DREAM DREAM

勹

PURSUE VISIONS

## by virtue of its relationship with

FULL POWER DESIGN WORKS

## is pleased to present these opportunities for project fun山ng

For an advanced method of applying GRAPHENE to large surfaces through

## Thermal plasma sputtering of graphene

HISTORY: THE DISCOVERY OF GRAPHENE AS A SINGLE ATOM LAYER DATES BACK ALMOST 15 YEARS. SEVERAL PAPERS HAVE BEEN PUBLISHED TO DEMONSTRATE THE MATER 趴 L' S HIGH ELECTRON MOBILITY, EXCELLENT THERMAL AND MECHANICAL AS WELL AS OPTICAL PROPERTIES.

DILEMMA: THERE A SEVERAL REASONS WHY LARGE-SCALE GRAPHENE COATING HAS BEEN DIFFICULT TO ACCOMPLISH. SOME OF THE MORE NOTABLE ONES ARE: 、、

1. DEVELOPING COMMERC趴 L- SCALE GRAPHENE COATINGS FOR THE FABRICATION OF LARGE­ AREA, DEFECT-FREE GRAPHENE FILMS SUITABLE FOR INDUSTRIAL USE.
2. THE LIST OF: CONTROL OF GRAPHENE. MATERIALS; SCALABLE DEPOSITION. OF GRAPHENE BASED COATINGS ON SUBSTRATES; LONG LASTING CORROSION PROTECTION STRATEGIES; COST OF MANUFACTURING VS RELIABILITY OPTIMIZATION; ONE OF THE MOST NOTEWORTHY, MUST BE SEGREGATED FROM THIS GROUP AND THAT IS THE ENVIRONMENTAL IMPACT IN TODAY'S "ZERO FOOTPRINT" WORLD.

THE FPDW DETERMINATION: OUR SUGGESTION FOR ACTION CONCENTRATES ON THE DEVELOPMENT OF EQUIPMENT THAT WILL PROVIDE SUPERIOR BENEFITS THROUGH THE DEVELOPMENT OF A THER归 SPRAY WELDING MACHINE FOR APPLYING GRAPHENE TO A LARGE DIMENSION SUBSTRATE. OUR DESIGN WILL INCLUDE PROVIDING THICK COATINGS OVER A LARGE AREA AT A HIGH DEPOSITION RATE. THIS WILL BE A SIGNIFICANT IMPROVEMENT CONTRASTED TO OLDER COATING PROCESSES, LIKE ELECTROPLATING AND PHYSICAL AND CHEMICAL VAPOR DEPOSITION.



DETAIL

1. GRAPHENE

## 1 a. Material description

Graphene 1s a matenal made of carbon atoms arranged in a hexagonal lattice, like a honeycomb in a single layer, two-dimensional hexagonal atomic lattice structure of carbon. Being merely one atom thick it is thought to be the thinnest material known. It was a theoretical substance until it was isolated from graphite in 2004 by Andre Geim and Konstantin Novoselov at the University of Manchester. Graphene features a wealth of odd and useful characteristics . It has interesting light absorption ab 山 ties and unlimited potential for integration in almost any industry

A list of the most outstanding of these characteristics includes

* + High thermal conductivity;
  + 200 times stronger than steel by weight and 1,000 times lighter than paper;
  + Highly transparency;
  + High electrical conductivity (conducts electricity better than any other known material at room temperature);
  + Can convert light at any wavelength into a current;
  + High elasticity and flex伽 lity

Still more detail and further explanation can be viewed at: https: //en.wi伈pedia.orq/wiki/Graphene

Wagner & Partners UG Donaus trasse 27

40699 Erkrath - Germany

空 +49 ( 0 ) 2104 5080 558

## 巳 info@wagner-partners.com

www.wagne r-partners.com Geschaftsfuhrer:Wagn er, Gisbert

Ust-1D Nr.:DE317 682 413

HRB 28823 Wuppertal

口 OWER DESIGN VVO 口

1 b. USE OF REINFORCED THERMAL PLASMA SPRAYING FOR PREPARING EXFOLIATED GRAPHENE

As yet, large commercially viable quantities of graphene have been difficult to procure. V; 叩 OUS processes have been examined involving some manner of chemical interactions. Although chemical vapor deposition (CVD) does produce high quality graphene depositions on various substrates, continuous, high-volume production proves to be challenging

# METHOD OF PRODUCTION

2a. UNIVERSITY AND INDUSTRY RESEARCH STUDIES AND LABORATORY TRIALS

Graphene

In the last few years, several studies have been performed attempting to develop a commercially viable methods that would enable large volumes of graphene to be consistently generated and deposited These trials involving reinforced thermal plasma spraying have been tested for prep 扛 ing exfoliated graphene. Researchers have reported an ultrafast way to peel graphene flakes a few atoms thick from

graphite using a high-temperature plasma spray process. The method involves melting powdered coating materials in a jet of plasma— a high-temperature gas of ions —and spraying them on a surface. The

thermal shock from the 3,000 K temperature and the turbulent eddies in the resulting plume rip apart the graphite into graphene flakes. The researchers collected the sprayed powder, put it in deionized water, and spun it in a centrifuge to remove unexfoliated clumps of graphite

Further details on the different experimental processes can be found at:

https://en.w 如 pedia.org/w 如 /Thermal spraving https://weldingpros.net/sprav-welding/ https://weldguru.com/sp rav-weldin幻https://weldinginsider.com/thermal-sprav-welding/

2b . Employing high temperature plasma spraying from numerous carbon sources such as graphite, soot, carbon black and other carbon rich materials. By combining the use of a high temperature plasma source along with high velocity sputtering in an inert environment, this carbon rich media is converted into a high purity graphene overlay



# The Request for Funding

Still, to date there is no commercially viable method OF PRODUCTION for large scale graphene application

However, researchers are working on developing new methods to produce graphene at a lower cost and in larger quantities. Therefore, time is of the essence to push forward on our proof-of-concept for the plasma spray process that is the subject of this Request for Funding

# THE FPDW PROPOSED METHOD OF PRODUCTION

Them叫 spray welding is a means of depositing a coating layer of material onto the su甘ace ofa substrate.

2D films and heterostruct ures re皿re high crystal quality and homogeneous thickness for applications such as electronics and spintronics, whereas high-porosity powders with vast specific surface area can be used in contexts such as catalysts and energy storage

* 1. Benefits of our intended process (Overview):

The benefits of developing a thermal spray welding machine for applying graphene to a large dimension substrate include providing thick coatings over a large area at a high deposition rate compared to other coating processes such as electroplating and physical and chemical vapor deposition. The use of large. multi-la er ra hene sheets has been shown to deliver hi h them 设 1 conducti vit com osites. However, controllin electrical and thermal ercolation in com osites with ra hene usin filler o timization and erha s combinin ra hene with other electricall insulatin 2D fillers such as hexa onal boron nitride h-BN\* . remains an im ortant challen e for further develo ment of ra hene thermal com ositse

口 OWER DESIGN VV0°

\*= traditionally used in various applica tions such as transformer oil nanofluids. epo芍 resin, and multi/aver h-BN They are highly appreciatedfor their excellent insula ting performance and absence of dangling bonsd

* 1. Benefits of our intended process (further detail):

As a means of conveniently delivering the carbon media to the plasma flame, supplementary examination would involve ultrasonic homogenization of the carbon-based media (graphite, soot, carbon black) with a carrier liquid such as purified water, utilizing compressor generated nebulization of this mixture to produce a fine aerosol, and exposing this to the high temperature plasma jet. Entrairunent of the media with a liquid would account for the elimination of dust caused by the dry carbon powder and provide a more precise method of metering the compound at the plasma arc. For metallic substrates, an electrical connection to the main plasma power supply would allow the sprayed graphene nanoparticles ejected from the plasma arc to electrostatically adhere to the target surface very similar to the powder coating process.

NB. Liquid carrier subst ances other than wat er may also qualify; but that would need to be studied separately

1. Repurposing existing equipment

Focused discov ery has revealed that a typical, readily avai lable plasma cutting apparatus can be converted to provide the fundamental means necessary to produce graphene on a metal surface reliably

Examples of equipment that may lend themselves well to the necessary requirement s for higher volume production

can be studied at:



htt [s://www.](http://www/) ro enesis.com/ roducts-services/ lasma-torches/mini htt [s://www.](http://www/) ro enesis.com/ roducts-services/ lasma-torches/a t/

# MARKETS

The equipment required to reliably produce these larger volumes of graphene is relatively simple, which makes it easy to adapt for use in many different market areas. As a result, users of this equipment would be quite diverse.

To make it more convenient for users of graphene producing equipment , a consumable component of carbon black and purified water could be offered for purchase. The finely ground carbon black material may be obtained from the used tire industry, which adds to the environmental desirability of this product and production technique . This system may also provide users with a channel for benefiting from the carbon credit program For convenience purposes, and in conjunction with the appropriate equipment for producing graphene, a consumable component of carbon black and purified water could also be offered for purchase. The finely ground carbon black material may be ob即 ned from the used tire indust序adding to the environmental desirab山ty of this product and production technique . This system may also provide users a channel for benefiting from the carbon credit program

An obvious market segment that would benefit substantially from easily applied graphene coatings is the internal combustion engine sector as coated surfaces reduce friction, improve thermal conductivit y, and enhance strength. Because of graphene' s minute friction characteristics, carbon deposits may not stick as easily to coated intake man 心 ld and cylinder heads, thereby improving airflow and enhancing volumetric efficiency. Further investigation may reveal that adding graphene directly to molten metals just before they are cast could produce additional desirable properties of wear resistance, increased strength and improved thermal and electrical conductivity

口 OWER DESIGN WO 口

The Taurozzi Pendulum Engine would be an ideal demonstration example to coat, as oil lubrication is inherently unnecessary and would be completely eliminated with a graphene coating. Thermal conductivity could be improved even more, aiding in the air cooling of the engine

[https://www.youtube.com/watch?v=Gl9pkcFJXV4](http://www.youtube.com/watch?v=Gl9pkcFJXV4)

[https://www.youtube.com/watch?v=5ekoNVc6pmO](http://www.youtube.com/watch?v=5ekoNVc6pmO)

The elimination of these liquids reduces the compl exity of the overall engine design as lubricant and coolant passages, as well as pumps, are no longer required. Since these items can be eliminatedfrom this engine configuration , a considerably smaller environmental imp ac t could also be realized

1. Another engine configuration that could benefit from graphene coatings is the Omega 1 engine [https://www.youtube.com/watch?v=CKK6Ev-](http://www.youtube.com/watch?v=CKK6Ev-) Mug

h[ttps://www.youtube.c](http://www.youtube.com/watch?v=paAlx9EoNwE)o[m/watch?v=p](http://www.youtube.com/watch?v=paAlx9EoNwE) aAlx9[EoNwE](http://www.youtube.com/watch?v=paAlx9EoNwE) https://astronaerospace.com/

1. As hydrogen becomes a greater focus as a substitute for petroleum use, emphasis on increasing the efficiency of hydrogen production provides greater motivation to employ the use of graphene for this purpose Conventional electrolysis cells use electricity to 小 ssociate water into its hydrogen and oxygen components Coating the electrodes involved in this process with a layer of graphene may facilitate si 如 fi cant hydrogen production efficiency improvements .
2. The 3D printing sector would also benefit by embedding graphene nanoparticles in v 叨 ous processes 3D printed structures with graphene added to granular nylon material used in the selective laser sintering (SLS) or the UV sensitive stereo lithography (SL) resin would have greater strength and higher temperature characteristics allowing for even broader applications.
3. Graphene can also e妇 ce battery and capacitor attributes and will lead to the reduction or elimination of hard to source materials such as lithium and cobalt for batteries. Construction costs could be significantly reduced by employing continuous roll manufacturing of ultra-capacitor and batte 盯 substrates
4. . As the focus on renewable energy intensifies, escalation of the use of rare earth materials can instigate political consequences affecting manufacturing costs and creating supply chain issues. Since magnets play such a large central role in the field of renewable energy, they are in great demand. Recent discoveries in alternative sustainable elements appear to indicate that a magnetically viable amalgamated compound called tetrataenite can be viably commercially produced by ad 中 ng a small amount of phosphor to the iron and nickel base. By adding or substituting sm 斗 1amounts of graphene to tetrataenite mixtures, magnetic properties may be markedly boosted , as the graphene could provide a seed crystalline lattice structure for the amalgamated material to form on as it cools. Additional information can be found here:

htt s://onlinelibrar .wile .com/doi/10.1002/advs.202204315 htt [s://www.nature.com/articles/s41598-020-634](http://www.nature.com/articles/s41598-020-63478-7)78-7

口 OWER DESIGN VV O 口

1. APPENDIX

Foundational papers relating to high volume, commercially viable formation of graphene through the use of high temperature plasma spraying:

htt s:// ubs.acs.or /doi/ fu ll/10 . 10 21/acs a m i.9 b04239 htt s:// u bs.acs .or /doi/fu ll/10 . 10 21/acs na no .Oc 09451

