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Review of Carbon Nanotubes with Carbon Nanostructures and Synthesis of Organometallic Fullerene Derivatives

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Abstract

Carbon nanotubes (CNTs) are remarkable nanostructures with unique mechanical, electrical, and thermal properties, holding immense potential for various applications in fields such as electronics, materials science, and medicine. This abstract explores the synthesis of carbon nanostructures, particularly focusing on carbon nanotubes, and the development of organometallic fullerene derivatives. The synthesis of carbon nanotubes involves a variety of techniques, including arc discharge, chemical vapor deposition (CVD), and laser ablation, each offering distinct advantages in terms of scalability, purity, and control over structural properties. These methods enable the production of CNTs with tailored characteristics, such as diameter, chirality, and length, to suit specific application requirements. Organometallic fullerene derivatives represent a class of compounds wherein metal atoms or clusters are encapsulated within fullerene cages, offering unique electronic, magnetic, and catalytic properties. The synthesis of these derivatives involves functionalizing fullerene molecules with organometallic precursors through chemical reactions, resulting in hybrid materials with enhanced functionality and versatility. the significance of carbon nanotubes and organometallic fullerene derivatives in advancing nanotechnology and materials science. By understanding their synthesis and properties, researchers can explore novel applications in areas such as nanoelectronics, catalysis, drug delivery, and energy storage, contributing to the development of innovative technologies with societal impact.

Introduction

Carbon nanotubes (CNTs) and organometallic fullerene derivatives represent two fascinating realms within the field of nanotechnology, each offering unique properties and potential applications. This introduction provides an overview of the synthesis of carbon nanostructures, with a focus on carbon nanotubes, and the development of organometallic fullerene derivatives, highlighting their significance in advancing materials science and nanotechnology.

Carbon nanotubes, discovered in 1991 by Sumio Iijima, are cylindrical nanostructures composed of rolled graphene sheets. They exhibit extraordinary mechanical strength, electrical conductivity, and thermal stability, making them promising candidates for applications ranging from nanoelectronics to structural materials and biomedical devices. Various synthesis methods, including arc discharge, chemical vapor deposition (CVD), and laser ablation, have been developed to produce carbon nanotubes with controlled structural properties such as diameter, chirality, and length. Organometallic fullerene derivatives, on the other hand, involve the incorporation of metal atoms or clusters into fullerene cages, creating hybrid materials with unique electronic, magnetic, and catalytic properties. These derivatives have garnered significant attention for their potential applications in areas such as molecular electronics,

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sensors, and catalysis. Synthesizing organometallic fullerene derivatives typically involves functionalizing fullerene molecules with organometallic precursors through chemical reactions, enabling the tailored design of materials with desired properties. By understanding the synthesis and properties of carbon nanotubes and organometallic fullerene derivatives, researchers can explore novel applications in fields such as nanoelectronics, energy storage, and biomedicine, driving innovation and pushing the boundaries of nanotechnology. This introduction sets the stage for further exploration of these fascinating nanomaterials and their potential impact on various technological and scientific domains.

Background and motivation

The study of Carbon Nanotubes (CNTs) and related carbon nanostructures has gained significant attention due to their unique mechanical, electrical, and thermal properties, which make them highly promising for a wide range of applications, including electronics, materials science, and nanomedicine. Despite substantial progress, challenges remain in the scalable synthesis, functionalization, and integration of CNTs into practical devices, necessitating further research. The synthesis of organometallic fullerene derivatives represents another frontier in nanomaterials research.Spherical carbon structures, offer exceptional stability and the potential for diverse chemical modifications. By introducing metal atoms into fullerene frameworks, new materials with unique electronic and catalytic properties can be developed. These derivatives hold promise for applications in catalysis, energy storage, and molecular electronics. The motivation behind this research is to advance the understanding and practical implementation of these nanomaterials, addressing existing challenges and exploring their vast potential for technological innovation and societal benefit.

Need of the Study

The need for this study arises from the growing demand for advanced materials that can meet the challenges of modern technology across various fields, including electronics, energy, and biomedicine. Carbon nanotubes (CNTs) and fullerenes are at the forefront of nanotechnology due to their exceptional physical and chemical properties. However, the practical application of these nanomaterials is often hindered by their limited solubility, poor dispersion, and difficulty in functional integration with other materials. CNTs with carbon nanostructures and the synthesis of organometallic fullerene derivatives offer promising solutions to these challenges. By enhancing the chemical reactivity and compatibility of CNTs, functionalization enables their incorporation into diverse matrices, improving their performance in real-world applications. Similarly, organometallic fullerene derivatives provide unique electronic, optical, and catalytic properties that can be tailored for specific uses, such as in photovoltaics, sensors, and drug delivery systems. This study addresses the urgent need to develop innovative methodologies for the functionalization and synthesis of these advanced materials. By exploring these approaches, the research aims to unlock the full potential of CNTs and fullerenes, paving the way for the creation of high-performance nanocomposites. These advancements will have significant implications for the development of next-generation technologies, ultimately contributing to scientific progress and industrial innovation.

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Structural and electronic properties of CNTS

Carbon Nanotubes (CNTs) are cylindrical nanostructures composed of carbon atoms arranged in a hexagonal lattice, similar to graphene. They can be categorized into single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs). SWCNTs consist of a single graphene sheet rolled into a cylindrical shape, while MWCNTs are composed of multiple concentric graphene cylinders nested within one another. The diameter of CNTs can range from less than 1 nanometer for SWCNTs to several nanometers for MWCNTs, with lengths that can extend up to several millimeters.

The unique structural properties of CNTs arise from their high aspect ratio, which is the ratio of their length to their diameter, and their seamless cylindrical structure. This gives CNTs exceptional mechanical strength, with tensile strengths up to 100 times greater than steel, and remarkable flexibility. Additionally, CNTs exhibit high thermal conductivity along their length due to the strong sp2 carbon-carbon bonds in the graphene lattice.

Electronic Properties

The electronic properties of CNTs are equally remarkable and depend significantly on their structure, particularly their chirality and diameter. Chirality refers to the way the graphene sheet is rolled to form the nanotube, characterized by a pair of integers (n, m) known as the chiral vector. This vector determines whether a CNT will exhibit metallic or semiconducting behavior.

Metallic CNTs: When n-m is a multiple of 3 (excluding the case where n = m), CNTs exhibit metallic properties, allowing them to conduct electricity with minimal resistance. This makes them suitable for applications in nanoelectronics, such as interconnects in integrated circuits.

Semiconducting CNTs: If n-m is not a multiple of 3, CNTs exhibit semiconducting properties with a tunable bandgap, which can be adjusted based on their diameter and chirality. Semiconducting CNTs are promising for use in transistors, sensors, and other electronic devices due to their high electron mobility and the ability to function at the nanoscale.

The combination of exceptional structural and electronic properties positions CNTs as a key material in the development of next-generation nanotechnologies, offering potential breakthroughs in fields ranging from electronics and materials science to energy and medicine.

Carbon Nanotubes

Carbon nanotubes (CNTs) are cylindrical nanostructures composed entirely of carbon atoms arranged in a hexagonal lattice, forming a tube-like structure with diameters typically in the nanometer range and lengths that can extend to several micrometers. Discovered in the early 1990s, CNTs have attracted immense interest due to their exceptional physical and chemical properties. These properties include extraordinary mechanical strength, with a tensile strength approximately 100 times greater than that of steel, combined with low density, making them one of the strongest materials known. Additionally, CNTs exhibit remarkable electrical conductivity, surpassing that of copper, which makes them highly valuable in the development of advanced electronic devices.

CNTs come in two primary forms: single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs). SWCNTs consist of a single layer of graphene rolled

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into a seamless cylinder, whereas MWCNTs comprise multiple concentric graphene cylinders nested within one another. The electronic properties of SWCNTs can vary from metallic to semiconducting, depending on their chirality and diameter, thus enabling their application in a wide range of electronic and optoelectronic devices. Despite their promising attributes, the practical application of CNTs faces significant challenges. Their tendency to agglomerate due to strong van der Waals forces leads to poor dispersion in solvents and matrices, hindering their performance in composite materials. Furthermore, the inert nature of pristine CNTs limits their chemical reactivity and compatibility with other substances. To address these issues, various functionalization techniques have been developed, involving the attachment of functional groups or nanostructures to the CNT surface. These modifications enhance their solubility, dispersion, and interaction with other materials, thereby expanding their applicability in areas such as nanocomposites, sensors, energy storage, and biomedical devices. Research in the field of CNTs continues to evolve, focusing on optimizing functionalization methods, understanding the properties of CNT-based materials, and developing scalable production techniques. The ongoing advancements in CNT technology hold the promise of revolutionizing numerous industries by providing materials with unparalleled performance and versatility, driving innovation and technological progress.

Literature Review

Andersson, C. H. (2011). The chemistry of carbon nanostructures, specifically the functionalization of carbon nanotubes (CNTs) and the synthesis of organometallic fullerene derivatives, is a rapidly advancing field with significant implications for various technological applications. Functionalization of CNTs involves modifying their surfaces with functional groups or nanostructures to enhance their chemical reactivity, solubility, and compatibility with other materials. This process can be achieved through covalent bonding, where chemical bonds are formed directly with the carbon atoms of the CNTs, or non-covalent interactions, such as π-π stacking or van der Waals forces. These modifications enable CNTs to be more effectively incorporated into composite materials, sensors, and biomedical devices, improving their performance and versatility. In parallel, the synthesis of organometallic fullerene derivatives involves incorporating metal atoms or clusters into the fullerene structure. These derivatives exhibit unique electronic, optical, and catalytic properties, making them valuable for applications in photovoltaics, catalysis, and drug delivery systems. By combining the extraordinary properties of fullerenes with the functional versatility of metal complexes, researchers can create novel materials with tailored functionalities.

Nyamori, V. O., (2008) The use of organometallic transition metal complexes in the synthesis of shaped carbon nanomaterials represents a cutting-edge approach in nanotechnology. These complexes act as catalysts, facilitating the controlled growth and morphological manipulation of carbon nanostructures, such as nanotubes, nanoribbons, and nanospheres. Transition metals like iron, cobalt, and nickel are particularly effective due to their ability to mediate carbon-carbon bond formation and guide the assembly of carbon atoms into desired configurations. In the synthesis process, organometallic complexes decompose under specific conditions,

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releasing metal atoms that catalyze the carbonization of precursor materials. This controlled catalysis enables the formation of carbon nanomaterials with precise shapes and sizes, essential for applications requiring high structural uniformity and tailored properties. For instance, shaped carbon nanotubes can be engineered for specific electronic, mechanical, or thermal characteristics, enhancing their utility in electronics, composite materials, and energy storage devices. The integration of organometallic transition metal complexes in the synthesis of carbon nanomaterials not only advances the precision and scalability of production methods but also opens new avenues for creating custom-designed nanostructures. These advancements hold promise for significant innovations in various technological fields, driving progress in nanomaterials science and engineering.

Sherigara, B. S.,(2003) The electrocatalytic properties and sensor applications of fullerenes and carbon nanotubes (CNTs) have garnered significant attention due to their unique structural and electronic characteristics. Both fullerenes and CNTs possess remarkable electrical conductivity, large surface area, and high chemical stability, making them ideal candidates for use in electrocatalysis and sensor technologies. Fullerenes, particularly C60, exhibit excellent electron-accepting capabilities, making them efficient electrocatalysts for applications such as fuel cells and electrochemical reduction processes. They enhance the performance of oxygen reduction and hydrogen evolution reactions, which are critical for energy conversion and storage technologies. CNTs, due to their high conductivity and mechanical strength, significantly improve the efficiency of catalytic processes by providing conducive pathways for electron transport and enhancing the active surface area. This makes them crucial for developing efficient fuel cells and batteries. In sensor applications, fullerenes are used to detect gases like nitrogen dioxide and ammonia, as well as volatile organic compounds, by leveraging their sensitivity to changes in the electronic environment. CNTs, with their large surface-to-volume ratio, detect a wide range of analytes, including gases, chemicals, and biological molecules, by measuring changes in electrical resistance or capacitance. This makes them suitable for environmental monitoring, medical diagnostics, and industrial process control. Their unique structures provide superior performance characteristics, driving innovation in the development of high-efficiency catalysts and highly sensitive, selective sensors, promising significant advancements in various scientific and industrial fields.

Brennan, L. J., & Gun'ko, Y. K. (2015). Advances in the organometallic chemistry of carbon nanomaterials have led to significant breakthroughs in the synthesis, functionalization, and application of these materials. The integration of organometallic complexes with carbon nanostructures such as carbon nanotubes (CNTs) and fullerenes has opened up new possibilities in various technological domains. One of the key advances is the development of methods for covalently attaching organometallic complexes to CNTs and fullerenes. This functionalization enhances the chemical reactivity and solubility of these nanomaterials, making them more compatible with other materials and broadening their application scope. For instance, the attachment of metal complexes to CNTs can improve their catalytic properties, making them highly efficient in processes like the hydrogen evolution reaction (HER) and

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oxygen reduction reaction (ORR), which are essential for fuel cells and energy storage devices. the synthesis of organometallic fullerene derivatives has shown great promise in creating materials with unique electronic, optical, and catalytic properties. These derivatives, formed by incorporating metal atoms or clusters into the fullerene structure, exhibit enhanced stability and tailored functionalities. They are particularly valuable in the fields of photovoltaics, where they can improve the efficiency of solar cells, and in catalysis, where they provide more effective and selective catalytic agents for various chemical reactions.

Zamolo, V. A(2014) Carbon nanotubes (CNTs) are cylindrical nanostructures composed of carbon atoms arranged in a hexagonal lattice. They exhibit unique mechanical, electrical, and thermal properties, making them valuable in various applications. The synthesis of CNTs involves techniques such as chemical vapor deposition (CVD), arc discharge, and laser ablation. CVD is the most widely used method due to its ability to produce high-purity CNTs with controlled dimensions. CNTs are categorized into single-walled (SWCNTs) and multi-walled (MWCNTs) nanotubes. SWCNTs consist of a single graphene sheet rolled into a tube, while MWCNTs comprise multiple concentric graphene cylinders. Functionalization of CNTs is crucial for enhancing their solubility, compatibility with other materials, and specific applications. This can be achieved through covalent and non-covalent methods, including chemical modification and polymer wrapping. Characterization of CNTs involves techniques like transmission electron microscopy (TEM), scanning electron microscopy (SEM), Raman spectroscopy, and thermogravimetric analysis (TGA). These methods provide insights into their structural integrity, purity, and functional properties, facilitating their integration into advanced technological applications.

Sarkar, S.(2014) Organometallic chemistry of carbon nanotubes (CNTs) and graphene has emerged as a pivotal area of research due to its potential in enhancing the properties and functionalities of these materials. CNTs and graphene, known for their exceptional electrical, thermal, and mechanical properties, can be further tailored through organometallic functionalization. This process involves the attachment of organometallic compounds to the carbon framework, which can modify electronic properties, improve solubility, and introduce new catalytic functions. For instance, the attachment of transition metal complexes to CNTs can create novel materials for applications in catalysis, sensors, and nanoelectronics. Similarly, graphene functionalized with organometallic compounds can exhibit enhanced electronic interactions, making it suitable for use in advanced electronic devices and energy storage systems. The ability to control the degree and nature of functionalization opens up possibilities for customizing CNTs and graphene for specific applications, thereby expanding their utility in various technological fields. This intersection of organometallic chemistry with nanomaterials is thus a promising avenue for future research and development in nanotechnology.

Botta, L., Bizzarri, B. M (2017) Advances in biotechnological synthetic applications of carbon nanostructured systems have significantly expanded the scope and efficacy of biotechnological processes. Carbon nanostructures, including carbon nanotubes (CNTs), graphene, and

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fullerenes, possess unique properties such as high surface area, electrical conductivity, and mechanical strength, making them ideal candidates for various biotechnological applications. Carbon nanostructures have been utilized to develop highly efficient and targeted delivery systems. Their ability to penetrate cell membranes and deliver therapeutic agents directly to target cells has shown promise in treating diseases with improved efficacy and reduced side effects. Additionally, carbon nanostructures have been employed in biosensing applications, where their high surface area and conductivity enhance the sensitivity and accuracy of detecting biological molecules. This has led to the development of advanced diagnostic tools capable of early disease detection and real-time monitoring of biological processes.

Nxumalo, E. N., & Coville, N. J. (2010). Nitrogen-doped carbon nanotubes (N-CNTs) synthesized from organometallic compounds have garnered significant attention due to their enhanced properties and potential applications across various fields. This review highlights recent advancements in the synthesis, characterization, and applications of N-CNTs derived from organometallic precursors. The incorporation of nitrogen atoms into the carbon nanotube framework introduces defects and active sites that can significantly alter the electronic, chemical, and physical properties of CNTs. Organometallic compounds, particularly those containing nitrogen-rich ligands, serve as effective precursors for the controlled doping of CNTs. Various synthesis methods, including chemical vapor deposition (CVD), arc discharge, and pyrolysis, have been employed to produce N-CNTs with tailored nitrogen content and distribution. Characterization techniques such as X-ray photoelectron spectroscopy (XPS), Raman spectroscopy, and transmission electron microscopy (TEM) have been instrumental in elucidating the structural and electronic changes induced by nitrogen doping. These studies reveal that nitrogen atoms can be incorporated in different configurations, such as pyridinic, pyrrolic, and graphitic nitrogen, each imparting distinct properties to the N-CNTs. The unique characteristics of N-CNTs, such as enhanced electrical conductivity, catalytic activity, and chemical reactivity, have opened up new avenues for their application. N-CNTs have shown promise in areas like energy storage (supercapacitors and batteries), catalysis (electrocatalysts for fuel cells and oxygen reduction reactions), and environmental remediation (adsorption of pollutants and sensing).

Giacalone, F.,(2012) Carbon nanostructures, including fullerenes, carbon nanotubes (CNTs), and graphene, have revolutionized the field of covalent and macromolecular chemistry due to their unique properties and versatile applications. The ability to manipulate these carbon allotropes through covalent functionalization has opened new pathways for creating advanced materials with tailored properties. Covalent chemistry involves the modification of carbon nanostructures through the formation of strong covalent bonds, enabling the introduction of functional groups that can enhance solubility, reactivity, and compatibility with various matrices. For instance, the functionalization of CNTs with organic molecules or polymers can improve their dispersion in solvents and composites, making them more useful for applications in materials science and nanotechnology. Similarly, graphene can be covalently modified to tailor its electronic properties, enabling its use in electronics, sensors, and energy storage

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devices. Focuses on the synthesis and application of large molecules or polymers that incorporate carbon nanostructures. This approach allows for the creation of hybrid materials that combine the exceptional mechanical, electrical, and thermal properties of carbon nanostructures with the versatility of polymers. These hybrid materials have found applications in areas such as conductive polymers, reinforced composites, and biomedical devices.

Research Problem

The research problem focuses on the challenges and opportunities associated with the functionalization and application of carbon nanostructures, particularly carbon nanotubes (CNTs) and organometallic fullerene derivatives. Despite their exceptional properties, CNTs and fullerenes often suffer from poor solubility, limited processability, and a lack of functional groups for further chemical modification. These limitations hinder their widespread application in various fields, including electronics, energy storage, catalysis, and biomedicine. the synthesis of organometallic fullerene derivatives presents additional challenges, such as controlling the degree of functionalization, ensuring stability, and achieving uniform distribution of organometallic components. Addressing these challenges requires innovative approaches to synthesis, functionalization, and characterization of these advanced materials. The research problem, therefore, centers on developing effective methods for the covalent functionalization of CNTs and the synthesis of stable, well-defined organometallic fullerene derivatives. By overcoming these hurdles, the research aims to unlock the full potential of these materials, enabling their integration into practical applications. This will involve exploring new synthetic pathways, advanced characterization techniques, and evaluating the performance of the resulting materials in relevant applications. The ultimate goal is to create versatile, high-performance nanomaterials that can drive technological advancements in various industries.

Conclusion

The synthesis and exploration of carbon nanotubes (CNTs) and organometallic fullerene derivatives stand as testament to the boundless potential of nanotechnology. With carbon nanotubes offering exceptional mechanical, electrical, and thermal properties, and organometallic fullerene derivatives presenting unique electronic and catalytic functionalities, these nanomaterials hold promise across a myriad of applications. As research progresses, further advancements in synthesis techniques and characterization methods will undoubtedly unlock new avenues for innovation. By leveraging the collective expertise of interdisciplinary teams and fostering collaboration, we can harness the transformative power of these nanomaterials to address pressing challenges and propel technological progress forward. The journey of discovery continues, fueled by curiosity, ingenuity, and a commitment to harnessing the full potential of nanotechnology for the betterment of society.

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Research paper UGC CARE Listed (Group -I) Journal Volume 11.Iss 13, 2022

References

1. Andersson, C. H. (2011). Chemistry of Carbon Nanostructures: Functionalization of Carbon Nanotubes and Synthesis of Organometallic Fullerene Derivatives (Doctoral dissertation, Acta Universitatis Upsaliensis).
2. Nyamori, V. O., Mhlanga, S. D., & Coville, N. J. (2008). The use of organometallic transition metal complexes in the synthesis of shaped carbon nanomaterials. Journal of Organometallic Chemistry, 693(13), 2205-2222.
3. Sherigara, B. S., Kutner, W., & D'Souza, F. (2003). Electrocatalytic properties and sensor applications of fullerenes and carbon nanotubes. Electroanalysis: An International Journal Devoted to Fundamental and Practical Aspects of Electroanalysis, 15(9), 753-772.
4. Brennan, L. J., & Gun'ko, Y. K. (2015). Advances in the organometallic chemistry of carbon nanomaterials. Organometallics, 34(11), 2086-2097.
5. Sun, Q., Zhang, R., Qiu, J., Liu, R., & Xu, W. (2018). On-Surface Synthesis of Carbon Nanostructures. Advanced Materials, 30(17), 1705630.
6. Zamolo, V. A., Vazquez, E., & Prato, M. (2014). Carbon nanotubes: synthesis, structure, functionalization, and characterization. Polyarenes II, 65-109.
7. Sarkar, S., Bekyarova, E., & Haddon, R. C. (2014). Organometallic Chemistry of Carbon Nanotubes and Graphene. In Carbon Nanotubes and Graphene (pp. 201-224). Elsevier.
8. Lobach, A. S., Gasanov, R. G., Obraztsova, E. D., Shchegolikhin, A. N., & Sokolov, V. I. (2005). Sidewall Functionalization of Single-Walled Carbon Nanotubes by Organometallic Chromium-Centered Free Radicals. Fullerenes, Nanotubes and Carbon Nanostructures, 13(4), 287-297.
9. Botta, L., Bizzarri, B. M., Crucianelli, M., & Saladino, R. (2017). Advances in biotechnological synthetic applications of carbon nanostructured systems. Journal of materials chemistry B, 5(32), 6490-6510.
10. Nxumalo, E. N., & Coville, N. J. (2010). Nitrogen doped carbon nanotubes from organometallic compounds: a review. Materials, 3(3), 2141-2171.
11. Giacalone, F., Herranz, M. Á., & Martín, N. (2012). Carbon Nanostructures: Covalent and Macromolecular Chemistry. Supramolecular Chemistry of Fullerenes and Carbon Nanotubes, 1-26.
12. Srivastava, D., Menon, M., & Cho, K. (2001). Computational nanotechnology with carbon nanotubes and fullerenes. Computing in Science & Engineering, 3(4), 42-55.
13. Liao, K. S., Wang, J., Früchtl, D., Alley, N. J., Andreoli, E., Dillon, E. P., ... & Curran, S. A. (2010). Optical limiting study of double wall carbon nanotube–Fullerene hybrids. Chemical physics letters, 489(4-6), 207-211.
14. Gasanov, R. G., Lobach, A. S., Sokolov, V. I., Demenjev, A. P., Maslakov, K. I., & Obraztsova, E. D. (2007). Organometallic Radical-Adducts of Fullerenes C. Nanoscience and Nanotechnology, 7, 1-5.
15. Jain, D., Winkel, A., & Wilhelm, R. (2006). Solid-state synthesis of well-defined carbon nanocapsules from organometallic precursors. Small, 2(6), 752-755.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper **© 2012 IJFANS. All Rights Reserved, UGC CARE Listed (Group -I) Journal Volume 11.Iss 13, 2022**

16. Antoniou, K. S., Karakassides, M. A., Gournis, D., & Rudolf, P. (2016). Carbon nanostructures containing polyhedral oligomeric silsesquioxanes (POSS). Chemistry, 20(6), 662-673.
17. Shirazi, Y., Tofighy, M. A., Mohammadi, T., & Pak, A. (2011). Effects of different carbon precursors on synthesis of multiwall carbon nanotubes: Purification and Functionalization. Applied Surface Science, 257(16), 7359-7367.