GRAPHENE HEAT TRANSFER

Field

[0001] This invention relates to graphene coatings for use in improved heat transfer, and particularly high purity graphene including graphene nanoplatelets and graphene nanoparticles derived from carbon containing gas. The invention also relates to methods of forming such coatings.

Background

[0002] Heat exchangers are important for removing heat from one location to another. For example, heat exchangers find common use in industrial settings for heating or cooling industrial streams. In other examples, heat exchangers find common use as components of electrical equipment for cooling electrical components which heat during use. It is desirable to provide heat exchange surfaces that have high heat transfer properties to facilitate heat exchange.

[0003] It is an object of the invention to address one or more shortcomings of the prior art and/or provide a useful alternative.

[0004] Reference to any prior art in this specification is not, and should not be taken as, an acknowledgement or any form of suggestion that the prior art forms part of the common general knowledge of a person skilled in the art.

[0005] As used herein, except where the context requires otherwise, the term "comprise" and variations of the term, such as "comprising", "comprises" and "comprised", are not intended to exclude further additives, components, integers or steps.

Summary

[0006] There is provided a heat exchange coating composition for coating a surface of a substrate, the composition comprising graphene nanoparticles derived from a carbon gas and one or more dispersing agents dispersed in an emulsion or a resin, the coated surface having higher efficiency heat transfer than the uncoated surface.

[0007] In an example, the composition includes graphene nanoparticles in an amount equal to or less than a wt% value selected from the group consisting of: 0.01%, 0.05%, 0.10%, 0.5%, 1%, 2%, 3%, 5%, 10%, 20%, 30%, 50%, by weight of graphene nanoparticles. Alternatively, or additionally, the composition comprises graphene nanoparticles in an amount equal to or greater than a wt% value selected from the group consisting of: 0.01%, 0.05%, 0.10%, 0.5%, 1%, 2% by weight of graphene nanoparticles. In preferred forms of the above examples, the composition comprises graphene nanoparticles in amount of from about 0.01 wt% to about 50 wt%.

[0008] In an example, the graphene nanoparticles are in the form of particles or platelets or flakes with a size in the range of 2 nm to 100 microns.

[0009] In an example the dispersing agents are selected from the group consisting of anionic, nonionic, cationic dispersants or additives, and combinations thereof.

[0010] In an example, the emulsion or resin comprises one or more additives selected from the group consisting of anionic, nonionic, cationic dispersants or additives, and combinations thereof.

[0011] In an example, the graphene nanoparticles are in the form of solid flakes or powders.

[0012] In an example, the emulsion has a primary phase, and the primary phase or the resin is selected from the group consisting of acrylic, acrylic and epoxy, acrylic epoxy copolymer, styrene acrylic, polyurethane, epoxy, ethyl silicate, polysiloxane, polyurea, saturated or unsaturated polyester, polyaspartic, and combinations thereof.

[0013] In an example, the composition has a viscosity of about 50 s to about 70 s as measured using a Zhan type cup no. 2. Preferably the viscosity is about 55 s to about 65 s. The inventors have found that this viscosity is useful since it allows the composition to be readily applied onto a surface using a variety of coating techniques whilst also forming a cohesive coating that is substantially free of defects.

[0014] In an example, the composition has a pH greater than 7. Preferably the pH is from about 7 to 11. More preferably, the pH is from about 7.5. Most preferably, the pH is from about

8. Additionally or alternatively, it is preferred that the pH is up to about 10.5. Most preferably, the pH is up to about 10.

[0015] In an example, the composition has a density of greater than 1 kg/L. Preferably the density is greater than 1.05 kg/L. Most preferably, the density is greater than 1.10 kg/L. Additionally or alternatively, the suspension has a density of up to 1.2 kg/L. Most preferably, up to about 1.15 kg/L.

[0016] In an example, the emulsion or resin is not and/or does not comprise a base oil, a lubricant, a lubricating oil, a grease, or a coolant.

[0017] There is provided a method for producing a graphene containing suspension for use as a heat exchange coating for coating a surface of a substrate, the method including:

combining the graphene nanoparticles derived from a carbon gas with one or more dispersing agents to form a combination; and

mixing the combination with an emulsion or resin to form the suspension for use as the coating, the coated surface having higher efficiency heat transfer than the uncoated surface.

[0018] In an example, the graphene nanoparticles are derived from a carbon gas and one or more other carbon containing precursors including graphite, carbon black, activated carbon and hard and soft carbons; graphene derived from gas, graphene derived from graphite, graphene oxide derived from graphite, modified carbon, carbon black or a composite of various carbon nanostructures. The carbon source may be graphite, gas and liquids containing carbon, and or biosolid feedstock.

[0019] In an example, the method comprises combining the graphene nanoparticles in an amount equal to or less than a wt% value selected from the group consisting of: 0.01%, 0.05%, 0.10%, 0.5%, 1%, 2%, 3%, 5%, 10%, 20%, 30%, 50%, by weight of graphene nanoparticles. Alternatively ,or additionally, combining the graphene nanoparticles in an amount equal to or greater than a wt% value selected from the group consisting of: 0.01%, 0.05%, 0.10%, 0.5%, 1%, 2%, 3%, 5%, 10%, 20%, 30% by weight of graphene nanoparticles.

In preferred forms of the above examples, the method comprises combining the graphene nanoparticles in amount of from about 0.01 wt% to about 50 wt%. The weight % values are preferably based on the total weight of the coating composition.

[0020] In an example, the graphene nanoparticles are in the form of particles or platelets or flakes with a size in the range of 2 nm to 100 microns.

[0021] In an example, the graphene nanoparticles are in the form of solid flakes or powders.

[0022] In an example, the dispersing agents are selected from the group consisting of anionic, nonionic, cationic dispersants or additives, and combinations thereof.

[0023] In an example, the emulsion or resin comprises one or more additives selected from the group consisting of anionic, nonionic, cationic dispersants or additives, and combinations thereof.

[0024] In an example, the step of mixing comprises high shear mixing with a shear rate of 10,000 s^{-1} or greater. Preferably the shear rate is from about 40,000 to about 60,000 s^{-1}. Preferably, the step of mixing is conducted for a time of from about 3 minutes to about 72 hours. More preferably, the mixing time is from about 1 to about 4 hours. The shear rate and mixing time are dependent upon varying dispersion and distribution combinations. However, the inventors have found that this shear rate and/or time is useful to disperse and distribute the graphene nanoparticles into the emulsion or resin.

[0025] In an example, the step of mixing is carried out using a ball mill or bead mill or a jet mill or other milling equipment.

[0026] In an example, the emulsion has a primary phase, and the primary phase or the resin is selected from the group consisting of acrylic, acrylic and epoxy, acrylic epoxy copolymer, styrene acrylic, polyurethane, epoxy, ethyl silicate, polysiloxane, polyurea, saturated or unsaturated polyester, polyaspartic, and combinations thereof.

[0027] In an example, the suspension has a viscosity of about 50 s to about 70 s as measured using a Zhan type cup no. 2. Preferably the viscosity is about 55 s to about 65 s.

[0028] In an example, the emulsion or resin is not and/or does not comprise a base oil, a lubricant, a lubricating oil, a grease, or a coolant.

[0029] There is provided a heat exchange wall or a heat exchanger comprising a substrate having a thermally conductive coating of graphene nanoparticles applied to at least a first surface thereof, wherein the graphene nanoparticles are derived from a carbon gas, the coated first surface having higher efficiency heat transfer than the uncoated first surface. The heat exchange wall may have a second surface in conductive contact with the first surface. The substrate may be metal, plastic or any other heat conducting surface. Preferably, the second surface is in thermal conductive contact with the first surface.

[0029a] In one aspect of the disclosure, there is provided a heat exchange wall or heat exchanger comprising: a substrate having a thermally conductive coating of graphene nanoparticles applied to at least a first surface thereof, wherein the graphene nanoparticles are derived from a carbon gas and combined with one or more dispersing agents in an emulsion or a resin comprising acrylic, epoxy, or combinations thereof, the coated first surface having higher efficiency heat transfer than the uncoated first surface.

[0030] The heat exchange wall may be in the form of a shell, tube, plate, baffle, coil, fin, or other such heat exchange surfaces that are commonly used in heat exchangers or heat exchange devices.

[0031] The coating is a coating as defined herein and/or examples and/or forms thereof.

[0032] The coating is formed according to the method as defined herein and/or examples thereof.

[0033] In one example, the coating of graphene nanoparticles is configured to receive heat from the substrate and transmit or otherwise conduct heat from the substrate. In an alternative example, the coating of graphene nanoparticles is configured to receive heat from a heat source and conduct heat to the substrate.

[0034] In an example, the substrate is a thermally conductive material, and the heat exchange wall is configured such that heat is received by a second surface and is conducted through the substrate to the first surface. In one form the second surface is substantially free of the conductive coating of graphene nanoparticles. However, in an

alternative form, the second surface has a conductive coating of graphene nanoparticles applied thereto.

[0035] There is provided a method of preparing a heat exchange surface, the method comprising: coating a surface of a substrate with a layer of graphene nanoparticles, wherein the graphene nanoparticles are derived from a carbon gas, the coated surface having higher efficiency heat transfer than the uncoated surface. The substrate may be metal, plastic or any other heat conducting surface.

[0036] In an example, the step of coating the surface comprises applying one or more layers of the graphene containing suspension as defined herein and/or examples and/or forms thereof, to the surface to form a coating thereon.

[0037] In an example, the step of coating the surface comprises applying one or more layers of the graphene containing suspension formed according to the method as defined herein and/or examples and/or forms thereof to the surface to form a coating thereon.

[0038] Preferably, the method further includes drying or curing the graphene containing suspension to form the coating.

[0039] In an example, the heat exchange wall is part of a thermal system, and the thermal system comprises apparatus or means for applying vibration and/or strain to the coating of graphene nanoparticles and/or apparatus or means for applying a voltage across the coating of graphene nanoparticles.

[0040] There is provided a method of operating a thermal system comprising applying vibration and/or strain to the coating of graphene nanoparticles and/or applying a voltage across the coating of graphene nanoparticles. Preferably the method comprises applying heat to a first surface or a second surface thereof.

[0041] There is provided a solar panel comprising a thermally conductive material having a coating of graphene nanoparticles applied thereto, wherein the graphene nanoparticles are derived from a carbon containing gas.

[0041a] In another aspect of the disclosure, there is provided a solar panel comprising the wall or heat exchanger as defined herein.

[0042] In an example , the coating of graphene nanoparticles is a dried or cured layer of the coating composition as defined herein and/or examples and/or forms thereof.

[0043] In an example, the solar panel has a sun facing surface, and a rear facing surface, and wherein the rear facing surface has the coating of graphene nanoparticles applied thereto. Preferably, the sun facing surface comprises one or more photovoltaic cells.

[0044] Further aspects of the present disclosure and further examples of the aspects described in the preceding paragraphs will become apparent from the following description, given by way of example.

Figures

[0045] **Figure 1** is a photograph showing an experimental rig for testing the thermal heat transfer and retention properties of a material sample having a coating according to the present invention.

[0046] **Figure 2** is a photograph showing an uncoated material sample used in the experimental rig of Figure 1.

[0047] **Figure 3** is a photograph showing a coated material sample used in the experimental rig of Figure 1.

[0048] **Figure 4** is a thermal image of an uncoated and coated material during thermal testing in the experimental rig of Figure 1.

[0049] **Figure 5** is an illustration depicting heat transfer in the experimental rig of Figure 1 for an uncoated material sample as compared with a coated material sample.

Description of Embodiments

[0050] The present invention relates to graphene suspensions for use as coatings, graphene coatings, or graphene coated surfaces to improve and facilitate heat transfer effects. The coating can be applied to improve thermal transmission. The thermal transmission can be enhanced by coating an emissive / radiative surface.

[0051] In relation to enhanced thermal transmission, the inventors have found that coating a surface with graphene nanoparticles facilitates highly efficient heat transfer. In particular, the inventors have found that heat exchange surfaces that are coated with graphene nanoparticles are able to facilitate rates of heat transfer generally exceed that possible through standard physical heat transfer mechanisms such as conduction and/or convection. Without wishing to be bound by theory, the inventors are of the view that the graphene coatings of the invention are able to