

Advances and Horizons in Ceramic Materials Research

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Abstract

In this Special Issue entitled Novel Ceramic Materials: Processes, Properties and Applications, 18 articles are brought together. The contributions illustrated the remarkable versatility of ceramics—from bioceramics that heal bone and fight infection, to solid electrolytes and multiferroics powering clean energy, and glass ceramics and zeolite composites safeguarding our environment. Articles on glazes, archaeological pottery, and innovative joining methods reminded us that ceramic science has bridged deep traditions and modern frontiers.

1. Introduction

Ceramics have accompanied human civilization for approximately 30,000 years [1], from the first clay vessels and glazes that defined early civilizations, to the engineered materials that now enable high-speed communication, clean energy technologies, and advanced medical treatments; from stoneware to superconductors, and from pottery to space shuttles [1]. As David Kingery observed in his pioneering text in 1976 [2], ceramics are “the art and science of making and using solid articles which have as their essential component, and are composed in large part of, inorganic nonmetallic materials.” This definition, both expansive and pragmatic, underscores the diversity of ceramic materials—extending well beyond pottery and porcelain to include high-temperature superconductors, inorganic semiconductors, transparent conductors, engineered single crystals, glasses, glass ceramics, bioceramics, and nanostructured systems [3].

Ceramics are a class of materials defined not by a single property, but by their capacity to surprise [3,4]. They can be strong and brittle, yet also superplastic. They insulate against electricity, yet they also enable superconductivity. They can withstand the highest temperatures known, while also serving as the active layers in low-power microelectronic devices. Some ceramics are nearly inert, making them ideal for implants, while others are bioactive, capable of bonding directly with living tissue. Contemporary ceramics is an extraordinary material that defies and transcends existing boundaries—scientific, technological, and even conceptual.

This Special Issue, Novel Ceramic Materials: Processes, Properties and Applications, brings together 18 contributions that illustrate the extraordinary range of modern ceramic science. Together, they highlight how far the field has come—and how far it can go. In celebrating both the heritage and the horizons of ceramics, this volume underscores a simple truth: ceramics are not just materials of the past, but essential building blocks of the future.



Received: 23 September 2025

Revised: 29 September 2025

Accepted: 17 October 2025

Published: 21 October 2025

Citation: Lisińska-Czekaj, A.; Pikula, T. Advances and Horizons in Ceramic Materials Research. *Appl. Sci.* **2025**, *15*, 11272. <https://doi.org/10.3390/app152011272>

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2. An Overview of Published Articles

This section presents a comprehensive review of the Special Issue, Novel Ceramic Materials: Processes, Properties and Applications, summarizing the key contributions of the published articles.

This Special Issue comprises 18 high-quality contributions. The articles gathered in this collection reflect the extraordinary breadth of ceramic science today—from ancient pottery traditions to cutting-edge functional materials for energy, health, and environmental protection. Across 18 contributions, we see a unifying thread: how control of structure and composition unlocks new performance, and how applications continually expand as ceramics meet the challenges of our time.

The articles featured here span a remarkable spectrum of ceramic research. They can be grouped into the following five sections.

2.1. Bioceramics and Bioactive Glasses for Health and Biomedicine

Several contributions explore the growing role of bioceramics and bioactive glasses in medicine. Gallium-containing glass polyalkenoate cements offer antibacterial performance and improved compatibility for bone applications (contribution 1), while magnesium whitlockite granules (contribution 2) and 3D-printed forsterite bioceramics demonstrate promise as scaffolds for bone regeneration (contribution 3). Boron carbide nanoparticles are functionalized for targeted boron neutron capture therapy (contribution 4), and mesoporous bioactive glasses doped with silver and cerium provide antibacterial defence against resistant pathogens (contribution 5). Together, these studies underline the pivotal role of ceramic chemistry and morphology in advancing next-generation biomaterials.

2.2. Energy and Electronic Functionalities

A second cluster highlights ceramics at the heart of energy conversion and storage. From NASICON-type solid electrolytes for seawater batteries (contribution 6) to LaMnO_3 perovskite oxides doped with Ga, Y, Ag, or Pd for fuel cells (contribution 7) and water splitting (contribution 8), these works demonstrate the ability of ceramic frameworks to carry ions, electrons, or both with high efficiency.

2.3. Multiferroic and Functional Ceramics

Contributions on BiFeO_3 – BaTiO_3 (contribution 9) and Aurivillius-phase multiferroics (contribution 10), as well as PZT-based materials (contribution 11) and composites with Terfenol-D (contribution 12), showcase how ferroelectric, piezoelectric, and magnetoelectric couplings can be engineered for multifunctional sensing, actuation, and energy harvesting applications.

2.4. Environmental and Protective Ceramics

Environmental applications are another defining theme. Studies on glass ceramics derived from bricks for immobilizing radionuclides (contribution 13), zeolite-based composites for adsorption of toxic cations (contribution 14), and kaolin–fly ash composites (contribution 15) for wastewater purification demonstrate how ceramic science supports safe nuclear waste management and clean water technologies. These works are striking not only in their functionality but also in their use of waste-derived precursors, underscoring the growing role of circular economy principles in materials research.

2.5. Traditional Ceramics, Manufacturing, and Joining

Ceramics also continue to evolve in their more traditional domains. One study investigates the subtle influence of alkali ratios on the properties of multicomponent glazes (contribution 16), while another traces the provenance of prehistoric pottery from archae-

ological excavations (contribution 17). At the frontier of processing, innovations include the tailoring of morphology and phase evolution in synthetic ceramics, as well as ultrasonic soldering of SiC ceramics with Zn–Mg alloys (contribution 18). Together, these studies show how advances in fabrication and joining remain central to both heritage and modern applications.

3. Conclusions

What emerges from these 18 contributions is a vision of ceramics as materials of both tradition and transformation. They carry forward the knowledge of glazes and clays while simultaneously enabling biomedicine, renewable energy, and environmental resilience. As we look to the future, the message is clear: ceramics, once thought of as brittle relics of the past, continue to prove themselves as adaptable, versatile, and indispensable for shaping technologies that are sustainable, functional, and life-enhancing.

Author Contributions: Conceptualization, A.L.-C. and T.P.; methodology, A.L.-C. and T.P.; software, A.L.-C. and T.P.; validation, A.L.-C. and T.P.; formal analysis, A.L.-C. and T.P.; investigation, A.L.-C. and T.P.; resources, A.L.-C. and T.P.; data curation, A.L.-C. and T.P.; writing—original draft preparation, A.L.-C. and T.P.; writing—review and editing, A.L.-C. and T.P.; visualization, A.L.-C. and T.P.; supervision, A.L.-C. and T.P.; project administration, A.L.-C. and T.P.; funding acquisition, A.L.-C. and T.P. All authors have read and agreed to the published version of the manuscript.

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

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