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Graphene Coatings Technology on Tribologyperspective

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ABSTRACT: ***Graphene is a two-dimensional carbon allotrope that has developed as an extraordinarily flexible material and has gotten overall consideration on the 21st century. In this concise survey, we have exhibited a portion of the ongoing disclosure of carbon-based materials especially graphene. This paper additionally examined the graphene developing technique that was directed by past research and concentrating on the Chemical Vapor Deposition (CVD) strategy. The tribologicalconduct of graphene at full scale were likewise talked about dependent on past investigation concentrating on the wear and coefficient of grating. A review of full scale tribological properties of broadly utilized strong greases including Diamond like Carbon (DLC), graphite, shapeless carbon, Ultrananochrystalline precious stone, and furthermore graphene oxide were likewise talked about. Outline of the collaboration between steel-to-steel contact and steel-to-graphite/graphene/graphene oxide were additionally talked about. It was discovered that the graphene had the best execution even contrasted with the business graphite due with its capacity to wipe out erosion. This paper closed with the future prospect for graphene as application to different fields. The brilliance tribological conduct of graphene had guaranteed its future towards this field as covering materials and oil added substances. In different fields, graphene has possibilities in electronic and optical. By the by, look into around there is still in an early improvement stage and considerably more work is expected to understand graphene's innovative potential.***

KEYWORDS : *Wear, Mechanisms, Carbon, Coating, Sliding,*

1. INTRODUCTION

Consistent interest in decreasing rubbing and wear in different enterprises has expanded enthusiasm for analysts in discoveries front line innovation towards this issue. After incredible revelation towards carbon nanotubes (CNTs), graphene has turned out to be exciting disclosure in late twentieth century.

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Graphene is the sp2 allotrope which has monolayer film comprising of carbon molecule that were masterminded in two-dimensional hexagonal grid [1]. As indicated by [2], there are four types of measurement, for example, zero-dimensional, one-dimensional, two-dimensional and three-dimensional. It is said that nanotubes, graphite and graphene are carbon allotropes that present in there structures. Up until this point, inside the carbon allotropes family, graphene had the most brilliance mechanical, electrical, optical, basic and warm properties [1]– [9] .Due to these perfection properties, graphene has potential in gigantic application range, for example, power module, sun oriented cell, terminals, transistors, sensors, and furthermore as antifriction materials. Previously, before the discovery of graphene multi-potentials, there were many attempted in producing frictionless materials or at least super-low friction materials in order to reduce friction and wear in tribology field. This field were constantly demanded by automotive and machinery industries as they are highly dependable towards the ability to control the behavior of friction and wear. Various materials and methods has been studied not only focusing on liquid lubrication, but also gas and solid lubrication[10]–[18]. Among those study, the potential of carbon as self-lubricating materials has been discovered[19], [20].

2. COATING TECHNOLOGY

The potentials of carbon does not stop there, researchers also found that carbon as coating materials gives super-low friction between two contacting surface. These type of coating were called as Diamond like Carbon (DLC) coating and its ability surpass other types of lubrications including oil and grease[21]–[24]. This successful findings able the DLC technology to be implemented, however only in several parts of luxury vehicles as it is expensive[25], [26]. Due to thigh cost of graphite and carbon-nanotubes, alternatives solution has been demanded.

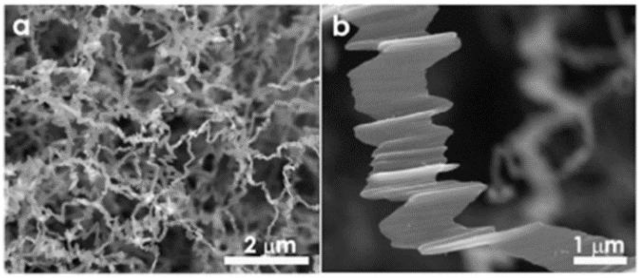
According to today, there were a few technique distributed on developing carbon, for example, Thermal Chemical Vapor Deposition (T-CVD), Plasma Enhanced Chemical Vapor Deposition (PE-CVD), Electron

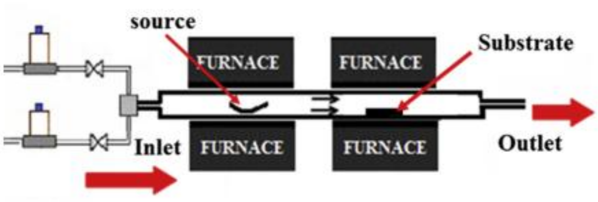
Cyclotron Resonance Chemical Vapor Deposition (ECR-CVD), Physical Vapor Deposition (PVD), Thermal Spraying (TS), micromechanical shedding of graphite (strip off strategy), epitaxial development on electrically protecting surfaces, and compound/arrangement based decrease of graphene oxide [5], [8], [9], [27], [28] Among those strategies, CVD were considered as the most solid strategy as it has potential on expansive scaled creation [29].

2.1 Graphene Growth via CVD Method

As mentioned previously, there were several ways to grow carbon, however this paper are only discussed briefly towards the graphene growth via CVD method. This is because graphene has the most excellent physical-mechanical properties among other carbon allotropes and CVD method are the most realistic method to be applied for large-scaled production. Through previous study, researchers have been decided that study towards graphene can be divided into three sub-areas which are; the characterization of the special physical properties, device applications, and the materials science of graphene. Previous research on graphene growth through CVD shows the graphenenano-ribbons obtained in Figure 1.

Graphene growth process can be conducted by using either liquid source or solid source[30]. Theoretically, both process are the same where the graphene were growth on vertical quartz tube with constant gas flow with source feed. The schematic diagram of CVD were illustrated in Figure 2.





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The distinction between graphene, graphite, and carbon nano-cylinders can be acquired through Raman Spectroscopy investigation. The Raman Spectroscopy examination introduced results in term of pinnacle readings comprise of D, G, D', G', and 2D top. The power, move position, and the width (FWHM) esteem decides these allotropes. As indicated by [31], their discoveries get that the Raman Spectra demonstrate an extremely little deformity initiated D band, which introducing high caliber of graphene precious stone. Graphitic G and second request 2D Raman pinnacles are seen at 1590 and 2700 cm-1, separately. The higher force of 2D top than that of G top, exhibits a solitary layer graphene. Once more, FWHM of G and 2D tops are observed to be 19 and 44.2 cm-1, separately which they asserted it reliable with revealed esteems for graphene.

2.2 Tribological Behavior of Graphene at Macro-Scale

As indicated by [1], there were less examination on tribological properties of graphene at large scale contrasted with miniaturized scale and nano-scale. They additionally organize as appeared table 1, their speedy audit of other known strong oil materials generally utilized by different ventures worldwide with the new potential strong ointment dependent on graphene.

Table 1: Overview of macro-scale tribological properties of widely used solid lubricants
(source:[1])

Solid lubricant coating	Deposition methods	Coating thickness (µm)	Typical friction coefficient	Wear/friction mechanism
Graphite	Evaporation, Pyrolysis	0.2-5	Dry : 0.5-0.6 Humid: 0.1-0.2	Interlayer shear and water intercalation
DLC	Sputtering, Ion-beam, PE-CVD	1-3	Dry : 0.001-0.05 Humid: 0.2-0.3	High chemical inertness and repulsive forces due to hydrogen termination
Tetrahedral amorphous carbon	Ion-beam, Cathodic arc, Pulsed laser	0.01-1	Dry : 0.7 Humid: 0.1	Tribo-chemically induced surface reaction and termination of top carbon atoms
Ultrananochrystalline diamond	MP-CVD, HF-CVD	0.5-1.5	Dry : 0.05-0.13 Humid: 0.007-0.1	Tribo-chemically induced reaction with H, O, or OH
MoS_2 and WS_2	Sputtering, TE-CVD, ALD	0.2-2	Dry : 0.02-0.06 Humid: 0.15-0.25 (initial & increasing)	Interlayer shear and transfer film formation Interlayer
Graphene/graphene oxide	CVD, Chemical & mechanical exfoliation	0.001-0.002	Dry : 0.15-0.2 Humid: 0.15-0.02	Interlayer shear and prevention of tribo-corrosion

As indicated by [32] , their investigation on CVD developed graphene demonstrates that grating power of graphene are higher on its outskirts contrasted with different zones because of the arrangement of graphene oxide. Thus, when looking at the bond drive, the attachment powers are higher because of the nearness of graphene oxides. It is trusted that the glue constrain between surfaces has the hairlike power, van der Waals drive, electrostatic power and compound holding power. In surrounding air, it is said that the hairlike power is a primary supporter of the attachment and firmly identified with surface wettability. Likewise, it has been affirmed that the unpleasantness of test surface has solid impact on its wettability. In the mean time, at hydrophilic surface, the wettability increments with the unpleasantness of test surface.While hydrophobic surface will be increasingly hydrophobic with the expansion of surface harshness.

The tribological conduct of graphene oxide at large scale is observed to be very little unique in relation to the graphene layers. Anyway it is as opposed to the nano-scale and miniaturized scale thinks about on graphite oxide [1]. There were diverse instrument occurred and needs further examinations to comprehend the precise component. The discoveries on wear rate and coefficient of rubbing for exposed steel and covered steel were exhibited in Table 2. They likewise presumed that graphene layers give the best wear assurance by lessening the wear contrast with the exposed steel. They additionally guaranteed that the finding is great as the measure of graphene layers from ethanol arrangement utilized was the littlest to accomplish great, stable oil enduring a huge number of cycles. In the interim, the wear rate for graphene oxide are bigger than the graphene layers. This distinction were accepted were because of the way that the oxygen nearness in graphene oxide may cause erosion of steel, therefore expanding the wear, while sliding between graphene oxide layers guarantees low coefficient of grinding. Along these lines, the similarly low coefficient of contact for graphene oxide does not give as great wear insurance.

Table 2: Wear volume, wear rate, and coefficient of friction for bare steel and graphite/graphene/graphene oxide coated steel (source:[1])

Tribo pair	Test condition	Wear volume	Wear rate	Coefficient of Friction
Steel/Steel	Air Nitrogen	6.8×10^{-3} mm^3 4.9×10^{-4} mm^3	1.8×10^{-5} mm^3/Nm 1.31×10^{-6} mm^3/Nm	1.00 0.90
Steel/ Graphene	Air Nitrogen	11.4×10^{-7} mm^3 9.6×10^{-7} mm^3	3.01×10^{-9} mm^3/Nm 2.54×10^{-9} mm^3/Nm	0.15 0.15
Steel/ Graphite	Air Nitrogen	1.9×10^{-5} mm^3 1.9×10^{-4} mm^3	4.94×10^{-8} mm^3/Nm 5.07×10^{-7} mm^3/Nm	0.17 0.80
Steel/Graphene Oxide	Water/Air Nitrogen	2.5×10^{-5} mm^3 7.8×10^{-5} mm^3	6.51×10^{-8} mm^3/Nm 2.08×10^{-7} mm^3/Nm	0.17 0.16

Despite the fact that graphite produce moderately low coefficient of contact and wear on air, it become more regrettable on nitrogen. Not just graphite unfit to deliver great dainty film inclusion as graphene, it likewise does not shield the surface from consumption, which results in higher wear. In addition, for graphite to build up a likewise low coefficient of erosion requires an a lot bigger measure of material.

Interestingly, study conducted by[33], by comparing the effect between nanocrystalline diamond (NCD) and microcrystalline diamond (MCD) coatings, they found that the average coefficient of friction of NCD are slightly lower compared to the MCD [34]. They also claimed that MCD coating presents a higher value of coefficient of friction initially, but it becomes comparable to that of NCD coating after longer sliding time [35].

2.3 Prospect for Graphene

The exceptional properties of graphene has made this materials compelling for various engineering applications. Besides being used as self-lubricating materials and coatings technology, graphene also has potentials in becoming additives for lubricants. Particularly, engine oils requires additives to reduce friction and wear inside the engine oil that able to perform at extreme condition [36]. Previous research had found that graphene platelets were added into oils as an attempt to reduce friction and wear. This attempt were successful as the graphene were able to reduce the friction and wear.

In other diverse investigation, graphene platelets can decrease the wear of other strong ointments. The wear rate of polytetrafluoroethylene (PTFE) was diminished when certain measure of graphene platelets was joined as nano-fillers. The graphene fillers ready to meddle between the breaks and sub-surface split that shaped before, along these lines decreasing the wear of the PTFE.

Another utilization of graphene were including the use of graphene as polymer composites for mechanical parts, vitality stockpiling, for example, power device, sensors, and furthermore gadgets segments. Towards optical application, graphene were utilized in optical magnifying lens with assistance of reasonable substrates to make differentiate between various layers. In any case, more research is expected to build up a straightforward discovery strategy for unblemished graphene that is autonomous of help material.

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