Processed Text

molecule article fluorine containing flow modifier bn pps composite enabled low surface energy bocao1 2 xiaodanhuang1 wenxiangzhang1andpengwu1 1 schoolofmaterialsscienceandengineering southchinauniversityoftechnology guangzhou510640 china 2 keylabguangdonghighproperty functionalpolymermaterials andkeylaboratoryofpolymer processingengineering ministryofeducation guangzhou510640 china correspondence shawn78521 sina com abstract inthisstudy afluorine containingflowmodifier si df withlowsurfaceenergyissuc cessfullysynthesized whichisappliedtofabricateidealelectronicpackagingmaterials bn pps composite withhighthermalconductivity excellentdielectricproperties processability andtough nessbyconventionalmeltblending si dpfislocatedattheinterfacebetweenthebnfillersandthe ppsmatrix whichnotonlyimprovesthedispersionofbnfillersbutalsostrengthenstheinteraction withthehelpof5wt si df bn pps si df 70 25 5 stillexhibitsthehighthermallyconductive coefficient 3 985w k andlowdielectricconstant 3 76at100mhz althoughbnfillersare loadedashighas70wt moreover thesampleprocessesalowerstabletorquevalue 2 5n andtheareaunderthestress straincurvesisalsoincreased thisworkprovidesanefficientwayto develophigh performancepolymer basedcompositeswithhighthermallyconductivecoefficients andlowdielectricconstantsforelectronicpackagingapplications keywords bn ppscomposites fluorine containingflowmodifier dispersion thermalconductivity dielectricproperty citation cao b huang x zhang w wu p fluorine containingflow modifierforbn ppscomposites enabledbylowsurfaceenergy 1 introduction molecules2022 27 8066 http polyphenylenesulfide pps hasbeenwidelyusedaselectronicpackagingmaterialin doi org 10 3390 molecules27228066 thefieldofelectroniccommunicationsduetoitsoutstandingthermaldimensionalstability academiceditors nadyavasileva superiorchemicalresistance andhighflameretardance withcontinuousminiaturization dencheva andzlatandenchev andincreasedpowerinelectronicdevices thecomprehensiveperformanceofelectronic packagingmaterialsmakesmorestringentrequirements 1 4 anidealelectronicpackag received 31october2022 ingmaterialshoulddemonstratehighthermalconductivity excellentdielectricproperties accepted 17november2022 processability andtoughness unfortunately theppsmatrixhasarelativelylowthermally published 20november2022 conductivecoefficient 0 4w k whichneedstobeenhancedbyincorporatingther publisher snote mdpistaysneutral mallyconductiveparticles 5 8 somestudieshaveshownthatintroducingalargenumber withregardtojurisdictionalclaimsin ofthermallyconductiveparticlesleadstoadramaticincreaseinthethermalconductivityof publishedmapsandinstitutionalaffil thepps basedcomposites suchasboronnitride bn expandedgraphite eg aluminum iations nitride aln andcarbonnanotubes cnt 9 12 however ahighloadingofparticleseasilyformsalargenumberofagglomerates deterioratingtheprocessabilityandtoughnessofthecomposites 13 14 moreover seriousagglomerationofparticlesalsoleadstomoreinterfacialthermalbarriers whichis copyright 2022 author notconducivetothefabricationofcompositeswithhighthermallyconductivecoefficients licensee mdpi basel switzerland low dielectric constant 15 thus major challenge fabrication ideal article open access article electronicpackagingmaterials pps basedcomposites istoachievetheuniformdispersion distributed term ofthermallyconductiveparticlesintheppsmatrix conditionsofthecreativecommons attribution ccby license http usually pps based composite high thermal conductivity prepared creativecommons org license hot compression technique surface modified particle premixed 4 0 pps matrix greatly improves dispersion particle 16 19 molecules2022 27 8066 http doi org 10 3390 molecules27228066 http www mdpi com journal moleculesmolecules 2022 27 x peer review 2 11 molecules2022 27 8066 usually pps based composite high thermal conductivity prepare2do fb1y1 hot compression technique surface modified particle premixed pps matrix greatly improves dispersion particle 16 19 yang et al 16 modified bn filler using silanization reaction γ aminopropyl triethoxy yangetal 16 modifiedbnfillersusingasilanizationreactionwithγ aminopropyltri silane aminopropyllsobutyl polyhedraloligomeric silsesquioxane f bn found f ethoxysilane aminopropyllsobutylpolyhedraloligomericsilsesquioxane f bn andfound bn filler better dispersion pps matrix thermally conductive coefficient thatf bnfillershadbetterdispersionintheppsmatrix thethermallyconductivecoeffi cλ ie n v ta λlu e v ao lf u eth oe f tf h b en f bp np pc po sm cp oo m pit oe w iteit wh i6 th0 6w 0t w f b f n bn w sim imp pr ro ov ed 11 11 22 22 ww k k f fo ou ur r ti im e hh ii gg hh ee rr tt hh aa nn tt hh aa tt oo ff tt hh ee pp pp s mm aa tt rr ii xx 00 22 88 66 ww k k r ry yu u e et al l 1 19 9 r ep po rt te ed th ha tthhee ggrraaffttiinngg ooff 3 3 ammininoopproroppyyl l trtireitehtohxoyxsyislailnaen oenotnot toheth seursfuarcfea coef bonf b fnillefirsll erersdurecdedu caegd gaglogmloemraetriaotnio nt hte hλe vλavluaelu oef o3f 039 0w9 wm km w kasw eaxsheixbhitiebdit bedy bthyet mheomdiofideidfi ebdnb cnonctoanintainingi n6g0 w60t w h wheovweer v deur ed tuoe thtoe cthoemcpolmexpitlye xoift ythoisf tmheisthmoedt h ito dca nitncoat nbneo etxbteenedxetden tdo eldartgoe lsacraglee isncdaluesitnridaul sptrrioadlpurcotidounc titohne rtehfoerree f otrhee tuhneiufonrimfolrym dlyisdpiesrpseerds epdaprtairctliecsl eisni nththe eppppss mmaattrriixx ccoouullddd bbee eeaassiillyy rreeaalilzizeeddb byym meletltb lbelnednidnigngte tcehcnhonloolgoyg yw hwichhicihs oisf porf impreimime pimorptaonrctaenfcoer tfhoer tdheev deleovpemloepnmteonfti doefa ildeelaelc etrloecntircopnaicc kpaagciknaggminagt meraiatlesriianlsin idn uinstdruy stry iinn tthhiiss wwoorrkk aa fflluuoorriinnee ccoonnttaaiinniinngg fllooww mmooddiiffiieerr ssii ddff iis ddeessiiggnneedd aanndd ssyynnttheessiizzeedd ffiigguurree 11 wwhhiicchh iis iinnttrroodduucceedd iinnttoo bbnn ppppss ccoommppoossiitteess tthhee wweeiigghhtt rraattiioo ooff bbnn ttoo ppppss iis 6600 4400 aanndd 7700 3300 bbyy aa ccoonnvveennttiioonnaall mmeelltt pprroocceessssiinngg tteecchhnniiqquuee tthhee ccff 33 tteerrmmiinnaall ggrroouuppss eennddooww ssii ddff wwiitthh loloww susurfrafacec eeneneregryg wwhhicihc heneanbalbelse ssis di fd tfo tloocloatcea taet aa ttwaotw poh apshea isneteinr ftaecrfea c 1e4 1 4i iist iesxepxepcteecdte tdhatht atthteh benbn filfilellresr swwilli llbbe eddisipspeersresded inin tthhee ppppss mmaattrriixx aanndd tthhee bbnn ppppss ccoommppoossitietess wwilill lpprreesseenntt hhiigghh tthheerrmmaall ccoonndduuccttiivviittyy eexxcceelllleenntt pprroocceessssaabbiilliittyy aanndd ttoouugghhnneessss tthhee ccoommppoosistiete wwilill allaslos ommaianitnatiani na laowlo wdiedlieecltercitcr ciconcostnasntta nwtitwhi tthhet hheelhpe olpf soi f dsif ifn iandadditdioitnio nth eth deisdpiesprseirosnio mnemcheachnaisnmis mi eisxpexloprleodre figure 1 synthesis route si df figure1 synthesisrouteofsi df 22 eexxppeerriimmeennttaall 22 11 mmaaiinn mmaatteerriiaallss ppoollyypphheennyylleennee ssuullffiiddee ppppss wwaass ppuurrcchhaasseedd ffrroomm nnaannjjiinngg ddeeyyuuaann sscciieennccee aanndd tteecchh nologyco ltd nanjing china boronnitride bn meandiameterof20 30µm thermally nology co ltd boron nitride bn mean diameter 20 30 µm thermally conductive co conductivecoefficientof33w k wasreceivedfromqinhuangdaoenohigh tech efficient 33 w k received qinhuangdao eno high tech material devel material development co ltd qinhuangdao china amino silicone oil pur opment co ltd amino silicone oil purchased shin etsu chemical industrial chasedfromshin etsuchemicalindustrialco ltd tokyo japan 9 10 dihydro 9 oxa co ltd tokyo japan 9 10 dihydro 9 oxa 10 phosphaphenanthrene 10 oxide dopo 10 phosphaphenanthrene10 oxide dopo and3 trifluoromethyl benzaldehydewere 3 trifluoromethyl benzaldehyde purchased shanghai aladdin biochem purchasedfromshanghaialaddinbiochemicalco ltd shanghai china ical co ltd shanghai china 2 2 synthesisofsi df 2 2 synthesis si df aminosiliconeoil 17 2g 0 02mol 3 trifluoromethyl benzaldehyde 6 96g 0 04mol amino silicone oil 17 2 g 0 02 mol 3 trifluoromethyl benzaldehyde 6 96 g 0 04 100 ml ethanol added sequentially 250 ml round bottom glass flask mol 100 ml ethanol added sequentially 250 ml round bottom glass equippedwithanitrogeninlet acondensingdevice andamagneticstirrer themixture wfla sk se tiq ru reip dp ae td 8 w 0i ch fo n ri 8tro hg uen n tii lnl te ht e c oc mon pd lee tn esi cn og n vd ee rv si ic oe n oan fd inm oag sin lie ct oic n esti ir le ar n dh 3e mixture stirred 80 c 8 h complete conversion amino silicone oil trifluoromethyl benzaldehyde asconfirmedbyftir andthentheintermediate si cf 3 trifluoromethyl benzaldehyde confirmed ftir intermediate si wasobtained dopo 8 64g 0 04mol wasaddedintothesystemandthenfurtherreacted 12 h room temperature complete conversion dopo tested via ftir ethanol removed using rotary evaporator residual solid wasmolecules 2022 27 x peer review 3 11 cf obtained dopo 8 64 g 0 04 mol added system molecules2022 27 8066 3of11 reacted 12 h room temperature complete conversion dopo tested via ftir ethanol removed using rotary evaporator residual solid recrystallized ethyl acetate yield yellowish powder named si df 30 76 g yield recrystallizedfromethylacetatetoyieldayellowishpowdernamedsi df 30 76g yield 9 93 3 8 8 g gp pc c da ta mn 1 13 39 98 8 g g mol lp pdi 1 12 2 2 2 n 2 3 preparation bn pps composite 2 3 preparationofbn ppscomposites b bn n nd p pp p ww ee rr ee dd rr ii ee dd ii nn aa vv aa cc uu uu mm oo vv ee nn aa tt

99 00 cc ff oo rr 11 22 hh tt hh ee bb nn p pp p c co om mp po o si te e prepared melt blending twin screw extruder temperature prepared melt blending twin screw extruder temperature eexxttrruuddeerr wweerree sseett iinn tthhee rraannggee ffrroomm 226655 cc ttoo 229955 cc aatt aa ssccrreeww ssppeeeedd ooff 112200 rrppmm aaffteerr bbeeiinngg ggrraannuullaatteedd aanndd ddrriieedd tthhee ppeellllleettss wweerree iinnjjeeccttiioonn mmoollddeedd oonn aann iinnjjeeccttiioonn mmoollddiinngg mmaacchhiinnee ttoo oobbttaaiinn ddiiffffeerreenntt ssppeecciimmeennss tthhee mmoollddiinngg wwaass ccoonndduucctteedd aatt zzoonnee tteemmppeerraattuurree pprroofifilleess ooff 227755 228800 2 29900 2 29900 2 29955 c c thehec ocmompopsoitseitpe rpepreapraatriaotniopnr opcreoscseasns dancodm cpomospitoiosnitiaorne asirme spilmypilllyu siltlruastterdatiends icnh esmcheem1 ea n1 atnhde tchoem cpoomspitoiosnitsioannsd acnodd ceondaem neasmoefst hoef tshaem spalmespalerse alirset eldistiendt ianb ltea1b le 1 scheme 1 schematic illustration pps composite preparation scheme1 schematicillustrationofppscompositespreparation ttaabbllee 11 ccoommppoossiittiioonnss aanndd ccooddee nnaammeess ooff tthhee ssaammpplleess samplseasmples bn g bn g pps gp p g si di df fg g bn pps 60 40 60 40 bn pps 60 40 60 40 bn pps si df 60 35 5 60 35 5 bn pps si df 60 35 5 60 35 5 bn ppbsn 7p0p s3 0 70 30 70 70 30 30 bn ppbsn ip dpsf 7i 0d f2 5 705 25 5 70 70 25 25 55 2 4 characterization 2 4 characterization th e f ft ti ir r s pp ee cc ttr ra s cc aa nn nn ee dd bb ee tt ww ee ee nn 44 00 00 aa nn dd 44 00 00 00 cc mm 11 w er e ob bt ta ai ne ed n n ni ic co ol le et 5 50 0x xc c sp pe ec ct trr oo mm ee tt ee rr nn ii cc oo ee tt gg ee nn dd aa ee ww ii uu s aa tt hh ee 11 hh nn mm rr aa nn dd 3311p p n nm mr r sp pe ec ct tr ra w er e recorded av400 unity spectrometer bruker billerica usa operated 400 recordedonanav400unityspectrometer bruker billerica usa operatedat400mhz mwihthz dwmiths od mdsaos da6s aosl vae snotl vtenhte tnhuem nbuemr abvere raavgeerdagmedol maromlaar smsa ms mann anpdo lpyodliysdpiesrpseitry 6 n mity w mmwn onf soif dsif dwfe rweemree amsuearesudrbedy gbeyl gpeelr mpeeramtieoanticohnr ocmhraotmogartaopghrayp hwy twerast emrsi l fmoridl fmorad umsaa u tshae c tohneta ccotnatnagctl easnwgleerse wdeertee rdmeitneremdionneda odns aa d10s0ac1o0n0t accotnatancgtl eaninglsetr iunmsterun kernut sksr huasms b huargm bguerrgm ganeyrm wanityh wwaittehr wanatderd aiinodd odmiioedthoamneetahta2n5e act 2 r5e scp e rcetisvpeelcyt isvcealyn sncinangneilnegct erolenctmroincr mosiccorposyc ospeym eimma g imesawgeesr ewoebrtea oinbetadinoenda onn oav naonvaan nosaenoms4e3m04s3ca0n sncainng neliencgt reolnecmtroicnr omsciocrpoesc fopeei hfeilil bhoirlols boorro uosra u tshae totrhqeu teovrqauluee vsaolfueths eosf atmhep lseasmwpeleres wmeeraes umreedasounreadh oana kae htoarqaukee xtosrsq u30e0 xrshse o3m00e terhre homaaekteer v hreadaekne g verremdaenny gaetramroatnayti ant oaf r5o0tarptimona otf2 5805 r pcmf oatr 21805m cin f otr h1e0 tmheinrm tahlley thcoenrmdualcltyiv ceoncodeufcfitcivieen ctoveaffliuceiesnotf vtahleuesas mofp tlhees swaemreplmese awseurree dmoenasautrepds 2o2n0 a0 htpost2d2i0s0k hinostt rduimske nints tarubmceonrtp oarabt iconor pvoärsatteiroåns vswäsetdereåns sdwieeldecetnri c dcoinelsetcatnrticv caolunesstaonftt vhaelsuaems pofle tshwe searemmpleeass uwreerde omneaashuigrehd f roenq ua ehnicgyh qfrienqsutreunmcye nqt ionfsqtrubmg e3ndt f hqabngg h3adi sihyaineglehcatir oaniiyci eeqleucitpromneicn te qsuhiapnmgehnati schhainngah aia ccchoirndai n gatcocoirsdo i5n2g7 t2os tiasnod a5r2d7 2th setatenndsailreds ttrhene gttehnssoilfe thsteresnamgtphlse sofw tehree tseasmtepdleosn wanerae gtess t1e0dk noni uanni vaegrssa l materialtestingmachine shimadzu kyoto japan atthespeedof10mm min molecule 2022 27 x peer review 4 11 10kni universal material testing machine shimadzu kyoto japan speed 10 molecules2022 27 8066 mm min 4of11 3 result discussion 3 31 crheasrualcttserainzadtidoni socfu ssis diofn 3 1 characterizationofsi df typical synthetic process intermediate si cf first synthesized via schiff bdausrei nregacatitoynp ibceatlwseyennt haemtiicnop rsoilciecsosn et hoeil ianntedr m3 etdriiaftlueosrio cmfetihsyfil r sbtensyznaltdheehsiyzdeed ivni ana estcohhiff sboalsuetiroena c ttihoen fbloewtw meeondaifmieirn soi sdilfic iosn teheonil paenrdfo3r terdifl tuhororoumghe tthhyel adbdenitzioanld reehaycd e tioinn aonf deotopho saonldu tsiio nc f fhieguflroew 2 smhoodwisfi tehres iin dfrfariesdt shpeenctprear ofof rsmi cedf tahnrdo usgi hdfth ethaed dsyitnio n threesaisc toiofn thoef dsio cpfo inantedrmsie dcifa tfe iigsu preer2fosrhmoweds bthye tihnef rcaorneddesnpseacttiroano offs ia mcfinaon sdilsicio dnef otihl e ansdy n3t h etsriisfloufotrhoemseit hcyfl inbteenrzmaelddeiahtyedies poebrfvoiromuseldy b tyhteh estcroonngd epnesaakti oonf cfahm nin ssiclihciofnf e oiland3 trifluoromethyl benzaldehyde obviously thestrongpeakof ch n schiff base appears 1650 cm 1 peak cf3

appears 1650 cm 1 indicates base appearsat1650cm 1 andthepeakof cf appearsat1650cm 1 whichindicates triggered aldimine polymerization amin3o silicone oil 3 trifluoromethyl thetriggeredaldiminepolymerizationbetweenaminosiliconeoiland3 trifluoromethyl benzaldehyde si df performed addition reaction dopo si cf benzaldehyde thesi dfisperformedthroughtheadditionreactionofdopoandsi cf additionally peak ch n absent wavenumber si df indicating additionally thepeakof ch n isabsentatthesamewavenumberforsi df indicat dopo successfully carried addition reaction intermediate con ingthatdopohassuccessfullycarriedouttheadditionreactionwiththeintermediate taining ch n group 14 20 22 containingthe ch n group 14 20 22 fifgiugruer 2e 2f tfitri rspsepcetrcatr oafo sfi sci fc afnadn dsis di fd f the1hnmrspectrumofsi dfisdisplayedinfigure3a thepeaksat 0 12 0 16ppm 1h nmr spectrum si df displayed figure 3a peak 0 12 0 16 0 32 0 46ppm and1 16 1 42ppmareattributedtotheprotonsin si ch si ch ppm 0 32 0 46 ppm 1 16 1 42 ppm attributed proton si 3ch3 si c2h2 ch ch respectively peak 5 29 5 32 ppm 5 07 5 11 ppm attributed c2h2 c2h2 respectively peak 5 29 5 32 ppm 5 07 5 11 ppm attributed totheprotonsin nh andp ch thepeaksat6 5 8 2ppmareattributedtotheprotons proton nh p ch peak 6 5 8 2 ppm attributed proton inthebenzenering the31pnmrspectraofdopoandsi dfareshowninfigure3b benzene ring 31p nmr spectrum dopo si df shown figure 3b basedonthe31pnmrspectrumofdopo thepeaksat14 40 15 75ppmareobserved based 31p nmr spectrum dopo peak 14 40 15 75 ppm observed molecule 2022 27 x peer revwiew hwih leil e thth e e pp ee aa kk s aa rr ee aa bb s ee nn tt th e sa ew wav aven eu num mbe br ef ro fr o ri sd f fn ann de w nep wea pk e aa kr se ab r5es eoorf bv1 e1d at31 50 34 85ppm theresultsfromftir 1hnmr and31pnmrshowthattheflow served 31 50 34 85 ppm result ftir 1h nmr 31p nmr show modifiersi dfhasbeensuccessfullysynthesized flow modifier si df successfully synthesized figure3 1hnmrspectrumofsi df b 31pnmrspectraofsi dfanddopo figure 3 1h nmr spectrum si df b 31p nmr spectrum si df dopo 3 2 phase morphology highly filled polymer based composite disperse filler matrix key issue presenting challenge fabrication high performance composite display effect si df dispersion bn filler morphology bn filler sample observed sem figure 4 exists serious agglomeration bn filler sample bn pps 60 40 figure 4a1 bn pps 70 30 figure 4b1 addition si df morphology bn filler present striking contrast obviously found bn filler exhibit homo geneous dispersion sample bn pps si df 60 35 5 figure 4a2 bn pps si df 70 25 5 figure 4b2 figure 4 sem image bn pps 60 40 a1 bn pps si df 60 35 5 a2 bn pps 70 30 b1 bn pps si df 70 25 5 b2 previous work demonstrated fluorine containing flow modifier pmfs low surface energy located mh lldpe interface highly filled mh lldpe composite 80 20 weight improved dispersion mhmolecules 2022 27 x peer review 5 11 figure 3 1h nmr spectrum si df b 31p nmr spectrum si df dopo 3 2 phase morphology highly filled polymer based composite disperse filler matrix key issue presenting challenge fabrication high performance composite molecules2022 27 8066 display effect si df dispersion bn filler morphology5 ooff 1t1he bn filler sample observed sem figure 4 exists serious agglomeration bn filler sample bn pps 60 40 figure 3 2 phasemorphology 4a bn pps 70 30 figure 4b addition si df morphology 1 1 bn fillefrosr phirgehsleynfitsll ead sptroilkyimnger c boansterdascto itp io oitbesv ihoouwslyto fdoiuspnedr stehtahte bfinlle frisllienrsth eexmhiabtriitx ai shomo akeyissuepresentingachallengeinthefabricationofhigh performancecomposites geneous dispersion sample bn pps si df 60 35 5 figure 4a bn pps si 2 displaytheeffectofsi dfonthedispersionofbnfillers themorphologyofthebnfillers df 70 25 5 figure 4b 2 inthesamplesisobservedbysem figure4 figfuigruer 4e 4 esemm imimaaggeess ooff bbnn ppppss 6600 4400 1 1 b bnn p ppp ssi id dff 6 06 03 53 55 5 2a 2 b nbn p ppsps 7 07 03 03 0 b 1b 1 bna npdpbsn pdpfs s7i0 2f5 57 0 b252 5 b2 int ohuerre pexriesvtsioseursio wusoargkg l owmee rdaetimonoonfsbtnraftiellder tshinatt htehsea fmlupolerbinne pcposnt a60in 4i0n g f filgouwre m4ao1 difiers andbn pps 70 30 figure4b withtheadditionofsi df themorphologyofthebn pmfs low surface energ1y located mh lldpe interface highly fillerspresentsastrikingcontrast itisobviouslyfoundthatbnfillersexhibitahomoge filled mh lldpe composite 80 20 weight improved dispersion mh neousdispersioninthesamplesbn pps si df 60 35 5 figure4a andbn pps si df 2 70 25 5 figure4b 2 inourpreviouswork wedemonstratedthatthefluorine containingflowmodifiers pmfs withlowsurfaceenergywerelocatedatthemh lldpeinterfaceinthehighly filledmh lldpecomposites 80 20byweight whichimprovedthedispersionofmh particle 23 meanwhile thedistributionofflowmodifierscanbeestimatedbyevaluating thewettingcoefficient ω 24 herein young smodelisusedtocalculatetheω ofsi df additionally 1 ω 1 si dfispreferredtolocateattheinterface thesurface energy individual component pps bn si df examined measuring contact angle interfacial energy calculated using surface energy individual component using geometric mean equation harmonic mean equation 25 27 allofthedataarelistedintables2and3 respectively molecules2022 27 8066 6of11 table2 contactanglesandsurfaceenergiesofpps bnandsi df contactangle γ γd γp sample water diiodomethane mj m2 mj m2 mj m2 pps 90 37 24 76 46 99 46 63 0 36 bn 89 12 64 89 26 8 22 5 4 3 si df 98 45 51 20 34 08 33 78 0 3 table3 preferentialdistributionofsi dfinthebn ppscompositesaccordingtointerfacialenergies γandwettingcoefficientsωa basedon basedon interfacial flowmodifiers energy geometric mean harmonic mean ωg ωh distribution equation mj m2 equation mj m2 γ 6 52 11 75 bn pps γ si df pps 1 04 2 06 0 37 0 31 bn ppsinterface γ 3 47 5 74 si df bn asseen thevaluesofω forsi dfare 0 37and 0 31 respectively ascalculated geometric mean equation harmonic mean equation young model indicatingthatsi dftendstolocateattheinterfacebetweenthebnfillersandppsmatrix combiningwiththephasemorphologyandtheoreticalcalculations itisconcludedthatthe distributionofsi dfatthetwo phaseinterfaceiseffectivelyabletoreducetheformation ofagglomerationinthematrix 3 3 thermalconductivity figure5presentsthethermallyconductivecoefficient λ valuesofthepps matrixand bn ppscomposites theλvalueofthepps matrixis0 372w k thecompositesreveal adramaticenhancementinthermalconductivityincomparisonwiththepps matrix theλ valuesofbn pps 60 40 andbn pps 70 30 are3 379w kand3 569w k areapproximately9and9 6timeshigherthanthatofthepps matrix respectively withthe additionofsi df thesamplespresenthigherthermalconductivity andthecorresponding λvaluesareincreasedto3 873w kofbn pps si df 60 35 5 and3 985w kof bn pps si df 70 25 5 respectively thisimpliesthatefficientthermaltransferpathways couldbeformedatahighloadingofbnfillersinthepps matrixbytheintroductionof si df 16 28 additionally itisbelievedthatthehomogeneousdispersionofbnfillers inthepps matrixisthekeytotheformationofthermaltransferpathways furthermore si dfformsaprotectivelayeronthebnsurfaces whichshowsrelativelylowerinterfacial molecule 2022 27 x peer review 7 11 thermalbarrierswiththepps matrixcomparedtothesampleswithoutsi df resultingin higherλvalues figure5 thermalconductivityofpps matrixandbn ppscomposites figure 5 thermal conductivity pps matrix bn pps composite table 4 summarizes reported thermally conductive coefficient thermal con ductivity enhancement bn pps composite noted bn pps composite higher bn filler content work show high thermally conductive coefficient highest thermal conductivity enhancement work provides relatively efficient facile method improve thermal conductivity bn pps composite table 4 comparison thermally conductive coefficient thermal conductivity enhancement bn pps composite thermally thermal filler loading conductive conductivity sample strategy year ref wt coefficient enhancement w k bn pps 60 2 638 822 3 hot compression 2017 15 surface modification bn pps 60 1 122 292 3 2017 16 hot compression bn pps 40 vol 2 45 880 hot compression 2017 18 bn pps 60 3 1 785 8 surface modification 2017 19 bn pps 60 2 7 610 5 melt blending 2017 19 bn pps 60 3 873 941 1 melt blending work bn pps 70 3 985 971 2 melt blending work 3 4 dielectric property key parameter electronic packaging material low dielectric constant con ducive reducing signal propagation time electronic component important practical application dielectric constant frequency curve pps matrix bn pps composite displayed figure 6 pps matrix posse di electric constant value 3 32 100 mhz seen dielectric constant value sample increased loading bn filler corresponding value increased 3 75 bn pps 60 40 3 98 bn pps 70 30 worth noting introduction si df beneficial decreasing dialectic constant sample sample bn pps si df 60 35 5 bn pps si df 70 25 5 dielectric constant value decreased 3 55 3 76 respectively lower dielectric constant attributed weakening interface polarization 29 30 si df improves dispersion bn filler also strengthens interaction bn filler pps matrix weakening polarization bn filler pps matrix resulting relatively lower dielectric constant value bn pps composite molecules2022 27 8066 7of11 table4summarizesthereportedthermallyconductivecoefficientandthermalconduc tivityenhancementforthebn ppscomposites itisnotedthatthebn ppscomposites withhigherbnfillercontentsinthisworkshowahighthermallyconductivecoefficient andthehighestthermalconductivityenhancement thisworkprovidesarelativelymore efficientandfacilemethodtoimprovethethermalconductivityofbn ppscomposites table4 comparisonofthermallyconductivecoefficientandthermalconductivityenhancementin bn ppscomposites thermally thermal fillerloading conductive conductivity sample strategy year ref wt coefficient enhancement w k bn pps 60 2 638 822 3 hot compression 2017 15 surface modification bn pps 60 1 122 292 3 2017 16 hot compression bn pps 40 vol 2 45 880 hot compression 2017 18 bn pps 60 3 1 785 8 surface modification 2017 19 bn pps 60 2 7 610 5 meltblending 2017 19 bn pps 60 3 873 941 1 meltblending thiswork bn pps 70 3 985 971 2 meltblending thiswork 3 4 dielectricproperty key parameter electronic packaging material low dielectric constant conducive reducing signal propagation time electronic component veryimportantinpracticalapplications thedielectricconstant frequencycurvesofthe ppsmatrixandbn ppscompositesaredisplayedinfigure6 theppsmatrixpossesses adielectricconstantvalueof3 32at100mhz itcanbeseenthatthedielectricconstant valueofthesamplesisincreasedastheloadingofbnfillers andthecorrespondingvalues areincreasedto3 75forbn pps 60 40 and3 98forbn pps 70 30 itisworthnotingthat theintroductionofsi dfisbeneficialindecreasingthedialecticconstantofthesamples forsamplesbn pps si df 60 35 5 andbn pps si df 70 25 5 thedielectricconstant valuesdecreasedto3 55and3 76 respectively thelowerdielectricconstantshouldbe attributedtotheweakeningofinterfacepolarization 29 30 si dfnotonlyimprovesthe molecule 2022 27 x peer reviewdi spersionofbnfillersbutalsostrengthenstheinteractionbetweenthebnfillersandpps8 11 matrix weakeningthepolarizationbetweenthebnfillersandppsmatrix resultingin relativelylowerdielectricconstantvaluesofthebn ppscomposites fif gi ug ru er e 6 6 dd ieie lele cc tt rr ii cc cc oon n st ta nt fr fe req qu uen ec ny cycu cr uve rv eo sf p op f ppm sa mrix ata rn ixd ab nn bpp n pco pm p co o mite p site 3 5 processability processability bn pps composite evaluated torque rheology test 31 figure 7 show torque v time curve bn pps composite expected stable torque value sample increased loading bn filler pronounced decrease torque value bn pps composite addition si df observed sample bn pps 60 40 bn pps 70 30 stable torque val ues 3 0 n 11 7 n 5 wt si df added corresponding value decreased 2 1 n bn pps si df 60 35 5 2 5 n bn pps si df 70 25 5 respectively indicating si df obvious advantage improving processability bn pps composite si df tends located interface effectively reduces melt viscosity prevents bn filler aggregation de crease friction bn filler bn filler pps matrix figure 7 torque versus time bn pps composite 3 6 mechanical property mechanical property critical composite especially tensile strength toughness work tensile testing pps matrix bn pps composite con ducted result shown figure 8 tensile strength pps matrix 38 mpa addition bn filler tensile strength sample increased corresponding strength increased 48 mpa bn pps 60 40 43 mpa bn pps 70 30 tensile strength slightly decreased sample si df tough ness sample evaluated calculating fracture work derived areamolecules 2022 27 x peer review 8 11 figure 6 dielectric constant frequency curve pps matrix bn pps composite molecules2022 27 8066 8of11 3 5 processability processability bn pps composite evaluated torque rheology test 3 5 processability 31 figure 7 show torque v time curve bn pps composite expected statbhleep troorcqeussea bvialiltuyeosf obfn hpep ssacmomplpeoss aitrees iisnecvreaalusaetded wbiythth tehteo rloquadeirnhgeo olofg bynte sftil l3e1r figure 7 show torque v time curve bn pps composite expected pronounced decrease torque value bn pps composite addition thestabletorquevaluesofthesamplesareincreasedwiththeloadingofbnfillers si df observed sample bn pps 60 40 bn pps 70 30 stable torque val apronounceddecreaseinthetorquevaluesofthebn ppscompositeswiththeaddition ues 3 0 n 11 7 n 5 wt si df added corresponding value ofsi dfisobserved forsamplesbn pps 60 40 andbn pps 70 30 thestabletorque decreased 2 1 n bn pps si df 60 35 5 2 5 n bn pps si df value 3 0 n 11 7 n 5 wt si df added corresponding 7 v0 l2 u5 e s5 r ere d ep cre ec si ev del ty 2i n 1d nic mati fgb nth aptp ssi sdi fd fha 6s0 3n5 o5b v anio du 2 5a ndv man ot fabgne ipnp ism spir dovfing p r7o0c 2e5s s5a b irleistpye octfi vtheley binnd ipcaptsin cgotmhaptossi idtefs h sais danf otbevnidous stoa dbvea nlotacgaeteidn iamt pthroev iinngtetrhfeace efpfreoccteivssealbyi lrietyduofceths ethben peplts vcioscmopsiotsyi ew hsici hd pfrteevnednsttso bbne lfoicllaetresd farotmthe aigngterrefgaacetioannd de creeffaescetisv tehlye frreidcuticoens btheetwmeeeltn vtihseco bsnity fiwllehricsh anpdre vbeentwtsebenn tfihlele brsnfr foimllerasg garnedg atthioen papnsd matrix decreasesthefrictionbetweenthebnfillersandbetweenthebnfillersandtheppsmatrix fifgiguurree 77 ttoorrqquuee vveerrssuusst itmimeeo fobf nb np ppspcso cmopmospiotessi te 3 6 mechanicalproperties 3 6 mechanical property mechanicalpropertiesarecriticalforcomposites especiallytensilestrengthandtough nessm inecthhaisnwicoarlk ptreonpsielerttieesst inagreo fctrhiteicpapls fmora trcioxmanpdosbinte sp pesspcoemciaplolsyi tetsenissciloen dsturcetnedg th toaungdhtnheesrse iunlt sthairse wshoorwk n teinnsfiilgeu trees8ti ntgh oeft ethnesi lpepsstr emnagttrhixo fatnhde pbpns pmpastr cixomisp38osmitpesa con dwucitthedt h aenadd dthiteio rnesouflbtsn arfiel lsehrso wthne inte nfsigileursetr 8e n tgthhe otfenthseiles asmtrpenlegsthin ocrfe tahseed p pasn dmtahterix 38 mcoprar e wspiotnhd tihneg asdtrdenitgiothni onfc rbenas efdillteors4 8 tmhep taenfosrilben st rpepnsg t6h0 o4f0 haen dsa4m3pmlepsa ifnocrrbeans epdp 70 30 thetensilestrengthisslightlydecreasedforthesampleswithsi df thetoughness corresponding strength increased 48 mpa bn pps 60 40 43 mpa bn pps ofthesamplesisevaluatedbycalculatingthefractureworkderivedfromtheareaunder 70 30 tensile strength slightly decreased sample si df tough thestress straincurve 32 33 theworkofthefractureofthepsmatrixis13 66mj m3 ness sample evaluated calculating fracture work derived area work fracture decreased loading bn filler sample bn pps 60 40 andbn pps 70 30 theworkofthefracturedecreasedto7 46mj m3and 5 53mj m3 respectively thisisunderstandablebecausebnfillersaggregateeasilyand formagglomerationsinthepsmatrix asexpected afteradding5wt ofsi df thework fracture sample increased 11 05 mj m3 bn pps si df 60 35 5 8 97mj m3ofbn pps si df 70 25 5 indicatingthatsi dpfhasanobviousadvantage inimprovingthetoughnessofthehighlyfilledbn ppscomposites thisresultismainly ascribed distribution si df si dpf tends located interface andformsa barrierlayer forbnfillers si dfnotonlyreducestheagglomerationbut alsotransferstheexternalforcereceivedbythesamplestothesmallaggregateofbnfiller whichisabletoactasthestressconcentrationpointstodissipatetheexternalenergy thetoughnessofthesampleisachieved molecule 2022 27 x peer review 9 11 stress strain curve 32 33 work fracture pps matrix 13 66 mj m3 work fracture decreased loading bn filler sam ples bn pps 60 40 bn pps 70 30 work fracture decreased 7 46 mj m3 5 53 mj m3 respectively understandable bn filler aggregate easily form agglomeration pps matrix expected adding 5 wt si df work fracture sample increased 11 05 mj m3 bn pps si df 60 35 5 8 97 mj m3 bn pps si df 70 25 5 indicating si dpf obvious ad vantage improving toughness highly filled bn pps composite result mainly ascribed distribution si df si dpf tends located terface form barrier layer bn filler si df reduces agglomeration also transfer external force received sample small aggregate bn molecules2022 27 8066 filler able act stress concentration point dissipate external ener9goyf1 1 toughness sample achieved fif gi ugu rer e 8 8 t rt ar ia ni n t rt er se s cucu rvrv ese ofo f pp pp mm ata rt ir xi x anan dd bb nn p pp sp c oc mom pop eit se 4 conclusion 4 conclusion afluorine containingflowmodifiersi dfwassuccessfullysynthesizedandapplied fluorine containing flow modifier si df successfully synthesized applied tothefabricationofidealelectronicpackagingmaterials bn ppscomposites byconven fabrication ideal electronic packaging material bn pps composite conven tionalmeltblendingtechniques si dfwithlowsurfaceenergywasdominantlylocatedat tional melt blending technique si df low surface energy dominantly located thebn ppsinterface leadingtotherelativelyhomogeneousdispersionofthebnfillers bn pps interface leading relatively homogeneous dispersion bn fill thussuccessfullyachievingsimultaneouslyhighthermalconductivity excellentdielectric er thus successfully achieving simultaneously high thermal conductivity excellent die property processability andtoughnessinbn ppscomposites solvingthewell known lepcrtoribcl epmroptheartiepso lpyrmoecer sbsaasbeildityco manpdo tsoituegshwnietshs hinig bhnlo papdsin cgotmhperomsiatellsy scoolnvdinugc ttihvee wfilellel r kunsouwanll yprporbelseemnt thhiagth ptohlyermmearl bcaosneddu ccotimviptyosbituets pwoiothr phriogche lsosaadbiinligty thanerdmtoalulyg hcnoensdsudcutieveto fitlhleersu nuasuvaolildya pbrleesaegngt rhegigahti othneormftahl ecofinllderusc titvhitey sbiu dt fpoloocra pterdocaetsstahbeiliintyte rafnadc etoeuffgehctnivesesly dcuoen tsotr tuhcet eudntahveorimdaablllceo angdgurcetgivaetiopnat ohfs tahned firleledrusc etdheth sei idntfe rlfoaccaitaeldh eaat tthrees iinsttaenrfcaecbe eetfwfeece n titvheelyb nconfisltlerursctaendd ththeermpapls cmonadtruixctaivsew pealtlh sm aenadn wrehdiulec etdh ethcea rienftuelrlfyacdiaelv heleoapt erdesaisdtdanitcive e bwetewaekeenn etdhet hbenp ofillalreirzsa tainodn btheetw pepesn mthaetfirilxle ar awnedllt h meemaantwrixh ilwe h tihche rceadreufcueldlyt hdeevdeielolepcetrdi c adcodnitsitvaen twoefatkheenceodm thpeo spitoelsa riiznaatidodni tbioentw teheenb tnhe fpilplesres xahnidb itthede mexacterlilxe n wtphricohce rsesdaubcileitdy tahned dtioeluegchtrnice scso nmstoasntt imof ptohret acnotmlyp tohsiistews oirnk apdadvietdiotnh ethwea bynfo rppcosn esxtrhuibctiitnedg iedxecaellleelnetc tproron ic cepsascakbaigliitnyg amnda tteoruiaglshnthersosu mghotsht

eimraptioorntaanldtleys itghniso fwfloorwk pmaovdedifi ethrse way constructing ideal electronic packaging material rational design flow modifier authorcontributions conceptualization b c methodology b c andx h software w z val aiudtahtioorn c oxn htr ibauntdiopn w c oinnvceespttiugaaltiizoant iobn c b acn mxe hth ddoaltoagcyu rba tcio nan dx xh h w sroitfitnwga reo rwig izna l vdarlia ft dpatrieopna r axt ihon abn cd pw writ nign versetvigieawtioann dci ianngd b x c h v idsuaatali zcautrioanti opn w x shu p ewrvriistiinogn wo rzig ainlalla udtrhaoftr phreapvaerraetaiodna nbd ca g wrereidtintog therepvuiebwli sahnedd evdeirtsiinogn obf cth e vmisaunauliszcartiipotn p w supervision w z au thor read agreed published version manuscript funding
thisresearchwasfundedbyguangdongbasicandappliedbasicresearchfoundation 2021a1515110134 andtheopeningprojectofkeylaboratoryofpolymerprocessingengineer ing southchinauniversityoftechnology ministryofeducation kfkt2102 institutionalreviewboardstatement notapplicable informedconsentstatement notapplicable dataavailabilitystatement thedatathatsupportthefindingsofthisstudyareavailablefromthe authorsuponreasonablerequest conflictsofinterest theauthorsdeclarenoconflictofinterest sampleavailability samplesofthecompoundsareavailablefromtheauthors reference
1 shahil k balandin graphene multilayergraphenenanocompositesashighlyefficientthermalinterfacematerials nanolett 2012 12 861 867 crossref pubmed 2 han z fina thermalconductivityofcarbonnanotubesandtheirpolymernanocomposites areview prog polym sci 2011 36 914 944 crossref molecules2022 27 8066 10of11 3 lee g w park kim j lee j yoon h g enhancedthermalconductivityofpolymercompositesfilledwithhybrid filler compos partaappl sci manuf 2006 37 727 734 crossref 4 song h park k h kim b h choi w jun g h lee j kong b paik k w jeon enhancedthermalconductivity ofepoxy graphenecompositesbyusingnon oxidizedgrapheneflakeswithnon covalentfunctionalization adv mater 2013 25 732 737 crossref pubmed 5 xu l chen g wang w li l fang x afacileassemblyofpolyimide graphenecore shellstructurednanocomposites withbothhighelectricalandthermalconductivities compos partaappl sci manuf 2016 84 472 481 crossref 6 kim h jang j u yu j kim thermalconductivityofpolymercompositesbasedonthelengthofmulti walledcarbon nanotube compos partbeng 2015 79 505 512 crossref 7 gu j yang x lv z li n liang c zhang q functionalizedgraphitenanoplatelets epoxyresinnanocompositeswith highthermalconductivity int j heatmasstransf 2016 92 15 22 crossref 8 huang x zhi c jiang p golberg bando tanaka polyhedraloligosilsesquioxane modifiedboronnitridenanotube basedepoxynanocomposites anidealdielectricmaterialwithhighthermalconductivity adv funct mater 2013 23 1824 1831 crossref 9 han shi x yang x guo zhang j kong j gu j enhancedthermalconductivitiesofepoxynanocompositesvia incorporatingin situfabricatedhetero structuredsic bnnsfillers compos sci technol 2020 187 10944 crossref 10 guo xu g yang x ruan k zhang q gu j wu liu h guo z significantlyenhancedandprecisely mod eledthermalconductivityinpolyimidenanocompositeswithchemicallymodifiedgrapheneviainsitupolymeriz ation andelectrospinning hotpresstechnology j mater chem c2018 6 3004 3015 crossref 11 xie h zhu b k li j b wei x z xu z k preparation property polyimide aluminum nitride composite polym test 2004 23 797 801 crossref 12 jiang q wang x zhu hui qiu mechanical electrical thermal property aligned carbon nan otube polyimidecomposites compos partbeng 2014 56 408 412 crossref 13 guan x cao b cai j ye z lu x huang h liu zhao j designandsynthesisofpolysiloxanebasedsidechainliquid crystalpolymerforimprovingtheprocessabilityandtoughnessofmagnesiumhydrate linearlow densitypolyethylene composite polymers2020 12 911 crossref pubmed 14 cao b wang cai j xie w liu zhao j silicone fluorine functionalizedflowmodifierwithlowsurfaceenergyfor improvinginterfacesinhighlyfilledcomposites compos sci technol 2021 214 108984 crossref 15 gu j guo yang x liang c geng w tang l li n zhang q synergisticimprovementofthermalconductivitiesof polyphenylenesulfidecompositesfilledwithboronnitridehybridfillers compos partaappl sci manuf 2017 95 267 273 crossref 16 yang x tang l guo liang c zhang q kou k gu j improvementofthermalconductivitiesforppsdielectric nanocompositesviaincorporatingnh possfunctionalizednbnfillers compos partaappl sci manuf 2017 101 237 242 2 crossref 17 pan c kou k jia q zhang wu g ji improvedthermalconductivityanddielectricpropertiesofhbn ptfe compositesviasurfacetreatmentbysilanecouplingagent compos partbeng 2017 111 83 90 crossref 18 jiang liu min p sui g bn mwcnt ppscore shellstructureparticlesandtheir3dsegregatedarchitecturecomposites withhighthermalconductivities

compos sci technol 2017 144 63 69 crossref 19 ryu kim k kim j silanesurfacemodificationofboronnitrideforhighthermalconductivitywithpolyphenylenesulfide viameltmixingmethod polym adv technol 2017 28 1489 1494 crossref 20 chao p li gu x han jia x wang zhou wang novelphosphorus nitrogen siliconflameretardantsand theirapplicationincycloaliphaticepoxysystems polym chem 2015 6 2977 2985 crossref 21 ding c hu x lai shao g fabricationandmicrostructureevolutionofmonolithicbridgedpolysilsesquioxane derivedsicceramicaerogels ceram int 2022 48 25833 25839 crossref 22 shao g shen x huang x multilevelstructuraldesignandheterointerfaceengineeringofahost guestbinaryaerogel towardmultifunctionalbroadbandmicrowaveabsorption acsmater lett 2022 4 1787 1797 crossref 23 cao b zhou wu cai j guan x liu zhao j zhang simultaneousimprovementofprocessabilityandtoughness ofhighlyfilledmh lldpecompositesbyusingfluorine containingflowmodifiers compos partaappl sci manuf 2020 134 105900 crossref 24 zhang w li x z wang xiao surfacemodificationofmagnesiumhydroxidebywetprocessandeffectonthe thermalstabilityofsiliconerubber appl surf sci 2019 465 740 746 crossref 25 jalali dil e favis b localization micro nano silica particle heterophase poly lactic acid poly butylene adipate co terephthalate blend polymer2015 76 295 306 crossref 26 zha x j pu j h l f li bao r bai l liu z yang b yang w particular interfacial strategy pvdf obc mwcnt nanocomposites high dielectric performance electromagnetic interference shielding compos partaappl sci manuf 2018 105 118 125 crossref 27 wang x peng chen h yu x zhao x mechanical property rheological behavior phase morphology high toughnesspla pbatblendsbyin situreactivecompatibilization compos partbeng 2019 173 107028 crossref molecules2022 27 8066 11of11 28 yuan c duan b li l xie b huang luo x thermalconductivityofpolymer basedcompositeswithmagneticaligned hexagonalboronnitrideplatelets acsappl mater interfaces2015 7 13000 13006 crossref 29 guo ruan k shi x yang x gu j factorsaffectingthermalconductivitiesofthepolymersandpolymercomposites review compos sci technol 2020 193 108134 crossref 30 kim k kim kim j thermalandmechanicalpropertiesofepoxycompositeswithabinaryparticlefillersystemconsisting ofaggregatedandwhiskertypeboronnitrideparticles compos sci technol 2014 103 72 77 crossref 31 hidalgo j jiménez morale torralba j torquerheologyofzirconfeedstocksforpowderinjectionmoulding j eur ceram soc 2012 32 4063 4072 crossref 32 zhou chen c zhu sui c wang c kuang ray u liu brozena leiste u h etal aprinted recyclable ultra strong andultra toughgraphitestructuralmaterial mater today2019 30 17 25 crossref 33 shah maiti p jiang batt c giannelis e p effectofnanoparticlemobilityontoughnessofpolymernanocomposites adv mater 2005 17 525 528 crossref

Top Keywords

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