

Properties, Microstructure and Forming of Intermetallics

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1. Introduction

Intermetallic compounds and intermetallic-based alloys occupy a distinctive position in modern metallurgy. Unlike conventional substitutional solid-solution alloys, many intermetallics are characterized by long-range atomic order, defined stoichiometric ranges, and crystal structures that give rise to property combinations difficult to achieve in disordered metallic systems. Aluminides, silicides, Laves phases, Heusler phases, and related ordered compounds have therefore attracted sustained interest for structural, functional, and environmental applications. Their appeal is particularly clear in situations where low density, high specific strength, high-temperature stability, oxidation or corrosion resistance, and functional electronic or thermal behavior must be combined within a single material system [1,2].

The development of useful intermetallics is not simply a matter of identifying a promising phase. It requires control over composition, solidification path, deformation route, heat treatment, surface reaction, and component-scale geometry. The relation among properties, microstructure, and forming is therefore central to the field: microstructure is the bridge through which atomic order becomes engineering performance. High-temperature structural intermetallics illustrate this balance especially well. TiAl-based alloys have long been studied as lightweight alternatives to nickel-based superalloys in selected aerospace and automotive components, including turbine blades and turbocharger rotors [3]. Their progress has depended on microalloying, lamellar and duplex microstructure control, investment casting, powder metallurgy, hot working, and heat-treatment strategies that mitigate brittleness while preserving high specific strength. Orthorhombic Ti₂AlNb-based alloys offer another example: they can provide attractive strength, creep resistance, and ductility relative to earlier titanium aluminides, yet their usefulness at elevated temperature is constrained by oxidation behavior and the formation, adherence, and protectiveness of complex oxide scales [4,5].

Recent research also shows that intermetallic design increasingly extends beyond traditional ways. Computational approaches can now connect crystal structure, bonding, elastic anisotropy, thermodynamic response, and electronic structure before extensive experimental campaigns are attempted. Meanwhile, experimental studies of casting, thin-wall filling, dynamic loading, electrochemical corrosion, oxidation, and precipitation strengthening continue to reveal how sensitive these materials are to processing history and service environment. This Special Issue, “Properties, Microstructure and Forming of Intermetallics”, brings these threads together. The contributions range from first-principles prediction and critical review to component-oriented casting verification and high-temperature environmental testing. Collectively, they emphasize that intermetallics should be evaluated not



Received: 30 May 2026

Accepted: 16 June 2026

Published: 30 June 2026

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as isolated compounds, but as designed material systems in which performance emerges from the coupled effects of phase constitution, microstructure, forming route, and operating condition.

2. Overview of the Published Articles

A total of six articles have been published in this Special Issue.

Gong et al. [Contribution 1] studied the effect of Nb content on the oxidation behavior and microstructural evolution of Ti_2AlNb -based alloys at 800 °C in air. The oxidized alloys developed multilayer scales consisting of an outer TiO_2 layer and inner TiO_2 -rich and AlNbO_4 -rich sublayers. Thermodynamic analysis supported the formation of TiO_2 , Al_2O_3 , Nb_2O_5 , and AlNbO_4 , while also explaining why a continuous protective Al_2O_3 scale was difficult to form. Increasing Nb content reduced oxygen diffusion and the thickness of porous TiO_2 regions, making the 23Nb alloy more oxidation-resistant than the 14Nb alloy. The study clarifies the need to balance Nb and Al contents for mechanical and environmental performance.

Lopez-Dominguez et al. [Contribution 2] investigated the electrochemical behavior of Ni_3Al intermetallic alloy in a 60 wt% NaNO_3 -40 wt% KNO_3 eutectic mixture, commonly known as Solar Salt. The study combined mass-loss measurements for up to 1000 h with electrochemical testing for up to 100 h at 300 °C, 400 °C, and 500 °C. Ni_3Al showed excellent corrosion resistance, especially at 300 °C and 400 °C where corrosion rates were very low. Increasing temperature reduced corrosion resistance and promoted more aggressive salt chemistry. Surface characterization indicated the formation of protective Al_2O_3 - and NaAlO_2 -type layers, suggesting that Ni_3Al is promising for molten salt thermal storage or heat-transfer systems below about 500 °C.

Pei et al. [Contribution 3] prepared a high-strength WMoZrNiFe energetic structural material and studied its dynamic mechanical response and ignition behavior using a split-Hopkinson pressure bar. Samples were loaded at initial tilt angles of 0°, 30°, and 45° to clarify how loading orientation affects failure and reaction. The material exhibited a strain-rate effect between approximately 1000 s^{-1} and 3000 s^{-1} , with yield strength increasing as strain rate increased. Fractography indicated mixed ductile-brittle failure features, while elemental analysis suggested that W and Mo participated in oxygen reactions after fracture. The work links microstructure, absorbed energy, failure mode, and ignition threshold under high-rate compression.

Tetsui et al. [Contribution 4] examined how alloy composition affects the melt fillability and impact resistance of TiAl alloys for thin-blade turbine wheels. The study combined simple laboratory tests with verification using actual turbine wheel products, making it directly relevant to component-scale forming. Melt fillability was estimated from the amount of molten alloy passing through an alumina-silica mesh, and the trend was consistent with real blade filling behavior. The binary TiAl alloy showed the best fillability, while additions such as Cr, Mn, and Si reduced it. Charpy tests showed that Cr and Mn improved impact resistance, whereas Nb, W, Mo, and Si tended to reduce it, highlighting the trade-off among castability, toughness, oxidation resistance, and creep requirements.

Yu and Cheng [Contribution 5] used density functional theory to investigate monoclinic CuP_2 and hexagonal Cu_3P , two copper phosphide compounds relevant to soldering, brazing, and microelectronic packaging. Their calculations confirmed the mechanical stability of both compounds while revealing different anisotropic and bonding behaviors. Cu_3P showed greater resistance to volumetric compression, whereas CuP_2 exhibited higher shear and Young's moduli. Ductility and brittleness indicators, thermodynamic descriptors, thermal conductivity, and electronic structures further distinguished CuP_2 as a semicon-

ducting, more covalent phase and Cu₃P as a metallic conductor, providing useful guidance for reliability-sensitive packaging materials.

Li et al. [Contribution 6] provided a critical review of Cu-Ni-Co-Si alloys, focusing on processing methods, microstructural evolution, properties, and strengthening mechanisms. These alloys are important candidates for electrical and electronic applications because they can combine high strength with good electrical conductivity while avoiding the toxicity concerns associated with Cu-Be alloys. The review discusses casting, vacuum induction melting, additive manufacturing, alloying effects, and thermal treatments. Particular attention is given to precipitation hardening by nanoscale (Ni,Co)₂Si-type phases, together with grain-boundary and solid-solution strengthening. The paper identifies future opportunities in optimizing alloying additions and heat treatment schedules to balance conductivity, strength, and reliability.

3. Conclusions and Outlook

The articles collected in this Special Issue demonstrate the breadth of current research on intermetallics. They cover first principles prediction, thin-wall casting, dynamic impact, precipitation-strengthened copper alloys, molten salt corrosion, and high-temperature oxidation. Despite this diversity, a common message emerges: the practical value of intermetallics depends on the controlled interaction of composition, microstructure, forming route, and service environment. A phase that is attractive in equilibrium may fail if it cannot be cast into a thin section, resist cracking during loading, maintain a protective scale, or preserve the required balance of strength and conductivity.

Future work should therefore move further toward integrated design. Computational predictions need to be linked more tightly with experiments that test real processing histories and real component constraints. Forming studies should be coupled with microstructural characterization across length scales, especially for thin-walled, additively manufactured, or dynamically loaded parts. Environmental resistance should be evaluated under longer, more application-relevant exposures, where oxide, salt, and stress effects may interact. Finally, multi-objective alloy design will be essential, because intermetallics rarely need only one optimized property. They must often deliver stiffness, toughness, conductivity, oxidation resistance, corrosion resistance, and formability at the same time. Progress in this field will come from treating these requirements as coupled design variables rather than independent targets.

Acknowledgments: The Guest Editors wish to thank all the authors for their contributions, as well as all the reviewers for their work and efforts to improve the quality of the articles. The Editors appreciate the support from the Metals Editorial Office throughout the publication process.

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

List of Contributions

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