Recent Progress of Hybrid Architectures Based on Nanomaterials

V Dhinakaran¹, B Stalin², M Ravichandran³, M Balasubramanian⁴, C Anand Chairma⁵ and S Marichamy⁶

¹Centre for Applied Research, Department of Mechanical Engineering, Chennai Institute of Technology, Kundrathur, Chennai-600 069, Tamil Nadu, India.
²Department of Mechanical Engineering, Anna University, Regional Campus Madurai, Madurai-625 019, Tamil Nadu, India.
³Department of Mechanical Engineering, K.Ramakrishnan College of Engineering, Tiruchirappalli -621 112, Tamil Nadu, India.
⁴Department of Mechanical Engineering, University College of Engineering, Ramanathapuram Campus, Anna University, Ramanathapuram-623 513, Tamil Nadu, India.
⁵Department of Mechanical Engineering, K.Ramakrishnan College of Engineering, Tiruchirappalli -621 112, Tamil Nadu, India
⁶Department of Mechanical Engineering, Sri Indu College of Engineering and Technology, Hyderabad-501 510, Telangana, India

* Corresponding author: dhinakranv@citchennai.net

Abstract. The recent development in environment and energy of hybrid structures with excellent and multifunctional properties aims to promote single-component nanomaterials. In this phase, Noble Metals are rationally integrated in carbon dots (CD), which is one of the most common nano-hybrids that combine their material strength with mechanical properties including electrical characteristics, enhancing and putting surface resonance plasma (LSPR). In this research work, synthetic approaches, physicochemical properties and recent developments are investigated in the applications of noble nanohybrid metal / carbon dots (NMs / CDs. The CD / NMs will help coordinate the synthesis of nanohybrids to accomplish the goals in the manufacturing and architectural industries accordingly. In these implementations, special focus is put on processes and synergistic activity between the two components. Lastly, for further improving these nanohybrids, limitation and opportunities are suggested for NMs / CDs.

Keywords: hybrid structures, carbon dots, nanohybrid metal, putting surface resonance plasma.

1. Introduction
In order to overcome these issues as a result of adverse environmental and energy problems, the development of multifunctional materials with improved or vital properties has been rising. Beneficial metals (NMs) nanoparticles have become a form of material for many applications due to their unusual electronic and optical properties. Specifically, NMs may be used under visible light radiation under photocatalytic fields by the localised surface resonance Plasmon (LSPR) that is induced by group free electrons oscillations of the electromagnet incident light fields [1]. The catalytic behaviour of NMs is
well known to be closely related to particle size and porosity. As nanostructures with one component, NMs will be severely aggregated due to the high surface energy, which will alter particle size and minimise NM dispersivity with one component and are represented in figure 1 [2]. In order to preserve adequate catalytic efficiency in the treatment and processing of organic contaminants, NMs could not be efficient. A rational incorporation of NMs and other nanomaterials, such as the immobilisation of NMs into materials or the containment of NMs into materials that form core shell structure, was also a source of research concern [3]. It not only avoids the violence of NMs but it also carries in multiple benefits over single component materials for the characteristics of both NMs and other nanomaterials. Carbon-based nanomaterials, e.g. carbon nanotubes, familial graphics and newly evolving carbon-based dots have excellent chemical stability, conductivity and usability properties used as suitable materials for integrating NMs or intermediate metals, and metallic oxides for intermediate. In specific, carbon-based dots (CDs) such as carbon dots (C dots) and quantity carbon / graphene dots (QGDs or CQDs) were used to combine with NMs to easily spread NMs with several advantages, with plenty of functional categories [4]. In addition, the tuning and excellent upgrade ability of CDs and NM excitation LS Presenting visible and/or near-Infrared (NIR) LSPR ribbons will optimise full-speed solar power usage and thus expand the range of nanohybrids of the NMs /CDs in many applications, including Plasmon photocatalytic and enhanced fluorescence. However, few articles concentrate on CD-based NMs that thoroughly sum up the manufacture of nanohybrids and discusses the variations between different approaches. Furthermore, implementation in the fields of NMs / CDs relevant to climate and electricity have seldom been outlined. In recent years, we have also researched the combination of CDs with current and improved NM with the use of the environmentally friendly fields (pollutant identification, treatment) and energy dependent area of NM / CDs. Synthesized processes, physicochemical characteristics and application of nano hybrids are outlined [5]. In this sense, the NM / CDs nanohybrids synthesis may help direct NMs / CDs controlled nanohybrids in the obtaining of target materials that are not routinely summarised by the NMs or CDs methods in a single part. Furthermore, the synergistic effect of NMs / CDs and how NMs / CDs can obtain better properties in different applications are explored so that the process is better seen [6]. Future research methods for this group of nanohybrids are often described as drawback and challenges.

Figure 1. Classification of nanohybrids [7]

2. Fabrication of NMs/CDs nanohybrids

There are diverse synthetic approaches for NMs / CDs, according to the literature. In general, NM / CDs are synthetic methods that involve primarily chemical reductions, hydrothermal procedures and installed processes, which also include a range of control measures for the size and distribution of NM and CDs. In order for NMs to expand onto CDs due to the abundant groups of CDs containing oxygen, the
production of NMs is facilitated through chemical reduction pathways. The outcome could be a core-shell structure (CDs-NMs) [8]. For example, on a surface of CDs a shell of Ag was formed using chemical pathways that were verified by TEM. In comparison, CDs tend to position on the surface of the NM, creating a "particle dot," under hydrothermal method and electro-static assembly method. Used by hydrothermal process, small diameter NMs may normally be collected [9].

3. Chemical reduction method
The traditional NM / CD synthesis technique for nanohybrids is chemical reduction. Generally, before chemical reductions are carried out, CDs are first synthesised using "Top-Down" or the "Bottom Up" approaches to prepare NMs / CDs. In a solution to minimise chemical consumption, the as prepared CDs, metal precursors and reduction agents are then added. In the synthesis of NMs / CDs different chemical agents, such as tri-sodium citrate and borohydride are used as reducing agents in the reduction of metal precursors. While precursors to metal can easily be reduced to nanoparticles (NP) metal, dangerous substances are needed and a few by-products can easily be added. The Au-Pd core shell structure, synthesised by a sequential decrease method, is used, for instance, by Tesfalidet Balcha et al. In order to remove leftover salts and AA, for example, the NPs had to dialysis overnight. Consequently, several studies focus on green and easy synthesis of NMs / CDs by chemical methods. CDs will speed up transmitting speeds to metal precursors and promise to act as a reducing agent, offering the excellent potential for donating electron [10].

4. Hydrothermal method
The hydrothermal process for synthesising nanohybrids is deemed environmentally sustainable with easy operations. Li et al., for instance, synthesised CQDs (Au / N-CQDs) with follic acid, a carbon and nitrogen source, glycerol, a carbon source and HauCl4 as a golden source using a 1 stage hydrothermal process at 180 ° C for 12 h. For example, As ready Au / N-CQDs normalised 4.01 ± 1 nm diameter. Likewise, a simple hydrothermal process, with a diameter of 4.8 ± 0.2 nm, has also been applied to synthesise a well-dispersed N-dot GQDs-supported Pd (N-GQDs / Pd) [11].

5. Assembled method
Assembled approach benefits from material interactions with complemen tal functional groups, including electrostatic interaction, hydrogen interactions or other intermolecular interactions. CQDs / Au Nanocluster (CQDs / Au NCs) is, for example, constructed by Shan et al. by carbodiamide-induced combination reaction. The first step is to synthesise CQDs using a modified hydrothermal process with (3-aminopropyl) triethoxysilane (APTES) and then synthesise Au NCs with a chemical decrease of the ceiling of 11-mercaptoundecanoic (MUA). The NH2 groups at CQD’s surface and COOH on Au NC ’s surface may interact with CQD’s and Au NC’s by means of a carbon-activated coupling response [12]. A layer-by-layer assembling approach was recently developed by Zeng et al. to assemble the prepared CQDs and the negative Au, Ag, or Pt NCs, which have been charged positively.

6. Physicochemical depiction of NMs/CDs nanohybrids
Usually, NMs / CDs are used by means of electron microscopy (TEM) to supply morphology, particle size information, distributors properties and morphological parameters. TEM is described in the surface-free Au NPs / reduced CDs (Sf-Au NPs / r-CDs) for the morphology of Au NPs and CDs. Visible-infringed (UV) diffuse reflexion spectroscopy (DRS), transient photo-current reaction and pre-emptive electromagnetism (EIS) and photoluminescence (PL) are routine instruments for evaluating the optical and photo-quality characteristics of NM / CDs. NMs are a single commodity, but NM / CDs nanohybrids in conjunction with other associated halves are not a photocatalyst that functions as an efficient photocatalyst for photocatalysis. DRS composite spectrum tests g-C3N4, N-GQDs / GCN-3, Ag / g-C3N4 and Ag / N-GQDs / g-C3N4 (AGCN-4). Calculation of DRS spectrum [13]. The LSPR effect of Ag NPs may be attributed to emerging peaks in the 450–550 nm scale. DRS Spectrum Comparison. In order to analyse the charge, transfer and differentiation of the NMs / CDs, transient photocurrent reaction and EIS were used.

7. Applications
A variety of manufacturing chemicals and everyday lives, including heavy metals and industrial toxins, threaten the environment’s stability and human health. Effective degradation and identification of different harmful chemical compounds is important for the prevention and regulation of contaminants. In different applications, the characteristics of each NM/CD can depend on the circumstances. In the image, the FRET operation occurred when the distance between the CDs and the NMs was too near [14].

In the fluorescent resonance transmission (RREST for example), a photographic fluorescent sensor was designed for the identification of the contaminant, for example, the imaging was lost. In recent research on the creation of sensors/biosensors, multiple NM/CD nanohybrids were then identified. A catalytic reduction of NM/CDs, in which pollutants are lowered to fewer and readily biodegradable materials rather than directly mineralised, are necessary for hydrogen reactions such as hydro deoxygenation, hydro dehalogenation, and hydrogeology. The NMs and CDs are excited to create electron hole pairs during the process of the photocatalytic polluter degradation, in which electrons on the conduction strip react with O2 to radical superoxide, and the oxidation-filled holes specifically react to contaminants and H2O to make radical hydroxylase capable of mineralizing contaminants [15].

**Figure 2.** Applications of nanohybrids [16]

8. Catalytic reduction

The catalytically decrease in water treatment in the laboratory has been extensively studied and its applications have also shown satisfactory results for actual wastewater, that can yield significantly cheaper and more biodegradable products for products. In the easy reduction of nitro-aromatic compounds to the required amino-aromatic compounds, for example, NM/CD composites have been used with the NaBH4 as a reducer that can minimise pollutant toxicity and is a convenient way to make
organics an intermediate of use. Recently Xiao et al., which exhibited remarkable catalytical efficiency in the decrease of 4-NPs and were important in practical applications, synthesised a multi-layer (Au/GQD) ten immobilised film on fluorinated tin oxide substrates [17].

9. Photocatalytic degradation of pollutants
A significant and substantial challenge in the science world is the photocatalytic degradation of contaminants. Photocatalyzes have proved to be a successful environmental purification system because of high performance and low energy consumption. NMs with specific electronic properties and high visible light absorption due to SPR effects have been proved. CDs with special electronic and light absorbance characteristics are a promising option in photocatalytic applications to QDs and molecular dyes. In NM the most studied metals with LSPR effect in visible areas, Au and Ag stand for CDs for photocatalytic applications. In addition, these metals are used. For example, Li et al. have synthesised a tremendous agg-GQDs-ZnO photocatalyst with visible light irradiation in relation to Rhodamine B (RhB). The synergistic effect between Ag NPs and GQDs has been the consequence of enhanced RhB-degradation performance for Ag-GQDsZnO. In some cases, they were used to create the full-spectrum multi-step charging channel that could significantly increase the photocatalytical performance of emission degradation by benefiting from superior electronic properties, high light absorption capability and a low recombination of load carriers, NMs and CDs [18]. In a study, ternary plasmonic CQDs / Ag / Ag2O have been synthesised with a homogenous plasmonic approach, which was performed for UV, visible and light NIR photocatalytic degradation of MB.

10. Fluorescent detection
Due to its particular fluorescence properties and stability, CDs and NMs (especially Au and Ag NPs) have emerged in recent years as two new groups of fluorescent nanomaterials. Nanohybrids of NMs / CDs are thus typically picked as metal ion sensors for fluorescent detection to determine ion concentration [19]. In these, CDs act as fluorescence reporters because they are energy-efficient donors that track pollutant by changing colour. In addition, the routes of design are focused on the interaction of the fluorescence properties of CDs and the plasmonic behaviour of individual NMs, namely, fluorescence upgrading of CDs might lead to the implementation, in a study reported by Ma et, of the standard Metal-enhanced fluorescence (MEF) technology is an advanced way of detecting heavy metalcopper ions (Cu2 +) with fluorescent effects [20].

11. Photocatalytic hydrogen evolution and CO2 reduction
Hydrogen (H2) has a high energy density of 140 MJ kg-1 as the most basic and desirable output power. A direct technology of solar-chemical energy transfer, photocatalytic water separated into H2 and oxygen (O2) is a world-wide study spot [21]. Photocatalytic H2 production typically goes away where photo-excited electrons reduce the solution protons to hydrogen atom chemisorbed on the surface of the catalyst to H2 [22]. NMs / CDs are usually used for energy transformations as photocatalysts. Noble metal Pt is commonly used to increase the photocatalytic efficiency of CDs as co-catalysts. In NMs / CD's, CD's play a significant function in light gathering, which consumes solar photons, making them more energy stable and allows electrons to be transferred. The electrons were then moved to the Pt clusters to reduce H+ to H2 [23]. In contrast with the unparalleled ZIS, ZIS fitted with Pt and ZIS adorned with CQDs, the Pt / C-ZIS composite, which is 1032.2 μmol·h−1 · g−1, substantially increased output volume [24]. The findings demonstrated that optical design, crystal phase, and electronic design are the key factors affecting the H2 output rate of Pt / C-ZIS. CQDs and Pt NPs can make adsorption of light simpler and increase Pt / C-ZIS crystalline, leading to decreased crystal defects and increased power conductivity [25].

12. Conclusion
Nanomaterials and carbon dots are typically being synthesised by chemical declines, hydrothermal methods and assembled process. Physicochemical features include primarily optical properties, photochemistry, and characterisation of surface chemistry and microscopy. A summary of the hybrid NMs / CDs based on their synthetic processes, the physicochemical properties, the applications related to the atmosphere (detection and treatment) and resources (water separating, RR and MOR) and the
synergistic process are described in a detailed manner. Although nano-hybrid multifunctional NMs / CDs are fine for different applications, the nanohybrid NMs / CDs obtained are still far from practical. Overall, continuous NM / CD studies are needed in order to thoroughly leverage and apply NM / CD in catalytic and detection applications. CDs and catalytic analysis should be carried out efficiently and effectively. The efforts made to explore NM / CDs can offer some insights into the mechanism behind the hybrids and lead to the creation of further combinations of nanomaterials.

13. Reference

[1] Fu, Yukui, Guangming Zeng, Cui Lai, Danlian Huang, Lei Qin, Huan Yi, Xigui Liu et al. "Hybrid architectures based on noble metals and carbon-based dots nanomaterials: A review of recent progress in synthesis and applications." Chemical Engineering Journal (2020): 125743.

[2] Tiginyanu, Ion, Lidia Ghipmu, Jorit Gröttrup, Vitalie Postolache, Matthias Mecklenburg, Marion A. Stevens-Kalceff, Veaceslav Ursaki et al. "Strong light scattering and broadband (UV to IR) photoabsorption in stretchable 3D hybrid architectures based on Aerographite decorated by ZnO nanocrystallites." Scientific reports 6 (2016): 32913.

[3] Huang, Xiao, Chao Liang Tan, Zongyou Yin, and Hua Zhang. "25th anniversary article: Hybrid nanostructures based on two-dimensional nanomaterials." Advanced Materials 26, no. 14 (2014): 2185-2204.

[4] Barrejón, Myriam, Luis M. Arellano, Francis D'Souza, and Fernando Langa. "Bidirectional charge-transfer behavior in carbon-based hybrid nanomaterials." Nanoscale 11, no. 32 (2019): 14978-14992.

[5] Dong, Chen, Deming Chen, Sansiri Haruehanroengra, and Wei Wang. "3-D nFPGA: A reconfigurable architecture for 3-D CMOS/nanomaterial hybrid digital circuits." IEEE Transactions on Circuits and Systems I: Regular Papers 54, no. 11 (2007): 2489-2501.

[6] Niu, Zhiquan, Lili Liu, Li Zhang, Qi Shao, Weiya Zhou, Xiaodong Chen, and Sishen Xie. "A universal strategy to prepare functional porous graphene hybrid architectures." Advanced Materials 26, no. 22 (2014): 3681-3687.

[7] https://lh3.googleusercontent.com/proxy/iaEy-YxstEHT_O-GZRGmxBsGxEpdrowsGpsAXB6q_oIOf-d3tZf_NQFQwZ76aRouS-5w4FlOqh25x4fho4-B9zmyhDYbyPNUOsChZKYlg5tB7jNpbEuW0fsyppQQwU8k3yopEIApXe

[8] Ng, Sing Muk. "Functionalized nanomaterials for chemical sensor applications." In Handbook of Functionalized Nanomaterials for Industrial Applications, pp. 435-477. Elsevier, 2020.

[9] Singh, Satarudra Prakash, Mohammad Israil Ansari, Brijesh Pandey, Janmejai Kumar Srivastava, Thakur Prasad Yadav, Humaira Rani, Ashna Parveen, Yotiji Mala, and Akhilesh Kumar Singh. "Recent Trends and Advancement Toward Phyto-mediated Fabrication of Noble Metallic Nanomaterials: Focus on Silver, Gold, Platinum, and Palladium." In Nanomaterials and Environmental Biotechnology, pp. 87-105. Springer, Cham, 2020.

[10] Chou, Kan-Sen, and Chiang-Yuh Ren. "Synthesis of nanosized silver particles by chemical reduction method." Materials chemistry and physics 64, no. 3 (2000): 241-246.

[11] Wang, Hongshui, Xueliang Qiao, Jianguo Chen, and Shiyuan Ding. "Preparation of silver nanoparticles by chemical reduction method." Colloids and Surfaces A: Physicochemical and Engineering Aspects 256, no. 2-3 (2005): 111-115.

[12] He, Fu-An, Jin-Tu Fan, Fei Song, Li-Ming Zhang, and Helen Lai-Wa Chan. "Fabrication of hybrids based on graphene and metal nanoparticles by in situ and self-assembled methods." Nanoscale 3, no. 3 (2011): 1182-1188.

[13] Narayanan, Sreeja, Binulal N. Sathy, Ullas Mony, Manzoor Koyakutty, Shantikumar V. Nair, and Deepthy Menon. "Biocompatible magnetite/gold nanohybrid contrast agents via green chemistry for MRI and CT bioimaging." ACS applied materials & interfaces 4, no. 1 (2012): 251-260.

[14] Zhao, Nana, Liemei Yan, Xiaoyi Zhao, Xinyan Chen, Aihua Li, Di Zheng, Xin Zhou, Xiaoguang Dai, and Fu-Jian Xu. "Versatile types of organic/inorganic nanohybrids: from
strategic design to biomedical applications." Chemical reviews 119, no. 3 (2018): 1666-1762.

[15] Wu, Bohua, Yinjie Kuang, Xiaohua Zhang, and Jinhua Chen. "Noble metal nanoparticles/carbon nanotubes nanohybrids: synthesis and applications." Nano Today 6, no. 1 (2011): 75-90.

[16] Jin, Yuhui, Aize Li, Sandra G. Hazelton, Song Liang, Carrie L. John, Paul D. Selid, David T. Pierce, and Julia Xiaojun Zhao. "Amorphous silica nanohybrids: Synthesis, properties and applications." Coordination Chemistry Reviews 253, no. 23-24 (2009): 2998-3014.

[17] Mao, Shun, Zhenhai Wen, Haejune Kim, Ganhua Lu, Patrick Hurley, and Junhong Chen. "A general approach to one-pot fabrication of crumpled graphene-based nanohybrids for energy applications." ACS nano 6, no. 8 (2012): 7505-7513.

[18] Di, Jun, Jiexiang Xia, Sheng Yin, Hui Xu, Li Xu, Yuanguo Xu, Minqiang He, and Huaming Li. "Preparation of sphere-like gC 3 N 4/BiOI photocatalysts via a reactive ionic liquid for visible-light-driven photocatalytic degradation of pollutants." Journal of Materials Chemistry A 2, no. 15 (2014): 5340-5351.

[19] Zhang, Shi-Wei, and Timothy M. Swager. "Fluorescent detection of chemical warfare agents: functional group specific ratiometric chemosensors." Journal of the American Chemical Society 125, no. 12 (2003): 3420-3421.

[20] Guo, Yongming, Lianfeng Zhang, Shushen Zhang, Yan Yang, Xihan Chen, and Mingchao Zhang. "Fluorescent carbon nanoparticles for the fluorescent detection of metal ions." Biosensors and bioelectronics 63 (2015): 61-71.

[21] Feng, Xuanyu, Yunhong Pi, Yang Song, Carter Brzezinski, Ziwan Xu, Zhong Li, and Wenbin Lin. "Metal–Organic Frameworks Significantly Enhance Photocatalytic Hydrogen Evolution and CO2 Reduction with Earth-Abundant Copper Photosensitizers." Journal of the American Chemical Society 142, no. 2 (2020): 690-695.

[22] Su, Yun, Zhe Zhang, Hong Liu, and Yong Wang. "Cd0. 2Zn0. 8@ UiO-66-NH2 nanocomposites as efficient and stable visible-light-driven photocatalyst for H2 evolution and CO2 reduction." Applied Catalysis B: Environmental 200 (2017): 448-457.

[23] Liao, Wei-Ming, Jian-Hua Zhang, Zheng Wang, Yu-Lin Lu, Shao-Yun Yin, Hai-Ping Wang, Ya-Nan Fan, Mei Pan, and Cheng-Yong Su. "Semiconductive amine-functionalized Co (II)-MOF for visible-light-driven hydrogen evolution and CO2 reduction." Inorganic chemistry 57, no. 18 (2018): 11436-11442.

[24] Li, Xu-Bing, Chen-Ho Tung, and Li-Zhu Wu. "Quantum Dot Assembly for Light-Driven Multielectron Redox Reactions, such as Hydrogen Evolution and CO2 Reduction." Angewandte Chemie International Edition 58, no. 32 (2019): 10804-10811.

[25] Zeng, Deqian, Ting Zhou, Wee-Jun Ong, Mingda Wu, Xiaoguang Duan, Wanjie Xu, Yuanzhi Chen, Yi-An Zhu, and Dong-Liang Peng. "Sub-5 nm ultra-fine FeP nanodots as efficient co-catalysts modified porous g-C3N4 for precious-metal-free photocatalytic hydrogen evolution under visible light." ACS applied materials & interfaces 11, no. 6 (2019): 5651-5660.