Processed Text

advance smart material application aerospace industry alarshbasheer departmentofmechanicalandaerospaceengineering stateuniversityofnewyork buffalo newyork usaand researchanddevelopmentdivision oetikerinc lancaster buffalo newyork usa abstract purpose smartmate rialsalsocalledintelligentmaterialsaregainingimportancecontinuouslyinmanyindustriesincludingaerospac eone itis unique feature material asself sensing self adaptability memory capabilitiesand manifold function long time thereisnoreviewofsmartmaterials therefore itisconsideredworthwhiletowriteareviewonthissubject design methodology approach athoroughsearchoftheliteraturewascarriedoutthroughscifinder sciencedirect springerlink wileyonline libraryandreputedandpeer reviewedjournals theliteraturewascriticallyanalyzedandareviewwaswritten finding thisstudydescribestheadvancesinsmartmaterialsconcerningtheirapplicationsinaerospaceindustries theclassification working principleandrecentdevelopments nano smartmaterials ofsmartmaterialsarediscussed besides thefutureperspectivesofthesematerialsare alsohighlighted muchresearchhasnotbeendoneinthisarea whichneedsmoreextensivestudy originality value certainly thisstudywillbehighlyusefulforacademicians researchersandtechnocratsworkinginaerospaceindustries keywords smart intelligent material classification application nano smartmaterials futureperspectives papertypeliteraturereview 1 introduction temperature stress magnetic field chemical electricity nuclear radiation acidity hydrostatic pressure itis interesting note thenumberof passenger change may size shape object rigidity approximately doubled 2036 totaling 7 8 billion yearly restrainingandviscosity schwartz 2002 allthesealterations perinternationalairtransportassociation tocompletethis areresponsibleforprovidingthevariousnecessaryfunctionsof requirement aerospace industry supposed great smart material per environmental change effort continuously july 2018 airbus predicted need common smart material related stimulus response approximately 37 400 new aircraft 5 8tn cost showninfigure1 next 20years matthew 2018 huge smart material also called intelligent one numberofpassengersandthedemandfortheaircraft thereisa intellectual performance great need advanced technology meet environmentalvariations thesmartnessofthesematerialslies requirement economically safety among various part fact manifold application structural componentsoftheaerospaceindustries thematerialisoneof aerospace bionics mechanical environment engineering themostimportant component many typesofmaterials bashir 2017 addington daniel 2005 besides beingusedinaerospaceindustriesbutthesmartmaterialsare materialscandetecttheerrorsandfissuresandareworkingas gaining importance continuously unique diagnostictoolsand consequently self repairingcapabilities feature basically smart material new generation calledaself repairingeffect inaerospaceengineering mostof constituent exceeding conventional functional theapplicationsarecarriedoutintheopenenvironmentwith structural material material called smart one exposure various change hence smart material self sensing self adaptability memory gaininggreat attention aerospace industry way capability manifold function ritter 2007 self thereisagreatdemandforsmartmaterials relatedstructuresand adaptation feature smart material great value instrumentsintheaerospaceindustries athoroughsearchofthe embedding adaptation smart material nowadays literature carried article found great demand smart material various advancement smart material aerospace industry industry capability alter physical duringthepastdecade itwasalsorealizedthattherearesome property precise way reaction change advancesinthesmartmaterialsinaerospaceindustriesduringthe environmental factor stimulus response factor pastfewyears therefore theeffortsaremadetowriteanarticle onthelatestdevelopmentsandapplicationsofsmartmaterialsin theaerospaceindustries thisarticledescribestheclassification thecurrentissueandfulltextarchiveofthisjournalisavailableonemerald insightat http www emerald com insight 1748 8842 htm working principle application recent development nano smart material future perspective certainly article aircraftengineeringandaerospacetechnology 92 7 2020 1027 1035 received10march2020 emeraldpublishinglimited issn1748 8842 revised23april2020 doi 10 1108 aeat 02 2020 0040 accepted28april2020 1027advancesinthesmartmaterialsapplications aircraftengineeringandaerospacetechnology alarshbasheer volume92 number7 2020 1027 1035 figure1 thecommonsmartmaterialsandrelatedstimulusresponses lead zirconate titanate pzt lead magnesium niobate polyvinylidene fluoride polymer piezoelectric material pbzr0 52ti0 48o pzt bi ti bit 3 4 3 12 pzt bit composite frequently presented thin sheet may easily anchored fixed composite structuresorloadedtoformseparatepiezoelectricactuators 2 2magnetostrictivematerials material reacting change magneticproperties thesematerialsaremono polarandnon linear showing hysteresis lesser piezoelectric material thesematerialsundergomechanicalstrainandwork asactuatorsandsensors thesematerialsproducelowstrains andmodestforcesacrossavariedfrequencyrange theseare thebestmaterialsfortheactuatorsbecauseoftherequiredcoil highly useful academician researcher magnetic return path generally material contain technocratsworkingintheaerospaceindustries sensorsandactuatorsandareofnickel ironandcobalt briefly material work permanent magneticbars themajor 2 classificationofsmartmaterials application material include motor hydraulic classification smart material based actuator small frequency high power sonar transducer best known magnetostrictive material terfenol property important property exploited whichelongatesonexposingtothemagneticfield thermal electric magnetic etc smart material classified per approach addington schodek ritter material classified based change 2 3thermo responsivematerials material reacting change occurringinshape phase color energy matter adhesionand temperature material also called temperature rheology possible discus material responsive generally polymer show classification important material used miscibility gap temperature composition diagram aerospaceindustriesarediscussedinbrief material shape memory polymer shape memoryalloys smas andcanbechangedindifferentshapes 2 1piezoelectricmaterials bychangingtemperature nitinolisanickelandtitaniumalloy thesearethematerialsreactingagainstthechangeinelectric work anti corrosion comparable stainless steel property thesearerelativelylinearatlowfieldsandbipolar useful many application major application positive negative strain exhibiting hysteresis typesofalloysareinsuperelasticspectacleframesandhot pot material polymeric ceramic type thermostat major application include thermostat air property wide bandwidth electromechanical response vehicle shockabsorbers breaksandautomotivedampers high generative force comparatively low power requirement thesematerialsundergomechanicalalterations 2 4shapememoryalloys changing electric field figure 2 produce smas material belonging thermo responsive voltageswhenstressisapplied contrarily ifvoltageisapplied material class material react response stressis produced thematerials consequently structure temperature change shape changing made material bent expand fold temperature theydeformtotheirmartensiticconditionsand applyingvoltage thesehavegoodapplicationsinthemagnetic regaintheiroriginalshapestotheirausteniteconditionswhen head optical tracking device dot matrix printer high heated theremarkablefeatureofthesematerialsistheirlarge frequencystereospeakers computerkeyboards microphone change modulus elasticity heating phase transducer sensor actuator igniter gasgrills change temperature e two four time low temperature mostwidelyusedpiezoelectricmaterialsarepiezoceramics e g value avarietyofalloyshavebeenfoundtoshowthiseffectby recurrent heat treatment example nitinol ni ti figure2 piezoelectricmaterialshowingtheexchangeofelectricaland alloy niticu cualni cuznal fe pt au cd mechanicalenergy 1980sandearly1990s somecompaniesstartedtoproduceni ti material different component many product desroches 2002 thesearethebestmaterialsfor manufacturing actuator option attaining largedisplacementsandexcitationforces thesematerialsare available thestandard stock wire rod tube spring band stripsandsheets 2 5electrostrictivematerials piezoelectric material mechanical change directly proportional square electric 1028advancesinthesmartmaterialsapplications aircraftengineeringandaerospacetechnology alarshbasheer volume92 number7 2020 1027 1035 field thesearealsoverysensitivetotemperaturebutshowtiny acidity mechanical load response smart hysteresis inthesematerials thedislocationsarealwaysinthe material observed term change shape viscosity direction important example magnesium composition color etc fundamentally smart structure niobate itrequiresanelectricfieldtocauseinducedstressand include five key essential e structural material distributed induced stress ability piezoelectric material sensor actuator power conditioning electronics theseareavailableintheformofstacks whichmaybeusedto control strategy material work changing formanydeviceeasily physical property first smart material transformation observationwasrecordedin1932ongold cadmium lateron hodgson brown 2000 observed transformation 2 6rheologicalmaterials shape memory effect nickel titanium alloy naval theseareliquidmaterialsreactingagainstthechangeinelectricor ordinancelaboratory magnetic property also termed electro rheologicalfluidandmagneto rheologicalfluidsasperthechanges basically material may exist two different phase various temperature austenite exists high becauseofchangeinelectricandmagneticfields thereactionsof temperature andmartensite existsatlowtemperature thesematerialsagainststimuliareveryfast thechangesareinthe twophasestransformintoeachotherattheexternaltemperature dynamic liquid solid phase major application stress condition alters besides martensite exists two includeshockabsorbers breaksandautomotivedampers different form e twinned detwinned figure 3 smart material show special feature 2 7photochromicmaterials thesearethematerialsreactingagainstthechangeintheoptical property major application include liquid crystal figure3 thedifferentphasesofsmartmaterials display lithium battery electrochromic device themostimportantphotochromicmaterialsarespiropyranes naphthopyranes spirooxazines chromenes spirodihydro indolizines fulgides diarylethenes bacteriorhodopsin azo compound thedifferent typesof smartmaterials withinput andoutputaregivenintable1 3 workinginthesmartmaterials fundamentally thesmartmaterials act againstcertain effect suchaselectricity pressure temperature light magneticfields table1 thedifferenttypesofsmartmaterialswithinputandoutput sl typesofsmartmaterials input output type1 propertychanging 1 mechanochromics twist colorvariations 2 electrochromics electricpotentialvariations colorvariations 3 photochromics light radiation colorvariations 4 thermochromics temperaturechanges colorvariations 5 liquidcrystals electricpotentialvariations colorvariations 6 chemochromics chemicalquantities colorvariations 7 suspendedparticles electricpotentialvariations colorvariations 8 magnato rheological electricpotentialvariations stiffnessandviscosityvariations 9 electrorheological electricpotentialvariations stiffnessandviscosityvariations type2 energyexchanging reversible 10 piezoelectric deformation electricpotentialdifference 11 thermoelectric temperaturedifference electricpotentialdifference 12 pyroelectric temperaturedifference electricpotentialdifference 13 magneto restrictive magneticfield twist 14 electro restrictive electricpotentialdifference twist type2 energyexchanging reversible 15 photoluminescence radiation light 16 electroluminescence electricpotentialdifference radiation light 17 thermoluminescence radiation light 18 chemoluminescence radiation light 19 light emittingdiodes electricpotentialdifference radiation light 20 photovoltics radiation light electricpotentialdifference 1029advancesinthesmartmaterialsapplications aircraftengineeringandaerospacetechnology alarshbasheer volume92 number7 2020 1027 1035 transformation super elasticity effect shape 3 4activestructures memoryeffectandtwo waymemoryeffect thesuper elasticity structure distribution material also significant property integrated sensor actuator load bearing hystereticdamping excellentfatigueproperties verydependable capacityi e structuralfunctionality energy dissipation ability repeatable phase conversion andgoodcorrosionresistance theausteniteoccursatlowstress 3 5intelligentorsmartstructures converted detwinned martensite high stress theseare thestructureshavinga sub set ofactivestructures figure4 depictsausualstress straincurveofsmartmaterials theseareused fortheextremelyintegratedcontrol logicand two phase figure 4 b depicts stress strain powerelectronics relationshipoftheusualphasechangesofsuper elasticitysmart materialsunderpressure theupperplateaushowsanalteration 4 application fromaustenitetomartensiteinpressurewhilethelowerplateau application smart material structure showsthereversephenomenonwithpressurerelease thesuper elasticity material also significant property increasing continuously various sector civil structure automotivesystems roboticsystems spacevehicles hysteretic damping fatigue property reliable energy rotary wingaircraft fixed wingaircraft machinetools marine intemperancecapabilityviarepeatablephasetransformationand systemsandmedicalsystems theincreasedusesarethrough excellentresistancetocorrosion technological revolution actuator sensor damping case piezoelectric material transducer betweenmechanicalstressandelectricitypropertyisbecauseof vibration shock absorption shape control stability thecrystallinestructure inacrystal eachmoleculeispolarized damping increase structural integrity operational one end negatively charged positively maintenance automatic switch image processing charged e justlikeadipole thisarrangementisaffectedby coatingsbecauseofspecialfeaturesofthesematerialssuchas thechangesinthemechanicalstressandelectricfield leading self adaptation self sensing self adaptability memory transducer property briefly simple piezoelectricity multiplefunctionalities thesematerialscandetectfaultsand concept alter alignment polarization crack hence useful diagnostic tool molecule itiswell knownthat smartstructuresaremadeof materialsmaybeusedtorepairthefaultduringanymechanical different combination smart material basically operation thephenomenon iscalled theself repairingeffect smart structure involve distribution actuator liangandrogers 1992 ghandi 1995 soroushianandhsu sensor processor control logic power electronics 1997 lagoudasetal 1999 ofcourse thesematerialshavea varioussmartstructuresarediscussedbelow widerangeofapplicationsbutinthisarticle theeffortswillbe madetorestricttheirapplicationsinaerospaceindustriesonly 3 1adaptivestructures thefeaturesofaircraftapplicationsaregivenintable2while thesearethestructureshavingthedistributionoftheactuators table3summarizesvarioussmartmaterialsusedinaerospace tochangethecharacteristicsinaprescribedway theyinclude industry conventional aircraft wing aileron flap rotor theaerospaceindustriesarefacinggreateconomicpressure bladeswithservoflaps tolowerdownthecosts withaugmentingtheperformanceand sustaining important protection standard therefore defense commercial airline space exploration industry 3 2sensorystructures aresearchingsmartmaterialsforthesepurposes theseshould thesearethestructureshavingthedistributionofthesensors consistent robust meet requirement highly screen characteristic structure e strain specialized application smart material good temperature electromagnetic property displacement industrial commercial application engineering damageandacceleration applicationsmaybecategorizedintosensorsorsensingdevices andmotorsandactuators thesmartnessofthesematerialsis 3 3controlledstructures developedbychangingtheircompositions specialprocessing thesearethestructureshavingthedistributionofthesensors inducingdefectsandmodificationofmicrostructures actuator used actively regulate smart material used load bearing characteristicsofthestructure actuator composite structure aircraft wing androtorblades liangetal 1996 garneretal 1999 jardine figure4 strain stressrelationshipofausteniteandmartensite et al 1996 smart material used overpower vibration variation helicopter rotor blade shape smartmaterial actuatedrotortechnologyisbeingused boeing reduces 80 vibration improving flight performance airbus helicopter sa formerly eurocopter group also developed similar system similarly variousadaptiveregulatorsurfacesareproducedfor airplane wing also recently research going emphasizethenewcontroltechniquesforsmartmaterialsand design procedure location actuator sensor theotherapplicationsdealwiththeabilitytoregulate 1030advancesinthesmartmaterialsapplications aircraftengineeringandaerospacetechnology alarshbasheer volume92 number7 2020 1027 1035 table2 thefeatures requirementsandtheeffectsofaircraftapplications sl requirement applicability effect 1 lightweight allaerospaceschemesand semi monocoquefabrication thin walledboxesorreinforcedstructures program useoflow densitymaterials wood alloysandcomposites highstrength weightandhighstiffness weight 2 passengersafety passengerscarriers useoffireretardantmaterials extensivetesting crashworthiness 3 highreliability allaerospaceschemesand strictqualitycontrol program extensivetestingforconsistentdata certification proofofdesign 4 degradation radiationandthermal spacecraft damageissuesandlifespanandextensivetestingforvariedenvironment thinmaterialswithhighreliability 5 sturdiness exhaustionandcorrosion aircraft extensiveexhaustiontesting analysis alloysdonothaveexhaustionlimit corrosioninhibitionplans 6 aerodynamicpresentation reusablespacecraft deformedshapeaero elasticity dynamic compoundcontouredshapes manufacturability moldingandmachining 7 aerodynamicpresentation aircraft greatlycomplexloading thinbendablewingsandregulatingsurface 8 weatheroperation aircraft lightningprotection erosionresistance 9 multi rolefunctions allaerospaceschemesand efficientdesign program compositeswithvariedfunctions 10 fly wire fighterandpassenger configurationcontrolexchanges aero servo elasticity aircraft wideuseofcomputersandelectronics electromagneticshielding 11 stealth specificmilitaryaerospace specificsurfaceandshapeofaircraft us stealthcoating table3 varioussmartmaterialsusedinaerospaceindustries sl requirement material purpose 1 designofsmartmaterialsfor magneto responsivematerials cyclicandactivecontrol actuatorsforrotorcontrol leadtoreducedmaneuverenvelopbecauseofweightandvolumeconstraints 2 controlpanelasextendingtowings smas tosolvelimitsofaircraftwingdesign ofaircraft 3 shape changingtechnology shape alteringsmartmaterials formilitaryaircraft nexttonewgenerationaircraft 4 shape changingtechnology smas engineeringbendingandstretchingabilitiesinwingsandhingelesssystems 5 shape changingtechnology piezoelectric engineeringbendingandstretchingabilitiesinwingsandhingelesssystems theaero elasticformofanaircraftwingtodecreasethepulland temperature variation used manufacture increase working efficiency regulate vibration satellite various aircraft part fuel line assembly lightweight structure observe structural reliability thermocouplesandgasturbineengines aluminaisusedto spacestructuresandaircraft make aircraft part thermal shock resistance high thepiezoelectricanddielectricmaterials electroceramic temperature occur plasma ignition besides material used make aerospace sensor aluminaislightinweightanddecreasesthecostsrelatedto transducer gyroscope accelerometer launching satellite piezoelectric actuator may gyroscope used measuring pitch aircraft executeamechanismofthecontrolsystembyincreasingthe acceleration satellite missile accelerometer maneuverabilityandperformanceowingtogoodflexibility used vibration measurement sensor used besides material used reduce vibration tomeasurethelevelsoffueltanks forexample boeing777 andnoiseintheaircraft theceramicfibersareusedasheat piezo ceramic material 60 ultrasonic fuel tank shieldsforfireprotection thermalinsulationinaircraft smartceramicmaterialsareusedinaircraftbecauseoftheir space shuttle resist heat capabilitytobearhighvibrationandmechanicalshockand lightweight corrode significant 1031advancesinthesmartmaterialsapplications aircraftengineeringandaerospacetechnology alarshbasheer volume92 number7 2020 1027 1035 characteristicsincludehighmeltingtemperature resiliency combination nanomaterials property smart tensile strength chemical inertness besides aircraft material featuresarethebestcombinationstoachievetheheights windshieldsareheatedbyatransparent electric conducting success material create innovation aerospace ceramic coating embedded glass keep clear engineering forexample thebodyofaircraftandsatellitesmade fromfogandice ofanano smart materialcouldpossibly alterthesurfacetexture smas used overcome limit normal depending temperature pressure electric current airplanewingdesigns generally wingsforhighspeedsfailto feature smart nanomaterials especially composite work low speed vice versa smas integration comprisingsensorsandactuatorsinthelayersofcompositesmay airplanewingsmaysolvethisproblem thesmashaveagood detectanycrackintheaircraft thesmartnanomaterialscanbe future used wing structure minimize prepared layered composition printed circuit board aerodynamiclossesandtomaximizespeed wingconcordance technique ihn chang 2004 developed sort may exploited sound reduction load reduction techniqueusingsmartlayerstodetectandmonitorhiddenfatigue meet motion necessity helicopter dong crack growth using built piezoelectric sensor actuator etal 2008 reportedtheapplicationofsmaasanactuatorfor network similarly akhras 2012 usedsmartandnano system anadaptiveairfoil smasprings areused toactuateprecisely forapplicationsinnon destructiveevaluationandperspectives point skin reach target airfoil system actuator stimulate composite material observedthatsmacouldgetgoodactuatingresults basedon producewaveswhenacrackisdeveloped thesewavesaresensed thesimulationstudies similarly hutapeaetal 2008 reported anddetectedbythepilotforalarmingthenecessaryaction asampleofasmartactuationstructureforanadaptiveairfoilby smasarebeingmadeinanano frameforwingsforflappingin regulatingtheflaps smaspringswerestationaryatoneterminal mannerssimilartobirds figure5 lietal 2009 describedthe tothewingboxtowardtheprimaryedgeoftheairfoilwhereasthe different way prepare polymer modified gold nanoparticles otherendwasinvolvedtangentiallytoarevolvingcylinderfixed author studied thermal ph sensitivity totheflap thespringactuatorswerecontrolledbysupplyingan nanomaterials may important designing developing appliedcurrent aspertheauthors thesamplepreparedshowed future nano electronics nano sensor author described asturdyprospectiveforfutureuses change morphology gold nanoparticles ph changeresponse figure6 5 nanotechnologyandsmartmaterials kuilla et al 2010 prepared graphene based piezoresistive smart nanomaterial tested piezoresistive feature course nanotechnology emerged independent finding possible application graphene based researcharea ali 2012 2018 butrecently thereisgrowing sensor author compared result cnts strain interest apply nanotechnology smart material sensor per author observed strain augment performance new design responseofthegraphene epoxysensorwasbetterthancnts application nanotechnologyisatooltotakesmartmaterials also symmetrical along reversible behavior next level nanotechnology enabled smart material furthermore graphene composite exhibited higher exhibit superior performance function coyle et al gaugefactorthan straingaugemadeofhigh qualitygraphene 2007 stimulus response nanomaterials better film high gauge factor may larger inter conventional smart material small size contactareasamongthegraphenenano fillersbecauseoftheir surface active site sometimes larger surface area two dimensionalstructure csetnekietal 2006 developnew dahmanetal 2017 thesefeaturessensethechangeinthe environmentevenatlowmagnitude theadvantagesofsmart figure 5 embedding smart nanomaterials composite andnano materialsareasgivenbelow structureusingprintedcircuittechnology cid 1 optimizationoftheresponsesofcomplexsystems thisis carried creating early cautionary system increasing range survivability situation giving adaptive response manage unexpected situationsandconditions cid 1 minimizing alteration response augmenting exactness providing good control system might lead improving design performance forspecialapplications cid 1 improvement functionality system appropriate defensive maintenance presentation optimization cid 1 noteworthy influence engineering processing technique cid 1 improvementinthehealthmonitoringofthesystemand goodcontrolofitsdynamicandaddictiveness cid 1 feature open entry use nano smart material multifold application aerospace industry

 figure6 changeinmorphologyofgoldnanoparticles composite gel membrane nano channel exfoliated graphite nano platelet xgnps nano graphene regulate membrane permeability response external platelet ngps author prepared sheet various stimulus increased temperature membrane lateral dimension length using different composition permeabilityincreased thechannelshaveawell orderedarray combination material showed piezoresistive ofthemagneticpolystyrenelatexparticles whichunderwentto characteristicsandindicatedavariationinelectricalresistanceon alterationinvolumeinreactiontooutsidestimuli venturaetal applyingthestrain thedependenceresistancevariationsonstrain 2017 described stimulus responsive material digitization via weredirectional nature different mixture ofxgnpsize integration network conductive nanomaterials mwcnt length mwcnt xgnp ngp ratio showed elastomermatrix thesensors wide range ofdetection various specific surface area nanoparticle interaction ability become promising author monitored rate authorsclaimedtheseservingasimportantfactorsforregulating anddegreeofmaterial sexpansiondownhole suchasinsand sensitivity hybrid sheet sensitivity inversely screen packer author claimed developed proportionaltothethicknessesofthesheets approachmaybeusedtodetectdegradation tooldeployment statusandchemicaldetection besides itwasobservedthatthe 5 1synthesisofnano smartmaterials author claimed thedetection thepresence water oil smart nanoparticles produced physical process precisechemicalsusingtheirwork based manufacturing particle pre synthesized hwang et al 2013 reported preparation nano smart polymer cross linking among polymer core material multi walled carbon nanotube mwcnts second method chemical synthesis nanoparticles table4 theadvantagesanddisadvantagesofthesynthesisofnano smartmaterials sl method advantage disadvantage reference 1 microwave reducedreactionorsynthesis sometimespoordispersion liuetal 2007 time smallparticlesizedispersal 2 electronbeamlithography wellmanagedinter particle highcomplexparaphernalia linandsamia 2006 spacing 3 gasphasedeposition practicalapproach sizecontrolofnanoparticles cuenya 2010 4 supercriticalfluids goodcontrolofnanoparticles needcriticaltemperatureandpressure zhanganderkey 2006 nouseoftoxicchemicals 5 pulsedlayerablation laserablation facileandsimplemethod lowmanufacturingrate zengetal 2012 inliquid geometrycontrolpossible noneedofanyotherchemical 6 flowinjection reproducibleandhomogeneous continuousmixingofsolvents salazar alvarezetal 2006 7 biological microbialincubation reproducible scalable good time consuming narayananandsakthivel 2010 yieldandlowcost alarshbasheer volume92 number7 2020 1027 1035 heterogeneous polymerization method discussed thesmartnanomaterialsmaybeusedinsmas thesemaybe highly useful material changing shape wing flappingtheneedforsmoothandeconomicperformance 5 1 1polymeradsorptiononnanoparticles smart nanomaterials need future thisistheclassicalandsimplemethodforthepreparationof shouldbepreparedinamoreadvancedwaytomeettheneeds stimulus responsivenanoparticles inthisapproach apolymeris future aerospace technology future looking sorbedontheparticlesurfaceanditcontrolsinteractionsinthe automatic damage arrest shock absorber self healing colloidal suspension owing different effect electrostatic thermal mitigation nano smart material nano steric depletionbridgingandmechanisms smart material highly beneficial useful future 5 1 2amphiphilicblockcopolymersandmicellesself assembly space mission certainly help make dream block copolymer make different type self assembled true nano smart material new one thus arrangement micelle constant bilayers subject industrial product available market solvent selectivity swelling packing particle patent restriction may take many year occurred solvent compatibility common proposed nanomaterial go conception desired physicaldeviationswithintheparticlesareinthecollectivesize application thechangestothecollectivearchitecture structureandstimuli responsestoionicstrength ph thermalandredoxstimuliare 7 conclusion amongthosewhichareusuallymeasuredmost examplesareof shearflow ionicexchangeandosmoticshock theadvantages thedevelopmentofsmartmaterialsisaninterdisciplinaryarea anddisadvantagesofthesynthesisofnano smartmaterialsare smartmaterialsarethenewgenerationmaterials whichhave summarizedintable4 greatlatenttointroducearevolutioninmanyareasincluding aerospace industry manufacturing nano smart 6 futureperspectives material understanding working mechanism improve property application aerospace thesmartmaterialsareprobablytobethemostrecentopening industry nano smart material highly useful humankind significant leap hopeful future space mission may starting material centurywillbedominatedbyawidevarietyofsmartmaterials initiatelifeonotherplanets thesesmartmaterialsarethehope thesewillbethefrontiermaterialsintheaerospaceindustries future certainly enhance quality thereisaneedtodevelopsmartmaterialsformanufacturing living true revolution aerospace industry airvehicleswiththecapabilitiesofalteringtheirshapesasper collaborative effort necessary among academician requirement specification also great researcher engineersanddesigners demand elastomeric matrix material cmt structure morphing technology property smart material accept challenge aerospace industry therefore reference research smart material promising field certainly addington anddaniel l 2005 smartmaterialsand themarketforsmartmaterialswillincreaseinthefuture newtechnologies elsevier importance smart material attract researcher akhras g 2012 smartandnano system applicationsfor toward solving aerospace engineering problem innovative ndeandperspectives 4thinternationalcanduin service research expected making control surface adaptive wing may significantly augment inspection workshop ndt canada 2012 conference maneuverability great need develop compact toronto ontario june18 21 smartmaterialsforcontrollingnoiseandvibrationcontrol ali 2012 new generation adsorbent water despite great demand future application smart treatment chemical review vol 112 10 material certain challenge development pp 5073 5091 smart material quality inexpensiveness ali 2018 microwave assistedtheeconomicsynthesisof researcher supposed improve quality without multi walledcarbonnanotubesforarsenicspeciesremovalin increaseincost still thereisaneedtomakesmartstructures water batch column operation journal molecular feasible developing excellent smart material ease liquid vol 271 pp 677 682 anchoring laminated structure coupling bashir 2017 smartmaterialsandtheirapplicationsin mechanical electrical property increase performance civilengineering anoverview internationaljournalofcivil low price advance microelectronics information engineeringandconstructionscience vol 4 pp 11 20 processingandsensortechnology coyle wu lau k derossi wallace g g nowadays nanotechnologyisgainingimportanceinalmost diamond 2007 smart nano textile review every sphere life oil gas industry already us material application mr bulletin vol 32 5 stimulus responsive nano smart material numerous pp 434 442 technologiesincludingswellableelastomersinreactivepackers csetneki filipcsei g zrinyi 2006 smart heat fluid activated expandable screen smart nanocomposite polymer membrane switching environmentally sensitive nano hydrogel ability control macromolecule vol 39no 5 pp 1939 1942 sense change ph temperature concentration cuenya b r 2010 synthesis catalytic property metabolitecanreleasetheirloadasaresultofsucha change metalnanoparticles size shape support composition 1034advancesinthesmartmaterialsapplications aircraftengineeringandaerospacetechnology alarshbasheer volume92 number7 2020 1027 1035 oxidation state effect thin solid film vol 518 12 liang c davidson f schetky l straub f k pp 3127 3150 1996 application torsional shape memory alloy dahman kamil baena 2017 smart actuator active rotor blade control opportunity nanomaterials dahman ed nanotechnology limitation spieproceedingsofmathematicsandcontrolsin functionalmaterialsforengineers elsevier smartstructures vol 2717 pp 91 100 desroches r 2002 applicationofshapememoryalloysin liang c rogers c 1992 one dimensional seismicrehabilitationofbridges technicalreportnchrp thermomechanical constitutive relation shape memory ideaproject65 feb material journal intelligent material system dong boming z jun l 2008 changeable structure vol 1no 2 pp 207 234 aerofoilactuatedbyshapememoryalloysprings material lin x andsamia c 2006 synthesis assemblyand scienceandengineering vol 485nos1 2 pp 243 250 physical property magnetic nanoparticles journal garner l j wilson l n lagoudas c andrediniotis magnetism magnetic material vol 305 1 k 1999 developmentofashapememoryalloyactuated pp 100 109 biomimetic vehicle smart material structure vol 9 liu z ling x guo b hong l andlee j 2007 5 pp 673 683 ptandptrunanoparticlesdepositedonsingle wallcarbon ghandi k 1995 shape memory ceramic actuation nanotubesformethanolelectro oxidation journalofpower adaptivestructures masterthesis mit source vol 167no 2 pp 272 280 hodgson e andbrown j w 2000 usingnitinolalloys matthew p 2018 current emerging trend reportofshapememoryapplicationsinc aerospace sector shifting priority developing hutapea p kim j guion hanna c heulitt n technology shaping industry today 2008 developmentofasmartwing aircraftengineering future snc lavalin satkins andaerospacetechnology vol 80no 4 pp 439 444 narayanan k b sakthivel n 2010 biological hwang h park h w park b 2013 synthesis metal nanoparticles microbe advance piezoresistivebehaviorandmulti directionalstrainsensing colloidandinterfacescience vol 156nos1 2 pp 1 13 ability carbon nanotube graphene nanoplatelet hybrid ritter 2007 smart material architecture interior sheetssmartmater smartmaterialsandstructures vol 22 architectureanddesign birkhäuserbasel frankfurt 1 p 015013 salazar alvarez g muhammed zagorodni ihn j b andchang f k 2004 detectionandmonitoring 2006 novel flow injection synthesis iron oxide ofhiddenfatiguecrackgrowthusingabuilt inpiezoelectric nanoparticles narrow size distribution chemical sensor actuator network ii validation using riveted joint engineeringscience vol 61no 14 pp 4625 4633 andrepairpatches smartmaterialsandstructures vol 13 schwartz 2002 preface smart material 3 pp 621 630 encyclopedia johnwiley son pp 5 7 jardine p kudva j martin c andappa k 1996 soroushian p hsu j w 1997 superelasticity based shape memory alloy ti ni actuator twist control rehabilitation post tensioning bridge structure smart wing design spie proceeding mathematics nchrp 96 ido29 nchrp idea aug controlsinsmartstructures vol 2717 pp 160 165 ventura dolog r darugar q khabashesku v kuilla bhadra yao kim n h bose andlee j hughes b 2017 nano enabled smart material h 2010 recent advance graphene based polymer sensor oil gas application document id spe composite progress polymer science vol 35 11 188345 m societyofpetroleumengineers pp 1350 1375 zeng h du x w singh c kulunich yang lagoudas rediniotis k khan 1999 j 2012 nanomaterials via laser ablation irradiation applicationsofshapememoryalloystobioengineeringand liquid review advancedfunctional material vol 22 biomedical technology proceeding 4th international 7 pp 1333 1353 workshop mathematical method scattering theory zhang erkey c 2006 preparation supported biomedicalapplication perdika greece pp 195 207 metallic nanoparticles using supercritical fluid review li q li j 2009 smart core shell journalofsupercriticalfluids vol 38no 2 pp 252 267 nanocomposites intelligent polymer modified gold nanoparticles advance colloid interface science correspondingauthor vol 149nos1 2 pp 28 38 alarshbasheercanbecontactedat alarshba yahoo com forinstructionsonhowtoorderreprintsofthisarticle pleasevisitourwebsite www emeraldgrouppublishing com licensing reprint htm orcontactusforfurtherdetails permission emeraldinsight com 1035

Top Keywords

material: 0.5952163775899308
smart: 0.3859095195363288
application: 0.1504393042260265
pp: 0.1504393042260265

vol: 0.14389846491185143
nano: 0.12427594696932623
property: 0.12427594696932623
shape: 0.12427594696932623
temperature: 0.1111942683409761
actuator: 0.10465342902680104
aerospace: 0.09811258971262597
change: 0.09811258971262597
structure: 0.09811258971262597
industry: 0.0915717503984509
sensor: 0.0915717503984509
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future: 0.07194923245592572
1035: 0.06540839314175065
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self: 0.06540839314175065
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different: 0.05886755382757558
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nanoparticles: 0.05886755382757558
piezoelectric: 0.05886755382757558
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2010: 0.039245035885050385
2017: 0.039245035885050385

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effect: 0.039245035885050385
elasticity: 0.039245035885050385
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magnetic: 0.039245035885050385
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phase: 0.039245035885050385
smas: 0.039245035885050385
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multifold: 0.006540839314175065
multiplefunctionalities: 0.006540839314175065

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nanoparticle: 0.006540839314175065
nanoplatelet: 0.006540839314175065
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nanotubesformethanolelectro: 0.006540839314175065
naphthopyranes: 0.006540839314175065
narayanan: 0.006540839314175065
narayananandsakthivel: 0.006540839314175065
narrow: 0.006540839314175065
nature: 0.006540839314175065
naval: 0.006540839314175065
ndeandperspectives: 0.006540839314175065
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necessary: 0.006540839314175065
necessity: 0.006540839314175065
needcriticaltemperatureandpressure: 0.006540839314175065
negative: 0.006540839314175065
negatively: 0.006540839314175065
newtechnologies: 0.006540839314175065
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noteworthy: 0.006540839314175065
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novel: 0.006540839314175065
nuclear: 0.006540839314175065
numberofpassengersandthedemandfortheaircraft: 0.006540839314175065
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object: 0.006540839314175065
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ofsmartmaterialsarediscussed: 0.006540839314175065
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onthelatestdevelopmentsandapplicationsofsmartmaterialsin: 0.006540839314175065
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operational: 0.006540839314175065
opportunity: 0.006540839314175065
optical: 0.006540839314175065
optimization: 0.006540839314175065
optimizationoftheresponsesofcomplexsystems: 0.006540839314175065
option: 0.006540839314175065
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practicalapproach: 0.006540839314175065
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reliability: 0.006540839314175065
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reproducibleandhomogeneous: 0.006540839314175065
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strictqualitycontrol: 0.006540839314175065
stripsandsheets: 0.006540839314175065
structuralfunctionality: 0.006540839314175065
structureandstimuli: 0.006540839314175065
structuresorloadedtoformseparatepiezoelectricactuators: 0.006540839314175065
structureusingprintedcircuittechnology: 0.006540839314175065
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sturdiness: 0.006540839314175065
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subject: 0.006540839314175065
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super: 0.006540839314175065
supercritical: 0.006540839314175065
supercriticalfluids: 0.006540839314175065
superelasticity: 0.006540839314175065
superior: 0.006540839314175065
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supported: 0.006540839314175065
survivability: 0.006540839314175065
suspendedparticles: 0.006540839314175065
suspension: 0.006540839314175065
sustaining: 0.006540839314175065
swelling: 0.006540839314175065
switch: 0.006540839314175065
switching: 0.006540839314175065
symmetrical: 0.006540839314175065
synthesized: 0.006540839314175065
systemsandmedicalsystems: 0.006540839314175065
table1: 0.006540839314175065
table2: 0.006540839314175065
table3: 0.006540839314175065
table3summarizesvarioussmartmaterialsusedinaerospace: 0.006540839314175065
table4: 0.006540839314175065
take: 0.006540839314175065
tank: 0.006540839314175065
target: 0.006540839314175065
technicalreportnchrp: 0.006540839314175065
techniqueusingsmartlayerstodetectandmonitorhiddenfatigue: 0.006540839314175065
technocratsworkingintheaerospaceindustries: 0.006540839314175065
technological: 0.006540839314175065
technologiesincludingswellableelastomersinreactivepackers: 0.006540839314175065
temperaturechanges: 0.006540839314175065
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theadvantages: 0.006540839314175065
theadvantagesanddisadvantagesofthesynthesisofnano: 0.006540839314175065
theadvantagesofsmart: 0.006540839314175065
theaero: 0.006540839314175065
theaerospaceindustries: 0.006540839314175065
theaerospaceindustriesarefacinggreateconomicpressure: 0.006540839314175065
theapplicationsarecarriedoutintheopenenvironmentwith: 0.006540839314175065
theausteniteoccursatlowstress: 0.006540839314175065
thebestmaterialsfortheactuatorsbecauseoftherequiredcoil: 0.006540839314175065
thebodyofaircraftandsatellitesmade: 0.006540839314175065
theceramicfibersareusedasheat: 0.006540839314175065
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thechangesinthemechanicalstressandelectricfield: 0.006540839314175065
thechangestothecollectivearchitecture: 0.006540839314175065
thechannelshaveawell: 0.006540839314175065
theclassification: 0.006540839314175065
thecommonsmartmaterialsandrelatedstimulusresponses: 0.006540839314175065
thecrystallinestructure: 0.006540839314175065
thecurrentissueandfulltextarchiveofthisjournalisavailableonemerald: 0.006540839314175065
thedependenceresistancevariationsonstrain: 0.006540839314175065
thedetection: 0.006540839314175065
thedevelopmentofsmartmaterialsisaninterdisciplinaryarea: 0.006540839314175065
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thedifferentphasesofsmartmaterials: 0.006540839314175065
thedifferenttypesofsmartmaterialswithinputandoutput: 0.006540839314175065
thedislocationsarealwaysinthe: 0.006540839314175065
theeffortsaremadetowriteanarticle: 0.006540839314175065
theeffortswillbe: 0.006540839314175065
thefeatures: 0.006540839314175065
thefeaturesofaircraftapplicationsaregivenintable2while: 0.006540839314175065
thefutureperspectivesofthesematerialsare: 0.006540839314175065
theincreasedusesarethrough: 0.006540839314175065
theliteraturewascriticallyanalyzedandareviewwaswritten: 0.006540839314175065
themajor: 0.006540839314175065
themarketforsmartmaterialswillincreaseinthefuture: 0.006540839314175065
thematerialisoneof: 0.006540839314175065
thematerials: 0.006540839314175065
themostimportant: 0.006540839314175065
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thenumberof: 0.006540839314175065
theory: 0.006540839314175065
theotherapplicationsdealwiththeabilitytoregulate: 0.006540839314175065
thephenomenon: 0.006540839314175065
thepiezoelectricanddielectricmaterials: 0.006540839314175065
thepresence: 0.006540839314175065
thereactionsof: 0.006540839314175065
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theremarkablefeatureofthesematerialsistheirlarge: 0.006540839314175065
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thermalinsulationinaircraft: 0.006540839314175065
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thermochromics: 0.006540839314175065
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thermoluminescence: 0.006540839314175065
thermomechanical: 0.006540839314175065
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theseareavailableintheformofstacks: 0.006540839314175065
theseareliquidmaterialsreactingagainstthechangeinelectricor: 0.006540839314175065
thesearerelativelylinearatlowfieldsandbipolar: 0.006540839314175065
thesearethebestmaterialsfor: 0.006540839314175065
thesearethematerialsreactingagainstthechangeinelectric: 0.006540839314175065
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theseareused: 0.006540839314175065
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thesimulationstudies: 0.006540839314175065
thesmartmaterials: 0.006540839314175065
thesmartmaterialsareprobablytobethemostrecentopening: 0.006540839314175065
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thestandard: 0.006540839314175065
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thinbendablewingsandregulatingsurface: 0.006540839314175065
thinmaterialswithhighreliability: 0.006540839314175065

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thisarticledescribestheclassification: 0.006540839314175065
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