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Editorial

New Advances into Nanostructured Oxides, 2nd Edition

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1. Introduction

The interest in inorganic nanostructured oxides is growing extensively, thanks to their remarkable features and their wide range of applications, which include (photo)catalysis [1–4], controlled drug-delivery and chemical release [5–7], environmental remediation [8–10], energy and batteries [11], smart materials [12], and so on. One interesting aspect of inorganic nanostructured oxides is the high level of control that can be achieved over particle morphology, size, shape, and porosity [13], as well as their surface properties [14,15], which further broaden the possible application of these materials in a wide variety of fields. In fact, the use of suitable synthetic pathways and ad hoc surface functionalization procedures provides a powerful tool to obtain pure inorganic or hybrid inorganic–organic composite materials that represent strategic materials in the most recent research literature [16,17].

In this context, after the success of the first edition published in *Inorganics* in 2022, the second edition of the Special Issue, entitled "New Advances into Nanostructured Oxides, 2nd Edition" was launched to bring together the most recent developments on the class of inorganic materials. This Special Issue is inserted in the "Inorganic Materials" section that, since its birth, has rapidly grown thanks to its attention to advanced inorganic materials, as well as their high technological demand. The aim was to collect research papers and reviews focused on the synthesis and characterization of inorganic oxide nanomaterials through soft chemistry approaches, favoring a high control on the particle morphology, size, porosity and surface functionalities. In addition, in view of their application, the materials' performances are described with the ambitious goal of identifying the structure–property relations to connect the surface, morphological and structural features to the material activity. This represents a shared interest in the development of innovative materials, as the modulation of the key structural parameters may be used to tune and improve the materials' resulting performances.

Prior to proceeding with the overview of the contributions, the Guest Editors would like to thank all of the reviewers who spent their valuable time thoroughly reviewing and improving the articles published in this volume. We also sincerely thank all the authors for choosing *Inorganics*, and, in particular, the "Inorganic Materials" section, as the recipient of their excellent science.

2. An Overview of the Published Articles

Overall, this Special Issue collected 10 original papers (i.e., seven research articles and three reviews) and received more than 16,000 views, which paved the way for the further proposal of a third edition of the same Special Issue. The published papers can be categorized into three main subsections as reported in Table 1, including: (i) environmental remediation, (ii) development and optimization of new synthetic routes for metal oxides, and (iii) drug-delivery and biomedicine. This classification was made considering both the materials applications and the applied synthetic routes for the preparation of the materials.

Table 1. Correlation between subsections and contributions collected in the present Special Issue.

Subsections	Title	References
Environmental remediation	"Efficient catalytic reduction of organic pollutants using nanostructured CuO/TiO_2 catalysts: synthesis, characterization, and reusability"	[18]
	"Core/shell ZnO/TiO_2, SiO_2/TiO_2, Al_2O_3/TiO_2, and $Al_{1.9}Co_{0.1}O_3/TiO_2$ nanoparticles for the photodecomposition of Brilliant Blue E-4BA"	[19]
	"Significantly enhanced self-cleaning capability in anatase TiO_2 for the bleaching of organic dyes and glazes"	[20]
	"Research progress of TiO_2 modification and photodegradation of organic pollutants"	[21]
	"Morphological dependence of metal oxide photocatalysts for dye degradation"	[22]
Development and optimization of new synthetic routes for metal oxides	"The influence of annealing temperature on the microstructure and electrical properties of sputtered ZnO thin films"	[23]
	"Synthesis and redox properties of iron and iron oxide nanoparticles obtained by exsolution from perovskite ferrites promoted by auxiliary reactions"	[24]
	"Mesoporous titania nanoparticles for a high-end valorization of *Vitis vinifera* grape marc extracts"	[25]
Drug-delivery and biomedicine	"Precipitative coating of calcium phosphate on microporous silica–titania hybrid particles in simulated body fluid"	[26]
	"The story, properties and applications of bioactive glass "1d": from concept to early clinical trials"	[27]

2.1. Environmental Remediation

A large portion of the contributions reported in this Special Issue is focused on the exploitation of inorganic nanomaterials (mainly TiO_2) for environmental remediation. In fact, the urgency of solving environmental pollution caused by the anthropogenic activities both in gaseous and liquid phases has driven research interest from more than a decade [28–30]. In this field, the use of photocatalysis is one of the most studied techniques to reduce the concentration of organic pollutants in wastewater, by using inorganic nanomaterials as efficient photo-catalysts. At the same time, organic pollutants can be degraded by using other catalytic reactions, such as catalytic reduction reactions in the presence of suitable nanostructured catalysts. In this first section, three research papers and two reviews were published [18–22].

Abouri et al. [18] reported the synthesis of nanostructured CuO/TiO_2 catalysts via a combustion technique, followed by calcination at 700 °C to achieve a rutile-phase TiO_2 structure with varying copper loadings (in the 5–40 wt.% range). Tests were performed aiming to reduce 4-Nitrophenol and Methyl Orange as target molecules with sodium borohydride ($NaBH_4$) in the presence of the CuO/TiO_2 catalysts. Results indicated a 98% reduction of 4-Nitrophenol in 480 s and 98% reduction of Methyl Orange in 420 s. The catalysts exhibited high stability over 10 reuse cycles, maintaining over 96% efficiency for Methyl Orange and 94% efficiency for 4-Nitrophenol.

Dolatyari et al. [19] reported the synthesis of core/shell ZnO/TiO_2, SiO_2/TiO_2, and Al_2O_3/TiO_2 nanoparticles using ethylene glycol for governing the nanoparticle size, followed by calcination at 400 °C to decompose the organic residues at the nanoparticles' surface. Furthermore, Cobalt (Co^{3+}) was added during the Al_2O_3 nanoparticle synthesis to form Co-doped nanoparticles with formula $Al_{1.9}Co_{0.1}O_3/TiO_2$. All of the synthesized nanoparticles were tested for the photocatalytic degradation of Brilliant Blue E-4BA under UV and visible light irradiation. Photocatalytic tests revealed that both Al_2O_3/TiO_2 and $Al_{1.9}Co_{0.1}O_3/TiO_2$ showed superior degradation under UV and visible light compared to ZnO/TiO_2 and SiO_2/TiO_2 with complete photodecomposition of the target dye (20 ppm) in only 20 min using a 10 mg of photocatalyst. Furthermore, the "Co-doped" $Al_{1.9}Co_{0.1}O_3/TiO_2$ nanoparticles showed the best performance under visible light irradiation, due to the increased absorption in the visible range as Co-doping introduces additional energy levels into Al_2O_3, resulting in improved electron–hole pair generation.

Zhao et al. [20] reported the hydro/solvothermal synthesis of Mg-doped TiO_2 anatase samples in water/ethanol environment at 180 °C for 36 h without using any surfactants or templates. Subsequently, glaze samples were prepared by sintering the raw powders (95% Kaolin clay, 5% Mg-doped TiO_2) at ca. 1200 °C. Photocatalytic experiments revealed that Mg-doped TiO_2 samples have higher photocatalytic activities (99.5% in 80 min under visible light) against Rhodamine B compared with undoped ones, due to pure anatase phase formation. Moreover, ceramic glaze materials present self-cleaning properties, achieving a water contact angle of ca. 6° at room temperature.

Mao et al. [21] analyzed the scientific literature describing the latest advances in the synthesis procedures and strategies to produce and/or properly modify TiO_2-based nanomaterials, aiming at maximizing/improving the photocatalytic performances in environmental remediation processes for the abatement of organic pollutants.

Lastly, Naggar et al. [22] reviewed the latest scientific literature describing the recent progress regarding the use of metal oxides in photocatalysis, with a particular focus on the critical role played by their morphology in the overall degradation process. The state-of-the-art analysis revealed that non-spherical morphologies exhibit enhanced photocatalytic performance due to their unique crystal facets and surface areas, which can promote charge transfer and improve catalytic efficiency. Furthermore, porous design and substantial specific surface area are responsible for an increased photocatalytic activity, whereas flake-like structures exhibit comparatively lower performance.

2.2. Development and Optimization of New Synthetic Routes for Metal Oxides

Careful consideration has been dedicated in this Special Issue to the development of new synthetic routes for metal oxides, and to the optimization of the synthetic approaches for the preparation of metal oxide nanostructures. In fact, the use of specific experimental conditions can drive the structural and morphological properties of the materials, and the fine control of these parameters play a key role in the determination of the material performances. Moreover, the use of innovative and more recent methodologies is reported, as well as the preparation of hybrid materials [23–25].

Alshoaibi [23] reported a study involving the deposition of a hetero-structured (ZnO/Zn/ZnO) thin film on a glass substrate using the DC magnetron sputtering technique. Subsequently, samples were annealed at different temperatures in the 100–500 °C range. Characterization results indicated the formation of both metallic zinc and the hexagonal ZnO crystal structure for samples annealed below 200 °C, whereas pure hexagonal ZnO formed for samples annealed at 300 and 500 °C, with a slight crystallinity decrease for the sample annealed at the highest temperature. Since both roughness and particle size are inversely proportional to the annealing temperature (with the exception of the sample annealed at 500 °C), the optimal annealing temperature was determined to be 400 °C.

Filimonov et al. [24] reported an original approach to synthesize hollow and layered oxide magnetic nanoparticles (either Fe_3O_4, γ-Fe_2O_3, or $Fe_3O_4/La_{1-x}Ca_xFeO_{3-\gamma}$), by a solid-state exsolution process carried out in a reducing environment at elevated temperatures from Ca- and La-based unsubstituted (and substituted) perovskite-related ferrites, and using h-BN as a reducing agent.

Lastly, Abduraman et al. [25] reported a synthetic sol–gel protocol assisted by solvothermal treatment (100 °C, 24 h) using either a triblock copolymer (Pluronic P123) or a nonionic surfactant (Pluronic F127) as soft-templating agents, followed by purification through either Soxhlet extraction or calcination at 400 °C for the production of mesoporous titania nanoparticles. The results indicated that samples prepared using Pluronic F127 presented a higher surface area and less agglomeration than the sample synthesized with Pluronic P123. Furthermore, an extract from *Vitis vinifera* grape marc (*Feteasca neagra* cultivar) with high radical scavenging activity was encapsulated in mesoporous titania and compared with reference SBA-15 silica support. Both resulting materials showed biocompatibility and even better radical scavenging potential than the free extract. Furthermore, the titania encapsulated sample showed better cytocompatibility than the silica one, thus making it suitable for skin-care products.

2.3. Drug Delivery and Biomedicine

In this last part, inorganic nanomaterials for drug delivery systems and for biomedicine purposes are discussed [26,27].

Kimura et al. [26] reported the development of a calcium phosphate-coating method to homogeneously cover silica–titania porous nanoparticles (with a well-defined spherical shape, uniform size, and tunable nanoporous structure) in simulated body fluids. The results indicated that the pore size distribution is a fundamental parameter significantly affecting the coating formation, with surfaces with bimodal pore sizes becoming rough after the calcium phosphate precipitation, whereas those with a unimodal pore size remaining smooth, thus indicating that pore sizes serve as different nucleation sites leading to different surface morphologies.

Lastly, Tulyaganov et al. [27] reviewed and critically discussed the genesis, development, properties, and applications of the bioactive glass “1d” (i.e., from the primary crystallization field of pseudo-wollastonite in the CaO–MgO–SiO_2 ternary system, after addition of P_2O_5, Na_2O and CaF_2) and its relevant glass-ceramic derivative products (i.e., diopside, fluorapatite, and wollastonite crystalline phases, formed by performing a thermal treatment), which are extremely appealing inorganic biomaterials alternatives to the reference 45S5 Bioglass® exploitable in a variety of bone-regenerative clinical applications, such as the repair of periodontal defects, ridge preservation and sinus augmentation.

3. Conclusions

With this Special Issue “New Advances into Nanostructured Oxides, 2nd Edition” published in the “Inorganics Materials” section, and also published as a book, the Editors hope that the high quality of the contributions collected here will receive the visibility and attention they deserve. These would help readers to increase their knowledge in the field of inorganic materials, and be a new source of inspiration for novel, focused investigations.

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References

1. Innocenzi, P.; Malfatti, L. Mesoporous ordered titania films: An advanced platform for photocatalysis. *J. Photochem. Photobiol. C* **2024**, *58*, 100646. [CrossRef]
2. Wang, L.; Zhang, J.; Zhang, Y.; Yu, H.; Qu, Y.; Yu, J. Inorganic metal-oxide photocatalyst for H_2O_2 production. *Small* **2022**, *18*, 2104561. [CrossRef] [PubMed]
3. Kumar, A.; Priyanka, C.; Kumar, A.; Camargo, P.H.C.; Venkata, K. Recent advances in plasmonic photocatalysis based on TiO_2 and noble metal nanoparticles for energy conversion, environmental remediation, and organic synthesis. *Small* **2022**, *18*, 2101638. [CrossRef] [PubMed]
4. Zhang, Q.; Gao, S.; Yu, J. Metal sites in zeolites: Synthesis, characterization, and catalysis. *Chem. Rev.* **2023**, *123*, 6039–6106. [CrossRef] [PubMed]
5. Qiao, R.; Fu, C.; Forgham, H.; Javed, I.; Huang, X.; Zhu, J.; Whittaker, A.K.; Davis, T.P. Magnetic iron oxide nanoparticles for brain imaging and drug delivery. *Adv. Drug Deliv. Rev.* **2023**, *197*, 114822. [CrossRef]
6. Wagner, J.; Goßl, D.; Ustyanovska, N.; Xiong, M.; Hauser, D.; Zhuzhgova, O.; Hočevar, S.; Taskoparan, B.; Poller, L.; Datz, S.; et al. Mesoporous silica nanoparticles as pH-responsive carrier for the immune-activating drug resiquimod enhance the local immune response in mice. *ACS Nano* **2021**, *15*, 4450–4466. [CrossRef] [PubMed]
7. Caldera, F.; Nisticò, R.; Magnacca, G.; Matencio, A.; Khazaei Monfared, Y.; Trotta, F. Magnetic composites of dextrin-based carbonate nanosponges and iron oxide nanoparticles with potential application in targeted drug delivery. *Nanomaterials* **2022**, *12*, 754. [CrossRef] [PubMed]
8. Chairungsri, W.; Subkomkaew, A.; Kijjanapanich, P.; Chimupala, Y. Direct dye wastewater photocatalysis using immobilized titanium dioxide on fixed substrate. *Chemosphere* **2022**, *286*, 131762. [CrossRef] [PubMed]
9. Danish, M.S.S.; Estrella, L.L.; Alemaida, I.M.A.; Lisin, A.; Moiseev, N.; Ahmadi, M.; Nazari, M.; Wali, M.; Zaheb, H.; Senjyu, T. Photocatalytic applications of metal oxides for sustainable environmental remediation. *Metals* **2021**, *11*, 80. [CrossRef]
10. Abdullah, F.H.; Abu Bakar, N.H.H.; Abu Bakar, M. Current advancements on the fabrication, modification, and industrial application of zinc oxide as photocatalyst in the removal of organic and inorganic contaminants in aquatic systems. *J. Hazard. Mater.* **2022**, *424*, 127416. [CrossRef]
11. Mezzomo, L.; Bonato, S.; Mostoni, S.; Di Credico, B.; Scotti, R.; D'Arienzo, M.; Mustarelli, P.; Ruffo, R. Composite solid-state electrolyte based on hybrid poly (ethylene glycol)-silica fillers enabling long-life lithium metal batteries. *Electrochim. Acta* **2022**, *411*, 140060. [CrossRef]
12. Sun, L.; Liu, H.; Ye, Y.; Lei, Y.; Islam, R.; Tan, S.; Tong, R.; Miao, Y.-B.; Cai, L. Smart nanoparticles for cancer therapy. *Sig. Transduct. Target. Ther.* **2023**, *8*, 418. [CrossRef] [PubMed]
13. Nisticò, R.; Scalarone, D.; Magnacca, G. Sol-gel chemistry, templating and spin-coating deposition: A combined approach to control in a simple way the porosity of inorganic thin films/coatings. *Microporous Mesoporous Mater.* **2017**, *248*, 18–29. [CrossRef]
14. Zhou, Y.; Liu, L.; Li, G.; Hu, G. Insights into the influence of ZrO_2 crystal structures on methyl laurate hydrogenation over Co/ZrO_2 catalysts. *ACS Catal.* **2021**, *11*, 7099–7113. [CrossRef]
15. Liccardo, L.; Bordin, M.; Sheverdyaeva, P.M.; Belli, M.; Moras, P.; Vomiero, A.; Moretti, E. Surface defect engineering in colored TiO_2 hollow spheres toward efficient photocatalysis. *Adv. Funct. Mater.* **2023**, *33*, 2212486. [CrossRef]
16. Masoud, M.; Khodamorady, M.; Tahmasbi, B.; Bahrami, K.; Ghorbani-Choghamarani, A. Boehmite nanoparticles as versatile support for organic–inorganic hybrid materials: Synthesis, functionalization, and applications in eco-friendly catalysis. *J. Ind. Eng. Chem.* **2021**, *97*, 1–78. [CrossRef]
17. Bona, G.; Viganò, L.; Cantoni, M.; Mantovan, R.; Di Credico, B.; Mostoni, S.; Scotti, R.; Nisticò, R. An experimental demonstration on the recyclability of hybrid magnetite-humic acid nanoparticles. *Sustain. Mater. Technol.* **2025**, *43*, e01275. [CrossRef]
18. Abouri, M.; Benzaouak, A.; Zaaboul, F.; Sifou, A.; Dahhou, M.; El Belghiti, M.A.; Azzaoui, K.; Hammouti, B.; Rhazi, L.; Sabbahi, R.; et al. Efficient Catalytic Reduction of Organic Pollutants Using Nanostructured CuO/TiO_2 Catalysts: Synthesis, Characterization, and Reusability. *Inorganics* **2024**, *12*, 297. [CrossRef]
19. Dolatyari, M.; Tahmasebi, M.; Dolatyari, S.; Rostami, A.; Zarghami, A.; Yadav, A.; Klein, A. Core/Shell ZnO/TiO_2, SiO_2/TiO_2, Al_2O_3/TiO_2, and $Al_{1.9}Co_{0.1}O_3/TiO_2$ Nanoparticles for the Photodecomposition of Brilliant Blue E-4BA. *Inorganics* **2024**, *12*, 281. [CrossRef]
20. Zhao, T.; Cao, T.; Bao, Q.; Dong, W.; Li, P.; Gu, X.; Liang, Y.; Zhou, J. Significantly Enhanced Self-Cleaning Capability in Anatase TiO_2 for the Bleaching of Organic Dyes and Glazes. *Inorganics* **2023**, *11*, 341. [CrossRef]
21. Mao, T.; Zha, J.; Hu, Y.; Chen, Q.; Zhang, J.; Luo, X. Research Progress of TiO_2 Modification and Photodegradation of Organic Pollutants. *Inorganics* **2024**, *12*, 178. [CrossRef]
22. Naggar, A.H.; Ahmed, A.S.A.; El-Nasr, T.A.S.; Alotaibi, N.F.; Chong, K.F.; Ali, G.A.M. Morphological Dependence of Metal Oxide Photocatalysts for Dye Degradation. *Inorganics* **2023**, *11*, 484. [CrossRef]
23. Alshoaibi, A. The Influence of Annealing Temperature on the Microstructure and Electrical Properties of Sputtered ZnO Thin Films. *Inorganics* **2024**, *12*, 236. [CrossRef]

24. Filimonov, D.; Rozova, M.; Maksimov, S.; Pankratov, D. Synthesis and Redox Properties of Iron and Iron Oxide Nanoparticles Obtained by Exsolution from Perovskite Ferrites Promoted by Auxiliary Reactions. *Inorganics* **2024**, *12*, 223. [CrossRef]
25. Abduraman, A.; Brezoiu, A.-M.; Tatia, R.; Iorgu, A.-I.; Deaconu, M.; Mitran, R.-A.; Matei, C.; Berger, D. Mesoporous Titania Nanoparticles for a High-End Valorization of *Vitis vinifera* Grape Marc Extracts. *Inorganics* **2024**, *12*, 263. [CrossRef]
26. Kimura, R.; Shiba, K.; Fujiwara, K.; Zhou, Y.; Yamada, I.; Tagaya, M. Precipitative Coating of Calcium Phosphate on Microporous Silica–Titania Hybrid Particles in Simulated Body Fluid. *Inorganics* **2023**, *11*, 235. [CrossRef]
27. Tulyaganov, D.U.; Agathopoulos, S.; Dimitriadis, K.; Fernandes, H.R.; Gabrieli, R.; Baino, F. The Story, Properties and Applications of Bioactive Glass "1d": From Concept to Early Clinical Trials. *Inorganics* **2024**, *12*, 224. [CrossRef]
28. Zamora-Ledezma, C.; Negrete-Bolagay, D.; Figuroa, F.; Zamora-Ledezma, E.; Ni, M.; Alexis, F.; Guerrero, V.H. Heavy metal water pollution: A fresh look about hazards, novel and conventional remediation methods. *Environ. Technol. Innov.* **2021**, *21*, 101504. [CrossRef]
29. Rahman, A.; Sarkar, A.; Yadav, O.P.; Achari, G.; Slobodnik, J. Potential human health risks due to environmental exposure to nano- and microplastics and knowledge gaps: A scoping review. *Sci. Total Environ.* **2021**, *757*, 143872. [CrossRef] [PubMed]
30. Siddiqua, A.; Hahladakis, J.N.; Al-Attiya, W.A.K.A. An overview of the environmental pollution and health effects associated with waste landfilling and open dumping. *Environ. Sci. Pollut. Res.* **2022**, *29*, 58514–58536. [CrossRef] [PubMed]