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Review

Modified Organized Systems by Incorporation of Carbon Allotropes and Derivatives for Electron Shuttle, ET, FRET, MEF, and Quantum Biology Coupling

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Abstract

This communication was brief to show how high conjugated carbon-based structures and carbon allotropes could participate as electron shuttles, semiconductors, quantum emitters, and Optoelectronic processors within confined nanostructured organized systems. In particular, it was focused on nanoassemblies such as vesicles, micelles, and lipidic nanoparticles and incorporated insights from other types of nanomaterials that could afford to develop new organized systems. In these cases, the term organized system was used for all types of molecular assembly and supramolecular systems that formed structures within the nanoscale. In this manner, the incorporation of 0pto-electronic materials permitted the development of critical photo-physical phenomena with high impact and perspectives within technology and life sciences. Thus, it was led to discuss the participation of carbon-based chemical structures incorporated in different confined molecular media to develop i) Electron Transfer (ET) processes, ii) Reaction Electron Transfers (RET), iii) catalysis, iv) quantum emissions, v) Fluorescence Resonance Energy Transfer (FRET); vi) non-classical Light; and vii) Nano-Optics. Therefore, it was intended to present the most important physical and chemical phenomena where they could participate as functional high electronic conjugated chemical structures highlighting carbon allotropes.

Keywords

Carbon allotropes; graphene; highly conjugated carbon chemical structures; Fluorescence Resonance Energy Transfer (FRET); Reaction Electron Transfer (RET); electronic shuttles; quantum biology; quantum properties; nanoelectronics; organized systems

1. Introduction

Carbon-based chemical structures with highly conjugated electronics provided important physical and chemical properties in various fundamental studies and applications [1]. Thus, varied organic molecules such as laser dyes [2] and carbon allotropes [3] should be mentioned. It is well known the expansion of graphene within different research fields and applications in recent years, such as from the control of their multilayered addition and control to interact between them with anions [4] and arriving to control porosity and inter-graphene bubbles formation by Laser irradiation with perspectives of other modes of energy conductions through matter and confined volumes to varied further uses [5]. Moreover, it was noted quantum emissions from graphene quantum dots [6], the generation of pseudo-electromagnetic fields [7], augmented conductions of electrons and photons within hybrid materials [8], and by this manner, developments of Nano-Optics and Optical lenses within a wide interval of electromagnetic wavelengths [9]. Similarly, other Carbon allotropes such as fullerenes [10], diamonds [11], carbon nanotubes [12], and modified chemical structures [13] showed important Optoelectronic and quantum properties [14]. All these materials showed different properties that could be used later to improve new materials and properties. In all cases, any mentioned structure studied at the moment did not offer the same optoelectronic or quantum behaviors in the presence of Optoelectro-active materials in their close surrounding. Thus, it is vital to know their properties to incorporate them in further studies within other Optical Setups and approaches [15]. In this regard, modifying the surrounding media within confined nanomaterials and quantum materials could also change their initial properties under study and generate new ones.

It should be noted that many designs based on highly conjugated organic molecules with variable sizes showed perspectives toward carbon allotropes and other types of highly conjugated carbon-based materials. The quantum dots of graphene and carbon nanotubes are highly interesting due to the perspectives from molecular to well-structured carbon-based nanostructures such as graphene. For this reason, this communication was intended to show this potential trend to afford in Research and developments projects for varied targeted objectives where carbon allotropes, derivatives and related structures could be considered in the next generation of designs within confined soft matter, for example.

The organized systems considering molecular assembling, nano-assembling, micelles, vesicles, Nanoaggregates, Lipid Nanoparticles, and nano-supramolecular systems could provide new alternative support materials to develop further fundamental studies and applications [16]. For example, incorporating only small, high conjugated molecules such as naphthalene within bi-layers of vesicles showed improved ET processes through the membranes acting in this manner as electron shuttles [17]. Thus, the confined optical active material showed augmented performances compared to their absence. Similarly, luminescent vesicles showed bright and highly stable properties with the possibility of tuning their properties by FRET [18]. In addition, organized systems showed excellent biocompatible properties for developing nanosensors [19], drug delivery systems, and multifunctional nanomaterials [20]. Similarly, micelles and lipid nanomaterials showed interesting developments for varied Nanomedicine applications [21].

In this context, the particular versatility of the mentioned organized systems based on their variable chemical properties depending on the different parts evaluated for incorporating the carbon-based materials and their applications should be noted. Thus, this versatility that permitted the development of different and new varied nano-optics, electronics, and quantum organized systems is shown in the following subsections.

2. Organized Systems and Self-Assemblies with Incorporation of Carbon Based Chemical Structures for RET, FRET, and MEF

Organized systems [22] as molecular non-covalent assemblies with variable sizes and chemical constitutions greatly impacted different research fields and applications [23]. In this direction, vesicles [24] and micelles [25] have been primarily studied and show particular interest in research within nanomedicine [26], pharmacy, and bio-applications [27]. Similarly, new organized systems with targeted properties that require the design of each part of the whole system could be developed [28]. This is the idea; however, the main properties of vesicles and micelles that can contribute to versatile structures and particular properties in the nano-scale and beyond (Figure 1a and Figure 1b) should be highlighted. Vesicles have been expanded and used in recent years for many developments and applications within nanotechnology, biotechnology, and nanomedicine. Thus, vesicles with variable sizes and shapes depending on conditions of preparation are formed by non-covalent assemblies of amphiphiles molecules [29]. These amphiphiles have a polarized chemical structure with a hydrophilic head joined to hydrophobic tails [30]. In this manner, vesicles have different physical and chemical properties that could interact with variable surrounding media [31]. Other types of chemical reactions could also be applied to modify their properties [32]. Therefore, the different parts of the amphiphiles and nanostructure could be tuned with desired properties. Based on their intrinsic constitution, different environments, polarities, and chemical reactivities should be highlighted. As a hydrophilic part, the polar head could interact with polar solvents and be chemically modified with varied and controlled functional groups (Figure 1c), polymeric chains, Biomolecules, and nanoparticles (Figure 1).

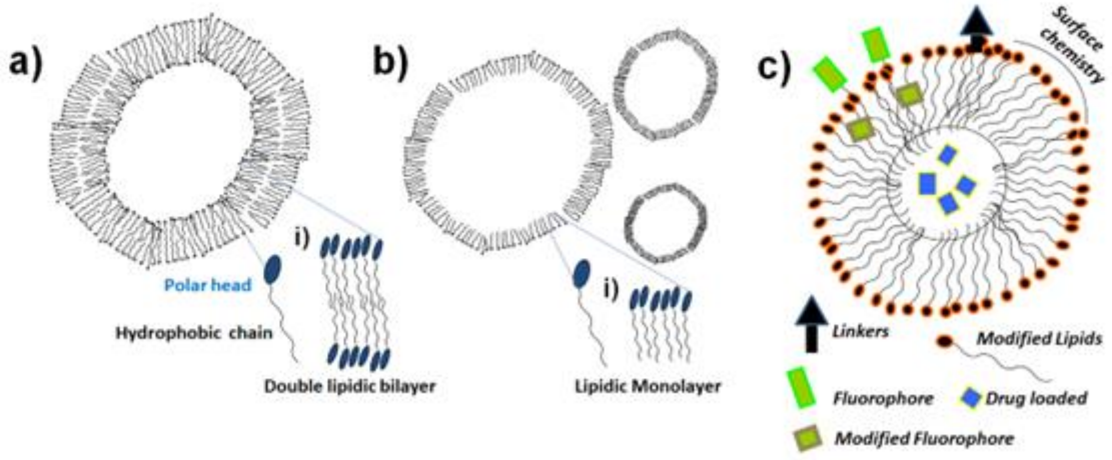

Figure 1 Schema of classical Organized systems: a) Vesicles formed by a bi-lipidic layer. Insert image with augmented chemical structures forming the bi-lipidic layer; b) Micelles formed by mono-lipidic layers; c) Hybrid modified micelles in the different parts of the nanoarchitecture, such as cargo loaded of drugs, fluorophores grafting or linking, and conjugated with linkers, polymeric chains, molecular spacers, etc, and reprinted with permissions of A. Guillermo Bracamonte et al. 2023.

It is a vital part of the functionality from where further modifications could be developed. The lipidic bi-layer has strong apolar characteristics [33] that permit other types of interactions such as highly conjugated organic chemical structures such as cholesterol [34], tiny Organic nanoparticles such as graphene quantum dots [35], and different types of inorganic nanomaterials as well [36]. Moreover, the hydrophobic tails could be chemically modified with double bonds and chemical, organic modifications such as cross-linkers [37]. In this manner, inter-crossed linking of tails could be obtained, leading to a higher stability of the nanoarchitecture [38]. In addition, in the interior of the vesicle, there is a free volume as a container that could be filled [39]. So, there is a large variety of strategies and possibilities to generate new nanostructures based on organic compounds with high impact within fundamental research towards real applications such as within nanophotonics [40], green photonics uses [41], biophotonics and nanomedicine [42].

In this context, it should be noted that carbon-based nanomaterials could be incorporated depending on their chemical surface functionalizations in the different environments mentioned. In this manner, their properties are exposed within varied media and other electronic and photonics donor/acceptors that could stimulate further photo-physical processes. In this regard, it could be mentioned that the critical research work focused on simple organic chemical reactions developed within aqueous media and in the presence of intermediate polar environments to tune dispersibility and biocompatible interactions. For example, it is known that controlled PEG linking on Nanostructures avoids Nanomaterial aggregation within cells, and varied bioconjugation techniques permit the develop these synthetic modification to tune nanomaterials for bioapplications. In this context, organized systems such as vesicles, micelles and lipidic nanoparticles could be modified on surfaces to increase dispersibility in water by adding as for example carboxylic groups or small peptides, or stimulating nanoaggregation by covalent liking with higher sized functional organic molecules such as pro-hormones based on cholesterols and related.

Therefore, in order to show and discuss the development of improved and enhanced electron transfer applications based on modified organized systems as soft matter approaches to be incorporated in further developments such as for Bioelectronics, Biocompatible Optical active materials, and wearables. Optical active organized systems could be tuned from inter-molecular interactions from where Energy Transfers (ET) would be generated by photo-or electro-stimulation. In order to accomplish that, it is necessary to tune these electroactive molecules where Carbon-based materials and related semiconductors play an important role in the nano- and micro-scales to develop modified electro-responsive substrates based on Organized systems (Figure 2).

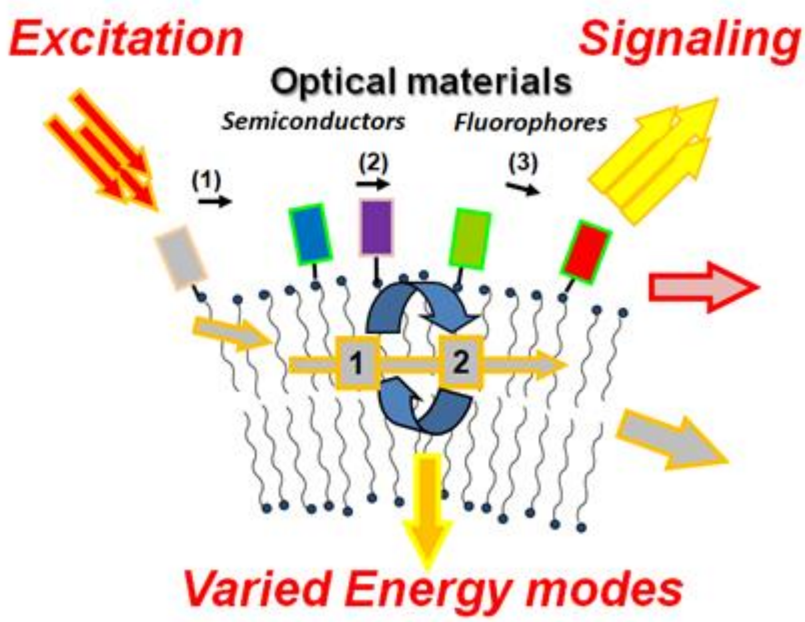

Figure 2 Schema of Optical active organized systems based on bi-lipidic layers modified with Optical active molecules on their surfaces that record optoelectronics signalling to generate varied energy directional and defined 3D pathways, such as reflecting, emitting, photonics and electronics conductions, waveguiding, transmissions of energy modes, across the surface and passing through the membrane. Note: the hydrophobic bi-lipidic layer could incorporate different Optical active materials such as energy transducers, wires, conductors, amplifiers, etc. nominated as 1 and 2. Reprinted with permissions of A. Guillermo Bracamonte et al. 2023.

In this regard it is noted the different pathways for Electronic-Transfer applications, including: i) efficient long-distance electron transfer mediated by hydrogen bonds, ii) energy and electron transfer through the walls of highly conjugated carbon chemical structures such as simple hemicarcerands; iii) internal electric fields with effect on the rate of electron transfer in a-helical peptides; and iv) construction of a biomimetic proton pump driven by photoinduced electron transfer [43].

The modification of media through electron transport conduction is highly desired. It could make modifications in the electronic flow by different phenomena and effects, as in i) ionic media, ii) applied organic and inorganic substrates, iii) multilayered composites, and iv) doping or incorporation of carbon-based materials such as graphene and derivatives as well as carbon allotropes. Yet, even with a large number of related research, there are many other studies and developments that were not accomplished yet. Similarly, new ways could be applied to transmit photonics and electronic signalling within liquids and colloidal dispersions in the presence of non-classical light Nano-emitters and semiconductors [44]. These could be considered as new approaches to studies; however, their basis is also generated from the use of Ionic Liquids within grafted substrates, Chips, and higher Hetero-junctions [45]. In this context, these mentions stimulate new ideas to develop fundamentals and new applications within soft matter approaches.

To understand the complexity of these systems based on the proper tuning of organic molecules and inorganic materials, some examples based on colloidal dispersion of modified vesicles could be provided, such as synthetic liposome as artificial photosynthetic reaction centers for conversion of light energy to proton [46]. In this case, within the double lipid bilayer, an electronic wire was added based on an unsaturated organic chain with a porphyrin for covalent linking of a donor/acceptor pair crossing the bilayer. Here, a reduction potential near the outer surface of the bilayer and an oxidation potential near the outer surface of the bilayer were generated by photoexcitation, accompanied with an oxidation potential near its inner surface. Thus, a free shuttle quinone alternated between its oxidized and reduced forms to ferry protons across the bilayer with a measurable quantum yield and pH gradient between the inside and outside liposome in aqueous media. In the absence of any of these components, these phenomena showed no electron transfer. As a result, these phenomena are susceptible to the electronic properties of the chemical structures involved, as previously discussed for other electronic transferences that occur through highly conjugated carbon structures. In addition, these electron transfer phenomena across bilayers [47] showed to be highly sensitive to other variables such as the charge of liposomes [48], constitutive donor/acceptor pairs [49], as well as the incorporation of a more efficient electron shuttle [50]. This field also motivated research into the origins of life [51], where protocells constituted by small organic molecules [52], carbon-based materials [53], and minerals could be part of efficient photosynthetic centers. However, from the knowledge to control synthetic biology, Nanotechnology [54] could be developed for biotechnology [55] applications. Therefore, joining optimized synthetic nanomaterials with excellent degrees of purity, conductions, and pseudo-electromagnetic properties, such as graphene, its derivatives, and other carbon allotropes, new approaches could be proposed and developed with potential applications in different fields.

Many studies and developments are underway concerning energy, electronic conduction, and photovoltaics, among others, including incorporating TiO_2 nanoparticles into electron-responsive substrates based on modified perovskites deposed on gold films [56]. Thus, the electron holes provided by TiO_2 nanoparticles acted as electron shuttles with diminished energy dissipation through the modified material. These previous results showed perspectives for incorporating carbon allotropes and derivatives that merit to be studied. Thus, it is possible to lead different Optoelectronic behaviours. Therefore, these similar studies where opto-active molecules and other nanomaterials differ from carbon allotropes showed potential developments using carbon-based materials to test designs and electron shuttle-based new Optoelectronic systems.

It showed improved conduction with potential application in electronic microdevices, photonics, storage, and transference of energy. A further example is the addition of fullerenes (C) within multi-layered substrates of Organic Solar Cells (OSC) [57] (Figure 3). Thus, we showed how sensitive was electron transfer and final performances by doping with variable fullerenes size such C_{60} vs C_{70}. The C_{70}, based on its stronger absorption properties, showed better performance than the C_{60}. Thus, minor chemical modifications below the nanoscale tuned far field electronic properties. Moreover, adjusting in the energy transfer was achieved by modifying the electron donor layers and their concentrations. On the other hand, more minor differences were found by synthetic mixtures of donors such as titanyl phthalocyanine (TiOPc), rubrene, and 5,5′′′′-bis(naphth-2-yl)-2,2′:5′,2′′:5′′,2′′′: 5′′′,2′′′′ (NaT_5), instead of TAPC in 5% concentration mixtures with C_{60}. These properties were explained by the loss of efficiency based on lack of homogeneous electronic waveguiding between HOMO donor-LUMO acceptors in the systems compared, thus affecting the potential of bandgaps involved. In all these topics, theoretical calculations exist for better understanding and explaining the phenomena developed. Therefore, multidisciplinary contributions serve an important role in tuning the property and signaling of matter. In this regard, it should be highlighted that the mention of micelles previously was not so frequently incorporated; however, they are also important for other properties and applications. They are similar in some extend, but smaller sizes with different intrinsic confined matter distribution in comparison to vesicles provide different smaller nanoplatforms to tune Nano-Optics within colloidal dispersions as well as on modified surfaces for targeted applications within technology, and life sciences such as for biotechnology, nanomedicine and biophotonics [58]. This mention it is to start further studies based on these organized soft organic matter-based Nano-systems.

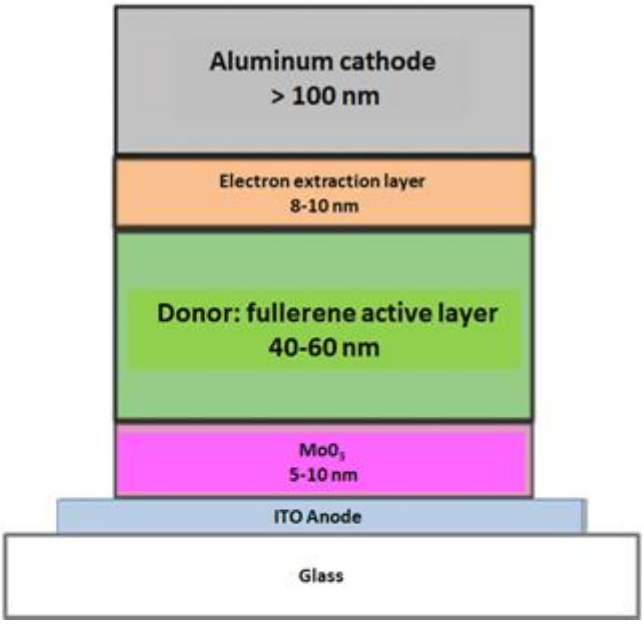

Figure 3 General structure of a Schottky junction Organic Solar Cells (OSC) with typical thicknesses of layers reported in the literature. Reprinted with permission from H. Aziz et al. Copyright 2014 Journal of Photonics for Energy [57].

In this manner, it was intended to show and discuss how carbon based materials such as highly conjugated molecules towards graphene quantum dots, carbon nanotubes, fullerenes and higher-sized chemical structures such as graphene layers, multi-layered graphene, etc. So, it is proposed to prototype new materials highlighting the use of soft matter bottom-up up on needs and Research aims due to there are exciting perspectives within life sciences [59] as well as high technology perspectives [60]. And it was showed how intrinsic properties could be modified by their close Optical active surrounding, as well as by changing the polarity of the media, and by this manner participating in varied processes that in absence of them the performances were below expectations.

Similarly, interesting Nano-Optical perspectives were shown by the incorporation of organic tails within apolar synthetic bi-lipidic inter-crossed membranes. This apolar interaction within bilayers permitted, for example, the development of self-assembled phospholipid vesicles that were easily functionalized with thrombin-binding aptamers using a thiol-click reaction. Thus, the resulting aptasensor signaling led to binding and detecting the analyte to the vesicle surface by changing the emission properties of the co-embedded membrane with luminescent reporter dyes. By this manner based on this proof of concept, it was developed the thrombin detection strategy in blood actual samples [61]. As noted previously, the apolar incorporation of highly conjugated organic molecules such as Laser dyes open to other new designs by considering higher aggregates of carbon-based materials and carbon allotropes. The carbon allotropes could provide a completely different apolar micro-environment, producing pseudo-electromagnetic fields with consequent electronic and photonics interactions within their close surrounding. In this regard, high electromagnetic fields known as Plasmons generated from metallic nanoparticles such as gold templates produced varied effects from the near field towards the far field. The near field is considered to distance within short and intermediate scale lengths with the highest Plasmonic intensities. The far field, is related to longer distances afforded by the transference of varied energy modes through space and time, producing long-range phenomena [62].

These highlights from similar studies where Metamaterials and varied organized nanocomposites provided particular and different Opto-electronics with interesting high-impact upcoming research works but applying other new modes of energy sources as focused on carbon allotropes and related materials by tuning the Nanoscale and assembling. For example, it could be mentioned cyclodextrins grafted by polymeric PEG linkers on gold Core templates showed variable Metal Enhanced Fluorescence (MEF) phenomena based on the interaction of the near field with Laser dyes complexed within the Supramolecular systems [63, 64]. This effect showed an increase in enhancements proportional to nano-assembling sizes [65]. Therefore, confined Opto-electronics, electromagnetic fields, and assembling tuned new modes of non-classical light [66].

3. Modified Quantum Optics and Biology

The previous section it was showed how carbon-based materials such as Carbon allotropes and derivatives could produce and participate in varied Opto-electronic processes; however these materials are highly sensitive to being involucred in other physical phenomena such as below the nanoscale and arriving at quantized electronic energies in different quantum phenomena.

The idea of this section intends to show and discuss how the confinement of carbon-based materials could be incorporated within confined Biological organized systems with varied exciting perspectives. Previously, it was delivered and discussed the participation of these types of chemical structures and related properties associated with confined volumes within bi-lipidic bilayers from vesicles, mono-lipidic layers from micelles, and further organized systems. It highlighted soft materials; however, it was mentioned the incorporation within heterojunctions and similars [67]. As for example, developments towards modified surfaces for Optical Waveguide

Lightmode Spectroscopy (OWLS) as Sensors focusing on thin Film and Quantum Dot Corrosions [68]. Therefore, the spectroscopic and Optoelectronic properties were developed surrounded by other materials with logic and consequent modifications, coupling, and improved photo-physical properties and phenomena [69]. And, highlighting the use of organized systems and Optical active materials where Graphene and Carbon allotropes in general could be applied for future developments.

Similarly the transference of the Carbon-based chemical Nanostructured properties into Biological media is of high interest for many reasons. Bio-Optics and bioelectronics have provided many important contributions in different research fields, such as studies focused on photosynthesis, genomics, biodetection, and biophotonics studies. In addition, the relative novel interest from the quantum perspective related to quantum biology should be highlighted. Thus, quantum phenomena generated from biological media were of interest not so far ago. In this regard, graphene biosensors could be considered a molecular approach to evaluating quantum interactions within biological media [70]. Graphene could be considered a material chosen to study molecules and monolayers at the molecular scale due to its chemical stability, electrical properties, and quantum properties. In this manner, advances in microscopy and new imaging techniques and methods permit to evaluation nanostructured scaffolds, and biodevices joined to organelle, membranes, and other cellular components. In similar manner, it should be mentioned that self-assembled monolayers of biomolecules on top of graphite with applications in biodevices and joined to porphyrin systems adsorbed on top of graphite structures that can anchor other biomolecules. These examples open a broad window to new designs and developments where fundamental Research and applied are involved (Figure 4).

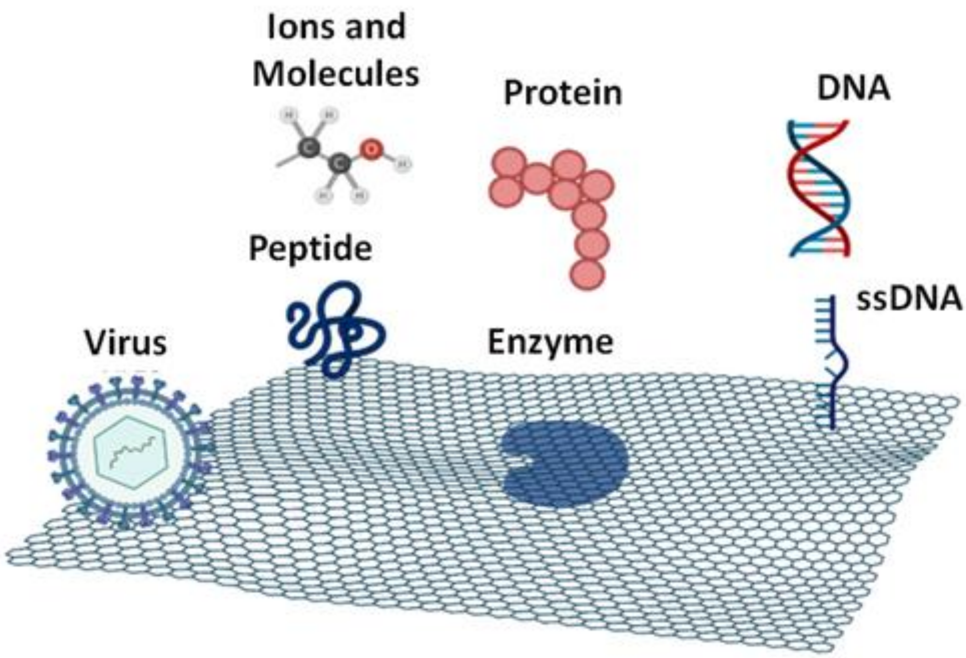

Figure 4 Schematic representation of the main biomolecular systems that can interact with graphene. Reprinted with permission from M. Machado and Q. Ferreira et al. Copyright 2022 Nanomaterials, MDPI [70].

In order to understand quantum phenomena within biology it could be discussed about quantum entanglement and related within photosynthetic receptors. The entanglement could be defined as Quantum states that are independent of each other, and they could be expressed as a sum of them, but they cannot be factored as a product of states of their local constituents. In this context, as example from the recent synthetic development of a plasmonic nanostructure, it could be mentioned the generation of two different and independent electronic states nominated as Q1 and Q2 based on their electronic surrounding interaction (Figure 5) [71].

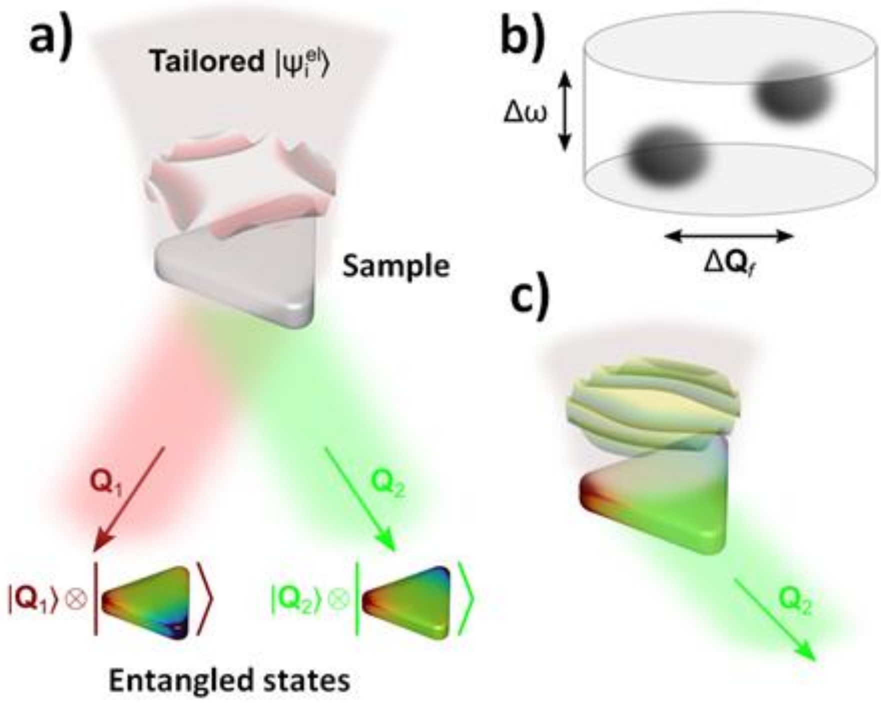

Figure 5 Proposed scheme for the generation of entangled electron–cavity states. a) A pre-shaped electron interacts with a nanostructure (a triangular Plasmonic cavity) supporting well-defined optical or vibrational modes. The incident electron wave function $< \Psi i^{el} >$ is tailored such that we obtain entangled states after the interaction, correlating different specimen excitations (colored triangles) with separated electron scattering directions (final electron state having components of transverse wave vectors Q1 and Q2). A maximally entangled electron-specimen state is thus produced as the sample is in a superposition of excited states correlated with different electron scattering directions. b) Electrons are emerging along separate spots within a finite region of size $\Delta\hbar\Omega \times \Delta\hbar Q_f$ in the configuration space of energy-loss and transverse-momentum transfers. c) Momentum filtering at the electron detector allows us to project on the desired sample mode and eventually explore its dynamics through subsequent interrogation, for example, by exposure to a synchronized light pulse. Reprinted with permission from A. Konečna, J. Garcia de Abajo et al., Copyright 2022 Sci. Adv., Sci. [71].

Photosynthetic complexes are exquisitely tuned to capture solar light efficiently and then transmit the excitation energy to reaction centers, where long-term energy storage is initiated.

The energy transfer mechanism is often described by semi-classical models that invoke excited-state populations along discrete energy levels. Thus, evidence for wavelike energy transfer through quantum coherence in photosynthetic systems was recorded by two-dimensional Fourier transform electronic spectroscopy [72]. These recordings were explained by mapping these energy levels and their coupling in the Fenna–Matthews–Olson (FMO) bacteriochlorophyll complex, which is found in green sulphur bacteria, and it acts as an energy 'wire' to connect the light-harvesting antenna, to the chlorosome, to the reaction centre. In this manner, the excited energy wave function mode was recorded through space and time. It should be noted that this phenomena was neglected and considered a simple energy transfer; however, the wavelike characteristic of the entangled phenomena by ET within the photosynthetic complex can explain its extreme efficiency. This performance showed to survive for a relatively long timescale period of time, despite the decohering effects of their environments. And it was inquired about how these phenomena could be quantified, their dependency on temperature, and conditions for all determinations [73]. Further developments and applications are expected based on densely packed molecular aggregates such as light-harvesting complexes.

Another example that could be mentioned is the quantum monitoring of cellular metabolic activities in single mitochondria demonstrated by relaxometry measurement, or T1, inherited from the field of diamond magnetometry that could be used to detect free radicals in living cells with subcellular resolution. This quantum sensing technique permitted the convert a magnetic signal into an optical signal, allowing nanoscale magnetic resonance measurements. And, the fluorescent modification of nanodiamonds (FNDs) afforded to the target single mitochondria within macrophage cells to detect the metabolic activity. Thus, it was permitted to see free radicals generated by individual mitochondria in either living cells or isolated mitochondria after stimulation or inhibition [74].

So, it should be highlighted that all the mentioned phenomena involved opto-electroactive active properties where graphene and carbon allotropes or carbon-based nanomaterials could participate as Optical transistors, electron shuttles, quantum couplers, and donor/acceptor energy sources. In this regard, the incorporation of single layered graphene as quantum emitters incorporated on wet cell membranes [75] permitted to detect by imaging intrinsic molecular distribution of lipids, such as cholesterol, phosphoethanolamine and various fatty acids, in untreated wet cell membranes without any labeling. It is shown that graphene-covered cells prepared on a wet substrate with a cell culture medium reservoir are alive and have their cellular membranes are intact. Thus, depending on their environment, it was tuned to varied resolutions (Figure 6). The addition of a modified macrocycle able to form molecular complexes for example with Cholesterol afforded to imaging cholesterol-enriched regions in cell membranes.

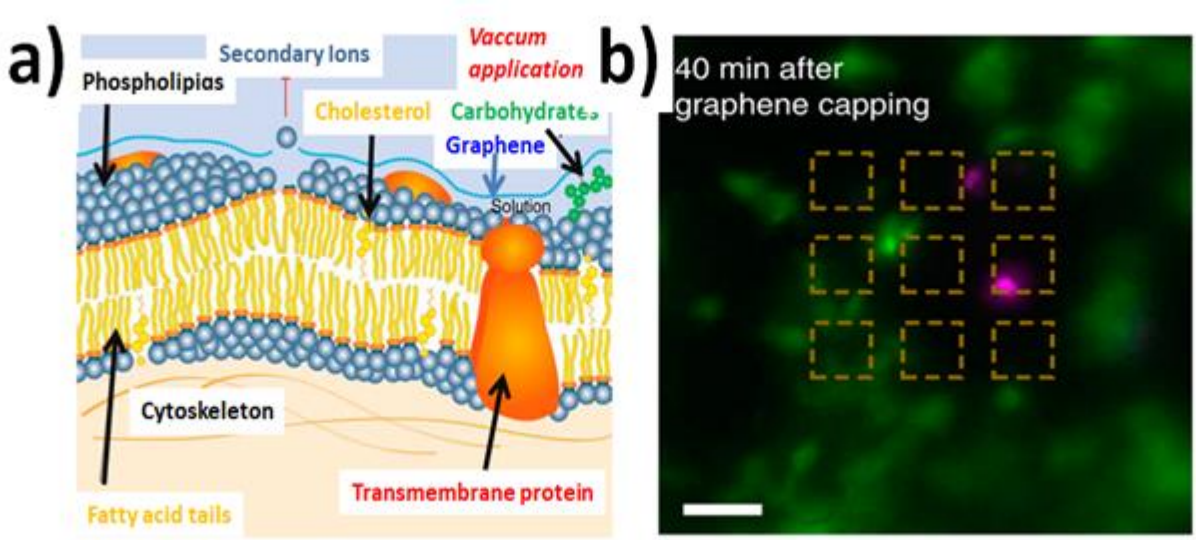

Figure 6 Schematic diagram of a) modified membranes by sputtering process for the head group of a phospholipid molecule from a wet cell membrane through single-layer graphene. b) Fluorescent images for the cell viability test using separately prepared graphene-covered wet cells after 5 min of vacuum at 1 × 10^{-5} mbar. b) Epifluorescence Microscopy imaging analysis. The images were taken at 5, 20, and 40 min after graphene capping. Green and magenta indicate live and dead cells before graphene capping, respectively. Scale bars represents 50 µm. The dashed boxes indicate the positions of the microholes. Reprinted with permission from H. Lim, Y. Park et al. Copyright 2021 Nature Methods [75].

Further interesting quantum properties related to high conjugated Carbon-based materials such as graphene are the Casimir Forces by varying Fermi levels. These types of forces depend on the spacer distances between layers and are generated from graphene inter-layers. Recently it was reported a multi-layered approach joined other two candidates than graphene. One was hexagonal boron nitride (hBN), a natural Hyperbolic Material. The other is porous silicon carbide (SiC), which can be treated as an artificial hyperbolic material by the practical medium theory. The Casimir force between graphene-covered hBN (porous SiC) bulks was presented at zero temperature.

The results showed that covering hyperbolic materials with graphene increases the Casimir force monotonically. In addition, it was shown that the force can be modulated by varying the Fermi level, especially within longer separation distances. This hybrid material showed an enhancement attributed to the interaction of surface plasmons (SPs) supported by graphene and hyperbolic phonons [76]. Moreover, it should be highlighted that using these types of hyperbolic materials, such as carbon nitrides quantum dots, was able to generate improved quantum yields and cell imaging applications. Therefore, for example novel graphitic carbon nitride quantum dots (g-C_3N_5-dots) were synthesized using an alkali-assisted hydrothermal method and applied fluorescence probes prepared by an alkali-assisted hydrothermal method, with low cytotoxicity and excellent Biocompatibility for cell imaging [77].

As it could be observed in the examples showed, it was highlighted the particular quantum and Opto-electronics properties that could participate within cells to sense Bioptical properties. And in this regard, Bio-Optics contemplates a broad spectra of properties from Biomolecular spectroscopies towards quantum phenomena and varied mechanisms and energy pathways. In addition, quantum Biology added further possibilities to study fundaments of non-classical light and quantum properties produced by the interaction of natural Optical active Biomolecules, complexes, organelle, etc. and synthetic carbon-based structures such as graphene, carbon nanotubes, fullerenes, etc.

4. Future Perspectives and Discussion

The perspectives are towards the fundamental study of confined electronics and photonics phenomena in order to develop new electronic states and varied energy modes associated with energy waves that could produce new matter properties. The concept of confine carbon-based materials within soft material assemblies is related to the idea of stimulating the development of new material properties and intrinsically, the generation of metamaterials with different chemical properties in comparison to initial components. In this context, pseudo-electromagnetic fields, electronics, photonics, energy transfer, Luminescence phenomena related such as FRET, and other non-classical light mechanisms such as Plasmonics related with high Energy Electromagnetic fields could be interacting to produce different final Optical active.

So, organized systems as soft matter assemblies could provide excellent support materials to generate these types of interactions and new chemical and physical properties. It should be noted that in this manner, new nano-emitters within variable sizes and shapes could be tuned. Moreover, quantum properties could be joined to Optical active Biomaterials to produce other properties and applications. In addition, it is under study the implication of quantum biology within different cellular components and functions associated with electron transport, energy generation, and signaling.

Finally, in order to highlight the discussion and perspectives within Biomaterials, it should be noted Optical active components and organized systems within biology. Photosynthesis is a highly optimized process that opened the interest to study the operating principles. Its primary steps involve energy transport operating near theoretical quantum limits in efficiency. Thus, it is motivated by the hypothesis that nature used quantum coherences to direct energy transfer, inter exciton coherences [78]. Thus, the quantum biology and explanations of how organized systems could produce highly efficient complex systems are of high interest. Moreover, the design and synthesis of hybrid Nano-Biostructures could afford new insights for Bioelectronics as well, as hard materials and electronics technology with high impact on fundamental knowledge accompanied with a potential transfer to devices and miniaturized instrumentations and life sciences tools.

5. Conclusions

This brief Review introduced the main characteristics of organized systems to develop functional materials where carbon-based structures are essential components in complex nanoarchitectures based on needs. In this context mainly, it was discussed and showed some developments using vesicles as support or platforms to develop targeted functional organized systems. In this regard, highly conjugated molecules such as aromatic nuclei, carbon allotropes as graphene derivatives, fullerenes, carbon nanotubes, and others provided particular properties within the organized systems platforms. Thus, an electron shuttle was achieved from apolar media within the bi-layer; however, based on chemical modification, applied carbon-based materials grafted the outer surface of membranes and were incorporated within colloidal dispersions into the free vesicular volume. In this context, varied chemical modification afforded to the incorporation in different parts of the Nanoplatform was highlighted. These observations considered spherical vesicles and micelles; however, more complex assemblies could be used. Similarly, it should be noted that combining different nanoarchitectures could provide additional support to design and synthesize functionally organized systems.

In addition, it was afforded to the discussion of different applications and particular interest focusing on quantum properties of carbon-based materials confined to organized systems and biological media. The creation of synthetic light from quantum emission permitted to obtaining luminescent vesicles and Bioimaging of membranes and cells. It depended on the strategy used for the final function achieved. Moreover, it was discussed how quantum biology is under study in many well-performed and known functions, such as photosynthesis and the creation of energy within cells. It was discussed as well the possibility of coupling quantum properties from carbon-based materials as well. Therefore, it was shown how combining organized systems and Optical active materials could develop metamaterials and hybrid materials with an interest in developing fundamental knowledge and transfer knowledge within technology for soft and hard materials. It is important to highlight that carbon-based materials with very well-organized chemical structures showed excellent properties and applications from the macroscale as strong support to the nano- and quantum scales. In this context, it was intended to discuss about the exciting perspectives not completely developed by carbon allotropes and shown from early studies at the molecular level.

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Author Contributions

A. Guillermo Bracamonte did all the research work of this study. Enrique G. Quismondo participated as Researcher and Collaborator.

Competing Interest

The authors confirm that this article content has no conflict of interest.

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