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Editorial

Featured Review Papers in Additive Manufacturing Technologies: From Industries to Biomedical Applications

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Additive manufacturing (AM), commonly known as three-dimensional (3D) printing, has rapidly evolved over recent decades and now plays a significant role across diverse areas, ranging from industrial production to biomedical engineering. As 3D printing technologies continue to advance—particularly with the decreasing cost of printers and printing materials—the scientific literature has seen a marked increase in reports documenting innovative AM applications [1–5]. This Special Issue was established to highlight high-quality review articles that explore the interdisciplinary uses of AM and 3D printing. A total of 17 manuscripts were submitted, of which 14 were accepted for publication.

Among the 14 featured review articles, 8 address engineering-related applications of additive manufacturing (contribution 1–8), 5 explore medical and biomedical uses (contribution 9–13). and 1 centers on the integration of machine learning techniques within 3D printing workflows (contribution 14). These contributions represent a diverse set of review types, spanning systematic, scoping, and narrative methodologies. The subsequent section outlines the principal strengths and limitations of each review.

Argyrou et al. conducted a comprehensive review of nanoindentation-based research on laser powder bed fusion (LPBF)-processed AlSi10Mg, an emerging alloy known for its highly heterogeneous microstructures [contribution 1]. Their review synthesizes reported methodologies and experimental findings related to nanoindentation in LPBF-fabricated AlSi10Mg, while also identifying unresolved discrepancies and key research gaps. The authors summarized nanoindentation results across the literature and systematically analyzed correlations between LPBF processing parameters and measured mechanical responses. They further outlined future research directions aimed at improving the reliability and performance of additively manufactured aluminum components.

Esquivel and colleagues reviewed four major sintering-based additive manufacturing technologies—powder bed fusion (PBF), direct energy deposition (DED), binder jetting (BJT), and material extrusion (ME)—highlighting the advantages, limitations, and technical challenges associated with each process [contribution 2]. The authors also examined the properties of four commonly used material classes in these technologies: stainless steels (SS), Ni-based alloys, Ti-based alloys, and Al alloys. In addition, the review outlined future research directions, emphasizing the development of physics-informed machine learning (ML) models and hybrid digital twins to enhance process adaptability and improve validation across multiple AM material systems.

Iervolino et al. conducted a review of polymer materials used in additive manufacturing by searching the Web of Science database for studies published between 2013 and 2015 [contribution 3]. The authors evaluated the advantages, applications, and limitations of a wide range of polymers used in electronic applications. Their analysis covered three major

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classes of polymers—intrinsically conductive polymers, extrinsically conductive polymers, and insulating polymers—with discussion focused on their suitability for 3D-printed electronic components. Notably, dielectric polymers emerged as the least investigated category within AM, despite their considerable potential for enabling the development of new materials for electronics-related additive manufacturing.

Koltsakidis and Tzetzis presented a comprehensive overview of strategies for fabricating hierarchically porous polymer structures by integrating fused filament fabrication (FFF) with complementary manufacturing methods [contribution 4]. Their review begins with a summary of FFF fundamentals, highlighting key printing parameters and characteristic features, followed by an examination of various approaches used to generate hierarchical porosity within FFF-produced components. The authors also emphasized several persistent challenges—such as viscosity control, thermal-gradient management, and the absence of standardized porosity-characterization protocols—that limit process reliability and reproducibility. To address these issues, the review points to emerging solutions, including machine learning-assisted process control and hybrid printhead systems, as promising pathways for advancing the fabrication of complex porous polymer architectures.

In their work, Korniejenko et al. approached additive manufacturing from a unique perspective by examining its use in the construction of artificial reefs [contribution 5]. Through a Scopus database search, the authors identified 52 relevant studies for inclusion in their review. They first summarized AM technologies applied to artificial reef design and fabrication, followed by an overview of the materials commonly used in AM-based reef construction. The review also presented case studies illustrating applications in marine ecosystems and the development of freshwater systems. Finally, the authors highlighted key challenges and limitations associated with implementing AM in artificial reef projects. Future directions emphasized the need for multifunctional reef structures, greater digitalization, and the design of advanced materials.

Tao et al. conducted a comprehensive review of material extrusion technology (MEX), a widely adopted additive manufacturing method known for its efficiency and cost-effectiveness [contribution 6]. The authors provided a systematic analysis of high-speed MEX applications across several domains, including automation, medicine, aerospace, and architecture. They also examined the core technical challenges associated with high-speed MEX, such as extrusion flow behavior, thermal management, printing accuracy, and the resulting structural and mechanical performance of printed parts. Furthermore, the review clarified the coupled relationships and dynamic trade-offs between achieving high precision and high deposition speed in MEX processes.

Wahlquist and Ali examined laser powder bed fusion (LPBF) from a defect-centric perspective, beginning with a detailed classification of common LPBF-related part defects, including geometrical and dimensional defects, surface quality defects, microstructural defects, and mechanical performance defects [contribution 7]. They then reviewed recent advances in numerical modeling techniques for LPBF defect prediction and detection, with emphasis on melt-pool-scale defect modeling and broader numerical simulation strategies. Finally, the authors summarized the growing integration of artificial intelligence in LPBF defect sensing, outlining applicable machine-learning methods and the combined use of ML with optical, thermal, and acoustic/ultrasonic sensor systems for real-time defect detection.

Yadegari et al. reviewed the environmental sustainability of aluminum laser-based powder bed fusion metals (PBF-LB/M), with the goal of enhancing both the profitability and overall performance of PBF-LB/M processes [contribution 8]. Their review spans several interconnected themes, beginning with global environmental challenges and ecological impacts, followed by an examination of feedstock production and the PBF-LB/M process itself—including structural design strategies and process-optimization approaches. They

also assessed the integration of post-processing techniques with PBF-LB/M to improve sustainability outcomes. Overall, the review underscores the critical role of powder-bed-fused aluminum alloys in advancing sustainable manufacturing goals.

Botezatu et al. conducted a systematic review evaluating the value of 3D-printed cages in foot arthrodesis by searching four major medical databases [contribution 9]. Twenty studies met the inclusion criteria, encompassing 148 patients treated with 3D-printed implants. The review found that 3D-printed titanium implant cages provide stable fixation and promote osseointegration, effectively addressing limitations of traditional approaches—particularly poor anatomical fit and high nonunion rates—by offering enhanced mechanical stability during arthrodesis. Across the included studies, spherical 3D-printed implants demonstrated fusion rates of up to 92%, representing a substantial improvement over conventional femoral head allografts. The authors also identified key future directions, including the development of new biocompatible materials, the optimization of 3D-printing processes to reduce cost, and long-term clinical studies to evaluate implant durability under physiological loading.

Lei et al. conducted a systematic review of current applications of 3D-printed models in the gastrointestinal (GI) tract [contribution 10]. Their search across PubMed/MEDLINE, Scopus, and Embase identified 25 eligible studies published over the past decade. Of these, 16 were experimental reports, 5 were descriptive surveys, and 4 were case studies. Most studies (76%) reported the use of 3D-printed models for procedure-specific training and preoperative planning in GI surgery, while the remaining studies focused on developing training models for GI procedures. Silicone emerged as the most commonly used printing material, accounting for nearly half of the studies. Eleven studies reported that the 3D-printed models provided high anatomical realism, including accurate structural representation and convincing visual and tactile feedback. Despite these promising outcomes, the review highlighted key limitations in the existing literature, particularly small sample sizes, limited comparative analyses, and the absence of longitudinal follow-up to assess long-term educational or clinical impact.

Tarba et al. conducted a scoping review on direct 3D-printed maxillofacial prostheses, identifying eleven eligible studies, five of which were in vivo investigations [contribution 11]. By examining the design software used and the clinical data-acquisition methods employed, the review emphasized the growing potential of fully digital workflows for producing maxillofacial soft-tissue prostheses, despite the limited number of clinical studies available. Several key limitations were highlighted, including the absence of standardized biocompatible materials, the need for specialized software tailored to maxillofacial prosthetic design to improve precision, and the lack of medium- to long-term clinical studies assessing the durability and performance of 3D-printed prostheses.

Palovcik et al. conducted a review of 3D-printed accessories and auxiliaries in orthodontics by searching PubMed and Google Scholar for studies published between 2020 and 2024 [contribution 12]. Seventy-five articles met the inclusion criteria and were incorporated into the final analysis. These studies were categorized into five groups: original and experimental research (n = 26), reviews (n = 20), case reports and case studies (n = 14), clinical studies (n = 13), and technical or methodological notes (n = 20). The authors examined the material properties, biocompatibility, and clinical applications of these 3D-printed orthodontic accessories, highlighting both their current capabilities and emerging opportunities. They also identified key limitations, challenges, and future directions for advancing 3D printing in orthodontics.

Turek et al. reviewed the current applications of 3D printing in mandibular resection and reconstruction [contribution 13]. Their search across four databases identified 77 studies published between 2020 and 2025, of which 51 research articles met their strict inclusion

criteria; the remaining 26 consisted of case reports, book chapters, or review papers related to the topic. The most commonly used additive manufacturing techniques for producing surgical guides and anatomical templates were powder bed fusion, vat photopolymerization (VPP), and material extrusion (MEX). Findings across these studies indicate that 3D printing enables the creation of highly accurate, patient-specific models that support improved mandibular reconstruction workflows and reduce procedural steps. However, the authors emphasized the need for future research to validate long-term clinical outcomes and assess durability, accuracy retention, and postoperative performance over time.

Rojek et al. reviewed the emerging applications of machine learning (ML) in 3D printing from multiple perspectives [contribution 14]. The authors searched several databases and identified 19 relevant articles published within the past five years for inclusion in their analysis. Their review examined the application of ML across various stages of the 3D printing workflow, including material selection, patient data analysis, design of 3D-printed products, process optimization, 3D-printed fabric design, assessment of potential harmful effects of 3D printing, and optimization of the use of 3D-printed products. The review also highlighted key limitations associated with ML in 3D printing, such as data requirements, computational costs, and model interpretability. Furthermore, future research directions were emphasized, particularly the need to improve the technological maturity and robustness of ML models in 3D printing applications.

This curated Special Edition offers an impressive collection of research, featuring 14 exceptional review articles, all authored by esteemed experts from various academic disciplines and diverse geographical locations around the globe. These thoughtfully crafted articles explore a wide array of subjects, delving into the fascinating and rapidly evolving field of 3D printing technologies and their innovative applications across different sectors, including healthcare, manufacturing, and art. It is our hope that this edition not only serves as an invaluable resource for readers eager to understand the latest trends and advancements in 3D printing but also inspires and encourages further research, informed by the insightful suggestions and future pathways outlined in these comprehensive reviews.

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