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Editorial

Novel Nanomaterials for Catalytic and Biological Applications

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Currently, nanotechnology has become an integral part of science and technology and has played a crucial role in the development of a variety of technological advancements in different industries [1]. Nanomaterials, i.e., materials with less than 100 nm in size in at least one direction, exhibit several unique properties due to their specific size and exceptional geometries, such as, excellent electrical and optical properties, high surface area, strong mechanical properties, etc. [2]. Nanomaterials exhibit a wide range of diverse properties based on their specific geometry, which include nano-colloids, nanorods, nanowires and other 2D nanomaterials, etc. [3]. Particularly, nanoparticles of various materials demonstrate completely different behaviour when compare to their bulk counterparts [4]. Scientifically, these fascinating properties are not only originating from their smaller sizes, but they also resulted from the particles consisting of a relatively limited number of molecules, which behave and interacts differently with its surroundings for fundamental physical reasons [5]. Due to these reasons, nanomaterials possess unique abilities, which allow us to customize their physicochemical properties including, surface properties, melting point, wettability, electrical and thermal conductivity, their interactions with light, etc., which ultimately result in enhanced performance [6]. Due to this, over several decades, the preparation of nanomaterials has emerged as a crucial branch of synthetic chemistry.

Thus far, a variety of different synthetic techniques for the preparation of nanomaterials have already been established and others are still continuing to evolve [7]. These techniques are optimized to achieve diverse morphology of nanomaterials with controlled composition, shape, size and surface chemistry, which are suitable to desirable applications. Indeed, several facile methods are reported, which were applied to prepare more and more complex nanostructures using the simple, easily available and appropriate molecular precursors [8]. Nanomaterials are constantly receiving recognition in a wide range of chemical, biomedical and engineering branches, and their applications in all the relevant fields are increasing rapidly [9]. Although considerable efforts have been made for the synthesis of advanced and functional nanomaterials, there is a large scope in the further development of new and novel nanomaterials in different fields for the progress and comfort of humankind [10]. In particular, researchers around the world are striving to develop controlled sizes and shapes of nanomaterials using facile and eco-friendly methods, which have less impact on the environment [11]. Additionally, the concept of the miniaturization of multifunctional devices using economical nanomaterials that can be utilized in the field of medicine and electronics is gaining considerably popular [12].

Catalysts are integral parts of chemical industries that are extensively utilized in a wide variety of processes including in the preparation of utility chemicals, pharmaceuticals, the workup of fuels such as oil, gas and coal, the purification of effluents and industrial waste gases, etc. [13]. Particularly, heterogeneous catalysts have gained significant recognition due to their high selectivity, efficiency and reusability [14]. Therefore, research for the development of novel catalytic materials or the optimization of existing catalyst systems has gained tremendous importance to increase the efficiency of the existing catalytic processes and to enhance the yield and purity of the products [15]. In these regards, nanostructured materials with enhanced physiochemical properties have received great

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attention [16]. Particularly in the field of catalysis, the high specific surface area and surface energy of nanomaterials play an essential role in enhancing the catalytic properties of the materials [17]. Nano-catalysts not only enhance the selectivity of the reactions by allowing reaction at a lower temperature, but they also diminish the chances of side reactions and thereby enhancing the yield of the final products and improve the energy efficiency of the processes [18]. Therefore, nanomaterials have been widely used in green chemistry, environmental remediation, efficient conversion of biomass, renewable energy development and other areas of interest [19].

Apart from catalysis, diverse forms of nanomaterials have also been extensively investigated for a variety of biological applications including molecular imaging, antimicrobial and anticancer therapies, biosensing, biological separation, etc. [20]. Due to their novel properties and smaller size, nanomaterials exert completely different biological functions compared to their bulk counterparts [21]. In particular, easy surface modifications, high volume/surface ratio, enhanced solubility and multifunctionality offer remarkable opportunities for nanomaterials in a wide range of biomedical applications [21]. In addition, intrinsic optical, electrical, magnetic and biological characteristics of nanomaterials have been successfully exploited to explore, influence and regulate complex biological mechanisms [22]. Due this heavy demand for nanomaterials, considerable efforts have been made to develop functional nanostructured materials using different types of physical and chemical methods, which are mainly categorized into top-down and bottom-up approaches [23]. Physical techniques include mechanical attrition, melt mixing, physical vapour deposition (PVD), laser ablation, sputter deposition and electric deposition, whereas chemical approaches include metal salt reduction, sol–gel chemistry, co-precipitation, photoreduction, thermolysis, spray pyrolysis and microemulsion-confined reaction [24].

Recently, due to growing environmental threats, researchers are avoiding synthetic processes that involve expensive instruments, high energy and harmful chemicals that are hazardous to both the environment and human life [25]. Therefore, currently, scientists are striving to explore novel alternatives involving the principles of "green chemistry" [26] for the preparation of advance functional nanomaterials. Moreover, green approaches have been very effective in enhancing the biocompatibility of nanomaterials, which is essential for biological applications [11]. Therefore, to highlight the importance of nanomaterials, particularly in catalytic and biological applications, we have invited articles related to this topic in the Special Issue of "Novel Nanomaterials for Catalytic and Biological Applications" in the journal *Crystals*. Invitations were sent to various eminent scientists all over the world who are active in the area of nanotechnology. The call was very successful, and we have received thumping submissions of 39 articles, which were subjected to an exhaustive peer review process. Based on the reviewers' recommendations, a total of 25 articles were published in the Special Issue, among which eight of them were related to the synthesis and catalytic applications of nanomaterials, while the studies in 17 articles were mainly focused on the biological application of nanomaterials. The articles published in this Special Issue offer a diverse exploration of the most crucial areas of nanomaterials, ranging from synthesis to catalytic and biological applications. We are thankful to all the authors who made this "Special Issue" a great success, as well as the editorial staff of Crystals for their hard work in processing all the articles in this issue. We (All the guest editors) strongly believe that the readers will find this "Special Issue" fascinating and helpful.

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References

1. Wang, J.; Gu, H. Novel metal nanomaterials and their catalytic applications. *Molecules* **2015**, *20*, 17070–17092. [CrossRef] [PubMed]
2. Villalba-Rodríguez, A.M.; Martínez-Zamudio, L.Y.; Martínez, S.A.H.; Rodríguez-Hernández, J.A.; Melchor-Martínez, E.M.; Flores-Contreras, E.A.; González-González, R.B.; Parra-Saldívar, R. Nanomaterial Constructs for Catalytic Applications in Biomedicine: Nanobiocatalysts and Nanozymes. *Top. Catal.* **2022**, 1–16. [CrossRef] [PubMed]
3. Navya, P.; Daima, H.K. Rational engineering of physicochemical properties of nanomaterials for biomedical applications with nanotoxicological perspectives. *Nano Converg.* **2016**, *3*, 1–14. [CrossRef] [PubMed]
4. Bratovcic, A. Different applications of nanomaterials and their impact on the environment. *SSRG Int. J. Mater. Sci. Eng.* **2019**, *5*, 1–7.
5. Moreno, F.; García-Cámara, B.; Saiz, J.; González, F. Interaction of nanoparticles with substrates: Effects on the dipolar behaviour of the particles. *Opt. Express* **2008**, *16*, 12487–12504. [CrossRef]
6. Pokhrel, S.; Nel, A.E.; Mädler, L. Custom-designed nanomaterial libraries for testing metal oxide toxicity. *Acc. Chem. Res.* **2013**, *46*, 632–641. [CrossRef]
7. Yin, Y.; Talapin, D. The chemistry of functional nanomaterials. *Chem. Soc. Rev.* **2013**, *42*, 2484–2487. [CrossRef]
8. Kolahalam, L.A.; Viswanath, I.K.; Diwakar, B.S.; Govindh, B.; Reddy, V.; Murthy, Y. Review on nanomaterials: Synthesis and applications. *Mater. Today Proc.* **2019**, *18*, 2182–2190. [CrossRef]
9. Gajanan, K.; Tijare, S. Applications of nanomaterials. *Mater. Today Proc.* **2018**, *5*, 1093–1096. [CrossRef]
10. Sharma, V.P.; Sharma, U.; Chattopadhyay, M.; Shukla, V. Advance applications of nanomaterials: A review. *Mater. Today Proc.* **2018**, *5*, 6376–6380. [CrossRef]
11. Khan, M.; Shaik, M.R.; Adil, S.F.; Khan, S.T.; Al-Warthan, A.; Siddiqui, M.R.H.; Tahir, M.N.; Tremel, W. Plant extracts as green reductants for the synthesis of silver nanoparticles: Lessons from chemical synthesis. *Dalton Trans.* **2018**, *47*, 11988–12010. [CrossRef]
12. Rodrigues, T.S.; da Silva, A.G.; Camargo, P.H. Nanocatalysis by noble metal nanoparticles: Controlled synthesis for the optimization and understanding of activities. *J. Mater. Chem. A* **2019**, *7*, 5857–5874. [CrossRef]
13. Roduner, E. Understanding catalysis. *Chem. Soc. Rev.* **2014**, *43*, 8226–8239. [CrossRef]
14. Schlögl, R. Heterogeneous catalysis. *Angew. Chem. Int. Ed.* **2015**, *54*, 3465–3520.
15. Fechete, I.; Wang, Y.; Védrine, J.C. The past, present and future of heterogeneous catalysis. *Catal. Today* **2012**, *189*, 2–27. [CrossRef]
16. Yang, F.; Deng, D.; Pan, X.; Fu, Q.; Bao, X. Understanding nano effects in catalysis. *Natl. Sci. Rev.* **2015**, *2*, 183–201.
17. Hu, M.; Yao, Z.; Wang, X. Graphene-based nanomaterials for catalysis. *Ind. Eng. Chem. Res.* **2017**, *56*, 3477–3502. [CrossRef]
18. Rossi, L.M.; Costa, N.J.; Silva, F.P.; Wojcieszak, R. Magnetic nanomaterials in catalysis: Advanced catalysts for magnetic separation and beyond. *Green Chem.* **2014**, *16*, 2906–2933. [CrossRef]
19. Khalil, M.; Kadja, G.T.; Ilmi, M.M. Advanced nanomaterials for catalysis: Current progress in fine chemical synthesis, hydrocarbon processing, and renewable energy. *J. Ind. Eng. Chem.* **2021**, *93*, 78–100.
20. Yaqoob, A.A.; Ahmad, H.; Parveen, T.; Ahmad, A.; Oves, M.; Ismail, I.M.; Qari, H.A.; Umar, K.; Mohamad Ibrahim, M.N. Recent advances in metal decorated nanomaterials and their various biological applications: A review. *Front. Chem.* **2020**, *8*, 341. [CrossRef]
21. Zhou, R.; Wang, C.; Xu, W.; Xie, L. Biological applications of terahertz technology based on nanomaterials and nanostructures. *Nanoscale* **2019**, *11*, 3445–3457. [CrossRef] [PubMed]
22. Lan, L.; Yao, Y.; Ping, J.; Ying, Y. Recent advances in nanomaterial-based biosensors for antibiotics detection. *Biosens. Bioelectron.* **2017**, *91*, 504–514. [CrossRef] [PubMed]
23. Adil, S.F.; Assal, M.E.; Khan, M.; Al-Warthan, A.; Siddiqui, M.R.H.; Liz-Marzán, L.M. Biogenic synthesis of metallic nanoparticles and prospects toward green chemistry. *Dalton Trans.* **2015**, *44*, 9709–9717. [CrossRef] [PubMed]
24. Rane, A.V.; Kanny, K.; Abitha, V.; Thomas, S. Methods for synthesis of nanoparticles and fabrication of nanocomposites. In *Synthesis of Inorganic Nanomaterials*; Elsevier: Amsterdam, The Netherlands, 2018; pp. 121–139.
25. Hasan, M.; Ullah, I.; Zulfiqar, H.; Naeem, K.; Iqbal, A.; Gul, H.; Ashfaq, M.; Mahmood, N. Biological entities as chemical reactors for synthesis of nanomaterials: Progress, challenges and future perspective. *Mater. Today Chem.* **2018**, *8*, 13–28. [CrossRef]
26. Soni, R.A.; Rizwan, M.A.; Singh, S. Opportunities and potential of green chemistry in nanotechnology. *Nanotechnol. Environ. Eng.* **2022**, *7*, 661–673. [CrossRef]