CNT-GRAPHENE HYBRID-BASED FIELD EMITTER: A REVIEW

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Abstract: Since the discovery in 1991, CNTs have found promising application in the various field, due to extraordinary properties like high electrical conductivity, unique electrochemical properties, outstanding mechanical strength, large surface-volume ratio etc. On the other hand, Graphene which has recently discovered as two-dimensional (2D) cousin of the CNT, can be predicted as futuristic material due to unparallel charge-carriers mobility, high specific surface area, conductivity, mechanical properties etc. Merging one-dimensional (1D) Carbon-nanotube and two-dimensional (2D) Graphene into hybrid structure provides a novel approach to three-dimensional (3D) material comprising of properties of both carbon allotropes. Therefore, this review will summarize the recent progress of highly ordered CNT-Graphene hybrid assembly/synthesis and their field emission properties such as "turn-on" electric field, low threshold electric field, maximum current density, and the field enhancement factor β.

Index Terms: **Graphene, Carbon-Nanotubes, field emission.**

1. Introduction

Carbon is 4th group element located in periodic table. There are numerous allotropes of carbon. Graphite, Diamond are the two classical examples which are known but since 1990. Newer forms of carbon have been discovered as Buckminster Fullerene in 1985, the Carbon Nanotubes in 1991 by Iijima et al., and Graphene in 2004. Graphene is one of the latest forms of carbon allotrope with a two-dimensional (2D) crystal structure based on a Hexagonal network structure. A graphene is like hexagonal tiles arrange next to each other along one direction. Carbon Nanotubes (CNT) – A rolled up sheet of graphene into a tube.

Carbon nanotubes (CNTs) are allotropes of carbon with a round and hollow nanostructure. These barrel-shaped carbon particles have unordinary properties, which are profitable for nanotechnology, equipment, optics, and diverse fields of materials science and advancement. Attributable to the material's remarkable quality and firmness, nanotubes have been built with a length-to-diameter proportion of up to 132,000,000:1, essentially bigger than that for some other material. What's more, inferable from their uncommon thermal conductivity and mechanical and electrical properties, carbon nanotubes find applications as added substances to various assistant materials. For example, nanotubes structure a minor bit of the material(s) in a few (principally carbon fibre) homerun sticks, golf clubs, vehicle parts, or Damascus steel. Nanotubes are individuals from the fullerene basic family. Their name is gotten from their long, empty structure with the dividers shaped by one-molecule-thick sheets of carbon, called graphene (just as Buckminster Fuller's name). These sheets are moved at unequivocal and discrete ("chiral") edges, and the blend of the moving point and breadth picks the nanotube properties, for example, paying little respect to whether the individual nanotube shell is a metal or semiconductor. Nanotubes are requested as single-walled nanotubes (SWNTs) and multi-walled nanotubes (MWNTs). Solitary nanotubes regularly change themselves into "ropes" held together by van der Waals powers, significantly more unequivocally, pi-stacking. The different technique has been made to convey nanotubes in sizeable sums, including circular segment release, laser removal, concoction vapor affidavit (CVD) and high-weight carbon monoxide disproportionation (HiPCO). Among this roundabout circular arc discharge strategy, laser removal, compound vapor deposition (CVD) are bunch by a gathering methodology and HiPCO is gas organize relentless procedure. Most of these strategies happen in a vacuum or with methodology gases. The CVD improvement method is outstanding, as it yields high sum and has a dimension of control over a separation over, length and morphology.

Graphene is the initial two-dimensional (2D) atomic crystal accessible to us. Countless material parameters, for example, mechanical solidness, quality and flexibility, high electrical and thermal conductivity, and numerous others are preeminent. These properties recommend that graphene could supplant different materials in existing applications. In any case, all these outrageous properties are consolidated in one material implies that graphene could likewise empower a few troublesome advances. The blend of straightforwardness, conductivity and flexibility will discover use in adaptable devices, though straightforwardness, impermeability and conductivity will discover application in straightforward defensive coatings and hindrance films; and the rundown of such blends is constantly developing. It had been produced accidentally in little amounts for a considerable length of time using pencils and other comparable graphite applications. It was watched initially in electron magnifying lens in 1962, however it was contemplated just while bolstered on metal surfaces. The material was later rediscovered, disconnected, and described in 2004 by Andre Geim and Konstantin Novoselov at the University of Manchester. The exploration was educated by existing hypothetical depictions of its synthesis, structure, and properties.

Since the main provide details regarding the disconnection of the single-layer graphene sheet in 2004, scaling up of graphene is a noteworthy concern which isn't just for its logical intrigue yet in addition for its effect on the attainability of various mechanical applications. So far graphene has been blended in either on SiC or metal substrates and exchanged to other adaptable substrates a while later to be utilized for adaptable hardware and sun-oriented cell electrodes. The outcomes due to the outstanding properties of graphene, even in the gadget model stage, has prompted the showing of different gadgets in a wide the scope of territories including field emission (FE) cathode, sensors, devices, solar-cells, Li-particle batteries thus on. Notwithstanding the applications dependent on either graphene or CNT, the graphene– CNT cross breed structure is exceedingly helpful for microelectronics applications as it can join the focal points from properties of graphene and CNTs in the planar and hub bearings, individually. Specifically, direct exchange of CNTs onto a polymer grid experiences absence of a homogeneous base contact for the CNT layers, as polymer substrates are a high obstruction in nature.

A few union techniques have been created for manufacturing CNTs since its isolation by Iijima. CNTs and graphene have various excellent properties and have been suggested for a wide extent of usage. In both graphene and CNTs, the carbon atoms are related by sp2 bonds, which are significantly more grounded than sp3 bonds found in a precious stone, and which give the two materials exceptional quality. Besides, both have an exceptionally high thermal conductivity, electron adaptability, and engineered reactivity. Graphene and Carbon-nanotube both display intriguing material science because of their two-dimensional and one-dimensional structures separately. Graphene is a zero-gap semiconductor and displays the strange quantum Hall Effect. Carbon nanotubes, contingent upon their structure, can be either semiconducting, with a variable band gap, or metallic. On the off chance that we consider their crossover mix 1D-Graphene and 2D-Carbon nanotubes, we become more acquainted with their noteworthy properties.

Field emission is a quantum mechanical tunneling phenomena. As field emitter, CNTs have novel characteristics including unrivalled mechanical quality, great conductivity, high aspect proportion (length-to-diameter across proportion), small radii of the arch and high concoction stability. Such emitters are equipped for creating noteworthy improvements of the electric-field qualities at the tips of the CNTs, prompting the properties of low turn-on voltages and high emanation flow densities, which far surpass the exhibitions of traditional field producers. Because of its one of a kind infinitesimal structure, graphene displays alluring properties like those of CNTs, i.e., high aspect ratio (territory to-thickness proportion), productive electrical and thermal conductivity, just as great mechanical properties. Particularly, the presence of various sharp-edged structures proposes that graphene is a promising possibility for the acknowledgement of another electron field outflow source. As of late, consolidating CNTs with graphene to structure CNT/graphene (GH) structures for the reason of field discharge applications has been recommended by a few examiners. For instance, Lahiri et al. examined the impacts on electron field discharge from on a level plane lying graphene, created utilizing a Cu-catalyzed chemical vapour deposition (CVD) approach and afterwards exchanging onto PET substrates. To accomplish a consolidated structure, they turn covered polyvinyl liquor secured multiwall CNT onto the graphene. Das et al. exhibited the possibility of an in-situ manufacture of a self-sorted out CNT/GH film through the utilization of thermal CVD. The crossbreed structure contained a top layer of graphene, which was in contact with vertical CNTs. It displayed radiant electro-mechanical properties, making the structure relevant to the improvement of adaptable devices. Deng et al. have displayed a strategy for growing few-layer graphene (FLG) on CNTs utilizing the method of radiofrequency hydrogen plasma sputtering testimony. Such FLG-CNT half breed structures demonstrated great field discharge properties contrasted with as-developed CNTs. CNT/GH field producers likewise have been demonstrated. These examinations showed that the mix of CNTs and graphene can result in a synergistic impact, which is promising for the advancement of field emanation applications. Be that as it may, these creation techniques, including the CVD procedure, are intricate and expensive. This is basically because of the numerous means and high temperatures required to manufacture such half breed films.

Dang et al. The combination of one-dimensional (1D) carbon nanotubes and two-dimensional (2D) graphene materials to produce three-dimensional (3D) CNT/graphene hybrid thin film, has attracted great attention owing to their intriguing properties via the combined effects of these two materials on their electrical, optical and electrochemical properties in comparison with their individual sample item. Song et al, (2015) have showed CNTs as an ideal cold cathode for field emission, but the poor inter-tube contacts and high-density bundles make them less resourceful for electron conduction. On the other hand, graphene is a semi-metal, its only secreting sources are defects and sharp-edges, and their electron yields are relatively low. The pros and cons of CNTs and graphene stir the idea of integrating CNTs and graphene into hybrid structures, in which CNTs behave as electron emitters and graphene as electron transport stations. Tai et al. (2012) uncovered an adaptable designed procedure reliant on quick warming and cooling chemical vapour deposition for the advancement of carbon nanotube (CNT)– graphene crossbreed materials where the thickness of graphene and thickness of CNTs are genuinely controlled. Graphene films are appeared as a beneficial limit layer for checking hurting of iron nanoparticles, which catalyze the advancement of CNTs on copper substrates. Thinking about this methodology, the optoelectronic and field release properties of graphene consolidated with CNTs can be shockingly hand crafted. A graphene film shows a sheet obstacle of 2.15 kΩ sq^{-1} with a transmittance of 85.6% (at 550 nm), while a CNT– graphene crossbreed film exhibits an improved sheet deterrent of 420 Ω sq-1 with an optical transmittance of 72.9%. Furthermore, CNT– graphene films are displayed as amazing electron field makers with low turn-on and edge electric fields of 2.9 and 3.3 V/µm, independently. The improvement of CNT– graphene films with a wide extent of tunable properties presented in this examination demonstrates promising applications in versatile optoelectronics, essentialness, and sensor devices.

Zhao et al. Field electron emission (also known as field emission (FE) and electron field emission is the emission of electrons induced by a highly electrostatic field. The performance of field emitters is generally estimated based on three criteria—extraction field, brightness, and monochromaticity. The vital importance of the electric field for extraction is influenced by the work function of the emitter as well as orderly field enhancement. The “turn-on” field exponentially decreases with the emitter-aspect ratio, given by the ratio of the height to tip radius. Tall, sharp tips are preferable, making non-material’s ideal candidates. Electron field emission (FE) is the phenomenon through which electrons are transmitted from the outside of materials into the vacuum under the impact of an external electrostatic field. Basically, an FE device comprises of an anode and a cathode. Under the impact of the electrostatic field, electrons escape from the cathode and are gathered by the anode. The key segment of the FE device is the emitter(s) in the cathodes, from which the electron pillars are produced. Because of the producers' capacity as the electron wellsprings of FE devices, their geometrical and physical attributes, just as their course of action, affect the execution of the gadgets. Preferably, the FE cathodes ought to have high mechanical quality, a high liquefying point, brilliant thermal and electrical conductivity, and stable compound properties. Also, the cathodes with the high angle proportion (i.e., length-to-radio proportion) will, in general, show high FE execution. Carbon nanotubes (CNTs) have been considered an incredible possibility for the electron producers because of their 1D cylindrical structures related to their amazing mechanical, thermal, and electrical properties. As of late, graphene has likewise been considered as a remarkable material for FE applications. Graphene has 2D drop structure (i.e., atomic thickness), exhibiting an incredibly high viewpoint proportion. Also, graphene shows prevalent mechanical quality, uncommonly high thermal conductivity, and high charge transporter versatility. These uncommon attributes make graphene a promising contender for FE applications. Lee et al. revealed an intriguing way to deal with become vertically adjusted MWCNTs on diminished graphene oxide platelets and proposed its relevance as an adaptable field emission device.

In this paper, we aim to briefly summarize the latest progress in highly ordered CNT/Graphene hybrid material and test their field emissions performance such as “turn-on” electric field, low threshold electric field value, maximum current density and a high field enhancement factor β. The extraordinary β is attributed to the strong edge emitter effect of graphene nanosheets based on their high aspect ratio and high surface area. We also theorize a probable mechanism for this enhanced field emission performance from the CNT/graphene hybrid.

2. Synthesis of CNT, graphene and CNT-graphene hybrid

Nanotechnology is a global cross-disciplinary undertaking that has extraordinary potential to change our lives by improving the existing potential to change our lives by improving existing products and enabling new ones. In this context, we have reviewed about CNT and graphene and their hybrid structure. CNT is an important new class of technological materials that have numerous novel and useful properties. The strength of the sp^2 carbon-carbon bonds gives carbon nanotubes amazing properties. No previous develop material has displayed the combination of superlative mechanical, thermal, and electronic properties attributed to them. CNTs are superior to all carbon fibers which approx. 5x stronger than steel. Carbon nanotubes are the strongest material ever discovered by mankind.

2.1 Classification of Carbon-Nanotubes CNTs

Carbon-Nanotubes classified into two type’s namely single-walled nanotube (SWNT) and multiple-walled nanotube (MWNT).

Single-walled nanotube (SWNT): Single-walled Carbon-nanotubes are characterized as one dimensional, empty circularly moulded allotropes of carbon that have a high surface zone and perspective proportion (length-diameter proportion). Due to their small diameter and substantial angle proportion, SWNTs are considered as one-dimensional (1D) material. SWNTs are named on account of their empty structure and number of walls. SWNTs are members of the fullerene family.

Multiple-walled nanotube (MWNT): Multi-walled Carbon-nanotubes are hollow, cylindrically shaped allotropes of carbon that have a high aspect ratio. Their name is derived from their structure and the walls are formed by multiple one-atom thick-sheets of carbon. MWNTs consist of multiple rolled layers of concentric nanotubes of graphene inside the other nanotubes.

Multiple-walled nanotube further classifies into two sub-points first is Russian Doll structure- Several concentric tube and second is Parchment structure- There is a single graphene sheet but that rolled itself like a parchment into a multiple-walled tube. Single and multiple walls structure provide different properties to the CNTs.

2.2 Synthesis of Carbon-Nanotubes (CNTs)

Arc discharge, laser ablation and chemical vapour deposition are the three main techniques primarily convey out at that time to produced carbon nanotubes. Scientists are researching more economically ways to produce nanotubes. In arc-discharge method, a vapour is created between the two carbon electrode rods by using catalyst or without it. Nanotubes self-assemble from the resulting carbon vapour. Now, laser ablation produces a small number of clean nanotubes, whereas arc discharge methods generally produce large quantities of impure material. In general, chemical vapour deposition (CVD) it is gas phase techniques results in MWNTs or poor quality SWNTs.

Arc Discharge and Laser Vaporization: The carbon arc discharge method, initially used for producing C60 fullerenes, is the most common and perhaps easiest way to produce carbon nanotubes as it is rather simple to undertake. However, it is a technique that produces a mixture of components and requires separating nanotubes from the soot and the catalytic metals present in the crude product. This method creates nanotubes through arc-vaporization of two carbon rods placed end to end, separated by approximately 1mm, in an enclosure that is usually filled with inert gas (helium, argon) at low pressure (between 50 and 700 mbar). Recent investigations have shown that it is also possible to create nanotubes with the arc method in liquid nitrogen.

Arc discharge and laser ablation were the first methods that allowed synthesis of SWCNTs in relatively large (gram) amounts. Both methods involve the condensation of hot gaseous carbon atoms generated from the evaporation of solid carbon. For the growth of single-wall tubes, a metal catalyst is needed in the arc-discharge system. For the growth of high-quality SWCNTs at the 1–10 g scale was also produced using a laser-ablation (laser oven) method. Besides the laser-oven method, there are reports regarding usage of a typical industrial continuous wave CO_2-laser system for production of SWCNTs. Nevertheless, the equipment requirements and the large amount of energy consumed by these methods make them less favorable for nanotube production. With the arc and laser methods, only powdered samples with nanotubes tangled into bundles can be produced. The common feature of arc discharge and laser ablation methods is the need for high amount of energy to induce the reorganization of carbon atoms into CNTs. The temperature used is even higher than 3000^0C, which is beneficial for good crystallization of the CNTs, thus, the products are always produced with good graphite alignment. However, the basic requirements of these systems, including vacuum conditions and continuous graphite target replacement, pose difficulties to the large-scale production of CNTs.

Chemical vapour deposition (CVD): Chemical vapour deposition (CVD) blend is accomplished by putting a carbon source in the gas stage and utilizing a vitality source, for example, plasma or a resistively warmed curl, to exchange vitality to a vaporous carbon atom. Regularly utilized vaporous carbon sources incorporate methane, carbon monoxide and acetylene. The vitality source is utilized to "split" the particle into responsive nuclear carbon. At that point, the carbon diffuses towards the substrate, which is warmed and covered with an impetus (often a first line progress metal, for example, Ni, Fe or Co) where it will tie. Carbon nanotubes will be shaped if the best possible parameters are kept up. Fantastic arrangement, just as positional control on the nanometer scale, can be accomplished by utilizing CVD. Authority over the distance across, just as the development rate of the nanotubes can likewise be kept up. The proper metal impetus can specially develop single as opposed to multi-walled nanotubes. CVD carbon nanotube blend is basically a two-advance procedure comprising of an impetus arrangement step pursued by the real combination of the nanotube. Among these strategies, five distinct methodologies have been appeared to be the most encouraging:

(i) Methane CVD: It was first revealed in 1998, where a mass measure of SWCNTs were integrated by CVD from methane at 900^{0}C. Su et al. essentially improved the yield of this technique utilizing Al_2O_3 aerogels impregnated with Fe/Mo nanoparticles as an impetus.

(ii) HiPCO, which represents high-weight reactant decay of carbon monoxide, utilizes high-weight CO as the carbon hotspot for the arrangement of SWCNTs. The impetuses utilized in a HiPCO procedure are in the gas stage created from an unstable organometallic impetus antecedent.

(iii) CO CVD utilizes CO as a feed gas. Contrasted and tests made utilizing a similar catalyst and methane, the measure of nebulous carbon can be decreased. A critical development in the CO CVD strategy is the improvement of the Co-Mo impetus. In that procedure Co-Mo bimetallic impetuses and a fluidized bed CVD reactor were utilized to create an extensive amount of SWCNTs. The most imperative preferred standpoint of fluidized-bed reactors is that they grant nonstop expansion and expulsion of strong particles from the reactor, ceaselessly the task.

(iv) Alcohol CVD was accounted for in 2002 by Maruyama et al., which produce exceedingly clear SWCNTs with no nebulous carbon covering utilizing alcohols, for example, methanol and ethanol as a carbon source. It was suggested that the OH radical framed at a high temperature from alcohols can evacuate the undefined carbon effectively amid nanotube development, leaving just unadulterated SWCNTs as an item.

(v) Plasma-improved CVD (PECVD) strategies have likewise been normally utilized for making carbon materials including MWCNTs and SWCNTs as of late. The receptive species in the plasma framework could influence the development of exceptionally little measurement tubes, with suggestions to both breadth control and specific drawing of metallic SWCNTs.

Graphene is an allotrope of carbon; whose structure is one-molecule thick planar sheets of sp2 fortified carbon atoms that are thickly stuffed in a honeycomb gem cross-section. It resembles hexagonal tiles organize alongside one another along the 2D plane. Graphene is most effectively envisioned as a nuclear scale chicken wire made of carbon molecules and their bonds. The crystalline or "flake" type of graphite comprises of numerous graphene sheets stacked together. The blend of graphene alludes to any procedure for creating or separating graphene, contingent upon the ideal size, immaculateness and flowering of the explicit item. Graphene can be integrated by means of any of mechanical exploitation thermal reduction-oxidation (redox) forms. Graphene was first gotten in the type of small flakes of the order of a few microns through mechanical shedding of graphite utilizing scotch tape. Even though this technique gives the most elevated quality graphene for large scale manufacturing creation strategy is required that can amalgamation wafer scale graphene.

2.3 Synthesis of Graphene

Synthesis of monolayer graphite was attempted as right on time as in 1975, when B. Lang et al. demonstrated the development of mono-and multi-layered graphite by thermal decay of carbon on single crystal Pt substrates. Be that as it may, because of the absence of consistency between properties of such sheets, framed on various precious stone planes of Pt and inability to distinguish the valuable utilization of the item, the procedure was not contemplated broadly, at that timeframe. After a long gap, dispersed endeavors to produce graphene was accounted for again from 1999. However, Novoselov et al. have been credited for the revelation of graphene in 2004. They have first appeared a repeatable combination of graphene through exfoliation. The system has been and is being pursued from that point forward, alongside endeavors to grow new preparing courses for the proficient blend of substantial scale graphene. The union courses of graphene can be comprehensively sorted into diverse areas, as portrayed beneath.

Exfoliation and Cleavage: Graphite is stacked layers of numerous graphene sheets, reinforced together by week van der Waals drive. Consequently, on a basic level, it is conceivable to deliver graphene from a high virtue graphite sheet, if these bonds can be broken. Peeling and cleavage utilize mechanical or compound vitality to break these week bonds, furthermore, separate out individual graphene sheets.

Thermal Chemical Vapor Deposition Techniques: Synthesis of graphene through thermal chemical vapour deposition (CVD) has been very new. The primary writes about planar barely any few-layer graphene (PFLG), incorporated by CVD, was found in 2006. In this work, a characteristic, eco-accommodating, ease antecedent, camphor, was utilized to orchestrate graphene on Ni foils. Camphor was first dissipated at 180 ºC and afterwards pyrolyzed, in another council of the CVD heater, at 700 to 850 ºC, utilizing argon as the transporter gas. Upon common cooling to room temperature, few-layer graphene sheets were seen on the Ni foils. Graphene, in this manner created, was found to have various folds (in HRTEM pictures) and evaluated to have roughly 35 layers of graphene sheets.

Plasma Enhanced Chemical Vapor Deposition Systems: Interest for integrating graphene through plasma enhanced chemical vapour deposition (PECVD) is contemporary to that of exfoliation. The most punctual report, by Obraztsov et al., has proposed a dc release PECVD strategy to create purported nanostructured graphite-like carbon (NG).67 The procedure utilized Si wafer also, Ni, W, Mo and some other metal sheets as substrates and a gas blend of CH_4 and H_2 (0% to 25% CH_4), with a complete gas weight of 10 to 150 Torr.

2.4 Synthesis of Hybrid film and Field emission properties:

Dai et al. (2017) perform an experiment test to prepare the Graphene/carbon nanofilament (G/CNF) hybrids by the synthesis technique by an electrochemical post-treatment of as-prepared CNFs. After the mild electrochemical exfoliation, the surface of CNFs was partially exfoliated and converted into graphene nanosheets. Compared to 2D/1D nanocarbon hybrids prepared by common CVD, the better interface between graphene and CNFs of our samples can be accomplished due to the in-situ formation of graphene via electrochemical self-exfoliation of CNFs. Field emission performance for G/CNF hybrids shows a low turn-on voltage of 1.34 V/μm, maximum current density 1.5 mA/cm^2 and a high field enhancement factor (β) of 4930. The extraordinary β is attributed to the strong edge emitter effect of graphene nanosheets based on their high aspect ratio and high surface area.

Zhao et al. (2015) have synthesis vertical aligned Graphene flakes grown on Cu particles by a CVD method and studied their field emission properties. The fabricated graphene flakes on Cu particles shows enhancement local electric field at the tips and edges of the vertical Graphene flakes as well as the electrical conductivity enhancement due to the existence of Cu particles compared with the flat Graphene layer grown by CVD method, the vertical Graphene flakes show a better field emission performance, with a lower turn-on voltage and a high current density. In this study, the vertical Graphene flakes were synthesized by the CVD method, which has been a widely used technique to develop a high quantity of Graphene samples. The two-sample output, flat Graphene sheets on Si substrate and vertical Graphene flakes on Cu particle. The morphology and microstructure of the sample were characterized by the scanning electron microscope (SEM) and Raman spectra. The experiment results show that the field emission performance of vertical Graphene flakes is significantly enhanced due to the Cu particle. Due to the vertical orientation, the maximum current raises from 0.12mA/cm^2 to 10mA/cm^2 but at a lower applied field of 4 V/μm. The Cu particle plays an important role in long time stability of field emission for graphene.

Song et al. (2015) prepared to integrate CNT/Graphene hybrid by using the water-processed method and test their field emission properties. This is a low-temperature process which exhibits a high yield and simple operability. GO which was used here prepared from graphite powder using improve Hummer method. Taken different proportion of mass-ratio of CNT was mixed with the GO solution, followed by ultrasonication process for hours. The output CNT/GO mixture was cool down and reduced in H_2 atmosphere. They tested properties of field emission by two methods, Method 1 is CNT/graphene hybrid and the Method 2 is CNT and rGO was directly mixed by ball mixing, the product is referred to CNT/graphene mixture. The 3D hybrid is assembled into field emission devices (FED) as cathode materials and tested at a base pressure of $1.0x10^{-4}$ Pa at room temperature. With the optimized mass ratio of CNTs to graphene, the hybrid shows a significantly enhanced field emission performance such as turn-on electric field of 0.79V/µm, threshold field of 1.05 V/µm, maximum current density of 0.1 mA/cm^2 and field enhancement factor $1.3x10^4$.

Hong et al. (2015) synthesized a simple, low-cost, and versatile approach based on the technique of electrophoretic deposition for developing high-performance carbon nanotubes (CNT)/graphene hybrid field emitters and examines their field emission properties. The fabricated CNT/graphene hybrid structure is found to display superior field-emission properties compared to those of pure CNT and pure graphene films. Low turn-on field and threshold field values of 1.0 and 2.3 V/µm, respectively, were demonstrated for the fabricated hybrid structure.

Zhao et al. (2015) studied and investigated the electron field emission characteristics of the CNT/Graphene hybrid. In his work, the CNT arrays were grown by Microwave plasma enhanced chemical vapour deposition (MPCVD) method using Fe film as the catalyst was transferred onto the Silicon (Si) substrate covered with graphene layer obtained by the technique of Thermal chemical vapour deposition (CVD). The fabricated CNT/Graphene hybrid structure was found to parade higher field-emission performance in comparison to CNT arrays directly grown on the Si substrate. With a diode configuration structure, the field emission current was measured in the vacuum chamber. The hybrid showed a significantly enhanced field emission performance such as high emission current of 1670 µA in compared with 950 µA emitted from CNTs emitter by using graphene as the electron transfer layer at the applied field of 3.25 V/µm. The result showed that the graphene layer effectively improved the electron transport from the substrate to the CNT emitter and transfer the joule heating which is generated from the resistance of the emitter.

Nayak et al. (2014) studied the highly protruded graphene sheets wrapped CNTs have been synthesized by CVD technique, and surface decoration by Ru, ZnO, and SnO_2 nanoparticles has been done by simple solar reduction technique. GWCNTs possess lower turn-on field and larger field-enhancement factor due to the combined advantage of high aspect ratio and projected graphene layers on CNT surface, which could act as emission sites to contribute to high FE current density. The results illustrate the best FE performance for Ru GWCNTs based emitters, with a low turn-on field of 0.61 V/µm, a current density of

2.5 mA/cm^2 at a field of 1V/µm and a field enhancement factor of 6958. The enhanced FE behavior of GWCNTs based emitters is attributed to the ease of an electron tunneling from the lumps created on CNT surface which increases the emission performance and hence the FE current density. In addition, the surface decorated M/ MO NPs could minor the work function, which contributes to local field enhancement, and hence the low value of “turn-on” field. Based on enhanced field emission performance and good stability, GWCNTs based composites may be promising for a high-performance cold cathode emitter.

J. Xu et al. (2013) perform an experiment test to prepare the graphene/DWCNT composite film by the technique of screen printing and test their field emission performance; they found that by adding a certain amount of graphene into DWCNT as the emission material, the field emission performance improved significantly. They got optimum FE performance with a turn-on electric field of 0.62 V/µm and a threshold field of 1.19 V/um at the maximum current density of 1 µA/cm^2 and field enhancement factor 13000 when the weight ratio of graphene is 20%. Firstly, CNT better-known candidate for the field emission because of their low turn-on field, high enhancement factor. The screen printing also has some drawbacks such as poor adhesive strength to subtract, residual organic bundles and high annealing temperature which result in the poor conductivity of CNT films the metal surface. By adding a certain amount of graphene into DWCNT it can reduce the contact barrier between the emitter and silver electrodes and increases the conductivity of emitter film, which causes an enhancement of field emission performance.

Xu et al. (2013) Graphene twofold walled carbon nanotubes (DWCNT) crossover films were set up by vacuum filtration and screen printing. Their electron field discharge properties have been contemplated deliberately. The electron emission properties of the hybrid films are vastly improved than those of unadulterated DWCNT films and unadulterated graphene films. Contrasting and the screen-printed films; the vacuum filtered films have numerous points of interest, for example, lower turn-on electric field, higher emission flow current density, better consistency, better long-term stability, and more grounded cement quality and conductive substrates. He advanced hybrid films with 20% weight proportion of graphene which was created by vacuum filtration, demonstrate the best electron outflow execution with a low turn-on field of 0.50 V/µm (at 1 µAcm^{-2}) and a high field enhancement factor β of 27000.

Shi et al. (2013) perform an experiment tested for “The electron field emission from a composite of CNT and graphene sheets by transferred method” In this graphene layer were used for CNT transferred onto it and to study the field emission property of this hybrid structure was tested by a diode structure device. And from the output result, it has been found that the hybrid emitter shows better performance in the field emission properties such a low turn-on field, high emission current in compared it with CNT directly grown on silicon substrates. Graphene was used due to its good emitter property for its excellent conductivity. The trial results because of the improvement of the graphene layer, the turn-on field was kept at 1.5 V/µm, yet there is the greatest current raised from 0.95 µA to 1.57 µA at the connected field of 3.25

V/µm. There are numerous components that may add to the improvement of the field outflow qualities. One reason most likely is the ohmic contact among graphene and CNT nanowires. These contacts decide the proficient electron exchange from the graphene layer to the CNT producer and improve the field discharge properties. Moreover, graphene is likewise a decent possibility for the field emission because of its edges and splits going about as the extra producer emitter dots.

Nguyen et al. (2012) reported a versatile synthesis process for the growth of carbon-nanotubes CNT)-graphene hybrid material by using the technique of rapid heating and cooling chemical vapour deposition. The thickness of graphene film and density of CNT are properly controlled by using copper foil and acetylene as the catalyst and varying the concentration of carbon feedstock gas (C_2H_2) respectively. The graphene film shows a sheet resistance of 2.15 kΩ sq^{-1} with a light transmittance of 85.6% (at 550 nm) while a CNT–graphene hybrid film reveals an improved sheet resistance of 420 Ω sq^{-1} with a light transmittance of 72.9%. Moreover, a CNT–Graphene film was demonstrated as an effective electron field emitter with low turn-on and threshold electric fields of 2.9 and 3.3 V/µm, respectively. The output shown from engineering graphene thickness and integrating CNTs onto graphene surfaces are useful for various applications in flexible electronics, such as transparent conductors and electron field emitters.

Lee et al. (2010) study Vertical N-doped carbon nanotube (VNCNT) arrays were decorated with Au, Ru, or Mn nanoparticles, and the effects of these particles on the field-emission properties were investigated. Homogeneous catalyst nanoparticles were all set by block copolymer lithography on a graphene film, and the VNCNT arrays were fully-fledged from the nanopatterned catalyst particles by plasma enhanced chemical vapour deposition (PECVD). The surfaces of the VNCNT arrays were subsequently decked out with metal particles, and the vertical alignment of the NCNT arrays was kept by high-vacuum annealing. The field-emission properties of the metal-particle-decorated VNCNT arrays diverse rendering to the changes in the work-function values, with the Mn-VNCNT field emitter showing the superlative performance among the emitters tested. Due to the presence of metal particles which cause an enhancement of field emission performance for Mn-VNCNT such as low turn-on electric field of 0.7 V/µm, the maximum current density 1.2 mA/cm^2 and the enhancement factor β value 6700 which is low because of the large particle size.

Van et al. has fabricated ultrathin freestanding carbon nanotube–graphene hybrid structures for field emission applications and device was able to generate an emission current of 846 µA, which is equivalent to one emitter generating 150 nA at 200 V. Li et. al. has deposited nitrogen-doped carbon nanotube arrays grown on graphene substrate by two-step process and found that density of CNTs can be control by catalyst nanoparticles.

Table 1: Field emission parameter of CNT-graphene hybrid

S.No.	Material	Synthesis Process	Turn-On Field	Max Current Density	Enhancement Factor	References
1.	CNT and Graphene	Microwave PECVD	1.6μm^{-1}	2.8 mA/cm^2	5540	Atul et al, 2015
2.	CNT and Graphene	Electrophoretic deposition	1.0 V/μm	2.3 mA/cm^2	6471	Hong et al, 2015
3.	Graphene and DWCNT	Vacuum filtration and screen printing	0.50 V/μm	1 μA/cm^2	27000	Xu et al, 2013
4.	Graphene/ carbon nanofilament hybrids	Electrochemical self-exfoliation	1.34V/μm	1.5 mA/ cm^2	4930	Dai et al, 2017
5.	rGO-CNT	Vacuum filtration method	2.8 V/μm	1.3 mA/cm^2	3976	Duc et al, 2014
6.	Vertical N-Doped Carbon Nanotube/Graphene Hybrid Films	PECVD	1.0 V/μm	1.2 mA/cm^2	7600	Lee et al, 2010
7.	CNT and Graphene	Radio Frequency Sputtering Deposition	0.956 V/μm	11.349 mA/cm^2	4398	Deng el at, 2012
8.	CNT and Graphene	Radio frequency hydrogen plasma sputtering deposition	0.98 V/μm	11.17 mA/cm^2	3980	Deng et al, 2012
9.	CNT and Graphene	CVD	4 V/μm.	10 mA/cm^2	-	Zhao et al, 2015
10.	Pd-CNTs-rGO	Microwave method.	3.2 V/μm	-	4230.4	Kumar et al, 2017
11.	CNT and Graphene	Transferred method	1.5 V/μm	-	-	Shi et al, 2013
12.	GO and CNT	Water-processed method	0.79V/μm	0.1 mA/cm^2	1.3 × 10^4	Song el al, 2015
13.	CNT and Graphene	CVD	2.9 V/μm	-	1373	Nguyen et al, 2012
14.	Graphene and DWCNT	Screen printing	0.62V/μm	1 μA/cm^2	13000	J. Xu et al. 2013
15.	Vertically oriented carbon nanosheet (VCNS) and carbon nanotube (CNT)	Microwave plasma-assisted chemical vapor deposition technique	1.0 V/μm	3.2 mA/cm^2	-	X.P Wang et al, 2013
16.	Graphene Wrapped	CVD	0.61 V/μm	2.5 mA/cm^2	6958	Nayak et al, 2014

	Carbon Nanotube Composites					
17.	rGO-CNTs	Electrophoretic deposition	0.26 V/µm	10 µA/cm^2	33431	Roy et al, 2013

3. Conclusion

In summary, we have first reviewed about Carbon-nanotubes and Graphene properties and their synthesis processes. CNT-Graphene hybrid structure and their field emission performance such as low turn-on electric field, low threshold electric field, the maximum current density and the β factor have also studied. There are many factors which are responsible for the enhancement of field emission properties like the ohmic contact between CNT and graphene. Also, the graphene is a good candidate for field emission due to sharp edges. The catalyst plays an important in altering the properties of hybrid material. By controlling CNTs and graphene in hybrid material, a highly stable, economic field emitter can be fabricated. Finally, we suggest that CNTs-graphene hybrid holds great promise as a material for novel research on planar as well as vertical aligned hybrid architectures of the future.

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