ISSN: 2640-5571

Review Article

Advances in Nanoscience and Nanotechnology

Recent Revolutions in Nanoscience and Nanotechnology with Its Application's

AnamIqbal[1]*, kanwalIqbal[2]* Wenwu Qin[3] Muhammad Mateen[4]

[1]*Department of Chemistry, University of Baluchistan Quetta 87300, Pakistan*

[2]*Department of Chemistry, Sardar Bahadur Khan Women's University Quetta 87300, Pakistan*

[3]*Key Laboratory of Nonferrous Metal Chemistry and Resources Utilization of Gansu Province and State Key Laboratory of Applied Organic Chemistry, College of Chemistry and Chemical Engineering, Lanzhou University, Lanzhou 730000, P. R. China*

[4]*State Key Laboratory of Alternate Electrical Power System with Renewable Energy Sources, North China Electric Power University, Beijing 102206, P. R. China*

***Corresponding author**
Anam Iqbal, Department of Chemistry, University of Baluchistan Quetta 87300, Pakistan, E-mail: anamiqbal25@yahoo.com,

KanwalIqbal, Department of Chemistry, Sardar Bahadur Khan Women's University Quetta 87300, Pakistan, E-mail: kanwaliqbal98@gmail.com

Submitted: 13 Sep 2019; **Accepted**: 18 Sep 2019; **Published**: 25 Sep 2019

Abstract
During the past decade, new directions of modern research, broadly defined as nanoscale science and technology have emerged. This is not a separate scientific field; instead it is a complex platform for the existing disciplines of biology, physics, medicine, chemistry, neurology, engineering, information technology, and a newmultidisciplinary scientific research area. In recent years, the nanoscience and nanotechnology have attract a great deal of attention in both synthesis methodologies and wide applications of medicine, energy, environmental, electronics etc. Despite of significant progress in nanotechnology and rise of many commercialized products involving nanomaterials, nanoscience, and technology are still facing many new challenges, especially in the areas of great concern to the public i.e. energy and health.

Introduction
Nanotechnology research is leading science into exciting and unknown frontiers in the new millennium. By definition, nanoscience is the study of materials and associated physical, biophysical, and biochemical phenomena on the scale of ~1 to 100 nm (nanometers). The National Institutes of Health (2000) described "nanotechnology" as involving research and technology development at the atomic, molecular, or macromolecular levels in the dimension range of approximately 1-100 nm to provide fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices, and systems that have novel properties and functions because of their small and/or intermediate size. The importance of particles in this range is in the sense that they can have different and enhanced properties compared with the same material at a larger size [1]. Increased surface area and quantum effects are two principal factors separating nanomaterials from other materials. These two factors can enhance properties such as strength, reactivity, electrical characteristics invivo and in vitro behavior [2]. Hence, nanotechnology and nanoscience are widely seen as having a great potential to bring benefits to many areas of research and applications [3]. The primary appeal of nanoscience (and attendant developments in nanotechnology) is the potential to create and manipulate matter at the nanoscale. This leads to the possibility of preparing novel materials (nanomaterials) that have specific, manipulable physical properties and functions. Such physical properties and functionsinclude enhanced electrical and electronic conductivities, lower thermal conductivities, and higher temperature deformation characteristics compared to their conventional bulk material counterparts [4].

Benefits Involved in Nanoscience and Nanotechnology
There are numerous benefits from nanoscience and nanotechnology including the application of nanotechnology in the field of health care (treatment of a large variety of medical conditions e.g. new nano materials are engineered and designed that are suitable for medical implants and also silver and gold nano particles with anti-microbial properties) has come under great attention in recent times. So, the developments in nanoscience and nanotechnology have allowed us to place man-made nanoscale things inside the living cells [5]. Dealing with economic benefits there are numerous treatments today that take a lot of time and are also very expensive (about 110 billion dollars in sales by an industry manufacturing fine chemicals). Using nanoscience and nanotechnology, quicker and much cheaper treatments can be developed.

Besides, there is another aspect to using nanotechnology in medicine, energy system. By using nanoscience &nanotechnology, nano particles can be inhaled and swallowed, and absorbed through the skin. Moreover, there are no adequate regulations regarding labeling or handling, environmental and health hazards; risks associated with molecular manufacturinghence, the drug can be targeted to a precise location which would make the drug much more effective and reduce the chances of possible side-effects [3]. For example cancer is one of the leading diseases and although there are many drugs available for treatment, using nanotech based approach increases the activity as well as reducing the side effects profile many fold [4].

Beside the biological applications the nanoscience and nanotechnology has vast application in energy. This technology provides us that the nanomaterials exhibits quite different and new properties compared with the corresponding bulk materials, which develop new ways to convert the solar energy into electricity or fuels [6].

In this review, we aim to discuss the nanotechnology based approach, especially the use of NPs and their various forms in anticancer drug delivery, cell imaging, and energy system.

Current Advancement in Scientific Technology

As the result of the development of new tools that have made the manipulation and characterization of nanostructures practical, and also as a result of new methods for preparation of these structures.

Tools for Characterization

Scanning probe microscopies have revolutionized the characterization of nanostructures, and development of new variants of scanning probe devices continues apace. Older tools, especially electron microscopy, continue to play essential roles. In biological nanoscience, the combination of X-ray crystallography and NMR spectroscopy offers atomic resolution structural information about structures as complex as entire particles.

Fabrication and Synthesis

Tremendous advances are currently occurring in the synthesis and fabrication of isolated nanostructures. These activities range from colloidal synthesis of nanocrystals to the growth of epitaxial quantum dots by strained layer growth. Related activities include the preparation of fullerenes, buck tubes, and other one-dimensional nanostructures, as well as the growth of mesoporous inorganics. Increased activity in the nanoscale design of polymers is also occurring, including the development of dendrimers and complex block copolymers.

The techniques of molecular biology have made a very wide range of biological nanostructures readily available through cloning and overexpression in bacterial production systems. While much has been accomplished in the growth of isolated nanostructures, work has only just begun in the use of self-assembly techniques to prepare complex and designed spatial arrangements of nanostructures.

Computation

Because nanostructures contain few atoms (at least relative to most materials), they are uniquely susceptible to high-level simulation using supercomputers. The capability to treat nanostructures with useful accuracy using computation and simulation will be invaluable both in fundamental science and in applied technologies.

Application of Nanoscience and Nanotechnology

Nanoscience and Nanotechnology in Biological system for Biomedicine

Theranostics is a term derived from therapy and imaging, which provide an integrated platform for the personalized medicine to meet the challenges in modern health care [7, 8]. The theranostics is quite related to the biocompatible nanoparticle based nanomedicine, which contain both imaging and therapeutic nanocomponents. The radio, gene, or chemo therapeutics may be integrated in one nanoparticle. After combine it with the intrinsic optical, magnetic, etc. physicochemical properties or appropriate biomarkers, the nanocomposites would not only allow us to diagnose disease, but also evaluate treatment efficacy by track the nanoparticles' pharmacokinetics and the drugs releasing [9-11]. The nano-theranostics will face a series of biological barriers during circulation in living subjects which will influence the nanoparticle delivery efficacy, the nanoparticles firstly should cross blood vessels, then escape the entrapment of organs and removal of phagocytic cells, finally reach the specific target [12-13]. An ideal theranostic nanoparticle should possess the following characters: rapid, selective, and high efficient accumulation in target diseased tissues, feedback the detailed information (biochemical, morphological, etc.) about the interest tissues or organs, release the guests (drugs, chemicals, etc.) with a controllable manner for the effective therapy, easy metabolism according to a safe with less side effects after its function completed. It has been demonstrated that the circulation and metabolism in living subjects are profoundly affected by the size, shape, rigidity, charge, surface chemistry of the nanoparticles [14-20].

The theranostic nanoparticlesare the complex of the delivery carriers and cargo, targeting ligands, and bio-imaging labels, which means that the clinical translation is nontrivial for these fancy materials [21-22]. There are many factors need to considered: the prerequisite robust scale-up synthesis; the biological responses for the theranostic nanoparticles including exposure levels, systemic accumulation, excretion profiles, tissue and organ distributions of test living subjects; the potential toxicity of the nanoparticle in short and long term [9,11].

As Drug-Delivery Vehicles

Nanotechnology has very useful drug delivery approaches. In nanomedicine formulation research, developing nano dosage forms (polymeric NPs and nano capsules, liposomes, solid lipid NPs, phytosomes and nano emulsion etc) have a number of advantages for delivery system, including enhancement of solubility and bioavailability, protection from toxicity, enhancement of pharmacological activity, enhancement of stability, improving tissue macrophages distribution, sustained delivery, protection from physical and chemical degradation etc k [23].

Nanoparticles (NPs) based drug-delivery systems have made a remarkable difference in site-specific release of drugs especially chemotherapeutic agents, owing to their physical and chemical characteristics and biological attributes [24]. Various researches in this exciting area have been conducted; several of the formulations are released in the market and are now routinely used in clinics. In the recent decades, several types of NPs and microparticles have been synthesized and proposed for use as contrast agents for diagnostics and imaging and for drug delivery; for example, in cancer therapy [25].

NPs offer the unique possibility to overcome cellular barriers in order to improve the delivery of various drugs and drug candidates, including promising therapeutic bio-macromolecules such as nucleic acids, antisense oligonucleotides, small interfering ribonucleic acid (siRNA), and plasmid. DNA that can only exert their function once inside the cells, and that otherwise may not be delivered [26]. As polar molecules, they cannot permeate the lipid bi-layer of plasmamembrane or other biological membranes (blood brain, air blood, gastrointestinal barriers). By using NPs these therapeutic agents can not only be delivered site specifically but also there is the possibility to load NPs with a high concentration of the desired drug. In carrying a large payload, nanocarriers can favorably modulate bio-distribution and pharmacokinetic profiles of the drug formulations [27]. They may be also used as carriers for contrast agents in vivo magnetic resonance imaging or, again, as an all-in-one system [28]. Nanocarrier cell internalization is highly influenced by NPs' physicochemical properties, such as size, shape, and chemistry [29]. Particle size can affect the bio-distribution, the efficiency (i.e., how many NPs are found inside the cell at a given timepoint), and the cellular uptake pathway for liposomes, polymeric, gold, and silica NPs by influencing their adhesion and interaction with cells [30].

Cellular components such as the endosomes, lysosomes cytoplasm, endoplasmic reticulum, mitochondria, golgi apparatus, and nuclei are known to maintain their own characteristic pH values, which range from 4.5 in the lysosome to about 8.0 in the mitochondria. Moreover, pH value is greatly affected by diseases: the hypoxic environment in cancer leads to an increase in production of lactic acid and hydrolysis of ATP, both contributing to acidification. In fact, most solid tumors have lower extracellular pH (pH 6.5) than the surrounding tissues (pH 7.5). By selecting the right material composition, it is possible to engineer nanocarriers that can exploit these pH differences and allow the release of the delivered drugs or genes to the selected target site. pH sensitive poly(β-amino ester), a biodegradable cationic polymer, in acidic microenvironment undergoes rapid dissolution and releases its content all at once, thus it may represent a good scaffold to deliver anticancer drugs [27,30].

For Cancer Treatment

Nanotechnology has very useful drug delivery approaches. In nanomedicine formulation research, developing nanodosage forms (polymeric NPs and nanocapsules, liposomes, solid lipid NPs, phytosomes and nano emulsion etc) have a number of advantages for delivery system, including enhancement of solubility and bioavailability, protection from toxicity, enhancement of pharmacological activity, enhancement of stability, improving tissue macrophages distribution, sustained delivery, protection from physical and chemical degradation etc [31].

Scientific advances have significantly improved the basic understanding of biology of cancer. Due to the lack of drug availability, adverse side effects and drug resistance, the conventional therapy failed to achieve proper treatment [32]. From there, the advancement of nanomedicine passed through various achievements, starting from gold NP, polymeric NPs, quantum dots, fullerenes etc, to the clinically approved nano medicines for chemotherapy [33]. The priority of developing nanomaterial for cancer treatment includes [33]: (i) multifunctionality, (ii) increased potency and multivalency, (iii) increased selectivity for targets, (iv)theranostic potential, (v) altered pharmacokinetics, (vi) controlled synthesis, (vii) controlled agent release and kinetics, (viii) novel properties and interactions, (ix) lack of immunogenicity and (x) enhanced physical stability.

The most common examples of nanotechnology platforms for cancer therapy include polymeric NPs, liposomes, dendrimers, nanoshells, carbon nanotubes, and superparamagnetic NPs. With small size and various structural and physicochemical features, these nanotechnology platforms can enter tumor vasculature through enhanced permeability and retention effect (EPR). The use of cancer specific targeting residues (e.g. antibodies, ligands, and lectins) can also achieve tumor cell targeting [34-43].

For Cell Imaging

Cardiovascular disease or atherosclerosis (CVD) is the leading cause of death and disability in both genders in the developed and developing world and the primary clinical endpoints are coronary heart disease and stroke. The major underlying pathology is an atherosclerosis leading to lipid accumulation in the arterial wall and plaque formation. Nanoscience and nanotechnology has also contributed to the field of atherosclerotic plaque imaging and help diagnosis of the disease. Psarros et al. summarize the increasing evidence of nanomedicines for targeted drug delivery and plaque imaging [33-34]. A range of molecular and cellular imaging have been applied to imaging techniques, such as ultrasound (US), positron emission tomography (PET), MRI, single photon emission computed tomography (SPECT) and computed tomography (CT). The materials used to enhance imaging of inflammation and atherosclerotic plaques including liposomes polyamidoamine (PAMAM) and diaminobutane (DAB) dendrimers gold nanoparticles silver nanoparticles quantum dots iron micro particles or dextran coated ultra-small particles of iron oxide (USPIO) [38,45-57].

Previous development of nanotechnology systems tended to focus on very specific applications while, recent development has placed more emphasis on the dual application for both therapeutic and diagnostic purposes. These products with dual applications are termed "theranostic" nanoparticles and are able to be delivered to a specific pathological area for imaging while simultaneously act as therapeutic agents. In addition, the ability to guide evaluation of the effects can provide critical information about the efficacy and efficiency of treatment.

Nanoscience and Nanotechnology in Energy System

Besides the high efficient conversion of the solar energy, the storage of the converted energy is also critical desired, because the night or cloudy weather can interrupt solar energy's steadiness. We should capture and store the solar energy for the usage during the interruptions of the sun light. So, energy storage is very important for the efficient consumption of energy sources. As one of the most important constituent part, the nanomaterials are closely related to the energy conversion and storage. Owing to the innovation and advancement of materials science, the energy storage nanotechnologies have also been well-developed in the decades, especially the researches on hydrogen storage and Li-ion batteries.

Efficient hydrogen storage is regarded as the key challenge in large-scale applications of hydrogen energy. Hydrogen storage materials are the core technology for the storage of hydrogen sources with efficient and safe manner. To meet the stringent requirements of application of hydrogen energy, people has devoted many efforts to develop the potential materials for hydrogen storage [58]. By setting up new reaction routes, several novel systems with well thermodynamic stability were developed based the hybrid nanomaterials. The intrinsic binding states can be tuned by substituting the cation/anion in host structures, which can induced the modification of the dehydrogenation thermodynamics and kinetics

[59]. For example, Wang et al. found that the peak dehydrogenation temperature can be effectively decreased by introducing potassium salts in the kinetic modification study of a Li-Mg-N-H material. By lowering the activation energy, catalytic activation also play a versatile and efficient role in the enhancement of the kinetically stability of the hydrogen sorption rate at the interface of solid, gas and liquid [60-62].

Li-ion batteries are one of the most important and widely used secondary batteries for the energy storage. The higher power/energy density, high speed recharge/discharge, and longer cycling life are much important for the newly emerging electronic devices, advanced communication and transportation facilities. In the past decades, many efforts were devoted to the development of the electrode materials with desirable electrochemical properties, including larger Li storage capacity, better cycling performance, and higher rate capability [62]. With the assistant of nanostructured materials with reduced Li-ion diffusion length and alleviated inner stress, the performance of the Li-ion batteries can be greatly improved in the rate capability and cyclability [63, 64].

It is very important for the development of the advanced Li-ion batteries to study the relationship between the performance and composition/nanostructure of an electrode material from the view of both theory and experiment. The compatibility of the electrode materials with electrolytes, redox sites, and surface conductivity can be greatly improved by surface engineering of the electrode materials, which further result in the improved electrochemical performance [65]. On the other hand, rate capability and cycling performance can also be improved by growing the active nanomaterials directly on a current collector with enhanced electrical conductivity and bonding of the components.

Accompanied by the notable advantages, the shortcomings are also along with the subtly designed electrode nanomaterials, including large irreversible capacity, low packing density, complex synthesis processes, high cost, and so on, which further result in the limited practical applications until now. The major challenges at the materialand electrode levels were large volume expansion and fracture; unstable SEI, slow electron/ion transport rate and movements of electrode atoms/molecule Future works on understanding the fundamental electrode and materials chemistry taking place in these electrode systems are needed. Detailed information about the electrochemical mechanisms involved in these battery systems is still absent due to their\ complexity. Meanwhile, investigation of the ion and electron kinetic transport at the electrode/electrolyte interface is also important [65].

Conclusion

In the past decade, various nanostructures have been fabricated to address the significant material and applications challenges that exist in health, environmentand energy. New nanomaterials and techniques are becoming available to improve bioavailability, drug delivery, tissue targeting efficiency, as well as to cell imaging. Although, there are diverse specific requirements for nanomaterials in different applications. By exploring synthetic routes to large-scale production with low cost is very important for the wide spread promotion of the new nanotechnology. Systemically evaluation on the toxicity and environmental risks of nanomaterials is essential. Over the last few years there have been tremendous advances in the field of nanoscience and nanotechnology.

References

1. Sweeney AE, Seal S, Vaidyanathan P (2003) The Promises and Perils of Nanoscience and Nanotechnology: Exploring Emerging Social and Ethical Issues. Bulletin of Science, Technology & Society 23: 236-45.
2. Thakur NK, Bharti P, Mahant S, Rao R (2012) Formulation and Characterization of Benzoyl Peroxide Gellified Emulsions. Scientia Pharmaceutica 80: 1045-60.
3. Yan Z, Bin Y, Deng Y (2005) Take the initiative to drug-loaded liposomes prepared by vincristine sulfate and the determination of encapsulation efficiency. Chinese Pharm J 10: 1559.
4. Salamanca-Buentello F, Persad DL, Martin DK, Daar AS, Singer PAJPM et al., (2005) Nanotechnology and the developing world. PLoS Med 2: e97.
5. Ebrahimi N, Mansoori GA (2014) Reliability for Drug targeting in cancer treatment through nanotechnology (A psychometric approach). Int J Med Nano Res 1: 8.
6. Nozik AJ, Beard MC, Luther JM, Law M, Ellingson RJ et al., (2010) Semiconductor quantum dots and quantum dot arrays and applications of multiple exciton generation to third-generation photovoltaic solar cells. Chemical reviews 110: 6873-90.
7. Chen X, Gambhir SS, Cheon J (2011) Theranostic nanomedicine. ACS Publications 44: 841.
8. Lammers T, Aime S, Hennink WE, Storm G, Kiessling F (2011) Theranostic nanomedicine. Accounts of chemical research 44: 1029-38.
9. Prabhu P, Patravale V (2012) The upcoming field of theranostic nanomedicine: an overview. Journal of Biomedical Nanotechnology 8: 859-82.
10. Li Y, Lin T-y, Luo Y, Liu Q, Xiao W et al., (2014) A smart and versatile theranostic nanomedicine platform based on nanoporphyrin. J Nature communications 5: 4712.
11. Muthu MS, Leong DT, Mei L, Feng S-S (2014) Nanotheranostics-application and further development of nanomedicine strategies for advanced theranostics. Theranostics 4: 660.
12. Kievit FM, Zhang M (2011) Cancer nanotheranostics: improving imaging and therapy by targeted delivery across biological barriers. Advanced materials 23: H217-H47.
13. Blanco E, Shen H, Ferrari M (2015) Principles of nanoparticle design for overcoming biological barriers to drug delivery. Nature biotechnology 33: 941.
14. Tang L, Yang X, Yin Q, Cai K, Wang H et al., (2014) Investigating the optimal size of anticancer nanomedicine. Proceedings of the National Academy of Sciences 111: 15344-9.
15. Shah S, Liu Y, Hu W, Gao J (2011) Modeling particle shape-dependent dynamics in nanomedicine. Journal of nanoscience nanotechnology11: 919-28.
16. Toy R, Peiris PM, Ghaghada KB, Karathanasis E (2014) Shaping cancer nanomedicine: the effect of particle shape on the in vivo journey of nanoparticles. Nanomedicine 9: 121-34.
17. Ghassemi S, Meacci G, Liu S, Gondarenko AA, Mathur A et al., (2012) Cells test substrate rigidity by local contractions on submicrometer pillars. Proceedings of the National Academy of Sciences 109: 5328-33.
18. Fröhlich E (2012) The role of surface charge in cellular uptake and cytotoxicity of medical nanoparticles. International journal of nanomedicine 7: 5577.
19. Mout R, Moyano DF, Rana S, Rotello VMJCSR (2012) Surface functionalization of nanoparticles for nanomedicine. Chemical Society Reviews 41: 2539-44.
20. Albanese A, Tang PS, Chan WC (2012) The effect of nanoparticle

size, shape, and surface chemistry on biological systems. Annual review of biomedical engineering 14: 1-16.
21. Ambrogio MW, Thomas CR, Zhao Y-L, Zink JI, Stoddart (2011) Mechanized silica nanoparticles: a new frontier in theranostic nanomedicine. Accounts of chemical research 44: 903-13.
22. Chow EK-H, Ho D (2013) Cancer nanomedicine: from drug delivery to imaging. J Science translational medicine 5: 216rv4-rv4.
23. Saraf SJF (2010) Applications of novel drug delivery system for herbal formulations. Fitoterapia 81: 680-9.
24. Lim E-K, Jang E, Lee K, Haam S, Huh Y-M (2013) Delivery of cancer therapeutics using nanotechnology. Pharmaceutics 5: 294-317.
25. Ranganathan R, Madanmohan S, Kesavan A, Baskar G, Krishnamoorthy YR et al. (2012) Nanomedicine: towards development of patient-friendly drug-delivery systems for oncological applications. International journal of nanomedicine 7: 1043.
26. De Jong WH, Borm PJ (2008) Drug delivery and nanoparticles: applications and hazards. International journal of nanomedicine 3: 133.
27. Munyendo WL, Lv H, Benza-Ingoula H, Baraza LD, Zhou J (2012) Cell penetrating peptides in the delivery of biopharmaceuticals. Biomolecules 2: 187-202.
28. Chen T, Shukoor MI, Wang R, Zhao Z, Yuan Q et al. (2011) Smart multifunctional nanostructure for targeted cancer chemotherapy and magnetic resonance imaging. ACS nano 5: 7866-73.
29. Schweiger C, Hartmann R, Zhang F, Parak WJ, Kissel TH et al., (2012) Quantification of the internalization patterns of superparamagnetic iron oxide nanoparticles with opposite charge. Journal of nanobiotechnology 10: 28.
30. Shapero K, Fenaroli F, Lynch I, Cottell DC, Salvati A et al., (2011) Time and space resolved uptake study of silica nanoparticles by human cells. Molecular Biosystems 7: 3718.
31. Shenoy D, Little S, Langer R, Amiji M (2005) Poly (ethylene oxide)-modified poly (β-amino ester) nanoparticles as a pH-sensitive system for tumor-targeted delivery of hydrophobic drugs: part 2. In vivo distribution and tumor localization studies. Pharmaceutical research 22: 2107-14.
32. Ma WW, Adjei AA (2009) Novel agents on the horizon for cancer therapy. J CA: a cancer journal for clinicians 59: 111-37.
33. Rani D, Somasundaram VH, Nair S, Koyakutty M (2012) Advances in cancer nanomedicine. Journal of the Indian Institute of Science 92: 187-218.
34. Scheinberg DA, Villa CH, Escorcia FE, McDevitt MR (2010) Conscripts of the infinite armada: systemic cancer therapy using nanomaterials. Nature reviews Clinical oncology 7: 266.
35. Tang M, Lei L, Guo S, Huang WJCJC (2010) Recent progress in nanotechnology for cancer therapy. Chin J Cancer 29: 775-80.
36. Alexis F, Rhee J-W, Richie JP, Radovic-Moreno AF, Langer R (2008) New frontiers in nanotechnology for cancer treatment. Proc. Urologic Oncology: Seminars and Original Investigations. Elsevier 26: 74-85.
37. Mody VV, Nounou MI, Bikram M (2009) Novel nanomedicine-based MRI contrast agents for gynecological malignancies. Advanced drug delivery reviews 61: 795-807.
38. Majoros IJ, Myc A, Thomas T, Mehta CB, Baker JR (2006) PAMAM dendrimer-based multifunctional conjugate for cancer therapy: synthesis, characterization, and functionality. Biomacromolecules 7: 572-9.
39. Jordan A, Scholz R, Maier-Hauff K, van Landeghem FK, Waldoefner N et al., (2006) The effect of thermotherapy using magnetic nanoparticles on rat malignant glioma. Journal of neuro-oncology 78: 7-14.
40. Huang C, Tang Z, Zhou Y, Zhou X, Jin Y et al., (2012) Magnetic micelles as a potential platform for dual targeted drug delivery in cancer therapy. International journal of pharmaceutics 429: 113-22.
41. Iqbal A, Tian Y, Wang X, Gong D, Guo Y et al., (2016) Carbon dots prepared by solid state method via citric acid and 1, 10-phenanthroline for selective and sensing detection of Fe2+ and Fe3+. Sensors Actuators B: Chemical 237: 408-15.
42. Iqbal A, Iqbal K, Xu L, Li B, Gong D et al., (2018) Heterogeneous synthesis of nitrogen-doped carbon dots prepared via anhydrous citric acid and melamine for selective and sensitive turn on-off-on detection of Hg (II), glutathione and its cellular imaging. Sensors Actuators B: Chemical 255: 1130-8.
43. Iqbal K, Iqbal A, Kirillov AM, Liu W, Tang Y (2018) Hybrid Metal–Organic-Framework/Inorganic Nanocatalyst toward Highly Efficient Discoloration of Organic Dyes in Aqueous Medium. Inorganic chemistry 57: 13270-8.
44. Wickline SA, Neubauer AM, Winter PM, Caruthers SD, Lanza GM (2007) Molecular imaging and therapy of atherosclerosis with targeted nanoparticles. Journal of Magnetic Resonance Imaging 25: 667-80.
45. Demos SM, Alkan-Onyuksel H, Kane BJ, Ramani K, Nagaraj A et al., (1999) In vivo targeting of acoustically reflective liposomes for intravascular and transvascular ultrasonic enhancement. Journal of the American College of Cardiology 33: 867-75.
46. Kobayashi H, Kawamoto S, Jo S-K, Bryant HL, Brechbiel MW (2003) Macromolecular MRI contrast agents with small dendrimers: pharmacokinetic differences between sizes and cores. Bioconjugate chemistry 14: 388-94.
47. Sato N, Kobayashi H, Hiraga A, Saga T, Togashi K (2001) Pharmacokinetics and enhancement patterns of macromolecular MR contrast agents with various sizes of polyamidoamine dendrimer cores. Magnetic Resonance in Medicine 46: 1169-73.
48. Iqbal K, Iqbal A, Kirillov AM, Wang B, Liu W et al., (2017) A new Ce-doped MgAl-LDH@ Au nanocatalyst for highly efficient reductive degradation of organic contaminants. Journal of Materials Chemistry A 5: 6716-24.
49. Loo C, Lin A, Hirsch L, Lee M-H, Barton J et al., (2004) Nanoshell-enabled photonics-based imaging and therapy of cancer. Technology in cancer research treatment 3: 33-40.
50. Iqbal K, Iqbal A, Kirillov AM, Shan C, Liu W et al., (2018) A new multicomponent CDs/Ag@ Mg–Al–Ce-LDH nanocatalyst for highly efficient degradation of organic water pollutants. Journal of Materials Chemistry A 6: 4515-24.
51. Michalet X, Pinaud F, Bentolila L, Tsay J, Doose S et al., (2005) Quantum dots for live cells, in vivo imaging, and diagnostics. science 307: 538-44.
52. McAteer MA, Choudhury RP (2010) Chapter 6 Endohedral Metallofullerenes, Iron Oxide Agents, and Gold Nanoparticles for Brain Imaging. CRC Press pp.81-94.
53. Iqbal A, Iqbal K, Li B, Gong D, Qin W (2017) Recent advances in iron nanoparticles: preparation, properties, biological and environmental application. J Journal of Nanoscience Nanotechnology17: 4386-409.
54. Schmitz Sa, Coupland Se, Gust R, Winterhalter S, Wagner S et al. (2000) Superparamagnetic iron oxide–enhanced MRI of

atherosclerotic plaques in Watanabe hereditable hyperlipidemic rabbits. Investigative radiology 35: 460-71.
55. Liu C, Li F, Ma LP, Cheng HM (2010) Advanced materials for energy storage. Advanced materials 22: E28-E62.
56. Kang X, Fang Z, Kong L, Cheng H, Yao X et al., (2008) Ammonia borane destabilized by lithium hydride: an advanced on board hydrogen storage material. Advanced Materials 20: 2756-9.
57. Xiong Z, Yong CK, Wu G, Chen P, Shaw W et al., (2008) High-capacity hydrogen storage in lithium and sodium amidoboranes. Nature materials 7: 138.
58. Bluhm ME, Bradley MG, Butterick R, Kusari U, Sneddon LG (2006) Amineborane-based chemical hydrogen storage: enhanced ammonia borane dehydrogenation in ionic liquids. Journal of the American Chemical Society 128: 7748-9.
59. Yang J, Sudik A, Siegel DJ, Halliday D, Drews A et al., (2008) A Self Catalyzing Hydrogen Storage Material. Angewandte Chemie International Edition 47: 882-7.
60. Berseth PA, Harter AG, Zidan R, Blomqvist A, Araújo CM et al., (2009) Carbon nanomaterials as catalysts for hydrogen uptake and release in NaAlH4. Nano letters 9: 1501-5.
61. Chen J, Cheng F (2009) Combination of lightweight elements and nanostructured materials for batteries. Accounts of chemical research 42: 713-23.
62. Lee KT, Jung YS, Oh SM (2003) Synthesis of tin-encapsulated spherical hollow carbon for anode material in lithium secondary batteries. Journal of the American Chemical Society 125: 5652-3.
63. Deng D, Lee JY (2008) Hollow core–shell mesospheres of crystalline SnO_2 nanoparticle aggregates for high capacity Li+ ion storage. Chemistry of Materials 20: 1841-6.
64. Sun Y, Liu N, Cui Y (2016) Promises and challenges of nanomaterials for lithium-based rechargeable batteries. Nature Energy 1: 16071.
65. Li W, Yang Y, Zhang G, Zhang Y-W (2015) Ultrafast and directional diffusion of lithium in phosphorene for high-performance lithium-ion battery. Nano letters 15: 1691-7.