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(54) **Title**: ELECTROMAGNETIC INTERFERENCE SHIELDING COATING COMPOSITION AND METHOD OF MANUFACTURING THEREOF

(57) **Abstract**: An electromagnetic interference shielding coating composition is provided. The electromagnetic interference shielding coating composition includes a) about 1 wt% to about 30 wt% of a electromagnetic interference absorbing filler consisting essentially or consisting of multi-walled carbon nanotubes; b) about 5 wt% to about 40 wt% of a solvent, a dispersant and at least one additive; and c) about 30 wt% to about 94 wt% of a polymeric carrier matrix. Wt% of the components in the composition add up to 100 wt% and is calculated based on total weight of the electromagnetic interference shielding coating composition. A method of manufacturing the composition, and a method of reducing electromagnetic interference to an article are also provided.

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ELECTROMAGNETIC INTERFERENCE SHIELDING COATING COMPOSITION AND METHOD OF MANUFACTURING THEREOF

TECHNICAL FIELD

[0001] The invention relates to a coating composition for electromagnetic interference shielding, and method of manufacturing the coating composition.

BACKGROUND

[0002] Electromagnetic interference (EMI) refers generally to undesirable disturbance caused by electromagnetic conduction and radiation emitted from electronic equipment. Many electronic and information technology (IT) products today are sources of EMI. EMI may degrade or affect performance of electronic equipment and in extreme cases; it may even destroy electronic circuits.

[0003] EMI has been known to cause malfunction of medical, military, and aircraft systems; interference in telecommunications, leakage of sensitive business information, as well as jamming and destruction of sensitive equipment. EMI has also impeded the development and continuing growth of compact electronic, communication and medical products that run at broadband speed. EMI may also cause adverse health effects to human. Many diseases have correlated positively with a high exposure to electromagnetic fields. Therefore, EMI is a serious problem in this electronic age.

[0004] International directives and global technical standards have been issued to enforce regulation of EMI emission. An increasing number of countries have enacted strict EMI control measures in telecommunication, medical, and transportation equipment. All electrical and electronic products and systems are now required to comply with electromagnetic compatibility (EMC) and EMI standards. There exists a high demand for use of an EMI shield coating to reduce EMI hazards and their associated problems.

[0005] State of the art EMI shielding materials are mostly metal and conductive plastics in the form of plates, foils and films, as well as plating layers on the housings and casings of the electrical and electronic products and systems. These metal based shielding materials tend to be thick, heavy and are prone to corrosion. Furthermore, EMI leakages are often observed at the joints, edges and overlaps in metal sheet and plate shielding applications. In addition, use of the conductive plastic casing and housing is costly, which requires tailored injection molding process to produce conductive casing and housing.

[0006] Even though metallic and carbon based paints for EMI shielding exists, they have several notable drawbacks, such as corrosion of metallic absorbent, inadequate conductivity of carbon absorbent, narrow shielding frequency range, thick and heavy coated layers, as well as poor bonding strength with the substrate.

[0007] In view of the above, embodiments of the present disclosure aim to provide an improved EMI shielding material that overcomes or at least alleviates one or more of the above-mentioned problems.

[0008] Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present disclosure as it existed before the priority date of each of the appended claims.

[0009] Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

SUMMARY

[0010] In a first aspect, there is provided an electromagnetic interference shielding (EMI) paint composition comprising a homogeneous mixture of

a) 20 wt% to 40 wt% of a solvent, a dispersant, and at least one additive;
b) 50 wt% to 75 wt% of a polymeric carrier matrix, which is any one or combination of poly(acrylic acid), poly(methacrylic acid), poly(methyl acrylate), poly(methyl methacrylate), silicone, and epoxy resin; and
c) 5 wt% to 30 wt% of a electromagnetic interference absorbing filler consisting of multi-walled carbon nanotubes being dispersed within the polymeric carrier matrix;

wherein the polymeric matrix is miscible with the solvent for forming the paint composition applicable onto a surface of an article to create thereto an EMI coating under ambient condition against electromagnetic interference and the multi-walled carbon nanotubes are

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dispersed into the polymeric carrier matrix through a dispersing process carried out at a speed ranging from 5000 rpm to 20000 rpm by a disperser.

[0011] In a second aspect, there is provided a method of manufacturing an electromagnetic interference shielding paint composition, the method comprising

providing 50 wt% to 75 wt% of a polymeric carrier matrix which is any one or combination of poly(acrylic acid), poly(methacrylic acid), poly(methyl acrylate), poly(methyl methacrylate), silicone, and epoxy resin;

providing 20 wt% to 40 wt% of a solvent, a dispersant, and at least one additive to form a mixture with the polymeric carrier matrix; and

dispersing 5 wt% to 30 wt% of an electromagnetic interference absorbing filler consisting of multi-walled carbon nanotubes homogeneously into the mixture using a disperser at a speed ranged from 5000 rpm to 20000 rpm to form the paint composition applicable onto a surface of an article to create thereto an EMI coating under ambient condition against electromagnetic interference,

wherein the polymeric matrix is miscible with the solvent for forming the paint composition.

[0012] In a third aspect, there is provided a method of reducing electromagnetic interference through a surface of an article. The method comprises applying an electromagnetic interference shielding coating composition according to the first aspect or an electromagnetic interference shielding coating composition manufactured by a method according to the second aspect to a surface of an article.

DETAILED DESCRIPTION

[0013] In one embodiment, there is provided an electromagnetic interference shielding coating composition. As used herein, the term “electromagnetic interference” refers generally to disturbance caused by electromagnetic conduction and radiation emitted from electronic equipment. The composition disclosed herein may be applied to a surface of an article to shield the article from undesirable electromagnetic waves.

[0014] Advantageously, the composition disclosed herein is lighter and has improved corrosion resistance compared to state of the art metallic filler based shielding coatings. It has a high shielding efficiency (SE) over a wide working frequency range for electromagnetic interference (EMI) shielding from 10 MHz to 20 GHz. Unlike conductive plastic shields, a tailored injection molding process to produce shielding casing and housing is not required in the EMI shield coating disclosed herein. The EMI shield coating is simple to fabricate, and the manufacturing process may be carried out under ambient condition, and temperature and pressure controls are not required. Irradiation by ultraviolet light is also not required. The EMI shield coating composition may be conveniently applied to surfaces of any shape by brushing or means of a roller at ambient conditions.

[0015] The electromagnetic interference shielding coating composition comprises about 1 wt% to about 30 wt% of a electromagnetic interference absorbing filler that consists essentially or consists of multi-walled carbon nanotubes; about 5 wt% to about 40 wt% of a solvent, a dispersant, and at least one additive; and about 30 wt% to about 94 wt% of a polymeric carrier matrix. The wt% of the components in the composition add up to 100 wt%, and is calculated based on total weight of the electromagnetic interference shielding coating composition.

[0016] The electromagnetic interference absorbing filler consists essentially of or consists of multi-walled carbon nanotubes. In various embodiments, the electromagnetic interference absorbing filler consists of multi-walled carbon nanotubes. As used herein, the term "multi-walled carbon nanotubes" refers to cylindrical structures having two or more layers, wherein the two or more layers are predominantly made up of carbon. The two or more layers of the multi-walled carbon nanotubes are generally concentric, and may have an inter-layer distance of about 0.34 nanometers.

[0017] Advantageously, use of multi-walled carbon nanotubes as electromagnetic interference absorbing filler in EMI shielding paint or coating may address or at least alleviate problems encountered using conventional metallic and carbon-based EMI shielding paints, due to their unique chemical properties and outstanding electrical and mechanical properties, as well as quantum-size effects due to their size.

[0018] Firstly, multi-walled carbon nanotubes, which have dimensions in the nanometer range, are more effective than micron-sized materials because of EMI shielding skin effect. Secondly, strength and ductility of composites formed from nanosized EMI absorbents tend to improve with decreasing material size. For example, nanoscale materials are able to provide improved, hence more desirable, mechanical properties. In addition, the nanoscale materials are able to reduce viscosity and weight of the EMI shielding paint, thereby enhancing processability of the paint.

[0019] Each of the multi-walled carbon nanotubes may have about 10 layers to about 20 layers. For example, the multi-walled carbon nanotubes may form a mixture, with each multi-walled carbon nanotube having number of layers in the range of about 10 layers to about 20 layers, such as 10, 11, 12, 13, 14 15, 16, 17, 18, 19, or 20 layers.

[0020] Each of the multi-walled carbon nanotubes may have an outer diameter in the range of about 5 nm to about 50 nm. For example, each multi-walled carbon nanotube may have an outer diameter in the range of about 5 nm to about 40 nm, about 5 nm to about 30 nm, about 5 nm to about 20 nm, about 10 nm to about 50 nm, about 20 nm to about 50 nm, about 30 nm to about 50 nm, about 40 nm to about 50 nm, about 10 nm to about 40 nm, about 20 nm to about 40 nm, or about 20 nm to about 30 nm.

[0021] Each of the multi-walled carbon nanotubes may have a length in the range of about 30 µm to about 100 µm. For example, each multi-walled carbon nanotube may have a length in the range of about 30 µm to about 80 µm, about 30 µm to about 60 µm, about 30 µm to about 50 µm, about 50 µm to about 100 µm, about 70 µm to about 100 µm, about 80 µm to about 100 µm, about 40 µm to about 90 µm, about 50 µm to about 80 µm, about 60 µm to about 70 µm, or about 45 µm to about 85 µm.

[0022] The electromagnetic interference absorbing filler accounts for about 1 wt% to about 30 wt% of the electromagnetic interference shielding coating composition, and may be present in any suitable amount within the above-mentioned range. For example, the electromagnetic interference absorbing filler may be in the range of about 1 wt% to about 25 wt%, about 1 wt% to about 20 wt%, about 1 wt% to about 15 wt%, about 1 wt% to about 10 wt%, about 5 wt% to about 30 wt%, about 10 wt% to about 30 wt%, about 15 wt% to about 30 wt%, about 20 wt% to about 30 wt%, about 10 wt% to about 20 wt%, about 15 wt% to about 25 wt%, or about 5 wt% to about 25 wt% of the electromagnetic interference shielding coating composition.

[0023] In specific embodiments, the electromagnetic interference shielding coating composition comprises about 5 wt% to about 20 wt% of an electromagnetic interference absorbing filler consisting essentially or consisting of multi-walled carbon nanotubes.

[0024] The electromagnetic interference absorbing filler which consists essentially of or consists of multi-walled carbon nanotubes has good conductivity and high electromagnetic interference absorbance. By mixing the electromagnetic interference absorbing filler with a

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polymeric carrier matrix, a solvent, a dispersant and one or more additives, an electromagnetic interference shielding coating composition is obtained.

[0025] The polymeric carrier matrix may comprise or consist of a polymer selected from the group consisting of poly(acrylic acid), poly(methacrylic acid), poly(methyl acrylate), poly(methyl methacrylate), silicone, epoxy resin, copolymers thereof, and mixtures thereof.

[0026] The polymeric carrier matrix accounts for about 30 wt% to about 94 wt% of the electromagnetic interference shielding coating composition. In various embodiments, the polymeric carrier matrix is present in the range of about 30 wt% to about 90 wt%, about 30 wt% to about 80 wt%, about 30 wt% to about 70 wt%, about 30 wt% to about 60 wt%, about 30 wt% to about 50 wt%, about 30 wt% to about 40 wt%, about 40 wt% to about 94 wt%, about 50 wt% to about 94 wt%, about 60 wt% to about 94 wt%, about 70 wt% to about 94 wt%, about 80 wt% to about 94 wt%, about 40 wt% to about 80 wt%, about 50 wt% to about 80 wt%, or about 40 wt% to about 60 wt% of the electromagnetic interference shielding coating composition.

[0027] In specific embodiments, the electromagnetic interference shielding coating composition comprises about 50 wt% to about 75 wt% of a polymeric carrier matrix.

[0028] The electromagnetic interference absorbing filler may be dispersed in the polymeric carrier matrix. In various embodiments, the electromagnetic interference absorbing filler is dispersed in the polymeric carrier matrix without covalently bonding thereto. For example, the electromagnetic interference absorbing filler may not be chemically bonded to the polymeric carrier matrix, and may merely be physically mixed or dispersed in the polymeric carrier matrix. By using a non-covalent approach to disperse electromagnetic interference absorbing filler such as multi-walled carbon nanotubes, in a viscous polymeric carrier matrix, electrical properties of the electromagnetic interference absorbing filler are not altered.

[0029] The electromagnetic interference absorbing filler may be at least substantially homogenously dispersed in the polymeric carrier matrix. In specific embodiments, the electromagnetic interference absorbing filler is dispersed homogenously in the polymeric carrier matrix. Advantageously, homogeneous dispersion of the electromagnetic interference absorbing filler in the polymeric carrier matrix translates into formation of a homogeneous electromagnetic interference shielding coating composition. This allows uniform shielding of

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the underlying article to which the electromagnetic interference shielding coating composition is applied on.

[0030] Apart from the polymer carrier matrix, the electromagnetic interference shielding coating composition comprises about 5 wt% to about 40 wt% of a solvent, a dispersant, and one or more additives. The solvent, the dispersant and/or the one or more additives facilitate mixing of the electromagnetic interference absorbing filler in the polymer carrier matrix. For example, agglomeration of the electromagnetic interference absorbing filler may take place during manufacturing and/or storage. Such agglomeration may result in reduction of electromagnetic interference shielding efficiency. This problem is not mitigated by using a high loading of nanomaterials since mechanical properties of the coating may be degraded.

[0031] By incorporating a solvent, a dispersant and one or more additives into the electromagnetic interference shielding coating composition, dispersability of the electromagnetic interference absorbing filler in polymer carrier matrix may be improved through a dispersion process. In addition, by varying the amount of solvent in the composition, the electromagnetic interference shielding coating composition may be varied thereby allowing dispensing of the EMI shielding coating composition in various forms, such as in paint liquor, which may be administered using a conventional paint brush or a paint roller. In various embodiments, the EMI shielding coating composition has an optimized viscosity that allows painting of the composition to a surface using a brush and/or a roller.

[0032] Choice of solvent may depend on the type of polymer used for the polymeric carrier matrix. Generally, a suitable solvent is one that is at least substantially miscible with the polymer used for the polymeric carrier matrix.

[0033] In various embodiments, the solvent is an organic solvent.

[0034] In specific embodiments, the solvent is selected from the group consisting of alcohols such as ethanol and isopropyl alcohol; ketones such as methyl ethyl ketone; aromatic compounds such as toluene, xylene, and benzene, ethyl acetate, tetrahydrofuran, dimethylformamide, dimethylsulfoxide, dimethylacetamide, N-methylpyrrolidone, and combinations thereof.

[0035] In specific embodiments, the solvent is selected from the group consisting of ethanol, isopropyl alcohol, methyl ethyl ketone, and mixtures thereof.

[0036] The dispersant may improve mixing of the electromagnetic interference absorbing filler in the polymeric carrier matrix. Examples of a dispersant include, but are not limited to structured acrylate copolymer with pigment affinic groups, and/or linear polymer with highly polar and different pigment-affinic groups. By use of the term "different pigment-affinic groups", it means that the pigment-affinic groups present on the linear polymer are different from the pigment affinic groups present on the structured acrylate copolymer.

[0037] Examples of pigment affinic groups include, but are not limited to, amine groups, carboxylic acid groups, phosphoric acid groups, ammonium groups, carboxylate groups and phosphate groups.

[0038] The electromagnetic interference shielding coating composition further comprises one or more additives. As used herein, the term "additive" refers to a substance that is added to the composition to modify or to affect its characteristics. Choice of additive may depend on the type and amount of polymer, and/or the intended application of the electromagnetic interference shielding coating composition. One or more additives may be added depending on the intended application of the EMI shielding coating composition. In various embodiments, the additive is selected from the group consisting of a wetting agent, an adhesion promoter agent, a defoamer, a thickener, and combinations thereof.

[0039] The term "wetting agent" as used herein refers to a compound that is used to enhance penetration of water into another material. For example, the wetting agent may be a surfactant with wetting properties. Examples of a wetting agent include, but are not limited to a surfactant with structured acrylate copolymer with pigment affinic groups and/or linear polymer with highly polar and different pigment-affinic groups. Examples of structured acrylate copolymer with pigment affinic groups and/or linear polymer with highly polar and different pigment-affinic groups have already been mentioned above.

[0040] The term "adhesion promoter agent" as used herein refers to a material that improves or enhances affinity of two surfaces towards each other. For example, when an adhesion promoter agent is added to an electromagnetic interference shielding coating composition, the adhesion promoter agent may improve adhesion or increase bond strength of the EMI shielding paint to the surface on which the EMI shielding paint is applied on. An example of an adhesion promoter agent is modified urea.

[0041] The term "defoamer" as used herein refers to a substance that prevents foam from forming, or destroys foam once it has formed. One example of a defoamer is polyether-modified polydimethylsiloxane.

[0042] The term “thickener” as used herein refers to a substance that increases viscosity of the material being added to. Examples of a thickener include, but are not limited to polyurethane with a highly branched structure.

[0043] In specific embodiments, the at least one additive is selected from the group consisting of a surfactant with the structured acrylate copolymer with pigment affinic groups, linear polymer with highly polar and different pigment-affinic groups, modified urea, polyether-modified polydimethylsiloxane, polyurethane with a highly branched structure, and combinations thereof.

[0044] As mentioned above, the electromagnetic interference shielding coating composition comprises about 5 wt% to about 40 wt% of a solvent, a dispersant, and at least one additive. In various embodiments, the solvent, dispersant, and at least one additive is present in the range of about 5 wt% to about 35 wt%, about 5 wt% to about 30 wt%, about 5 wt% to about 20 wt%, about 5 wt% to about 15 wt%, about 5 wt% to about 10 wt%, about 10 wt% to about 40 wt%, about 10 wt% to about 30 wt%, about 10 wt% to about 25 wt%, about 15 wt% to about 40 wt%, about 15 wt% to about 30 wt%, about 15 wt% to about 25 wt%, about 20 wt% to about 35 wt%, about 20 wt% to about 30 wt%, or about 25 wt% to about 35 wt% of the electromagnetic interference shielding coating composition.

[0045] In specific embodiments, the electromagnetic interference shielding coating composition comprises about 20 wt% to about 30 wt% of a solvent, a dispersant, and at least one additive.

[0046] In preferred embodiments, the electromagnetic interference shielding coating composition comprises about 5 wt% to about 20 wt% of a electromagnetic interference absorbing filler consisting essentially or consisting of multi-walled carbon nanotubes, about 20 wt% to about 30 wt% of a solvent, a dispersant, and at least one additive, and about 50 wt% to about 75 wt% of a polymeric carrier matrix. The wt% of the components in the composition add up to 100 wt%, and is calculated based on total weight of the electromagnetic interference shielding coating composition.

[0047] The electromagnetic interference shielding coating composition may be chemically stable under high temperature and high humidity. Advantageously, the electromagnetic interference shielding coating composition disclosed herein may be dried under ambient condition, and may be easily applied to the interior and/or exterior surfaces of enclosures, as well as non-metallic articles and installations by brushing or rolling.

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[0048] In another embodiment, there is provided a method of manufacturing an electromagnetic interference shielding coating composition. The method comprises providing a mixture comprising a polymeric carrier matrix, a solvent, a dispersant, and at least one additive; dispersing an electromagnetic interference absorbing filler consisting essentially or consisting of multi-walled carbon nanotubes into the mixture using at least one of a high speed dispersing process and chemical dispersant to form the electromagnetic interference shielding coating composition.

[0049] Examples of suitable polymeric carrier matrix, solvent, dispersant, additive, and multi-walled carbon nanotubes, as well as their respective wt% in the electromagnetic interference shielding coating composition have already been mentioned above.

[0050] A high speed dispersing process may be applied to disperse the fillers and one or more additives in the polymer matrix by using a disperser, such as a mixer or a miller. The high speed dispersing process may be carried out at a speed in the range of about 5000 rpm to about 20000 rpm. For example, the high speed dispersing process may be carried out at a speed in the range from about 5000 rpm, about 6000 rpm, about 7000 rpm, about 8000 rpm, about 9000 rpm; to about 10000 rpm, about 11000 rpm, about 12000 rpm, about 13000 rpm, about 14000 rpm, about 15000 rpm, about 16000 rpm, about 17000 rpm, about 18000 rpm, about 19000 rpm, or to about 20000 rpm.

[0051] The high speed dispersing process may be carried out for any suitable time period that is sufficient to disperse the electromagnetic interference absorbing filler in the mixture. Amount of time required may depend, for example, on content of the mixture, viscosity of the mixture, and amount of electromagnetic interference absorbing filler used.

[0052] In various embodiments, the high speed dispersing process is carried out for a time period in the range of about 1 hour to about 8 hours, such as about 1 hour, about 2 hours, about 3 hour, about 4 hours, about 5 hour, about 6 hours, about 7 hour, or about 8 hours. Sonication and/or ultrasonic methods may additionally be used to disperse the carbon nanotubes.

[0053] In addition to, or as an alternative to the high speed dispersing process, a chemical dispersant may be used to disperse the electromagnetic interference absorbing filler to form the electromagnetic interference shielding coating composition. In various embodiments, the chemical dispersant may be selected from the group consisting of the structured acrylate copolymer with pigment affinic groups and/or linear polymer with highly polar and different pigment-affinic groups.

[0054] In a further aspect, a method of reducing electromagnetic interference through a surface of an article is provided.

[0055] The method comprises applying an electromagnetic interference shielding coating composition according to the first aspect or an electromagnetic interference shielding coating composition manufactured by a method according to the second aspect to a surface of an article. The electromagnetic interference shielding coating composition may be present on the surface of the article in any suitable thickness that allows reduction of electromagnetic interference through the surface, which may in turn depend on the intended application.

[0056] As disclosed herein, the electromagnetic interference shielding coating composition has achieved more than 50 dB or 99.999 % of EMI SE, while the working frequency may be in a range from 10 MHz to 20 GHz. In specific embodiments, the electromagnetic interference shielding coating composition possesses high shielding efficiencies of up to 50 decibel (dB) or 99.999 %, broad frequency range coverage from 15 MHz to 20 GHz when coated on an acrylonitrile butadiene styrene (ABS) article.

[0057] Accordingly, the electromagnetic interference shielding coating composition disclosed herein may be used to reduce electromagnetic interference comprising frequency in the range of about 10 MHz to about 20 GHz. In various embodiments, the composition exhibits good corrosion resistance, cost effectiveness, environmentally friendly, light weight, and applicability as thin film coating layers for EMI protection.

[0058] The electromagnetic interference shielding coating composition developed may be applied to a myriad of application areas, such as electrical and electronic facilities, hospitals, transportation system, telecommunication system, and buildings, to name only a few. Specifically, the coating may easily be applied onto surfaces of any shape, including internal and external surfaces of articles and installations. Preferably, the articles and installations are made of non-metallic materials, such as plastics, concrete and wood. Examples include domestic appliances, electrical, electronic and IT products, medical devices, telecommunication systems, aerospace, transportation equipment, and electric trains. The electromagnetic interference shielding coating composition has high shielding efficiencies, broad shielding frequency range, good corrosion resistance, while being cost effective and easy to use.

[0059] As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0060] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0061] The invention illustratively described herein may suitably be practiced in the absence of any element or elements, limitation or limitations, not specifically disclosed herein. Thus, for example, the terms "comprising", "including", "containing", etc. shall be read expansively and without limitation. Additionally, the terms and expressions employed herein have been used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed. Thus, it should be understood that although the present invention has been specifically disclosed by preferred embodiments and optional features, modification and variation of the inventions embodied therein herein disclosed may be resorted to by those skilled in the art, and that such modifications and variations are considered to be within the scope of this invention.

[0062] The invention has been described broadly and generically herein. Each of the narrower species and subgeneric groupings falling within the generic disclosure also form part of the invention. This includes the generic description of the invention with a proviso or negative limitation removing any subject matter from the genus, regardless of whether or not the excised material is specifically recited herein.

[0063] Other embodiments are within the following claims and non- limiting examples. In addition, where features or aspects of the invention are described in terms of Markush groups, those skilled in the art will recognize that the invention is also thereby described in terms of any individual member or subgroup of members of the Markush group.

EXPERIMENTAL SECTION

[0064] An EMI shielding paint of high electromagnetic interference shielding efficiencies over a broad shielding frequency range to reduce EMI hazards has been developed. In various embodiments, effectiveness on prototypes made of acrylonitrile butadiene styrene (ABS) plastics and concrete has been demonstrated, whereby high shielding efficiency (SE) values have been achieved. For example, SE of an ABS article coated with the EMI shielding paint in the frequency range from 15 MHz to 20 GHz and above has been shown to be in the range of about 30 dB to about 50 dB (99.9 % to 99.999 %), which is a vast improvement over SE of less than 1 dB for an ABS article without the EMI shielding paint.

[0065] In various embodiments, multi-walled carbon nanotubes have been incorporated as EMI absorbent in EMI shielding paint to overcome drawbacks of state of the art EMI shielding paint formed of metallic and carbon based paints. As demonstrated herein, a high SE over a wide working frequency range has been obtained using an EMI shielding paint disclosed herein. Advantageously, the EMI shielding paint has stable chemical properties as well as good electrical and mechanical properties.

[0066] About 5 wt% to about 20 wt% of a electromagnetic interference absorbing filler consisting essentially or consisting of multi-walled carbon nanotubes and about 20 wt% to about 30 wt% of a solvent, a dispersant and at least one additive may be dispersed using a high speed dispersing process to produce a paste. The paste may be then added into about 50 wt% to about 75 wt% polymeric carrier matrix to form the EMI shielding paint.

[0067] In some embodiments, the EMI shielding paint disclosed herein has achieved more than 50 decibel (dB) or 99.999% of EMI SE. The working frequency range may be in a range from 10 MHz to 20 GHz.

[0068] While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.

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CLAIMS

1. An electromagnetic interference shielding (EMI) paint composition comprising a homogeneous mixture of
   a) 20 wt% to 40 wt% of a solvent, a dispersant, and at least one additive;
   b) 50 wt% to 75 wt% of a polymeric carrier matrix, which is any one or combination of poly(acrylic acid), poly(methacrylic acid), poly(methyl acrylate), poly(methyl methacrylate), silicone, and epoxy resin; and
   c) 5 wt% to 30 wt% of a electromagnetic interference absorbing filler consisting of multi-walled carbon nanotubes being dispersed within the polymeric carrier matrix;

   wherein the polymeric matrix is miscible with the solvent for forming the paint composition applicable onto a surface of an article to create thereto an EMI coating under ambient condition against electromagnetic interference and the multi-walled carbon nanotubes are dispersed into the polymeric carrier matrix through a dispersing process carried out at a speed ranging from 5000 rpm to 20000 rpm by a disperser.

2. The paint composition according to claim 1, wherein the electromagnetic interference has a frequency of 10 MHz to 20 GHz.

3. The paint composition according to claim 1 or claim 2, wherein each of the multi-walled carbon nanotubes has 10 layers to 20 layers.

4. The paint composition according to any one of claims 1 to 3, wherein each of the multi-walled carbon nanotubes has an outer diameter in the range of 5 nm to 50 nm.

5. The paint composition according to any one of claims 1 to 4, wherein each of the multi-walled carbon nanotubes has a length in the range of 30 μm to 100 μm.

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6. The paint composition according to any one of claims 1 to 5, wherein the dispersant is structured acrylate copolymer with first pigment affinic groups and/or linear polymer with polar second pigment-affinic groups which are different from the first pigment affinic groups.

7. The paint composition according any one of claims 1 to 6, wherein the solvent is ethanol, isopropyl alcohol, methyl ethyl ketone, and any mixtures thereof.

8. The paint composition according to any one of claims 1 to 7, wherein the at least one additive is a wetting agent, surfactant, an adhesion promoter agent, a defoamer, a thickener, and any combinations thereof.

9. The paint composition according to claim 8, wherein the surfactant is a structured acrylate copolymer with first pigment affinic groups, linear polymer with polar second pigment-affinic groups which are different from the first pigment-affinic group, modified urea, polyether-modified polydimethylsiloxane, polyurethane with a branched structure, and any combinations thereof.

10. A method of manufacturing an electromagnetic interference shielding paint composition, the method comprising

providing 50 wt% to 75 wt% of a polymeric carrier matrix which is any one or combination of poly(acrylic acid), poly(methacrylic acid), poly(methyl acrylate), poly(methyl methacrylate), silicone, and epoxy resin;

providing 20 wt% to 40 wt% of a solvent, a dispersant, and at least one additive to form a mixture with the polymeric carrier matrix; and

dispersing 5 wt% to 30 wt% of an electromagnetic interference absorbing filler consisting of multi-walled carbon nanotubes homogeneously into the mixture using a disperser at a speed ranged from 5000 rpm to 20000 rpm to form the paint composition applicable onto a surface of an article to create thereto an EMI coating under ambient condition against electromagnetic interference,

wherein the polymeric matrix is miscible with the solvent for forming the paint composition.

11. The method according to claim 10, wherein the dispersant is structured acrylate copolymer with first pigment affinic groups, linear polymer with polar second pigment-affinic groups which are different from the first pigment affinic groups, and any combinations thereof.

12. The method according to claim 10 or claim 11, wherein the solvent is ethanol, isopropyl alcohol, methyl ethyl ketone, and any combinations thereof.

13. The method according to any one of claims 10 to 12, wherein the at least one additive is a wetting agent, an adhesion promoter agent, a defoamer, a thickener, and any combinations thereof.

14. The method according to any one of claims 10 to 13, wherein the chemical dispersant is structured acrylate copolymer with first pigment affinic groups, linear polymer with polar second pigment-affinic groups which are different from the first pigment-affinic group, and combinations thereof.