

3. Conclusions

Collectively, the contributions in this Special Issue underscore the remarkable progress and ongoing challenges in the development of light alloys. From novel aluminium, titanium, and magnesium systems to advanced joining, processing, and surface engineering techniques, these studies highlight both scientific innovation and practical application. The insights provided not only advance fundamental understanding but also pave the way for future high-performance, sustainable, and clinically or industrially relevant light alloy technologies.

Author Contributions: Conceptualization, H.Q.A.; methodology, H.Q.A.; validation, H.Q.A., investigation, H.Q.A.; writing—original draft preparation, H.Q.A.; writing—review and editing, H.Q.A., G.K. and E.K. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: As Guest Editors, we would like to express our sincere appreciation to all authors whose valuable work was published in this Special Issue, contributing to its success, and to all anonymous reviewers who provided their expert evaluations and constructive feedback, supporting the peer review process.

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

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https://doi.org/10.3390/cryst16010011