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Article

Advancements in the Catalytic Acid Spray Method as a New Process for Carbon Nanostructures Scale Production

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Abstract: This review summarizes results concerning the greatest utility of carbon coating on the latest developed area of photocatalyst particles and electrode substances for rechargeable lithium-ion batteries as well as various metals and metal oxides. The most eye-catching features of these carbon-based coatings are their capability to increase the surface of medium besides heavily loaded components *via* imparting several significant material enhancements to the surface of components to improve their efficiency and perform through reduced lubrication regimes. Furthermore, the emphasis is placed on the investigation of the advanced manufacturing techniques for producing carbon structures with economically competitive large-scale productions.

Keywords: Coatings, catalytic, carbon, Chemical Vapour Deposition, nanostructure, ACTF

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1. Introduction

A coating is a covering that is applied to the surface of an object. The aim of using the coating may be decorative, functional, or both. The decorative functions of coatings span quite a broad spectrum.

Decorative coatings are mainly employed for their texture, color or other visual characteristic. The duties of coating are to change the surface substrate characters, like adhesion, wear resistance, corrosion inhibation, and wettability. In some instances, it provides a completely new assets which include a magnetic response or electrical conductivity and becomes the main part of the final product. Coatings may be applied in different techniques that are nearly classified into: spraying, vapor deposition, chemical and electrochemical techniques, and other process [1].

Carbon is able to form a lot of allotropes cause its valence. Known shapes of carbon include diamond and graphite. Lately, many other allotropes have been discovered, involving spherical forms as fullerene and sheet structure like graphene. Carbon structures of larger size include nanotubes, nanoparticles and Nano belts. We can find unusual types of carbon at extremely high temperatures or pressures. Nowadays, about 500 hypothetical allotropes of the 3-carbon paper are recognized for SACADA database [1].

This tutorial review, as an extension of our research in water treatment [2-6], we have chosen to provide a panoramic view of the new interesting applications of carbon nanostructures. We will present the characters and how these carbon nanomaterial's can be prepared and moved towards specific utilizations more particularly electrochemical energy storage.

2. Chemical of Carbon-Based Allotrope

There are eight allotropes of carbon: graphite; diamond; C60 buckminsterfullerene, lonsdaleite; C540; Fullerite; C70; single-walled carbon nanotube, and amorphous carbon graphite.

2.1. Graphite

i. The graphite is the mother of all carbon alloys that can be used as an electrical conductor due to the free movement of the pin-electrons around the carbon atoms. Its chemical stability was mainly applied as a standard state for determining the heat of carbon compound formation in thermochemistry. Modern researches investigated that great numbers of crystallographic defects bind with these planes together, lubrication properties of graphite are lost and become known as pyrolytic carbon that is used in the manufacture of artificial heart valves. Thermal stability of the pure graphite is highest among the materials hence it can be applied in nuclear reactors and for the manufacture of high-temperature crucibles which are applied in melting metals. The graphite can be changed into a diamond at evaleted temperatures and pressures.

ii. Synthetic forms of pyrolysis of graphite or carbon graphite are extremely durable, heat resistant (up to 3000 °C) materials used in throat shields for rockets, rocket motors, high reactor temperatures, electric brushes for electric motors. It can be also used in the fire gaskets located around the perimeter of the fire door. Through the fire, graffiti accumulates (Ektended characteristics) to counter the penetration of the fire and to inhibit the prevalence of smoke.

2.2. Graphite Low Friction Coatings

Plastic graphics have tested the most closely used films of hard-working films. Graphic triangle and crystal structure, with strong styling elements in the structure (primary heating element in the primary basin) compared to neighboring ports (discrete carbon dioxide) and disulfide-like molybdenum (MoS2) or disulfulfide tungsten (WS2) metal oxide metal [7]. Graphic graphs are not stacked with low plastic capacities. Graphic properties depend on the adsorption of moisture or other presentable condensate, such as carbohydrates to improve the lubricant capacity. This location with coal with chrysanthemum in graphical graphic graphs can be less than 0.0001 inches in pure form, and up to 0.0005 inches or so of rubber and ornaments. We can see that the composition of the coefficient is less than 0.05, except for the difference between the humidity and the environment. Therefore, a good graphic is air pollution, but not at high height or in vacuum. The dry graphs show that the temperature until then,.[8] There are a number of methods of inquiry, as well as simple or minimal resistance, wind or grafite, or rubber oils with air or organisms. Tests indicate that approximately approximately 50,000 psi (approximately 50,000 psi) will be reduced or faster. Like MoS2 or WS2, there is a relatively low plastics gap with the graph of the independent particle size, although larger parameters can keep the power more[9].

Although oxidation (carbon dioxide, CO_2) is more than 900 degrees Fahrenheit, it is possible to be done a low temperature pressure at 1200 degrees Fahrenheit, with other cinema films while the differences can be low [10]. We can say that the graphic ridge with a low quality plastic cover is covered in both plots, with a sloping roof and useful life, and the coordination of both levels.

We are not capable of stopping and start our motion easily, or alternate our path. But when it comes to moving machinery, in the existence of friction, there is considerable inefficiency related to energy loss, belittle performance, and certainly barriers on wear resistance [11, 12]. So without friction, life would positively be inopportune, if not risky.

Workstations are in the absence of boot loads. Hard / soft, or poor quality, static quality can be selected as a combination of poverty and challenging than dynamic variables. Often the result is a thyroid gland, that is, the practice of "cold welding". In the best case, a "slide" phenomenon, interconnected temporarily, sometimes associated with small spaces, is the closest approach. That is where dry plants like low quality graphics can serve you. As long as the energy is more than two volumes, there is no moving movement. So, for drying to dry, these links should be broken [13].

2.3. Amorphous Carbon

Amorphous carbon is the carbon without having crystal structure. Like all glass materials, a short range can be observed, but a long-term model of atomic positions is not present. In some cases, amorphous carbon can be produced completely, however, no one doubt that amorphous carbon has very tiny crystals of graphite [6] or diamond carbon[14] in its structure.

Coal and soot or soot are called unofficially amorphous carbon. Despite that, they are produced from pyrolysis (the process of decomposition of the substance by heat action), which in normally does not produce pure amorphous carbon [15].

By the deposition method, amorphous carbon (*a*-C) films grown are extremely amorphous [26, 27] and can be classified into diamond-like carbon (DLC) and graphite-like carbon (GLC). Poor nature is unsuitable for silicone anodic coatings, as it must maintain these benefits after extensive expansion and shrinkage. DLC has fragile features but GLC has better flexibility because sp^2 clusters are connected through sp^3 or sp^1 sites so it act as electrically conductor.

Over the last decade, Although TiN, CrN and polymers can improve corrosion resistance of a substrate, ultimately; they practically failed in corrosive environments. It is famous that the corrosion resistance of DLC coatings is generally determined by their chemical and physical Characteristics [17]. Powerful methods have been improved the corrosion resistance of DLC coatings in the past. For example, incorporation of different atoms was found to be a suitable method to increase the intrinsic properties of host materials. Thus, incorporation of foreign atoms into DLC coatings increase the corrosion inhibition of these coatings [18]. Despite, there were various defects hindering the development of corrosion resistance of DLC coatings in corrosive media such as nano-pores which directly allowing the penetration of water molecules, environmental oxygen and ions so electrochemical dissolution of the substrate occurs [15].

Moreover, the corrosion inhibition of DLC coatings increases by increasing the thickness of the coatings [19]. It is known that there exists a vital consideration should be taken into account: internal stress would be greater in situ-deposition processes with increasing thickness of the coatings so the coating thickness is limited to a range between 1 and 3 μm. If a coating thickness becomes more than 3 μm, cracking of the coating from the substrate would occur. On that account, the corrosion inhibition of the DLC coatings can be improved by reducing the nano-pores and increasing the coating thickness.

We can overcome these defects well by fabricating a multi-layer coating (MLCC),[19] since they could not only increase the thickness of the coatings, but also downscale the intrinsic internal stress so the probability of through-coating defects decreases [20]. Furthermore, the MLCC containing alternating interlayers and few nan pores not only enhanced good corrosion resistance in corrosive medium because of its better power of corrosion prevention,[20] but also low internal stress and high adhesion as shown in previous invitigations [21]. F or Si doped amorphous carbon coatings show positive effort to counteract corrosion resistance. Arguably, F and Si codoped amorphous carbon coatings should exhibit good corrosion inhibition in corrosive medium. As a result, the MLCC design with simplicity and durability would be worthwhile for enhancing the amorphous carbon coating corrosion resistance [22].

2.4. Carbon Nanotubes

Carbon nanotubes, bucky tubes, are cylindrical carbon molecules with particular characters that enable them to be used potentially in a different applications (e.g., nano-electronics, materials applications, optics, etc.) [23]. They are characterized by several properties such as exceptional hardness, unique electrical performance and effective thermal conductors. Scientists can also synthesize Inorganic nanotubes. The structure of nano tube has Fullestructure family with rods. While balls are spherical, the nanotube is cylindrical, with at least one arm ordinarily covered with a hemisphere of the buckiball structure. They are named according to their size, because the diameter of the nanotubes is in the order of several nanometers, while they can be several centimeters long. There are two kinds of nanotubes: multi-line nanotubes (MWCNTs) and single-wall nanostructures (SWCNT) [24].

2.4.1. Thin film solar ultrasonic coating systems

Carbon nanotube or graphene layers are increasingly being used in combination with insulating polymer layers to replace active layer transparent conductive oxides includes Zinc Oxide (ZnO) or Tin Indium Oxide (ITO) in bendy skinny film solar modules. This process leads to high efficiencies and optimal electrical conductivity properties making CNTs desirable. Sono-Tek has know-how to spray deposition of carbon nanotubes and graphene coatings, in addition to silver nanowires[25]. It is proved that Ultrasonic nozzle technology maintain-in suspension- a uniform dispersion of nanotubes. The ultrasonic vibration of the nozzle endures the dispersion of agglomerated particles, so highly functional thin film coatings layer is formed controllably. ERROR revise this part [26].

Benefits of Ultrasonic Spray for Carbon Nanotube Coatings:

a. Natural agglomeration tendency of dispersed particles

b. Choice of droplet size, according to nozzle frequency

c. Cost effective spray equipment with full lab R&D during manufacture

d. Soft, low-pressure ultrasonic spray will not diminish very fine structures

e. Convenient process spraying carbon nanotube suspensions

f. Precision, coating solutions with suitable cost

g. Non-clogging repeatable precision spray

h. Very fine lining or high surface area coatings

i. The low flow rate ability [27].

2.4.2. Thermal radiation coating dispersion characteristic of carbon nanotubes

1) Thin coating; 2) Small thermal resistance; 3) Can excite resonance effect metal radiator surface; 4) Significantly improving the far-infrared emission efficiency; 5) boost up speedy heat distribution from the radiator surface; 6) Carbon Nanotubes Thermal Radiation Coatings can be applied to copper foil, aluminum plate, LED lamp base, electrical enclosure cooling [28, 29].

3. Graphene

One layer of graphite is called graphite and has outstanding electrical, thermal and physical characters. With two layers of complex, two-layer graphite has different properties [30].

3.1. Graphene for Coatings

The enormous selection of stunning properties that graphene has can open the door to many outstanding types of coatings, inks, paints and more. The high resistivity of graphene enable its coating not to crack and to resist water and oil; its high electrical and thermal conductivity can be utilized to make various conductive paints, and a strong barrier effect can take part in to incredible anti-oxidant, scratch-resistant and anti-UVA coatings [31]. Graphene coating is characterized by high performance adhesives due to graphene's high adhesion property, anti-bacterial coatings, solar paints which can absorb solar energy and transmit it, paints that used in isolation for houses, anti-fog paints and UV ray blockers , anti-rust coatings, non-stick coatings for various domestic applications (like frying pans and countertops) and even a much-hyped possibility (currently under scientific examination) of a coating that turns a regular wall into a screen.

3.2. Commercial Activity

Graphene-enhanced products are yet to reach widespread commercialization. Nevertheless, given graphene’s stunning array of properties and the flourishing R&D that occur, graphene-enhanced coatings will not be too far away. The Sixth Element Materials, a Chinese company that concentrate on R&D, mass production and sales of graphene and related materials, showcased its graphene-zinc anti-corrosion primer used for offshore wind power tower, that can come at a reasonable price compared with zinc rich epoxy primer. Garmor spin-off formed to develop a production process for new flakes of graphene oxide. This develops graphene oxide-based coatings which are beneficial for limiting UV radiation so polymers and sensors are damaged. Garmor's transparent GO-films are reportedly derived from a commercial-available and scalable process that can be readily put into action with less constrains [33].

3.3. Protection with Pure Graphene

Graphene flakes grown straight on fibers with micron-sized of austenitic stainless steel as governments of porous metallic structures used in different applications such as heat dissipation systems, membranes for filtration process, sensors, and biomedical shells formed a blockade which consist of nano-flakes present as three-dimensional networks so they are considered a strong anti- corrosion shield. The performance was accredited to graphene is hydrophobic so water repelled from the surface a lot and graphene has unique electrical properties so redox reactions on the surface declined. Not only simple coatings which contain a few atomic layers but also more complex coatings with inter-connected 2–4-μm-long nano-pillars were synthesized and studied. The thickness of the graphene covering was controlled by two factors: the first factor variation in the temperature and the second factor is the flow rate of feed gas during deposition process. The coatings with complicated structure show massively improved specific surface areas, high hydrophobicity, and the highest ability to corrosion resistance to synthetic seawater [23].

At Massachusetts Institute of Technology, scientists recently reported that ultrathin, scalable, chemical-vapor-deposited (CVD) graphene coatings not only have higher chemical resistance than typical functional hydrophobic coatings but also promote drop wise rather than film wise condensation on copper tubes used in the systems of heat transfer.2 Heat transfer of chemical-vapor-deposited (CVD) was improved by a factor of four compared to that of a conventional monolayer hydrophobic polymer coating in pure water vapor at 100°C, and the graphene coating was found to be significantly offered a lower thermal resistance and more robust to chemical resistance. The polymer coating began to degrade within three hours and completely failed within 12 hours, while the grapheme coating showed no signs of measurable degradation over a two-week period. the improved condenser heat transfer could result in a 2–3% improvement in the effectiveness of power plants, which compares to investments of dollars per power plant[34].

We can said that Graphene coatings have higher protection against microbial-induced corrosion than typical polymer coatings. Also, graphene coatings provide good protection for metallic surfaces from corrosion under harsh microbial conditions more effectively than standard parylene-C (PA) and polyurethane (PU) protective coatings. Especially, when nickel is dissolute in a corrosion cell with electrodes has Ni-graphene coating, the order of magnitude becomes lower than that of PA- and PU-coated electrodes, even though the graphene thickness was approximately 25 and 4000 times thinner than the normal PA and PU coatings, respectively. The results are attributed to the significant resistance of graphene to microbial attack so we can say that the graphene coating was highly efficient with no defects. As a next step, the Researchers will investigate the performance of graphene coatings on other metals and on the larger, flat metal sheets used in building construction under aggressive atmospheric conditions [35].

Scientists face not-easy challenges in the development of production of large-area graphite films used in commercial scale. At the University of Manchester, Researchers have encountered this problem by applying graphite oxide laminates and then make chemical treatment using hydrogen iodide and ascorbic acid [35] This process leads to a highly efficient grafting of laminates with little damage on the surface and in the same time, the films resulted are highly impervious to gases, liquids and aggressive chemicals such as hydrofluoric acid.

3.4. Unique Properties of Graphene-Polymer Composite Coatings

Coat manufacturers have long used inorganic fillets to change the properties of polymer coatings. Nanoscale fillers are used for decades and consist mainly of layered clays, carbon nanotubes and derivatives and spherical nanoparticles, most commonly silica (SiO2). Most inorganic fillers, Despite that, exhibit poor compatibility with the organic polymer of the resin, and therefore filler surfaces often have to be modified to improve the interaction between the filler and the matrix. Graphene is attractive as a nano filler, because it is based on carbon of materials that has improved the interaction with organic polymers. Both Granolithic nanoplachets and nanoplasts and Graphy oxide were tested as carriers for different types of coatings [36].

GRAF Applied Materials (AGM), funded through AIM listing in the United Kingdom, have already developed technology for a scalable array of graphite nanoplateleta (A-BNP) or through a continuous synthesis process. To support its focus on the development of graphite dispersions in the industry, AGM has been cooperating with the Color Research Association in the United Kingdom to test modified polyurethane and epoxy coatings. Initial results based on small functions A-GNP10 nanoplateleta indicate for improvement of mechanical properties, such as scratch resistance, or equivalent with yield in reducing moisture transfer rate and anti-corrosion performance. AGM reports improvements of over 300% over time to failure in cyclic salt testing [37].

Scientists from Juan Iuanskiia University of Taiwan developed electroactive polyimides (EPI) / graphene NANOCOMPOSIT (EPGN) laminating imidizatsiia and showed that these coatings provide dual protection opposing corrosion of electrodes for cold rolled steel (CRS) of pure EPI coverage. [38] the improvement of corrosion protection on EPGN coatings minimize the catalytic capacity of existing EPGN aniline dimension (ACAT) ammonium acrylic units, which is thought to prompt the formation of layers of passive metal oxide on the electrode CRS. Furthermore, the nanochemical layers of carboxyl-graphene embedded in the EPGN matrix increase the sound insulation of the diffusion pathway for the molecules 02, which acts as a gas barrier and significantly aggravate the migration of oxygen [38].

4. Carbon Nanostructures Scale Production

Today, Many methods have been improved to produce carbon nanomaterials. The most interesting lately, however, are energy-saving reactions and cheap starting materials [39].

Here we start with the most spectacular and explored nanomaterials, graphene in the last decade. It should be noted that after the isolation in 2004 different methods of graphite production were used, which includes micro-mechanical separation [39], epitaxial growth on SiC substrates , chemical reduced exfoliated graphene oxide [40], liquid phase exfoliation , chemical vapor deposition (CVD) and carbon nanotube extraction. Each method has its advantages and limitations according to the purpose. The impact of the future of graphene as a material for making light, miniature, ultra-fast and high frequency electronic and optoelectronic devices is designed as a lightweight. In spite of that, this can only be occurred if the quality of the 2D material is not accurately done during its manufacture. Accordingly, the most convenient shape of this material for this type of application is considered to be uniform with many layers of a thin plate of high surface area with a large graft domain size and ordered thickness, surely pure and free of all forms of disorder in structure . Thus, the only way that can be considered suitable for the production of graphene with a number of properties is the use of a chemical deposit (CVD)[41].

Another beneficial material in the graphene family is graphene oxide which is commonly used substance for the high production of graphic material . In 1859, Brody published originally that the oxidation of graphite flakes generate a non-stoichiometric compound (graphite oxide) .[42]. From this year, a great attention has been taken in account to oxidized graphite due to its inimitable thermal, electrical and mechanical properties. The presence of reactive oxygen functional groups in the GO molecule is considered the cause of all these extraordinary features. For this reason, the material is used in many types of applications such as insulation materials (due to broken sp2 bonding networks), sensors, polymer composites, field effect transistors and energy related materials [43]. Recently, it has been employed in biomedical field [22,23] due to its unusual aqueous process ability, surface enhanced Raman scattering fluorescence quenching ability and potential of surface functionalization.

During the GO synthesis, it was not easy to manage and measure the relative proportions of the elements involved in the chemical reaction. Hence, stoichiometry and initial concentration of oxygen rely on the treatment conditions. Accordingly, factors such as elemental composition, particle width and graphite nature, synthesis process, oxidation duration and oxidation agent are considered to be actuators that result in variation in the density of functional groups during production of GO[43]. Graphene oxide, when introduced to a reductant, typically produces a conductive material in the form of reduced graphite oxide (rGO). Therefore, this material, which occurs when the functional groups of oxygen in GO (i.e., reduced) are removed, have a significant characteristic similar to the unusual graphene.

For coal nanotubes, SWCNT and MWCNT produce the same procedure. However, the only difference can be done by the use of an essential metal catalyst to the synthesis of fullerene. Many carbon precursors, including, acetylene ,methane, toluene, benzene, xylene etc. are used as a carbon source for the synthesis of carbon nanotubes. However, it is worrying that these stocks of carbon feed materials are based on fossil fuels. Consequently, they are non-renewable and non-sustainable.

In brief, the carbon AC is generally prepared in two steps. The first step is the carbonization of the initial raw material and the second step is the activation of carbon by chemical or physical methods. In the carbonization step, the raw materials dissolve by heat, remove all other substances except carbon, and create a constant mass of carbon with a very small porous structure. The second step (activation method) is occurred not only to improve small pores but also increasing the surface by creating new pores [44]. It is generally achieved through chemical or physical methods. Chemical activation is commonly established by thermal disintegration of the precursor impregnated with mostly alkalis such as potassium hydroxide sodium hydroxide or acids like sulfuric acid or phosphoric acid [44].

Despite that, physical activation also widely called thermal activation is conducted the usage of an oxidizing gas CO_2 to promote the carbon material then it exposed to temperature range between 800 to 1100 °C. The analytical pyrolysis of the material is normally conducted in a tube furnace, muffle furnace and glass reactors located in a modified microwave oven [44]. At the present time, the origin of major precursors used to produce activated carbon is mostly lignocellulosic materials such as wood, wastes of palm oil, coconut shells, etc. Lately, there have been abundance of research efforts in developing processes to produce ACs from biomass waste, which contains excessive quantity of natural constituents such as cellulose, hemicellulose, and lignin. Among biomass, bio-waste will be a better alternative because it is plentiful, renewable and cheap. The use of biological waste in the preparation of sorbent ads is extremely attractive as it helps to reduce waste disposal costs and enhance environmental protection. In fact, the use of agricultural waste and scrap, pirina pirinačke, palm trees, shell Orahovske, corn flakes, coconut husks, coconut coconut, macadamia, coconut endocarp, lignin and cherry stone have been explored and used. Activated carbon with high carbon content and low price. ACs are produced in an ecological and economic way by thermal conversion processes of pyrolysis and gasification for various biomass waste such as apricot stone shells, bean pods, olive stones, sugar cane bagasse, rice straw, rice hull, and pecan shells. The Council needs Member States to reduce the amount of biodegradable communal waste buried at 35% levels from 1995 to 2016, and for some countries by 2020. In Finland, biodegradable waste and any other organic waste containing more than 10% Organic matter. Carbon is banned from the beginning of 2016. One possibility is that these types of waste are used as precursors for the production of activated carbon and are used in many applications. Due to existing legislation and in order to avoid emissions from transport, there is a growing need for studying locally available waste materials as precursors.

5. Conclusions

Population growth rate and technological progress around the world increase the demand for energy. Common energy sources are insufficient, polluting the environment. Carbon, one of the many ingredients found on the ground can be used for the production of energy and heating. As described in this section, Actually, Carbon can be used in plants such as organic solar cells and supercapacitors in the form of one or several types of marks (e.g., graphene, carbon dioxide, fillers) using level synthesis. costs and methods of processing based on printing and rolling technology to rollers.

In this section, using color processing by carbon dioxide has been developed by different approaches . Nanomaterials used for organic solar cells have been totally improved. Graft which is produced by electrochemical electronics was considered as a trustworthy solution to be used as electrodes for solar cells. Gaining high quality, high-end products, competition challenges with simple transparent electronics, such as ITO, remain. Nevertheless, its production capacity is very attractive to separate solar panels for solar panels where there is a rolling technique used to increase production volumes. In addition, helicopters, CNT and graphic oxygen can help optical solar panels if they are attached in active layers or buffers. As a matter of fact, Scientist can change their semi-structural properties by doping with other materials and change their physical structure to expose a wide range of sunshine waves.

Day after day, researchers discover stunning features of carbon. All new carbon structures in the last twenty years are from 0D to 1D nanotubes and 2D graphs. Carbon will replace many substances in different fields because of low cost and its abundance on the earth.

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