Graphene/Research progress of polyurethane composites

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Abstract: Graphene is a new two-dimensional nano-layer carbon material, has extremely high mechanical strength, E-Migration, thermal conductivity and unique chemistry structure, The functional modification of polyurethane as a filler can effectively improve the mechanical properties of the matrix, conducting a conductive, Electromagnetic Shielding performance, therefore becomes a major hotspot in composite materials research over the years. In this paper, the modification of graphene and its research progress in polyurethane materials are reviewed, to compound Material Preparation methods, Performance Research classification, on composite materials common stretch, compression, the Thermal Model establishment method is summarized, Outlook on the stonographene/Challenges and opportunities for the industrialization of polyurethane composites.

Keywords: Graphene; Polyurethane; Preparation Method; Performance Research; Themodel establishes

Introduction Hundred

from the Year was first discovered so far, Graphene (Graphene) and its composite polymeric materials have attracted great interest from the scientific community with concern, because of its large surface area, Quality Light, High strength, Make graphene break through traditional graphite filler high dosage low performance bottleneck[1], polyurethane with excellent performance, widely used in industry for a long time, as a new generation of functional material, graphene in polyurethane The application of the has been the focus of material chemistry research, to give polyurethane better use performance, graphene used as efficient functional filler plus people to polyurethane base material, make it mechanical[2], surface performance[3], Heat resistance[4], conductivity[5] For better breakthroughs, article to recent graphene/Performance Study and structure design of polyurethane composite materials, and preparation of composite materials, and structure table sign Overview of the theoretical model for, performance test,

1. describes

Polyurethane (POLyurethane, PU) is a progressively added reaction of multiple isocyanate and polyols, after extension, cross-linked system-nested section copolymer, at ambient temperature, polyurethane elastomer[6], foamed Plastic[7], Paint[8] exists in many forms, such as, greatly broadens the making of polyurethane with scope. Depending on how the preparation method differs from the product form, Polyurethane mainly consists of thermoplastic polyurethane (TPU), Polyurethane foaming Material (PUR) and waterborne polyurethane (WPU) Three forms.

to enhance the practicality of polyurethane, is often modified for polyurethane substrates, to improve physical and chemical properties of materials, the consists primarily of The next two methods of modification.

1.1 material structure

By controlling the length of segments of different block monomers, can control the physical and chemical properties of the polymeric products, the structure of the product can be in the linear and shape free conversion, Optimizing process
difficulty and product performance of polyurethane production, but only by adjusting the system formula to improve performance is there a limit to, thus, the introduction of functional modifiers in the system is the focus of the study on modification of polyurethane. In the polyurethane monomer isocyanate N=C=O, the group is highly unsaturated. High reactivity, reaction products can have high key energy and stability, this The also provides basic conditions for its chemical modification.

1.2 Machining Process

Thermoplastic Polyurethane (TPU) is a polymer with high elasticity at room temperature. Soft segment content is longer so that it can undergo repeated heat treatment. Without affecting the use of, for TPU modified except for traditional in-situ modification (in situ modification), solution blending (solution

Mnang) outside, blending with fillers through melt blending, late processing, addition, Polymer processing Art is also gradually tilting toward environmental trends, for example, polyurethane material cross-linking process also from initial single heat cross-linking, Chemical cross-linking transition to new type UV solidify cross-linked way, not only reduces production costs, while avoiding environmental pollution, Become waterborne polyurethane in recent years (WPU). A development direction after UV solidify, Materials can have more excellent water resistance, alcohol resistance and good hardness and decoration effects [one].

The graphene is a carbon atom SP^2 hybrid monolayer of new carbon material formed by hybridization, a exists between its tiers TN Key. Graphene material in-E-Migration, thermal conduction is much better than traditional carbon material, even metallic materials, at the same time, due to single graphene thickness not to 1 nm, "The has a higher height aspect ratio and specific surface area with graphene. Special structure and excellent performance, make graphene much more scientific concern.

Conventional graphene preparation methods include the bottom to top (Bottom-Up) with top to bottom (top-down) two routes.

From bottom to top (Bottom-Up) method, name is refers to the process from carbon to graphite and its derivatives, including vapor deposition method [5] (chemical vapor deposition, CVD), SiC epitaxial growth [5] (cut (siceptial growth), Onecarbonredox [4] (coreduction)), Arc Discharge method [3] (arc discharge), Carbon nanotube solution chain [6] (unzipping carbon nanotube), Auto-assemble method [6] (self-assembly) etc. The method from bottom to top usually requires a large area of graphene in the case of a metal substrate such as a copper case, to meet electronic Product applications, for this reason, CVD the method becomes the main method of preparing large area graphene in electronic industry. Method although you can get a specific quality of graphene, But higher production costs, Low Output, cannot make a mass production.

From top to bottom (Top-Down) The method is obtained by oxidizing the natural graphite to the Graphite. Derivative preparation of graphene innessence, the extend the layer spacing by means of acid intercalation, achieve interlayer stripping by breaking the strong van der Waals force between graphite layers, then the uses the ultrasound-assisted the causes the slice layer to be completely expanded into a less layer structure, plus, year Gem with Novosel TM use tape to peel Graphite repeatedly away, that is, micro-mechanical stripping, finally get a small amount of high-quality graphene, Two people get Year Nobel prize in Chemistry. Mechanical Grinding method. Another simple method for preparing graphene, the huge shear force produced by ball milling can enlarge the layer spacing of graphite, generates a small structure of graphene. But the horizontal dimensions of the graphene slice are cut off during mechanical stripping, This results in an unstable size of the graphene product. Phase lower than, Liquid-phase ultrasound stripping can be a good way to avoid damage to the graphene structure. first, require strong oxidation reaction to graphite raw materials, Widening the layer spacing of graphite, This is easy to peel graphite oxide into monolayer graphite (graphite oxide), then through high-power ultrasound further peel off graphite to get oxidized graphene (graphite oxide), then restore using hydrazine hydrate, etc., consuming oxidation graphene surface containing oxygen groups, finally get good performance, Distribute evenly reduction graphene (reduced graphite oxide), this class method mainly includes Brodie [1], Staudenmaier [2], Hummers [3], etc.. Chemical
preparation for reduction of graphene oxide containing the ministry sub-hydroxy(oneOH),carboxyl(oneCOOH),epoxy-((OneCH2O)-et groups, weakens the conductivity of graphene oxide, but the method is for simple implementation, has become one of the main methods for the production of graphene.

2. Study on the modification of graphene in polyurethane matrix

2.1 Non-covalent law

As a new functional filler, the compatibility between graphene and polymers and the dispersibility in the matrix directly determine the high polymer material's structure and performance. Graphite oxide surface rich in hydroxyl group, group of hydrophilic functional groups, available in water—Graphene Interface Form strong hydrogen bond, oxidation stonographene can form well in water, But the restored graphene hydrophobic repellent oil, so add polymer before adding to the graphene. Line Surface modification varies by modification, roughly divided into covalent and non-covalent modification.

Non-covalent modification means the internal structure of graphene is not destroyed, only uses TN Key, A for the modification of graphene, such as hydrogen bonding, etc. Way, blending of graphene with polymers, between layers Strong van der Waals it's easy to make it happen two times, causes stress concentration to occur in composite, and not covalent modification can be a good way to avoid this happening.

The most commonly used non-covalent method of is to change the charge state of the graphene surface using ionic surfactants, hydrophobic end and graphene surface knot, hydrophilic End with positive charge on graphene sheet surface, The resulting electrostatic repulsion effect causes the graphene to be evenly dispersed in the matrix. Hsao et al modified graphite oxide, re-restore via hydrazine hydrate, Experiment results show, sulfonic acid base Group Modification reduction oxidation graphene (S-GNS") More original reduction of graphene oxide (P-GNS) increased dispersibility in water (See figure 1). Cho

When graphene interacts with the substrate, The interface binding force between the and the two determines the compatibility and stress-slip effects of the Force so, hydrogen bonding (hydrogen bonding interaction) is widely considered by scientists to be another non-covalent modification of graphene. Based on the above theory, Lang et al blended with a simple solution the graphene oxide (go) / polyvinyl alcohol (PVA) complex composite material, and Goin PVA the dispersion in is characterized by, The scanning electron microscope displays the amount of 07% (wt), Go the layer in is in the PVA The matrix can be well dispersed.

2.2 Covalent modification

The uses a covalent bond on the surface of the oxidized graphene to draw other small molecular modified groups or polymer chains and to restore another kind of graphene modification method. Because the key of the covalent bond can be strong, through proper control of modifier dosage, can make a large change in the surface properties of graphene, but total Valence modifier generally destroys the graphene surface structure, damage Intrinsic properties, reaction complex, and need a lot of organic solvents. Conventional covalent modification of graphene mainly includes the modification of the substrate with a modified, Modification of coupling agent and modification of polymer grafted on the surface of graphene.

Sex.

2.2.1 Modification of polyurethane substrate for graphene and isocyanate the earliest dates to 2006 Year, Stanko et al [7] Topic Group using isocyanate modified graphite oxide (go) modified go can be dispersed in N-JV-two methyl formamide, two methyl sulfoxide and some other Organic solvents. FTIREXperiment results show, Hydroxyl of the surface oxidized graphene, carboxyl group incrementally generate amide key, carbamate Key (See diagram 2). [8] Based on this research, Stanko et al further grafting of polystyrene into the top of the Isocyanates, Solution Blending, the polymer on the surface of the graphene oxide avoids a reunion, So that it can be
stably dispersed in the matrix.

Appel, and so on[2] Solvent-free in-situ reaction of functional graphene and polyols under high pressure homogenization, results found, with different. The content of the hard segment of cyanate ester increases, graphene on PU increased dispersibility in the matrix. In addition they also using potassium carbonate and carbonate ethyl hydroxy alkylation reaction, then graft poly (ether polyol), last in the mechanical mixing of people MDI Monomer in-place aggregation PU and Mold Curing Molding. The results of the show that the grafted graphene can disperse well in organic solvents.

2.2.2 coupling agent modification as a commonly used surface modifier. The coupling agent can be used to create a between the polymer and the filler Key Bridge (bonding Bridge), Improve the distribution of fillers in the matrix without affecting the internal structure of the substrate. Wanget[6] uses the KH simultaneous to oxygen Graphitization and PU for silane modification, in two cyclohexyl carbon diamine (DCC) catalysis, graphene oxide surface modified on silicone bond (f GNS); Modified silicone EndPU and F-GNSSol in the aqueous phase system-Gel (Sol-Gel) reaction got gfn s/PU Compositematerial, via atomic force microscope (AFM) The cross section of composite was observed to show the thickness of the modified graphene from 1.122nm increased to 2496nm (See figure 3). This is because the connections of silane molecular chains increase the radial dimensions of graphene. b. let [3] first with KH570 Modified Oxygenturn to graphene then restore with water hydrazine KH+ GNDispersion, finally use the Dip method to PU is placed in the dispersion. KH-Gn/PU Composite. from SEM (See figure 4) to see, hydrophilic on the inner skeleton of the foam to lipophilic.

2.2.3 polymer graft modification in polymer modified graphene, surface grafting of graphene (grafting) is preparation for best performance

diagram 2 mg/ml concentration GO/DMF Dispersion (left), Modification of benzeneisocyanate go/water dispersions (), Modification of benzeneisocyanate GO/DMF dispersant (Right). up to the top for placing 24h, below the bottom after the bottle is reversed"" What Figure 2 vials containing dispersions (1 MG/ML of Go in DMF (left), phenyl isocyanate-treated go INDMF. The top image shows the dispersions h after preparation. The bottom image shows the inverted dispersions with the precipitate clearly shown on the bottom. Of the left and middle vials[6].

One of the methods of the filler. surface grafting refers to a polymer active functional group on the surface of graphene, then polymer chemistry from active point anti-should have the method of grafting macromolecules. Fang wait[1] oxidize Graphene oxide, to react with the initiator bromine bromide to its covalent reaction, finally grow polystyrene on the surface of the graphene (PS), experiment to control the degree of heavy nitriding through ethanol, By initiator/monomer ' mo concentration ratio ([M]/[I]) to control PS Molecular weight (See figure 5). When the[M]/[I] to 250:1 when, The thickness of the modified graphene from ~2.2nm add to ~8NM. Raman spectra display, due to covalent function, Graphene microcrystalline area reduction.

3. Graphene/Preparation method for polyurethane composites

3.1 Melt Blending

for industrial production, Melting Blending is the easiest method to implement, not only avoids environmental problems caused by solvents, can also save cost of production, therefore suitable for mass production. Kim et al. Graphite, reduction of graphene oxide and Peel graphene respectively with thermoplastic polyurethane (TPU) on 180°C Melt Blending, and take advantage of TEM and WAXD characterize composite materials results show, no The graphite can not be stripped through the melting process, Peel oxidized graphene in the matrix tend to accumulate reunion, and reducing the oxidation of graphene can be
evenly spread, and the melting point is centered on the TPU-Hard segment of. If a polymer composite is to be prepared by melting method, must use Melt High temperature polymers, prevent material from degrading.

3.2 Solution Blending

In the reprocessing phase of graphene preparation, because of the strong Van der Waals force between graphene sheets, drying and grinding often results in a slice of there-stack, cause irreversible reunion, The eventually increases the number of graphene layers leading to graphitization. If graphene is dispersed in the blending phase-liquid form with polyurethane co-disperse deposition, to guarantee high surface area of graphene, Make it fully accessible to the polymer. Compared to molten blending, solution Blending easierto get molecular grade dispersed graphene/polyurethane composites.

Yousei, and so on(5) will aqueous solution and PUEulsion blends in Solution, Add people to a quantity of hydrazine hydrate without dispersing agent liquid in 80°C Lower Restore response H, Last inverted die molding, add compound dispersions Zeta Potential analysis discovery, Go/PUsurface PowerToFrom one year~aMVDropstoAMV, RGO/PUsurface potential drops to AMV, The charge density on the surface of the is increased before mixing, to probe that graphene oxide and reductive graphite can be uniformly dispersed at the time of wet preparation, PU Matrix, and anion group adsorbed

at the edge of the graphene layer. This further supports the author's assumption that isocyanate can be used as stabilizer in the process of graphene reduction.

Park, and so on(6) with allyl isocyanate to Go Modified, and then 4,4 'Two phenyl methanediisocyanate(MDI) with poly-hexyl (PCL) in the DMF Solution Pre-reaction generation Purepolymer, then ethyl acrylate(HEA) End with human light initiator, last downhuman polyethylene mould in UV light on crosslinking curing. test the tensile performance of PU, in the amount of modified graphene 1~1.5% (wt), material stretch modulus increased to varying degrees; Dosage greater than 2% (wt), tensile modulus less than pure PU. Combination DSC Heat flow data found at low levels, modified graphene can be used as an effective cross-linking agent to slow crystallization process. When the content increases, graphene provides more Thenucleation Point simultaneously disrupts the chain orientation. Asimilar theory has been int hekni(7) Research appears. Graphite graphene oxide surface contains a large number of hydroxyl groups, machine reaction with isocyanate, so graphene can act as a cross-linking agent.

3.3 In-place aggregation

The in-situ polymerization is the most commonly used preparation of graphene at the experimental level/methods for polyurethane composites. This method is generally from the liquid ring boundary inductive monomer and aggregation, to extend graphene sheet spacing. According to the synthesis process of polyurethane divided into one-step and two-step procedure, cyanideacid ester Group reactivity higher. Therefore, two-step method is the main method in actual production. First generate two of alcohols with isocyanate PU pre-clustered, plus people polyol for cross-linking.

3.3.1 Footwork &1, and so on[Panasi] designed a linear polyurethane macromolecules, with MDI is a monomer, PCL is two-dollar alcohol, with one-time feed

The method leads to the sealing of graphene at the end base of the cyanate ester, and take advantage of the SEM Characterization of graphene dispersion in a material cross-section, results found graphite allyl sheet in[mm The following, proofen PU The graphene in the matrix reaches the nanometer scale dispersion.

Scogumaluo, and so on[Panasi] in one step, IPD and HDI as reaction monomer and catechol reaction, take the 1,4-butyl alcohol as extension chain agent, in-situ reaction of the additive graphene tablets in an ultrasonic environment, build TPU/Graphene Composite through product viscoelastic flow change test found, within a certain test frequency range, Energy Storage modulus for composites G'Decreases as the amount of graphene filler increases, This is now The image can be interpreted as the lubrication effect of the graphene sheet.; with DSC to analyze thermal properties of the product and find that, No observation in the heating process to have exothermic peaks exist, The therefore determines that the aggregate reaction is complete, the glass-temperature and rheological properties of composites are
subjected to polyurethane systems and fillers changes in dosage, graphene in HDI-BD system can act as lubricant, and in IPDI-BD to act as reinforcing agent.

3.3.2 Two-Step by adding different amounts of hard segment monomers and chain Extender,?? Spiritual 1\(^{\text{et al}}\)\text{[41]}\text{A two-step method is prepare to a different chain segment length PU/GNP Composite material, and take advantage of the DSC, DMA and FE-SEM examines the performance of the material, from DSC map Analysis, on ~200°C a field observes an exothermic, and the peak strength increases with the increase of graphene addition, in-situ reaction, pluses people make pure PU on occurs two times during heating. This is attributed to the amino on carbonate and Go The reaction of the epoxy base on the causes two crystallization to be issued live, when cooling to 130°C, long hard segment PU shorter hard segment PUCrystal exothermic weaker, This is because the longer the length of the chain movement, the Shaoxing opera strong, lower cooling crystallization temperature from a stress-strain curve, via modified gum of pure PU has varying degrees of improvement, proof go The slice layer can play the purpose of transferring the payload, and different chain length PU composite, strain hardening is the main reason for improving tensile strength and break elongation rate, and Go The orientation of the layer along the soft segment and strain direction can be improved by PU strain hardening of, to improve the mechanics of the material performance.

to cross-linking the molecular structure of polyurethane, on the basis of guaranteed processing, You must use two-step method to control the end base of polyurethane and then cross-linked with polyols. ZhangWai\text{[41]} First Go Blend with bio-oil-based polyols, Top prepare a composite cross-linking agent, then ondibdexist with IPDI Pre-polymerization, the ends with a crosslinking agent for cross-linking and casting. \text{Preparation of thermosetting polyurethaneanester/graphene composites, tensile test shows, go The fracture elongation and toughness of the composites are greatly improved.} Author considers go Mechanical strengthening and toughening mechanism of thermosetting polyurethane and traditional thermoplastic polyurethane are different, because the experimental raw material does not add people two yuan alcohol as soft paragraph, instead of castor oil with Go as a cross-join, so Go can exist as a secondary soft segment in the base body.

3.3.3 Other methods except for the several methods mentioned above, Some special methods are also used to prepare Go/PU Composites. For example, \text{Use ball milling to prepare TPU/GNs Composites, First converts the polymer (Soft paragraph), GNs, BDO (chain Extender) with ethanol plus people grinding tank, Grinding in ethanol media \(1 \sim H\), to dry the mixture and add a person TDI as a hard segment, Stir3mm, finally cast the product Molding (See figure 6), and electrical properties and topography analysis of the product. The result shows that, when GNs Add amount to 2\% (WT) when, composites up to conductive threshold, in grinding 6hafter, The graphene is stripped off in alcohols and distributed in the PU Phase.}

because the thermal expansion coefficients of graphene and polyurethane are different, Many scientists also use hot pressing at high temperatures to make simple bonding, to Go Polyurethanes/graphene thin tissue for good electrochemical performance, is expected to appear in the next generation of electrode materials\text{[41]}.

4. Performance and Analysis

4.1 Mechanical Properties

4.1.1 Tensile Properties

Graphene as a filler can have a significant effect on the mechanical properties of the matrix, This is because of the high ratio area of graphenewith high surface activity.

Chen, and so on\text{[41]}\text{to modify the graphite oxide with pyrene methanol and PU Solution Blending, combines TEM Result Analysis, Heat Treatment Process Break} the long range order of graphene, and to render the graphenesurface wrinkled, and this behavior may be caused by graphene and pyrene derivatives. \text{The} \text{max keys interact to form a non-covalent connection PU Low poly molecular chain, in Graphene/ The polyurethane establishes a hydrogen bond with a stealth length, stretch data to indicate that, The release of recessive length are helpful for improving fill PU flexibility and strength, The elongation can be up to 900\%.
1.1 Use DSC and DMA to study the melting method. Graphene/polyurethane in the composite combines two kinds of real analyze data. Discovery, fill PUR [41], [42]. The crystallinity of the crystal increases rapidly with increasing padding usage. Shorten crystallization time, crystallization process acceleration, based on the AFM phase diagram analysis. Graphene/polyurethane crystalline size of the is less than the pure PUR.

Khan, and so on [31] in DMF and THF. The uses the spin coating method on thermopower-growth-process blending, Gothe mass fraction of the IS from 0% to 90% is not equal to. Go quality score greater than 50% (Wt) when, The extrusion modulus of the material is exponentially incremented, in strain rate 3% Young modulus when for 1 GPa, and the two solvents have little difference in the performance of the composites. DSC data display with go content elevated, PU soft segment crystal containing volume drop.

The young modulus values of the filler reinforcing nanomaterials are often used in HALP-M-Tsa Model [41, 42] to calculate, where graphene in polyurethane with machine orientation (ER) or orientation orientation (ER). The Young's modulus of the composite is used in the formula (1) and formula (2) to represent the:

\[ E = k \rho (9) \]

\[ \text{type: ER is randomly distributed Go Composite M2. (strain 200% Extrusion modulus) Eutogo orientation and sample surface parallel row column of composite M2. } \]

Eg to go M2; Em is PU for M2.; to go slice Layer Average length; dtogo Slice average into polyurethane solution, The last additive content is from 0.1% to 0.2% (wt). Different amount of modification Godispersant (AFG) prepared graphene/polyurethane paint, use the TG and thermal conductivity Analyzer to analyze heat efficiency of paints, finds AFG/PU. The thermal stability temperature of the is 307°C, is higher than Pure PU on 274°C, The thermal conductivity of the material from pure PU for 0.2492 up to 0.2810, 0.2947, 0.3491 w/mk, show stone. The graphene provides a low impedance propagation channel.

Debye Formula (8) is used to calculate the thermal conductivity of a material, and thermal conductivity is commonly used in heat flow or flat-panel testing and according to the formula (9) [x] evaluates:

\[ \chi = (8) \]

\[ k = \alpha C_p (9) \]

\[ \text{type: A The is the phonon thermal conductivity, } \]

\[ 4 \text{ is the material thermal conductivity, } C_p \text{ is the heat capacity of each unit volume is the average phonon speed, } Z \text{ is the phonon average from by Tri p a is thermal diffusivity, } \]

\[ \text{is the material density.} \]

Parallel Model [41] is commonly used to estimate the thermal conductivity of composite materials, in a parallel model, The overall thermal conductivity of each mixed relative material work alone, effect proportional to body integration rate, such as formulas shows,

\[ k_c = k_p \alpha + k_m \alpha \]

\[ k_p \alpha + k_m \alpha \]

\[ \text{type, } k_c \alpha \text{ is the thermal conductivity of composites, } k_p \alpha \text{ is the thermal conductivity of the filler, } k_m \alpha \text{ is the thermal conductivity of the polyurethane matrix, and } \alpha \text{ is the body of the filler and matrix Integration Rate. } \]

This theoretical model establishes a based on good dispersion of fillers, Therefore, there are some limitations to the poor dispersion of the filler.

4.2 Conductive Performance

for Polymers, The composition of a conductive network is not a conductive filler-between fillers, Instead of polymer-padding A Conductive tunnel between to conduct current conduction. Low padding content, filler as separate conductive unit rather than conductive network save on so the electrical performance improves very little until the filler volume increases enough to break through the polymer tunnel resistance, Conductive properties of composites gets a great boost, The amount of padding at this time is called a conductivity threshold [4, 5, 7, 58], by adding a person to the polyurethane matrix graphene, can reach improving the conductive properties of materials, and because of graphene's larger surface area, only a minimal amount of add is required to achieve the enhanced material guide. The purpose of the electricity.
Lee, and so on[3] to prepare the hot reduction graphene first(fgo), in-situ synthesis of waterborne polyurethane coatings phase with human graphene, successfully prepared out fgo/WPU 0.5 mm. The DC conductivity of the thickness film is measured by a miniature galvanometer, experimental results show, Add 3% (WT)'s Stonethe conductivity of the material increased by the 5 levels, and the amount of conductive range added 2% (wt), at this time WPU inside can form all even conductive network.

after the experiment in order to find the conductive threshold of the material, The relationship of the filler conductivity with the increase in filler mass can be based on the effective conductivity formula

Modeling[4],

\[ \sigma = \sigma_f \left( \frac{\rho_i}{\rho_f} \right)^{\frac{1}{n}} \]

This type, \( \sigma \) is the packing volume fraction, \( \sigma_f \) is the conductive domain, \( \rho_i \) is filler conductivity, \( \rho_f \) is composite conductivity, \( n \) is scale index.

stankcmch, and so on[2] the use of solution blending reduction method to prepare the Graphene/PS Composite material, with four-probe method for its conductivity enter All right, test, linear fit of test results, found, The conductive range of the composite is in the graphene content 0.1% (vol), add to 1% (vol) and 2.5% (vol) when, conductivity reached ~0.1 S•m\(^{-1}\) and ~1 S•m\(^{-1}\).

4.3 gas barrier

as a two-dimensional material, The thickness of graphene is only 0.3 nm around, The relatively large slice area is advantageous for the graphene to extend the gas through path in the polymer base (See figure 9, thus becoming ideal gas barrier material[6]).

Parent^<^<, and so on[3] by modifying Hummer The preparation of a low performance defect of the graphene flake layer, Modified graphene by 16 alkyl dispersants after solution casting hdanr/TPU Composite, for material breathability, The is measured by a dynamic vacuum pressure drop method. Dry results show, increase with low-defect graphene added, Team passes the total time of the air chamber from the blank samples, to add amount 0.1% (wt), s add to 0.2% (wt) for 1000s, when the dosage exceeds 0.5 (wt) when, material is almost completely airtight in a short time.

diagram8 Polystyrene-a function of the conductivity of graphene to vary with the volume fraction of the filler

The main diagram is the composite conductivity (=) About packing volume rate (less) fitting curve. Right illustration is log about Log (less angry) dot map,

Take The is the conductive range of the composites. Left illustration inside: on, Two diagrams in the represent two modes of four-probe settings, Planar mode and cross section mode;

The following figure is the sample current density in the direction of the arrow. (Contour) calculation map for, the thickness of the sample is twice the distance between the electrode width and the electrode[4].

Figure 8 electrical conductivity of polystyrene Graphene Composites as a function of filler volume fraction.

Main Figure, composite conductivity, \( R_c \), plotted against filler volume fraction, 0. Right inset, Loga, plotted against log (in the atmosphere), where 0c is the percolation Threshold. Left inset: top and Middle diagram show the Four \(<\) b20\(^{-1}\) probe

setup for In-plane and transverse measurements, respectively. Bottom Diagram, one of the computed distributions of the current density (contour lines) with local directions and MAgnitude (shown by arrows) in a specimen for the following

Conditions-the sample thickness is twice the electrode width and the gap between them[5].

diagram9 nano-layer modified polymer film after the gas through the path[6]

for, is not detected because of pressure changes (See figure Ten), inferred from this author, high aspect ratio graphene will be in polymer gas barrier performance play a significant rolein.

for elastomer material, Nielsen Model[7] can be used to establish a model of breathability contrast.
\[ P_0 \sim 1 + (R^\gamma < 5/3) \]

type, \( P \) is the theoretical gas permeability, \( P \) is the original sample gas permeability, \( r \) is filler aspect ratio, \( < 5 \) is packing volume ratio \([1] \).

Guo, and so on \( [1] \) a layer of graphene film is deposited on the surface of polyethylene film by drop coating, to investigate the permeability of composites, and passnelsen model results analysis and estimates. Results show, nm thick graphene makes the vapor transmittance of the polyethylene matrix lower, \( % \), and the ideal barrier effect of lamellar graphene is better than Nelsen Theoretical data for the model.

### 4.4 Dielectric Performance

Chen, and so on \( [5] \) the uses Atom transfer radical polymerization to react in G0 Surface Aggregation PMMA, and then associate it with the PU to blend and restore after casting-Molding, prepared MG-PU Composite material. Test dielectric properties of materials using Impedance Analyzer (See figure One), Results show, Increase frequency, increases the dielectric constant of all composites, dielectric loss also increased. From the change trend, Composite's medium The electrical constants of the increase as the amount of graphene increases. Based on the inferred Graphene polyurethane material can be used as a new type of electronic machinery application Square surface material.

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