Biomass-Based Renewable Materials For Environmental Remediation

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Abstract: The emergence of a global energy crisis and the enormous risk of climate change have significantly jeopardized the survival and development of the human race. Pervasive human activities, as a result of unchecked population growth and expanding industrialization, have resulted in an enormous increase in overall environmental degradation. Thus, itis now widely recognized that economically viable and environmentally benign strategies are necessary to address the current climate issues worldwide. Existing approaches to addressing this result in the generation of secondary pollutants, causing an insufficient resolution of the problem. Thus, the utilization of biomass-derived nano-structured materials emerges as the most effective approach for achieving an effective remediation strategy, realizing the circular economy, and achieving sustainable development goals.
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Introduction

Biomass is carbon-rich, sustainable, and green resource, abundantly available on planet earth[1–3]. In addition to its ample availability, biomass possesses many attractive properties like nontoxicity, biodegradability, and most importantly the renewability on a human time scale[4]. These properties make it the most desired candidate for the utilization as biomass-derived hierarchical structures naturally available for pollution abatement purposes or synthesize the materials of interest utilizing the biomass to fight the current climate challenges[5]. Biomass, having a biogenic origin, can be utilized as the starting material that includes agricultural and forest residues, animal residues, food waste from the kitchen, and other urban and rural waste sources[1]. The worldwide production of biomass was estimated to be approximately 150 billion metric tons a year[6]. It is simply disposed of or burned openly as an undesired material causing serious landfill problems, air pollution, and health hazards[7] and creates the uncertainty in pollutant estimation too[8]. Thus, it becomes imperative to convert biomass into novel nano structured material with a defined shape, size and superior qualities via utilizing green synthetic approaches for solving two problems in one go.

The biotic component of earth is abundantly rich in biodegradable substances, which represent myriad varieties of bio-based polymeric materials. A sustainable bio economy relies on biomass – derived organic materials such as green plants and animals derived waste rather than fossil fuels or the fossil fuels derived products. The realisation of such a system is possible only by encompassing the biomass-derived materials in multiple humanistic utilitarian fronts for responsible consumption and production.

Nano-structured materials

The term "nano-structured materials" refers to a collection of materials having structures with at least one dimension less than or equal to about 100 nanometres[9].

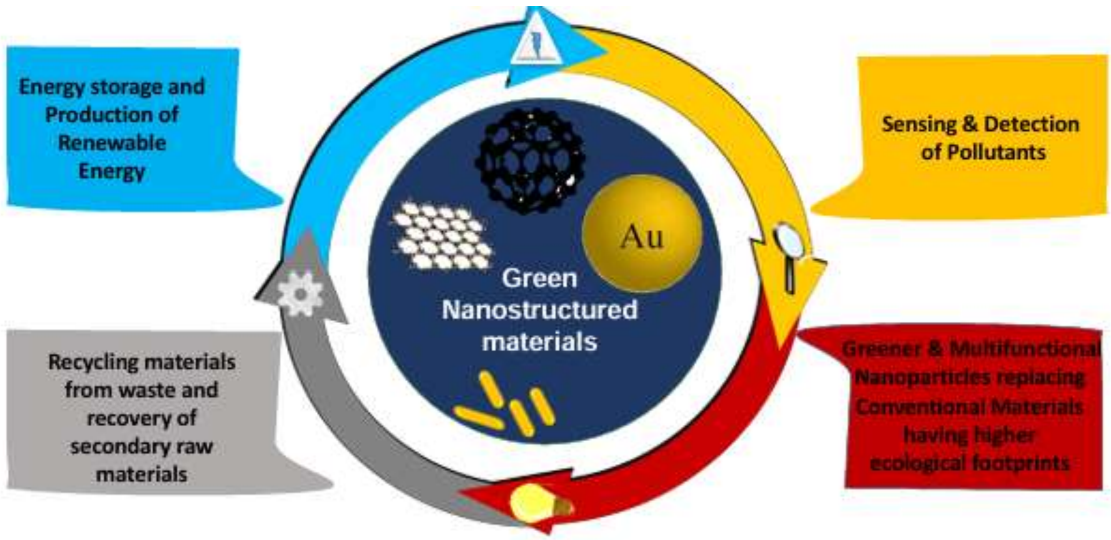

Figure.1.1*Schematic representing the integration of green nano-structured materials for enabling circular economy and sustainable development.*

Figure.1.2 *Renewable sources for biomass generation.*

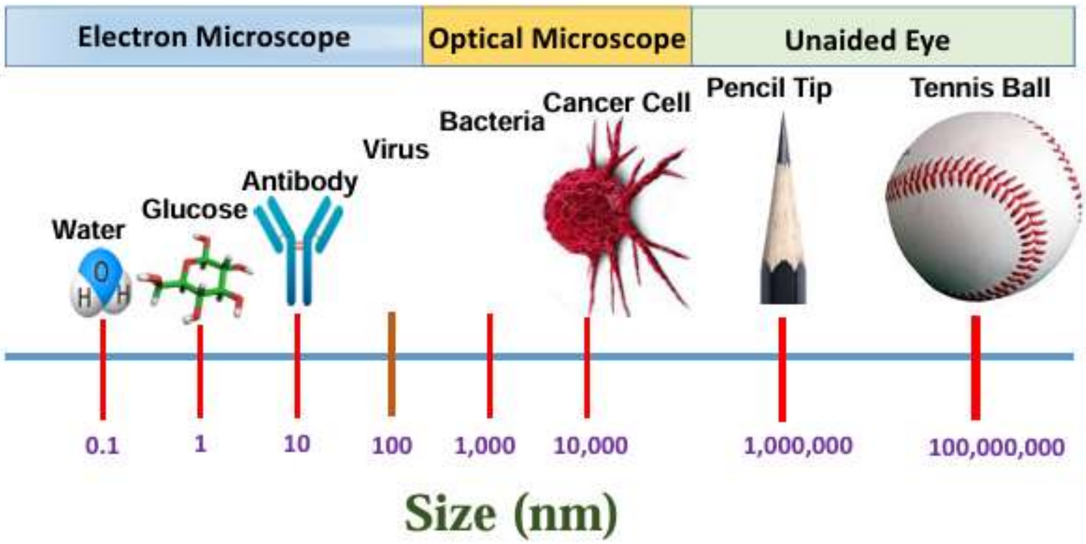

Figure.1.3 *Various things with aided and unaided visibility on a nanometer scale.*

Variousnano-structured materials have been explored so far which can be described as nano materials with zero-dimensional (0D), nanomaterials with one-dimensional (1D), nanomaterials with two-dimensional (2D), and nanomaterials with three-dimensions (3D) on the basis of the dimensionality [10]. The term 0D nanomaterials refers to nanomaterials 3 with a three-dimensional structure and a nanoscale size range of 1 to 100 nm in all the dimensions, such as quantum dots (QDs) and nanoparticles.

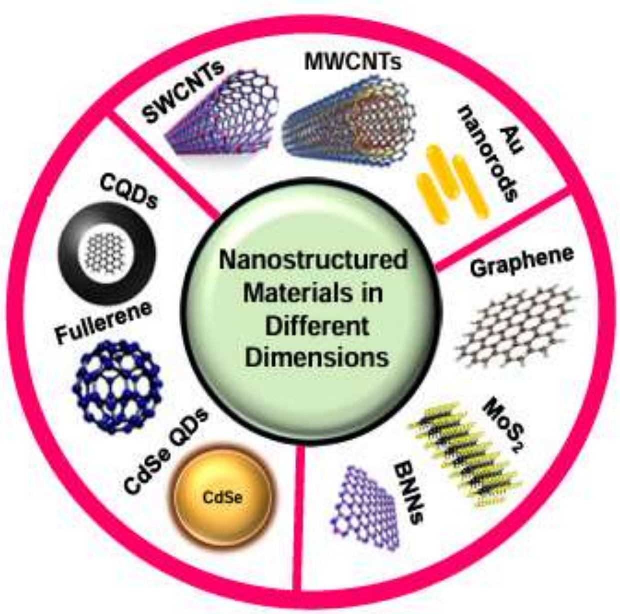

Figure.1.4 *An illustrative image for the categories of nanomaterials based on their size.*

Owing to the various unique phenomenon like surface, quantum size effect, and macro quantum tunnelling effect, these materials in nano-size range possess astounding electronic and optical properties [11, 12]. Due to their increased brightness, fluorescence, and photo stability, QDs have been used in developing fluorescent dyes[11] and probes, etc., and with these unique features, these nano-structured materials have influenced a variety of fields, including the physical, chemical, and biological scientific research and development[12–14].0D nanomaterials are frequently used in biology as probes for sensing[13]. Nano-structured materials have been studied in a variety of fields, including cosmetics[15], medicine[16], and environmental research [17]. Gold nanoparticles (AuNPs) are a particularly noteworthy type of nanoparticles due to their favoured stabilities for chemical and physical stresses and lesser toxicity to the living world[18,19]. The terminology"1D nanomaterials" refers to materials with two dimensions at the nanoscale and only one dimension remains outside the nanoscale, such as nanotubes, nanowires, and Nano rods with unidirectional anisotropy [20]. They have a high surface-to-volume ratio due to their astounding morphological properties, nano diameter, and height in micron scale[21].Carbon nanotubes (CNTs), one of the well researched 1D nanomaterials have been extensively studied by scientists in a wide variety of areas owing to their high efficiency for charge transport [22], capability for tuning the bandgaps in a widerange of spectrum [23], semiconducting characteristics and metallic features, and highly optical transparency with low resistivity values[24]. CNTs, the seamless cylinders are made up of graphene layers and can be classified as single-walled (SWCNTs) or carbon nanotubes with multiwall feature (MWCNTs)[25,26]. Cylindrical wires and rods in nano range, such as organic nanowires [27], also play a critical role in nanotechnology because they exhibit metallic or semiconducting properties. 2D materials are those which have their third dimension, i.e. thickness in nanoscale. In terms of two dimensional materials, along with its various oxides, graphene and transition metal dichalcogenides (TMDs) are well studied ones. Due to the ability of carbon to form sp2hybridization in graphene, it has been extensively studied in DNA research and plasma. graphene exhibits an unusually high carrier mobility [28]. Oxidized Graphene(GO), reduced form of oxidized graphene (rGO), and nanosheets of graphene (GNS) and graphene quantum dots (GQDs) are the most thoroughly studied graphene materials, the other emerging 2D nanomaterials are transition metal dichalcogenides, such as (MoS2),(WS2), and (MoSe2)[29].

Biomass-derived natural Fibers and their utilization in pollution abatement

Biomass is classified chemically into lignocellulosic and non-lignocellulosic material based on its chemical composition [3]. Ligno-cellulosic biogenic material is the most abundant non-palatable form of biomaterial obtained by agricultural residues and forests. 5 The primary components for which are cellulose, hemicellulose, and lignin[30,31]. Biomass devoid of lignocellulosic features (e.g., animal and kitchen discards) is a source of carbohydrates, polysaccharides, and proteins that has the potential for usage in the preparation of carbon based nano-structured materials derived from biogenic origin [2]. The naturally occurring fibers consist mainly of lignocellulosic biomass along with a thin waxy coating on top[32]. The use of naturally occurring and modified natural fibers for water remediation purposes, like the removal of chemical residues, oil, and organic solvent-based contaminants is a significant and cost-effective strategy for water pollution abatement purposes[32]. Natural fibers can broadly be divided into two categories viz. primary and secondary[33]. Primary natural fibers are those which are primarily produced for their fiber content and these include cotton, jute etc. Secondary natural fibers are those which are produced primarily for some other material of interest and the fibers are derived as secondary production and these include cereal stalks, oil palm, and coir, etc.[33]. The fibers can further be classified into six categories based on their source of origin. These include leaf fibers, seed fibers, reed fibers, core fibers, grass, and others such as wood and root fibers[34]. Among all these natural fibers, seed fibers[35] are an interesting class of natural biomass materials having intriguing properties and morphological assets[32]. The main purpose of seed fibers is to help in the long-range dispersal of the seeds. For this purpose, the seed fibers are naturally engineered for having a hollow tube-like structure and inherent hydrophobicity. The hydrophobicity and hollow structure of the natural seed fibers provide it with naturally buoyant characteristics and thus, these can be utilized for oil and organic solvent pollution abatement purposes[36]. Examples of naturally occurring seed fibers are Kapok, cattail, etc.[37–39]. The choice of natural fibers for developing new materials for oil sorption is determined by properties such as roughness and hierarchy at the nanoscale, which promoteboth oil absorption and retention capacity[35]. There are results obtained with Populus seed fibers, which are widely regarded as raw materials for the development of oil super-absorbents[35]. These are capillary fibers with hollow lignocellulosic micro tubes that have superior chemical and physical properties. The periodic arrangement of the microcrystalline cellulose and lignin in these fibers is a significant feature. As a result of van der Waals forces and hydrophobic interactions associated with the oleophilic behaviour of the seed fibers, exceptional performance in the absorption capacity of high-density oil and diesel is observed. These are the characteristics of superhydrophobic/superoleophobic surfaces that make them advantageous for the development of oil/water separating membranes. The main problem associated with the utilization of these fibers is their loose nature which hinders their utilization for oil spill clean-up in open waters.

References

M. Antar, D. Lyu, M. Nazari, A. Shah, X. Zhou, D.L. Smith, Z. Wang, D. Shen, T.X. Xd, D.X. Xd, D.X. Xd, S. V Vassilev, D. Baxter, C.G. Vassileva, S. Ravi, S. Vadukumpully, A. Manuscript, B. Song, R. Lin, C. Ho, H. Wu, T. Tsui, Y. Yu, H.G. Cha, K. Choi, Materials Chemistry A, Renewable and Sustainable Energy Reviews. 139 (2021) 33–86.

Z. Wang, D. Shen, C. Wu, S. Gu, State-of-the-art on the production and application of carbon nanomaterials from biomass, Green Chemistry. 20 (2018) 5031–5057.

T.X. Xd, D.X. Xd, D.X. Xd, Lignocellulosic biomass pyrolysis mechanism : A state-of-the-art review, Progress in Energy and Combustion Science. 62 (2017) 33–86.

J.Y. Zhu, U.P. Agarwal, P.N. Ciesielski, M.E. Himmel, R. Gao, Y. Deng, M. Morits, M. Österberg, Towards sustainable production and utilization of plant biomass-based nanomaterials: a review and analysis of recent developments, Biotechnology for Biofuels. 14 (2021) 1–32.

D. Woolf, J.E. Amonette, F.A. Street-Perrott, J. Lehmann, S. Joseph, Sustainable biochar to mitigate global climate change, Nature Communications. 1 (2010). M. Balat, G. Ayar, Biomass energy in the world, use of biomass and potential trends, Energy Sources. 27 (2005) 931–940.

N. De Oliveira Alves, A.T. Vessoni, A. Quinet, R.S. Fortunato, G.S. Kajitani, M.S. Peixoto, S. De Souza Hacon, P. Artaxo, P. Saldiva, C.F.M. Menck, S.R.B. De 119 Medeiros, Biomass burning in the Amazon region causes DNA damage and cell death in human lung cells, Scientific Reports. 7 (2017) 1–13.

H. Brown, X. Liu, R. Pokhrel, S. Murphy, Z. Lu, R. Saleh, T. Mielonen, H. Kokkola, T. Bergman, G. Myhre, R.B. Skeie, D. Watson-Paris, P. Stier, B. Johnson, N. Bellouin, M. Schulz, V. Vakkari, J.P. Beukes, P.G. van Zyl, S. Liu, D. Chand, Biomass burning aerosols in most climate models are too absorbing, Nature Communications. 12 (2021) 1–15.

F. Trotta, A. Mele, Nanomaterials: Classification and Properties, Nanosponges: from fundamentals to applications (2019) pp1–26.

V. V. Pokropivny, V. V. Skorokhod, Classification of nanostructures by dimensionality and concept of surface forms engineering in nanomaterial science, Materials Science and Engineering C. 27 (2007) 990–993.

W. Ren, G. Lin, C. Clarke, J. Zhou, D. Jin, Anticounterfeiting systems: Optical Nanomaterials and Enabling Technologies for High-Security-Level Anticounterfeiting, Advanced Materials. 32 (2020) 32: 2070141

A.M. Wagner, J.M. Knipe, G. Orive, N.A. Peppas, Quantum dots in biomedical applications, Acta Biomaterialia. 94 (2019) 44–63.

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