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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 chemistrystructure,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 nearA major hotspot in composite materials research over the years.inThis paper, the modification of graphene and its research progress in polyurethane materials are reviewed,to compoundMaterial Preparation methods,Performance Research classification,on composite materials common stretch,compressionthe,Thermal Model establishment method is summarized,Outlook on the stonegraphene/Challenges and opportunities for the industrialization of polyurethane composites.

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

Introduction Hundred

from#Year was first discovered so far,Graphene(Graphene)and its composite polymeric materials have attracted great interest from the scientific communitywith 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 along time.as a new generation of functional material,graphene in polyurethaneThe application of the has been the focus of material chemistry research.to give polyurethane better use performance,graphene used as efficient functional filler pluspeople to polyurethane base material,make it mechanical[2],surface performance[3],Heat resistance[4],conductivity[5]Forbetter breakthroughs.articleto recent graphene/Performance Study and structure design of polyurethane composite materials,and preparation of composite materials, andstructure tablesignOverview of the theoretical model for, performance test,.

1. describes

Polyurethane(P0Lyurethane,PU)is a progressively added reaction of multiple isocyanate and polyols,after extension,cross-linked system-nestedsection copolymer.at ambient temperature,polyurethane elastomer[6],foamedPlastic[7],Paint[8]exists in many forms, such as,greatly broadens the making of polyurethanewith 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 primarilyofThe next two methods of modification.

1.1 material structure

By controlling the length of segments ofdifferent block monomers,can control the physical and chemical properties of the polymeric products,The structure of the product can be in the linear andshape free conversion,Optimizing process difficulty and product performance of polyurethane production[9].but only by adjusting the system formula to improve performance is there alimit of,thus,The introduction of functional modifiers in the system is the focus of the study on modification of polyurethane..in polyurethane monomer isocyanateoneN=C= 0-theGroup is highly unsaturated group,High reactivity,reaction products can have high key energy and stability[a],thisThealso 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 treatmentWithoutaffecting the useof.forTPUmodified except for traditional in-situ modification(insitumodification),solutionBlending(solution

Mnang)outside,blending matrix with filler through meltblending,late processing.addition,Polyurethane processorsArt 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 newtypeUVsolidify cross-linked way,not only reduces production costs,while avoiding environmental pollution,Become waterborne polyurethane in recent years(WPU)A development direction.afterUVsolidify,Materials can have more excellent water resistance,alcohol resistance and good hardness and decoration effects[one].

Thegraphene is a carbon atomSP^{2}hybrid monolayer of new carbon material formed by hybridization,a exists between its tiersTNKey,Graphene material inE-Migration,thermal conduction is much better than traditional carbon material,even metallic materials.at the same time,due to single graphene thickness not to1nm,"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,nameis,refers to the process from carbon to graphite and its derivatives,including vapor depositionmethod[a](chemicalvaporDeposition,CVD), SiCepitaxial growth[cut(sicepitaxialgrowth,)Onecarbonredox[[](coreduction)),Arc Discharge method[?](arcdischarge),Carbon nanotube solution chain[a](unzippingcarbonnanotube),Auto-assemblemethod[[](self-Assembly)etc.Themethod from bottom to top usually requiresaLarge area of graphene in the case of a metal substrate such as a copper case,,,tomeet electronic Product applications,for this reason,CVDThe method becomes the main method of preparing large area graphene in electronic industry.methodAlthough 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)Themethod is obtained by oxidizing the natural graphite tothe.Graphite derivative preparation of graphene inessence, theextendthe layer spacing by means of acid intercalation,achieve interlayer stripping by breaking the strong van der Waals force between graphite layers,Thethen uses the ultrasound-assistedThecauses the slice layer to be completely expanded into a less layer structure.plus,yearGemwithNovoselovTMuse tape to peel Graphite repeatedlyaway,that is, micro-mechanical stripping,finally get a small amount of high-quality graphene,Two people getYear Nobelprize in Chemistry.Mechanical GrindingmethodAnother simple method for preparing graphene,the huge shear force produced by ball milling can enlarge the layer spacing of graphite,generates a small structure ofgraphene.But the horizontal dimensions of the graphene slice are cut off during mechanical stripping,This results in an unstable size of the graphene product.phaselower 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(graphteoxde),then through high-power ultrasoundfurtherpeel off graphite to get oxidized graphene(grapheneoxde),re-restore using hydrazine hydrate, etc.,consuming oxidationgraphene surface containing oxygen groups,finally get good performance,Distribute evenly reduction graphene(reducedgraphiteoxide).thisclass method mainly includesBrodie[/],staudenmaiEr[2°],]Hummers[/], etc..Chemical preparation for reduction of graphene oxide containing the ministrysub-hydroxy(oneOH),carboxyl(oneCOOH),epoxy-((OneCH2O-)et groups,weakens the conductivity of graphene oxide,But the methodisfor 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,Thecompatibility between graphene and polymers and the dispersibility in the matrix directly determine the high polymer material'sstructure and performance.Graphite oxide surface rich in hydroxylgroup,groupof hydrophilic functional groups,available in water-Graphene Interface Form strong hydrogen bond,oxidation stonegraphene can form well in water,But the restored graphene hydrophobic repellent oil.so,add polymer before adding to thegraphene.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 usesTNKey,A for themodification 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 happentwo times.,causes stress concentration tooccur in composite,,and not covalent modification can be a good way to avoid this happening..

Themost 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.hsaoetc[l]18 alkyl Three methyl bromide first(STAC)Modified graphite oxide,re-restore via hydrazine hydrate,Experiment results show,sulfonic acid baseGroup Modification reduction oxidation graphene(S-GNS")More original reduction of graphene oxide(P-GNS)increased dispersibility in water(See figure1.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(hydrogenbondinginteraction)is widely considered by scientists to be another non-covalent modification of graphene.break[4].based on the above theory,Langetc[[]blended with a simple solution the graphene oxide(go)/polyvinyl alcohol(PVA)complexcomposite material,andGoinPVAThedispersion in is characterizedby,The scanning electron microscope displays the amount of0 7%(wt),Gothe layer is in thePVAThe 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 modificationmethod.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 totalValence 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 to2006Year,StankoV1ch[?]Topic Groupusing isocyanate modified graphite oxide(go))modifiedgocan be dispersed inN,,JV-two methylformamide,two methyl sulfoxide and some otherOrganic solvents.FTIRExperiment results show,Hydroxyl of the surface of oxidized graphene,carboxyl group incrementally generate amide key,carbamate Key(See diagram2).based on this research,StankoV1ch[a]further grafting of polystyrene into the topof the Isocyanates,SolutionBlending,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 differentThe content of the hard segment of cyanate ester increases,graphene onPUincreased dispersibility in the matrix.In addition they[+]also using potassium carbonate and carbonateethyl hydroxy alkylation reaction,then graft poly (ether polyol),last in the mechanical mixing of peopleMDIMonomer in-place aggregationPUandMold 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 fillerKey Bridge(bondmgBrdge),Improve the distribution of fillers in the matrix without affecting the internal structure of the substrate.Wangetc[[]usestheKHsimultaneous to oxygenGraphitizationandPUfor silane modification,in two cyclohexyl carbon diamine(DCC)catalysis,graphene oxide surface modified on silicone bond(f GNS);Modified silicone EndPUandF-GNSSol in the aqueous phase system-Gel(Sol-Gel)reactiongotfgns/PUCompositematerial,via atomic force microscope(AFM)The cross section of composite was observed to show the thickness of the modified graphene from1.122nmincreased to2496nm(See figure3,This is because the connections of silane molecular chains increase the radial dimensions of graphene.b1etc[31]first withKH570Modified Oxygenturn to graphene then restore with water hydrazineKH^GNDispersion,finally use the Dip method toPUisplaced in the dispersion.KH-Gn/puComposite.fromSEM(See figure4)tosee,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

diagram2lmg/mlconcentrationGO/DMFDispersion(left),Modification of benzeneisocyanatego/water dispersions(),Modification of benzeneisocyanateGO/DMFdispersant(Right).up to the top for placing24h,below the bottom after the bottle is reversed""WhatFigure2vials containing dispersions (l MG/MLof Go in DMF (left),phenyl isocyanate-treatedgo in water

(middle), andphenyl isocyanatetreated go INDMF.The top image shows the dispersions h after preparation.The bottom image shows the inverted dispersionswith the precipitate clearly shown on the bottom Of the left and middle vials[a].

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.Fangwait[+]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 controlPSMolecular weight(See figure5).whenthe[M]/[I|]to250:1when,The thickness of the modified graphene from ~2.2nmadd to ~8NM.Raman spectra display,due to covalent function,Graphene microcrystalline area reduction.

3. Graphene/Preparation method for polyurethane composites

3.1 MeltBlending

for industrial production,Melting Blending is the easiest method to implement,not only avoids environmental problems caused by solvents,,can alsoto save cost of production,therefore suitable for mass production.Kimetc[a]Graphite,reduction of graphene oxide and Peel graphene respectively with thermoplasticpolyurethane(TPU)on180°cMeltBlending,and take advantageofTEMandWAXDcharacterize composite materials.results show,noThe 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 theTPUHard segment of.If a polymer composite is to be prepared by melting method,must use MeltHigh temperature polymers,prevent material from degrading.

3.2 solutionBlending

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 phaseliquidform with polyurethane co-disperse deposition,to guarantee high surface area of graphene,Make it fully accessibleto the polymer.comparedtomolten blending,solution Blending easierto get molecular grade dispersed graphene/polyurethane composites.

Yousei, and so on[%]willGoaqueous solution andPUEmulsion blends in Solution,Add people to a quantity of hydrazine hydrate without dispersing agentliquid in80°CLower Restore responseH,Last inverted die molding.add compound dispersionsZetaPotential analysis discovery,Go/PUsurface PowerTofromone year~ aMVdropstoaMV,RGO/PUsurface potential dropstoaMV,The charge density on the surface of the is increased before mixing.toprove that graphene oxide and reductive graphite can be uniformly dispersed at the time of wet preparation.PUMatrix,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[a]with allyl isocyanate toGoModified,and then4,4 'Two phenyl methanediisocyanate(MDI)with poly-hexyl (PCL)intheDMFSolution Pre-reaction generationPUprepolymer,then ethyl acrylate(HEA)End with human light initiator,last downhuman polyethylene mould inUVlight on crosslinking curing.test the tensile performanceofPU,in the amount of modified graphene1~1.5% (wt)),material stretch modulus increased to varying degrees;Dosage greater than2% (wt),tensile modulus less than purePU.combinationDSCHeat flowdata 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 moreThenucleation Point simultaneously disrupts the chain orientation.asimilar theory has been inthekrni[+]Research appears:Graphite grapheneoxide surface contains a large number of hydroxylgroups,machine()reaction with isocyanate,so graphene can act as a cross-linking agent..

3.3 In-placeaggregation

Thein-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 ringboundary 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 isocyanatePUpre-clustered,pluspeople polyol for cross-linking.

3.3.1 footwork &1, and so on[Panax]designed a linear polyurethane macromolecules,withMDIis a monomer,PCLis two-dollar alcohol,with a one-time feed

The method leads to the sealing of graphene at the end base of the cyanate ester,and take advantageof theSEMcharacterization of graphene dispersion in a material cross-section,results found graphiteallyl sheet in[nmThe following,provenPUThe graphene in the matrix reaches the nanometer scale dispersion.

Scognamulo, and so on[pdf]in one step,IPDIandHDIas reaction monomer and catechol reaction,takesthe1,4-butyl alcohol as extensionchain agent,in-situ reaction of the additive graphene tablets in an ultrasonic environment,buildTPU/GrapheneComposite.through product viscoelastic flowchange test found,within a certain test frequency range,EnergyStorage modulus for compositesG'Decreases as theamount of graphene filler increases,This is nowThe image can be interpreted as the lubrication effect of the graphene sheet.;withDSCto analyze thermal properties of the product and find that,No observation in the heating processto have exothermic peaks exist,Thetherefore determines that the aggregate reaction is complete,the glass-temperature and rheological properties of composites are subjected to polyurethane systems and fillerschanges in dosage,graphene inHDI-BDSystem can act as lubricant,and inIPDI-BDTo act as areinforcing agent.

3.3.2 Two-Stepby adding different amounts of hard segment monomers and chainExtender,?Spiritual1^^£;1etc[all]A two-step method is used to prepare a for a different chain segment lengthPU/GNPComposite material,and take advantageof theDSC,DMAandFE-SEMexamines the performance of the material.fromDSCmap Analysis,on ~200°CareaField observes a exothermic,And the peak strength increases with the increase of graphene addition,in-situ reactiongoplus people make purePUonoccurs two times during heating,This is attributed to the amino on carbamate andGoThe reaction of the epoxy base on the causes two crystallizationto be issuedlive.whencooling to130C,long hard segmentPUshorterhard segmentPUCrystal exothermic weaker,This is because the longer the length of the chain movement, the Shaoxing operastrong,lower cooling crystallization temperature.from a stress-strain curve,viagomodifiedpumore purePUhas varying degreesof improvement,proofgoThe slice layer can play the purpose of transferring the payload.and different chain lengthPUcomposite,strain hardening is themain reason forimproving tensile strength and break elongationrate,andGoThe orientation of the layer along the soft segment and strain direction can be improved byPUstrain hardening of,to improve the mechanics of the materialperformance.

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 polyurethaneand then cross-linked with polyols.Zhangwait[[]FirstGoBlendswith bio-oil-based polyols,Toprepare a composite cross-linking agent,then ondbtdlexist withIPDIPre-polymerization,the ends with a crosslinking agent for cross-linking and casting.,Preparation of thermosetting polyurethaneester/graphene composites.tensile test shows,goThe fracture elongation and toughness of the compositesare greatly improved..author considers,goMechanical 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 softparagraph,instead of castor oil withGoas a cross-join,soGocan 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 prepareGo/PUComposites.For example0^etc[41]Use ball milling to prepareTPU/GNsComposites,First converts thepemg(Soft paragraph),GNs,BDO(chainExtender)with ethanol pluspeople grinding tank,Grinding in ethanol media1~H,to dry the mixture and add a personTDIas a hard segment,Stir3mm,finally cast the productMolding(See figure6),and electrical properties and topography analysis of the product.Theresult shows that,whenGNsAdd amountto2%(WT)when,composites upto conductive threshold,in grinding6hafter,Thegraphene is stripped off in alcohols and distributed in thePUPhase.

because the thermal expansion coefficients of graphene and polyurethane are different,Many scientists also use hot pressing at high temperatures to make them simpleby bonding,toto Polyurethanes/graphene thin tissue for good electrochemical performance,is expected to appear in the next generation of electrode materials[%].

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[]]to modify the graphite oxide with pyrene methanol andPUSolutionBlending,combinesTEMResult Analysis,Heat Treatment ProcessBreak the long range order of graphene, and torender the graphenesurface wrinkled,and this behavior may be caused by graphene and pyrene derivativesThetnkeys interact to form a non-covalent connectionPULow poly molecular chain,in Graphene/The polyurethane establishes a hydrogen bond with a stealthlength.stretch data to indicate that,The release of recessive length are helpful for improving fillsPUFlexibility and strength,Theelongation can be up to900%.

1^1 (1$_{\&}$etc[]]useDSCandDMAThe studies the melting methodGraphene/purThe crystallinity of the composites,combines two kinds of realanalyze data Discovery,fillPUR[] [], []The crystallinity of the crystal increases rapidly.,with increasing padding usage,Shorten crystallization time,crystallization process acceleration,Isbased ontheAFMphase diagram Analysis,Graphene/purThe crystalline size of the is less than the purePUR.

Khan, and so on[\]inDMFandTHFThe uses the spin coating method on thepu/gowet-processblending,Gothe mass fraction of the IS from0%to90%is notequalto.Goquality score greater than50% (Wt)when,The extrusion modulus of the material is exponentially incremented,in strain rate3%Young modulus whenfor1GPa,and the two solvents have little difference in the performance of the composites.DSCdata display withgocontent elevated,PUsoft segment crystal containingVolume drop.

The young modulus values of the filler reinforcing nanomaterials are often used inHALPM-TsaModel[' [4]7]to calculate,where,graphene in polyurethane withmachine orientation(ER)or orientation orientation()The Young's modulus of the composite is used in the formula(1)and Formula(2)to representthe,

type:ERis randomly distributedGoCompositeM2.(strain200%Extrusion modulus)Eutogoorientation and sample surface parallel rowcolumnof compositeM_;EgtogoM_ ;EmisPUforM2.;togoslice layer Average length;dtogoSlice average

into polyurethane solution,The last additive content is from0.~0.2% (wt)Different amount of modificationGodispersant(AFG)prepared graphene/polyurethanepaint.usetheTGand thermal conductivity Analyzer to analyze heat performance of paints,findsAFG/PUThe thermal stability temperature of the is307°C,ishigher thanPurePUon2742°c,The thermal conductivity of the material from purePUfor0.2492up to0 2810,0.2947,0 3491w/mk,show stoneThe graphene provides a low impedance propagation channel.

DebyeFormula(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)[+]evaluates:

X=(8)

$k=aC_pp$(9)

type,AThe is the phonon thermal conductivity4is the material thermal conductivity,$C_p$is the heat capacity of each unit volume^is the average phonon speed,Zis the phonon average fromby Tripais thermal diffusivity$_P$is the material density[+].

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

k_C=kp<^p+k_m<^$_m$(a)

type,kis the thermal conductivity of composites,$k_p$is the thermal conductivity of the filler,kmis the thermal conductivity of the polyurethane matrix,and lessmis the body of the filler and matrixIntegration 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 apolymer-paddingAConductive tunnel between to conduct current conduction.low padding content,filler as separate conductive unit rather than conductive network saveonso theelectricalperformance improves very little;until the filler volume increases enough to break through the polymer tunnel resistance,Conductive properties of compositesGets agreat boost,The amount of padding at this time is called a conductivity thresholdthe[5758].by adding a person to the polyurethane matrix graphene,can reachimproving the conductive properties of materials,and because of graphene's larger surface area, only aminimalamount of add is required to achieve the enhanced material guideThe purpose of the electricity.

Lee, and so on[all]Toprepare the hot reduction graphene first(fgo),in-situ synthesis of waterborne polyurethane coatings phase with human graphene,successfully preparedoutfgo/WPU.0.5mmThe DC conductivity of the thickness film is measured by a miniature galvanometer,experimental results show,Add3% (WT)'s Stonetheconductivity of the material increased by the5levels,and the amount of conductive range added2%(wt),at this timeWPUinside can form allEvenly 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[a],

0C=-*(C)] (one)

type,*is the packing volumefraction,*is the conductive domain,(^is filler conductivity,ff.is composite conductivity¡îis scale index.

stankcmch, and so on[a]the use of solution blending reduction method to prepare theGraphene/PSComposite material,with four-probe method for its conductivity enterAll right, test,linear fit of test results, found,The conductive range of the composite is in the graphene content0.1%v0l).addtoto1%(vol.)and2.5%(vol.)when,conductivity reached ~0.1S•i-^{1}and ~1S•m-^{1}.

4.3 gas barrier

as a two-dimensional material,The thickness of graphene is only0.3nmaround,The relatively large slice area is advantageous for the graphene toextend the gas through pathin the polymer base(See figure9,thus becoming ideal gas barrier material[6○].

Parent^^, and so on[%]by modifyingHummerThe preparationof a low performance defect of the graphene flake layer,Modified graphene by 16 alkyl dispersantsafter solution castinghdanr/TPUComposite,for material breathability,The is measured by a dynamic vacuum pressure drop methodtry.results show,increase with low-defect graphene added,Team passes the total time of the air chamber from the blank samples,to add amount0.1%(wt)),s addto0.2%(wt)for1000s,when the dosage exceeds0.5(wt)when,material is almost completely airtight in a short time

diagram8Polystyrene-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 islog^aboutLog(less angry)dot map,

takeThe is the conductive range of the composites.left illustration inside:on,Twodiagrams in the represent two modes of four-probe settings,Planar mode and cross section mode;

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

Figure8electrical conductivity of polystyreneaGraphene Composites as a function of filler volume fraction.

Main Figure,composite conductivity,R_C,plotted against filler volume fraction,0.Rightinset,Loga$_c$plotted

against log(in the atmosphere),where $0_C$is the percolationThreshold.Left inset:top andMiddle diagramsshow the Foui</b20>probe

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

Conditions-the sample thickness is twice the electrode width and the gap between them[^].
diagram9nano-layer modified polymer film after the gas through the path[6○]

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

for elastomer material,NielsenModel[2]can be used to establish a model of breathability contrast,

P_0~1 +()R/^ <5/3)

type,Pis the theoretical gas permeability,P.is the original sample gas permeability,r/dis filler aspect ratio,<5is packing volume ratio[+].

Guo, and so on[]A layer of graphene film is deposited on the surface of polyethylene film by drop coating,to investigate the permeability of composites,and passnelsenmodel results Analysis and estimates.results show,nmthick graphene makes the vapor transmittance of the polyethylene matrix lower.%,and the ideal barrier effect of lamellar graphene is better thanNelsenTheoretical data for the model.

4.4 dielectric performance

Chen, and so on[$]the uses Atom transfer radical polymerization to react inGoSurface AggregationPMMA,andthen associate it withthePUto blend and restoreafter casting-Molding,preparedMG-PUComposite material.test dielectric properties of materials using Impedance Analyzer(See figureOne),Resultsshow,Increase frequency,increases the dielectric constant of all composites,dielectric loss also increased.from the change trend,Composite's mediumThe electrical constants of the increase as the amount of graphene increases./based on theinferred Graphenepolyurethanematerial can be used as a new type of electronic machinery application Squaresurface material.

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