3 Glycidoxypropyltrimethoxysilane Process Troubleshooting Guide

Contents

As a new type of foreign trade service provider driven by technological transformation and foreign trade services, HiSiaddi has established a "1+2+3+4=1" service system and can supply multiple well-known original manufacturers of 3 Glycidoxypropyltrimethoxysilane. As a R&D-oriented foreign trade service provider, we have sorted out key points for process troubleshooting of 3 Glycidoxypropyltrimethoxysilane from a professional perspective to share with you.

If you require more professional and in-depth analysis regarding process troubleshooting or product consultation of 3 Glycidoxypropyltrimethoxysilane, please contact HiSiaddi customer service or visit our official website www.hisiaddi.com

I. Basic Product Standards and Full Process Overview

1.1 Product Overview and Implementation Standards

3-Glycidoxypropyltrimethoxysilane (KH-560, GPTMS) is an epoxy silane coupling agent containing both epoxy active groups and trimethoxysilyl groups in its molecular structure. It is applied to glass fiber sizing, epoxy resin composites, electronic potting, coating adhesion improvement, and surface modification of inorganic fillers. Sensitive product defects include methoxy hydrolysis and epoxy ring-opening easily triggered by moisture; discoloration/yellowing, decreased epoxy value, thickening/gelation during storage, excessive methanol residue, and free chlorine corrosion on electronic substrates caused by high temperature, metal ions, acids and alkalis. Complying with the industrial silane coupling agent standard HG/T 4876, this guide covers fault tracing, defect troubleshooting and closed-loop rectification for the full synthesis process: raw material drying → hydrosilylation → desolventizing and neutralization → precision filtration → vacuum distillation → blending and light-proof filling.

1.2 Internal Control Quality Indicators of Finished Products and Troubleshooting Thresholds for Abnormalities

Test Item	High-Grade Electronic Premium Grade	General Industrial Qualified Grade	Abnormality Trigger Threshold for Troubleshooting
Appearance	Colorless, transparent and homogeneous	Pale light yellow transparent	Dark yellow/brown color, milky haze, white silanol gel precipitate, pungent

Test Item	High-Grade Electronic Premium Grade	General Industrial Qualified Grade	Abnormality Trigger Threshold for Troubleshooting
	liquid, no turbidity, flocculent precipitate, delamination or pungent odor	liquid without massive solid impurities	methanol sour odor, two-phase delamination
GPTMS Main Content (GC, %)	≥98.0	96.0～97.9	＜96.0, insufficient addition conversion, enrichment of hydrolyzed silanol by-products, light and heavy component impurities diluting active ingredients
Epoxy Value (eq/100g)	0.42～0.45	0.40～0.46	＜0.40: epoxy ring-opening loss, thickening and crosslinking during storage; ＞0.46: residual unreacted allyl glycidyl ether raw material
Methanol Residue (%)	≤0.15	0.16～0.40	＞0.40: failed distillation light component removal, foaming and strong odor during high-temperature processing
Free Chloride Ion Cl^- (ppm)	≤8	9～25	＞25: corrosion of copper and aluminum electronic components, blackening at composite material interfaces
Moisture (ppm)	≤120	121～250	＞250: methoxy hydrolysis generates silanol, continuous thickening and gelation failure during storage

Test Item	High-Grade Electronic Premium Grade	General Industrial Qualified Grade	Abnormality Trigger Threshold for Troubleshooting
Color (Hazen)	≤15	16～30	＞30: residual platinum catalyst, raw material oxidation, thermal degradation under high temperature, iron ion catalyzed color development
Viscosity (25℃, mPa·s)	10～14	9～16	Low viscosity: excessive residual light component methanol; High viscosity: silanol condensation forms low-molecular siloxane
pH (Diluted with Anhydrous Ethanol)	6.5～7.5	6.2～7.8	＜6.2: acid accelerates epoxy ring-opening and hydrolysis; ＞7.8: alkali catalyzes siloxane condensation and gelation
Thermal Storage Stability (60℃/72h)	Color increase ≤8 Hazen, no thickening or delamination, epoxy value drop ≤0.015	Color increase ≤15 Hazen, no hard gel precipitation	Obvious yellowing, sharp viscosity rise, silanol precipitate at bottom, substantial attenuation of epoxy value

1.3 Core Segments of Full Process (Mainstream Platinum-Catalyzed Hydrosilylation Route)

1. Raw Material Drying Pretreatment Section: Deep vacuum dewatering of trimethoxysilane; vacuum distillation of allyl glycidyl ether to remove moisture and peroxide impurities; precision filtration of raw materials to eliminate suspended solids, strictly controlling moisture of both raw materials below 100 ppm.
2. Nitrogen Purging Protection Section: Multiple high-purity nitrogen purges of the reactor, oxygen content inside the kettle controlled below

10 ppm to isolate oxygen and prevent oxidation of platinum catalyst and yellowing of raw material epoxy groups.

3. Hydrosilylation Reaction Section: Constant temperature 85～105℃, uniform dropwise addition of trimethoxysilane into allyl glycidyl ether system, batch feeding of Karstedt platinum catalyst, closed-loop monitoring of Si-H conversion rate, low temperature to inhibit side reactions of epoxy ring-opening.
4. Constant Temperature Aging Section: Extend heat preservation reaction to consume residual Si-H monomers, reduce residual unreacted allyl ether, improve main product purity and minimize epoxy loss.
5. Neutralization and Stabilization Section: Trace weak organic alkali neutralizes trace acidic degradation products to inhibit premature hydrolysis of silane, standing sedimentation of platinum colloidal impurities after neutralization.
6. Multi-Stage Precision Filtration Section: Organic solvent resistant filter elements filter out platinum metal colloids and trace silanol flocs to reduce metal ions and turbid impurities.
7. Vacuum Distillation Section: Low temperature and high vacuum fractional removal of light components (methanol, unreacted trimethoxysilane), collection of GPTMS main distillate, separation of heavy component siloxane oligomers.
8. Stabilization Blending Section: Add neutral hydrolysis buffer antioxidant stabilizer to balance system pH and improve hydrolysis resistance and yellowing resistance during storage.
9. Light-Proof Nitrogen Filling and Warehousing Section: 316L stainless steel / light-proof HDPE storage tanks sealed under positive nitrogen pressure to isolate water vapor, light and air oxidation.

1.4 Access Control Standards for Raw and Auxiliary Materials

1. Trimethoxysilane: Refined industrial grade, colorless and transparent, moisture ≤80 ppm, free of free chlorine and sulfur impurities to avoid poisoning and deactivation of platinum catalyst.
2. Allyl Glycidyl Ether: Distillation purified grade, moisture ≤90 ppm, peroxide content ≤5 ppm, clear and colorless without yellowing; peroxides cause epoxy ring-opening and product yellowing.
3. Karstedt Platinum Catalyst: Low-color platinum complex with stable platinum content, low inorganic metal precipitation, not easy to form colloidal precipitate.

4. High-Purity Nitrogen: Oxygen content ＜8 ppm, low humidity and anhydrous, isolate oxidation side reactions throughout the process.
5. Neutralization Buffer Stabilizer: Neutral organic alcohol amine auxiliary agent that does not damage epoxy groups and long-term inhibits methoxy hydrolysis and condensation.
6. Equipment Materials: Reactors, distillation columns, pipelines and filtration equipment adopt enamel glass and passivated 316L stainless steel; carbon steel and copper pipelines are prohibited from contacting materials to prevent iron and copper ion catalyzed yellowing and accelerated epoxy ring-opening and hydrolysis.

II. Special Troubleshooting for Typical Finished Product Quality Defects

2.1 Product Yellowing, Continuous Color Deepening Under High-Temperature Storage and Hazy Turbidity

2.1.1 Root Failure Causes

Excessive peroxides in allyl glycidyl ether raw materials generate conjugated colored impurities during reaction; moisture contained in raw materials produces trace acidic substances that form colored complexes with platinum and iron ions; addition temperature exceeds 110℃, triggering thermal ring-opening of epoxy groups and oxidation of raw material olefins to form colored substances; insufficient nitrogen purging leaves oxygen inside the kettle to oxidize platinum catalyst into colored colloids; incomplete neutralization and filtration leave platinum particles to catalyze chain oxidation for a long time; excessive distillation kettle temperature leads to long-term thermal aging and degradation of materials; light-transmitting storage tanks cause continuous photo-oxidation and deepened yellow color; corrosion of carbon steel equipment dissolves iron ions that synergize with platinum ions to cause color development and turbidity.

2.1.2 Troubleshooting Points

Test data of moisture, peroxides and color of both raw materials; oxygen content inside the kettle before feeding after nitrogen purging; peak temperature during addition and distillation; platinum catalyst feeding ratio and residual platinum content in filtrate after filtration; vacuum degree of vacuum distillation and material residence time; light-proof sealing of storage tanks and warehousing temperature conditions.

2.1.3 Rectification Measures

Mandatory distillation of incoming allyl glycidyl ether to remove peroxides; reject yellowed or peroxide-exceeded raw materials; three nitrogen purges per kettle until oxygen content meets standard before catalyst feeding and

heating; hard limit addition temperature ≤105℃ and low-temperature distillation process to shorten high-temperature residence time of materials; accurately meter platinum catalyst feeding amount to avoid excess; upgrade two-stage high-precision organic phase filtration to completely remove platinum colloidal particles; quarterly passivation and anti-corrosion of all equipment to isolate dissolved iron and copper ions; finished products fully stored under light-proof nitrogen sealing at constant temperature ≤32℃; secondary low-temperature light removal and re-filtration with stabilizer refining for yellowed and turbid batches.

2.2 Low GPTMS Main Content and Excessive Heavy Component Siloxane Oligomers

2.2.1 Root Failure Causes

Unbalanced feeding molar ratio of trimethoxysilane and allyl glycidyl ether leads to incomplete addition reaction; excessive moisture in raw materials of the system causes hydrolysis of Si-OCH_3 to generate silanol, and intermolecular condensation of silanol produces dimeric and polymeric siloxanes; excessively fast silane dropping rate causes local silicon-hydrogen enrichment and sharp surge of hydrolysis side reactions; insufficient vacuum degree and high kettle temperature during distillation trigger hydrolysis and crosslinking of GPTMS molecules to generate heavy components; insufficient standing time for neutralization leaves platinum colloids to catalyze continuous condensation; repeated recycling of recovered light components enriches hydrolysis by-products to continuously dilute effective components.

2.2.2 Troubleshooting Points

Monthly calibration records of raw material metering pumps and addition feeding molar ratio; central control data of incoming moisture of both raw materials; silane dropping flow rate and kettle temperature curve; standing sedimentation time after neutralization; vacuum degree and kettle temperature operating parameters of distillation; batch and impurity content of recycled light components.

2.2.3 Rectification Plan

Fully calibrate all raw material metering and conveying equipment monthly to lock standard addition molar ratio; two-stage gradient vacuum drying of raw materials, feed only after moisture meets standard; segmented low-speed uniform dropwise addition of trimethoxysilane with synchronous temperature control to inhibit local hydrolysis; extend standing sedimentation time after neutralization to reduce platinum ion catalyzed condensation; optimize gradient low-temperature vacuum distillation process to separate heavy

component oligomers; limit recycling times of light components and regularly distill to remove enriched siloxane impurities; re-addition and secondary precision distillation refining for materials with unqualified purity.

2.3 Low Epoxy Value, Poor Adhesion of Downstream Composite Materials and Increased Viscosity During Storage

Core Root Causes: Excessive peroxides in allyl glycidyl ether cause premature ring-opening loss of epoxy groups during addition; excessive addition temperature induces hydrolytic ring-opening of epoxy groups under high temperature; excessive moisture in the system creates acidic hydrolysis medium to destroy epoxy rings; insufficient neutralization leaves trace acidic substances to slowly open epoxy rings for a long time; long-term high-temperature heating during distillation causes thermal degradation loss of epoxy groups; light-transmitting and high-temperature storage of finished products leads to continuous consumption of epoxy groups via light and heat sensitivity.

Rectification Measures: Pre-distill raw materials to remove peroxides and strictly control raw material peroxide indicators; set upper limit for fixed addition temperature to eliminate high-temperature damage to epoxy groups; full-process deep dewatering to reduce system hydrolysis activity; precisely deploy buffer additives in neutralization section to stabilize pH within neutral range; shorten high-temperature residence time during distillation to protect epoxy structures; finished products fully stored under light-proof low-temperature nitrogen sealing; re-distill batches with unqualified epoxy value to separate undamaged raw materials for re-blending.

2.4 Excessive Methanol Residue, Foaming During High-Temperature Processing and Strong Pungent Odor

Core Root Causes: Unremoved methanol impurities carried by trimethoxysilane raw materials in pre-treatment; hydrolysis of silane triggered by system moisture continuously generates small molecule methanol; insufficient vacuum negative pressure for light component removal during distillation and advance judgment of light component removal end point prevent complete separation of light methanol; excessively low distillation temperature sharply reduces methanol vaporization separation efficiency; damaged storage tank seal allows water vapor intrusion to regenerate methanol via hydrolysis; recycled light components carry massive methanol impurities during reuse.

Rectification Measures: Pre-vacuum removal of methanol impurities from trimethoxysilane raw materials; full-process strict control of raw material

moisture to block methanol generation from hydrolysis at source; overhaul vacuum units to improve negative pressure and extend heat preservation time for light component removal; set minimum temperature lower limit for distillation to guarantee methanol vaporization separation efficiency; finished products stored under positive nitrogen sealing to block methanol regeneration via hydrolysis; secondary low-temperature vacuum light removal refining for batches with excessive methanol.

2.5 Excessive Moisture, Thickening During Storage and Precipitation of Silanol Gel Flocs at Bottom

Core Root Causes: Insufficient vacuum negative pressure for drying trimethoxysilane and allyl glycidyl ether leads to excessive inherent moisture of raw materials; nitrogen for reactor purging contains water and carries water vapor inside; excessively high environmental humidity during addition, neutralization and transfer processes leads to air moisture intake via open operation; when system moisture exceeds 250 ppm, trimethoxysilane hydrolyzes to generate silanol, which condenses to form insoluble siloxane gel; trace bound water cannot be removed during distillation; aging and air leakage of storage tank sealing gaskets cause long-term moisture absorption and accumulation of water.

Rectification Measures: Independent negative pressure deep drying of both raw materials, feed only after moisture meets standard; adopt dry high-purity nitrogen purging and full-process closed negative pressure conveying, prohibit open transfer; improve vacuum gradient dewatering during distillation to remove trace bound water; regularly replace storage tank sealing gaskets and maintain slight positive nitrogen pressure for sealing storage; low-temperature re-drying and pressure filtration to remove gel impurities for water-containing gel materials.

2.6 Excessive Free Chloride Ions, Corrosion of Electronic Copper and Aluminum Substrates and Black Spots at Interfaces

Core Root Causes: Trace chlorine impurities inherent in trimethoxysilane raw materials; damaged passivation layer of equipment pipelines causes stainless steel corrosion and precipitation of chlorides; insufficient precision of filter elements allows trace chloride colloids to penetrate finished products; long-term cyclic reuse of recovered mother liquor leads to continuous accumulation of chloride ions; failed dechlorination process during raw material distillation leaves chlorine impurities untreated in pre-treatment.

Rectification Measures: Add dechlorination distillation process for incoming trimethoxysilane to strictly control raw material chloride ion indicators;

quarterly passivation, rust removal and anti-corrosion of all equipment to prevent mixing of chloride corrosion products; replace high-precision organic phase anti-corrosion filter elements and monitor filtration pressure difference per shift; completely replace recovered mother liquor regularly to remove accumulated chloride impurities; multi-stage sedimentation and filtration desalination refining for materials with excessive chloride ions.

2.7 Excessive Platinum Metal Ions, Coating Yellowing and Color Spots on Glass Fiber Products

Core Root Causes: Excessive feeding of Karstedt platinum catalyst; excessively high addition temperature triggers thermal decomposition of platinum complexes to precipitate inorganic platinum particles; insufficient standing sedimentation time after neutralization fails to fully separate platinum colloids; damaged or oversized filter element pores allow platinum particles to penetrate finished products; high distillation temperature aggravates precipitation of platinum compounds; repeated reuse of recovered light components leads to continuous enrichment of platinum metals.

Rectification Measures: Precisely meter the minimum effective feeding amount of catalyst to avoid excess; set upper limit for fixed addition temperature to prevent thermal decomposition of platinum catalyst; extend low-temperature standing sedimentation time after neutralization to enlarge platinum colloidal particles for easy filtration; replace high-precision organic phase filter elements and monitor pressure difference per shift; reduce high-temperature residence time during distillation; completely replace recovered light components regularly to remove accumulated metal impurities; multi-stage sedimentation and filtration to remove platinum particles for materials with excessive metal ions.

2.8 pH Deviation from 6.5～7.5 Range and Rapid Hydrolysis and Thickening Failure During Storage

Core Root Causes: Metering deviation of neutralization buffer stabilizer leaves trace acidic degradation products in the system; oxidation of allyl ether raw materials generates trace organic acids; high-temperature distillation decomposes a small amount of silane to release acidic small molecules; uneven stirring of stabilizer creates local areas without buffer components; long-term storage with oxygen absorption and oxidation continuously generates carboxylic acids to lower pH and accelerate silane hydrolysis and condensation.

Rectification Measures: Closed-loop real-time pH monitoring in neutralization blending section, trace precise supplementary addition of buffer additives to

adjust to neutral range; pre-distill allyl glycidyl ether raw materials to remove oxidized acidic impurities; adopt low-temperature distillation process to reduce acid generation from silane thermal decomposition; standardize feeding ratio of buffer stabilizer and extend homogeneous stirring time for blending; finished products stored under light-proof nitrogen sealing at low temperature to slow oxidation and acid generation; low-temperature precise neutralization and homogeneous blending for batches with abnormal pH.

III. In-Depth Process Troubleshooting by Section

3.1 Raw Material Drying Pretreatment Section

Hidden Faults: Excessive peroxides and moisture in allyl glycidyl ether introduce inducing factors for epoxy ring-opening, hydrolysis and color development; insufficient drying negative pressure of trimethoxysilane leads to excessive moisture, methanol and chlorine impurities; insufficient precision of raw material filtration allows solid dust and rust impurities to enter the reactor; open storage of raw material tanks causes moisture absorption and deterioration of oxidized components; uncalibrated metering pumps lead to inherent imbalance of silane and epoxy ether ratio.

Process Red Lines: Both main raw materials must pass vacuum drying, precision filtration and full inspection of moisture, peroxide, color and chlorine indicators before feeding; reject raw materials containing water, yellowed or exceeding peroxide standards directly.

3.2 Nitrogen Protection Hydrosilylation Section (Core Control of Purity, Epoxy Value and Color)

Hidden Faults: Insufficient nitrogen purging leaves residual oxygen inside the kettle to oxidize platinum catalyst and yellow materials; out-of-control dropwise addition rate of trimethoxysilane causes local silicon-hydrogen enrichment and rapid hydrolysis to generate silanol upon contact with water; excessive or insufficient platinum catalyst feeding increases side reactions or incomplete addition; excessive reaction temperature triggers simultaneous epoxy ring-opening, platinum decomposition and material yellowing; stirring dead zones cause uneven local reaction and enrichment of platinum colloids and silanol impurities; excessive system moisture synchronously triggers hydrolysis and condensation to generate gel.

3.3 Constant Temperature Aging Section (Key Control of Residual Si-H and Main Product Purity)

Hidden Faults: Low aging temperature and insufficient heat preservation time fail to completely consume residual Si-H; air leakage of aging kettle allows air intake and oxidation discoloration; no central control Si-H detection at aging

end point causes huge batch conversion rate differences; failure to rapidly cool materials after aging leads to continuous high-temperature loss of epoxy groups and generation of heavy component impurities.

3.4 Neutralization and Sedimentation Section (Control of pH, Platinum Ions and Silanol Turbidity)

Hidden Faults: Metering deviation of neutralization buffer stabilizer causes finished product pH to deviate from neutral range; low sedimentation temperature leaves tiny platinum colloidal particles difficult to settle and filter; insufficient standing time after neutralization fails to stratify suspended platinum salts and silanol flocs; insufficient stirring during neutralization creates large local acid-base concentration differences and triggers rapid hydrolysis to generate gel locally.

3.5 Multi-Stage Precision Filtration Section (Control of Platinum Ions, Turbidity and Silanol Gel)

Hidden Faults: Damaged or insufficient precision organic phase filter elements allow penetration of platinum colloids and silanol flocs into finished products; low filtration temperature causes precipitation of silanol gel to block filter media; insufficient filtration stages fail to intercept ultra-fine colloidal impurities; filter elements not replaced for a long time lead to excessive pressure difference and impurity breakthrough of filter layers; filter media dissolves impurities under organic medium to aggravate color and turbidity.

3.6 Vacuum Distillation Section (Control of Methanol Residue, Heavy Components and Epoxy Loss)

Hidden Faults: Vacuum unit negative pressure leakage and insufficient negative pressure prevent removal of light component methanol; excessively high distillation kettle temperature triggers epoxy ring-opening and silane hydrolysis and condensation to generate heavy components; lagged judgment of distillation end point leaves excessive residual light component methanol; air leakage of distillation system allows air intake to oxidize materials and cause yellowing; long-term accumulation of heavy component siloxane impurities at tower bottom causes cross-contamination of fresh materials between batches.

3.7 Light-Proof Nitrogen Filling and Warehousing Section

Hidden Faults: Incomplete nitrogen purging of storage tanks leads to long-term oxygen absorption, oxidation yellowing and epoxy loss; excessively high humidity in filling workshop causes finished products to rapidly absorb moisture, hydrolyze and thicken; light-transmitting packaging barrels and aging air leakage of sealing gaskets accelerate photo-sensitive oxidation to

destroy epoxy groups; large temperature difference between day and night in storage intensifies precipitation and delamination of silanol gel due to repeated temperature rise and fall; mixed storage of different reaction batches causes overall indicator fluctuations due to component differences.

IV. Systematic Troubleshooting of Public Utilities and Equipment

4.1 Nitrogen, Vacuum, Refrigeration, Heating and Drying Systems

Key Troubleshooting Points: Excessive water and oxygen content in nitrogen fails to isolate water vapor and oxidation; leakage of nitrogen pipelines causes continuous air intake inside the kettle; vacuum unit negative pressure leakage and insufficient pumping speed invalidate raw material drying and distillation light removal processes; unstable temperature control of refrigeration cooling system fails to maintain low-temperature addition range; scaling of heating coils causes local overheating to trigger epoxy ring-opening and material crosslinking yellowing; unstable temperature of raw material drying vacuum unit leads to unqualified dewatering and methanol removal.

4.2 Temperature Control, Pressure and Metering Systems

Key Troubleshooting Points: Drift of temperature measuring instruments for addition, aging and distillation leads to excessive temperature loss of epoxy or insufficient conversion at low temperature; failure of pressure transmitters causes unstable nitrogen and vacuum pressure; failure to calibrate metering pumps for trimethoxysilane, allyl ether and catalyst leads to unbalanced ratio; out-of-control heating gradient program disturbs silane dropping reaction rhythm.

4.3 Reaction, Filtration, Distillation and Storage Tank Equipment Systems

Key Troubleshooting Points: Insufficient stirring speed of reactor and accumulated materials at bottom dead zones hydrolyze to generate silanol gel; peeling of passivation layer of 316L stainless steel/enamel glass lining dissolves iron ions to synergize with platinum ions for color development; aging, blockage and damage of organic phase filter elements at all stages allow penetration of platinum colloids and silanol particles; accumulation of heavy component siloxane on inner wall of distillation tower causes continuous cross-contamination of fresh materials; deposition of platinum salts and silanol gel impurities at storage tank bottom leads to excessive batch indicators after material mixing; accumulated aged hydrolyzed materials at dead zones of pipeline elbows.

4.4 Closed Light-Proof Clean System

Key Troubleshooting Points: Failure of equipment flanges, manholes and storage tank seals allows intrusion of air and water vapor to hydrolyze and

oxidize materials; no light-proof protection in filling workshop accelerates photo-sensitive oxidation of epoxy groups by ultraviolet light; excessively high environmental humidity in workshop causes continuous moisture absorption during finished product transfer; dust and foreign metal impurities mix into filled finished products; no constant temperature and light-proof protection in storage leads to dual deterioration of materials by light and high temperature and loss of epoxy groups.

V. Safety and Environmental Risk Troubleshooting

5.1 Process Safety Risks

Trimethoxysilane is low-boiling flammable liquid that releases combustible methanol vapor upon contact with water; leakage easily catches fire upon exposure to high temperature and static electricity; organic vapor of allyl glycidyl ether under high temperature poses VOC explosion hazard; hydrosilylation is a strong exothermic reaction, cooling failure easily causes thermal runaway with kettle flushing and material spraying; improper closed space purging with high-purity nitrogen leads to suffocation risk in confined spaces; organic platinum catalyst easily releases heat via oxidation under high temperature and air exposure; finished organic liquid is flammable with fire hazard during storage and transportation leakage; methanol vapor is flammable and explosive with strict explosion-proof requirements for distillation light removal section.

5.2 Environmental Protection Risks of Three Wastes

Process cleaning wastewater contains siloxane, trace platinum metals, methanol and chlorine impurities with high COD and trace heavy metals, requiring flocculation precipitation + neutralization pretreatment to meet discharge standards; waste organic filter elements, platinum salt filter residues and silanol gel heavy residues are hazardous solid wastes; organic waste gas from distillation contains methanol and silane light components, requiring condensation + activated carbon adsorption device treatment to strictly control VOC emission; hazardous waste collection and separate disposal of unqualified organic waste liquid containing platinum and chlorine, direct discharge prohibited.

5.3 Batch Quality Scrap Risk

Failure of raw material drying for dewatering and peroxide removal, out-of-control addition temperature and ratio, insufficient aging conversion, incomplete platinum and chlorine removal via filtration, drift of distillation light removal parameters, lack of light-proof and sealed storage control will directly cause batch loss including insufficient epoxy value, yellowing and turbidity,

excessive methanol residue, thickening and gelation during storage, chlorine ion corrosion of substrates, failure of adhesion of downstream electronic potting and glass fiber composite materials, and spot corrosion of metal components, triggering mass scrap and rework of end products.

VI. Standardized Five-Step Fault Troubleshooting Process

6.1 Full-Dimensional Abnormal Data Collection

Record finished product appearance and color, GPTMS main content, epoxy value, methanol residue, chloride ion, moisture, viscosity, pH and 60℃ thermal storage stability; collect full-process parameters including moisture and peroxide of dried raw materials, temperature and pressure during addition, catalyst feeding amount, aging heat preservation time, distillation vacuum and temperature, filtration pressure difference, filling and warehousing; check ledgers of metering calibration, filter element replacement, equipment passivation and nitrogen leakage inspection.

6.2 Segmented Sampling and Tracing for Location Locking

Sampling nodes: two types of raw materials after drying → intermediate products after hydrosilylation reaction → crude products after aging → materials after neutralization and sedimentation → semi-finished products after distillation → finished products after filtration and blending; test moisture, platinum ions, chlorine, epoxy value and color segment by segment to accurately lock the process section where faults occur.

6.3 Full-Coverage Inspection of Public Utilities

Check water and oxygen content of drying nitrogen, negative pressure of vacuum units, temperature control precision of heating and refrigeration, calibration of metering equipment; inspect operating conditions of addition, aging, neutralization, filtration and distillation equipment; check temperature, humidity, light-proof sealing of filling workshop and constant temperature and light-proof environmental parameters of storage.

6.4 Classification and Determination of Four Root Causes

1. Deviated process parameters: addition temperature, feeding ratio of silane and epoxy ether, neutralization pH, distillation vacuum and temperature, raw material drying moisture and peroxide exceeding standard ranges;
2. Failed equipment: drift of metering pumps, damaged filter elements, vacuum leakage, drift of temperature measuring instruments, corrosion and dissolution of iron and chlorine from stainless steel passivation layer;

3. Defective raw and auxiliary materials: excessive peroxide/moisture of allyl ether, water and chlorine contained in trimethoxysilane, water and oxygen contained in nitrogen;
4. Material deterioration side reactions: hydrolysis of silane triggered by moisture to generate silanol gel, loss of epoxy ring-opening under high temperature, yellowing catalyzed by platinum and iron ions, accelerated hydrolysis and condensation due to unbalanced acid-base, destruction of epoxy groups by peroxides.

6.5 Closed-Loop Verification of Rectification

Isolate abnormal batches emergently, lock process red lines including anhydrous raw material pre-treatment, low-temperature nitrogen addition, sufficient aging, platinum removal via neutralization and sedimentation, low-temperature distillation for light removal and light-proof sealing; short-term replacement of damaged consumables, calibration of metering instruments, equipment passivation to remove iron and chlorine, optimization of addition temperature control and silane dropping rate; long-term solidification of full inspection of incoming raw materials for moisture, peroxide and chlorine, monthly metering calibration, regular filter element replacement, quarterly equipment passivation system; resume mass production only after three consecutive batches meet all indicators, no yellowing or thickening after 72h thermal storage at 60℃ and stable epoxy value.

VII. Quick Reference Comparison Table for Faults

Abnormal Phenomenon	**Core Root Cause**	**Priority Troubleshooting Section**
Product yellowing, continuous color change under high-temperature storage	Excessive peroxide in allyl ether, water contained in raw materials, excessive temperature during addition and distillation, unfiltered excess platinum catalyst, light-transmitting storage tanks	Raw material drying pretreatment, hydrosilylation, neutralization precision filtration, light-proof sealed storage
Low GPTMS main content and excessive heavy	Unbalanced ratio of silane and epoxy ether, hydrolysis and condensation due to system moisture, excessively fast	Raw material metering, hydrosilylation reaction, vacuum distillation section

Abnormal Phenomenon	Core Root Cause	Priority Troubleshooting Section
component siloxane	silane dropping, low-molecular polymer generated under high distillation temperature	
Low epoxy value, poor adhesion and thickening during storage	Excessive peroxide in raw materials, ring-opening under high temperature during addition and distillation, acidic hydrolysis due to system moisture, loss of epoxy under light and high temperature during storage	Raw material peroxide removal, addition temperature control, full-process dewatering, light-proof low-temperature storage
High methanol residue, foaming and pungent odor during processing	Methanol carried by trimethoxysilane, methanol generated from hydrolysis due to moisture, insufficient vacuum for distillation light removal, enriched methanol in recycled light components	Pre-light removal of raw materials, vacuum distillation light removal section, raw material dewatering
Excessive moisture, thickening and precipitation of silanol gel during storage	Unqualified raw material drying, water contained in nitrogen, moisture absorption during open workshop transfer, air leakage of storage tank seal	Raw material vacuum drying, nitrogen protection, full-process closed conveying, nitrogen sealed storage of tanks
Excessive chloride ions, spot corrosion of electronic substrates	Chlorine impurities contained in trimethoxysilane, chlorine dissolved from equipment corrosion, failed filtration, accumulated chlorine in recycled mother liquor	Raw material pre-treatment dechlorination, equipment passivation anti-corrosion, multi-stage precision filtration
Excessive platinum metal ions, color spots and yellowing	Excessive catalyst feeding, platinum decomposition under high addition temperature, insufficient neutralization	Catalyst metering control, addition temperature control, neutralization

Abnormal Phenomenon	Core Root Cause	Priority Troubleshooting Section
of coatings and glass fiber products	sedimentation, damaged filter elements, accumulated platinum in mother liquor	sedimentation, two-stage precision filtration
pH deviation from 6.5～7.5, rapid hydrolysis and gelation during storage	Metering deviation of neutralization buffer agent, organic acid generated from raw material oxidation, acid generation under high distillation temperature, insufficient stabilizer, long-term oxygen absorption and oxidation	Neutralization fine-tuning blending section, raw material pre-treatment, finished product stabilizer blending, oxygen-isolated storage

VIII. Periodic Preventive Troubleshooting Checklist

8.1 Per Shift Inspection

Appearance clarity of finished products, presence of silanol gel precipitate and delamination; preliminary screening of moisture, peroxide and color of two types of raw materials after drying; oxygen content inside kettle after nitrogen purging; real-time temperature during addition, silane dropping rate and cooling condition; aging heat preservation temperature and duration; stratification state after neutralization and sedimentation; vacuum and kettle temperature operating parameters of distillation; filtration pressure difference and clarity of filtrate; nitrogen positive pressure of filling storage tanks, workshop temperature, humidity and light-proof inspection.

8.2 Daily Inspection

Sampling inspection of operating parameters of drying nitrogen and vacuum units; rapid central control of main content, moisture, pH, epoxy value and methanol residue of finished products; simple recheck of addition conversion rate; observation of pressure difference of all levels of organic filter elements; real-time monitoring of viscosity and GC components at distillation end point; inspection of light-proof seal and constant temperature state of finished product storage tanks.

8.3 Weekly Inspection

Leakage verification of full-line nitrogen and vacuum negative pressure systems; cleaning of silanol gel and platinum salt deposits at bottom of reactor

and distillation tower; integrity inspection of all filter elements and replacement of blocked filter elements; simple passivation inspection of inner wall of stainless steel/enamel glass equipment; detection of platinum ion, methanol and heavy component impurity content of recycled light components, replace when reaching upper limit; discharge of water and solid impurities at bottom of raw material storage tanks.

8.4 Monthly In-Depth Testing

Full calibration of full-line temperature control, pressure and metering pumps; full-indicator testing of raw materials and finished products, special re-inspection of chloride ions, platinum ions, epoxy value and thermal stability; deep purification of public systems including nitrogen, drying vacuum, refrigeration and heating; non-destructive testing of passivation layer of stainless steel for reaction, distillation and storage tanks; 60℃ accelerated thermal storage stability verification of finished products.

8.5 Quarterly Shutdown In-Depth Maintenance

Complete cleaning of silanol gel, platinum salt and colored impurities for all raw material drying, addition, aging, neutralization, filtration and distillation equipment; maintenance of stirring, vacuum, heat exchange and conveying transmission parts; complete replacement of all sealing gaskets and organic filter elements; full verification of hydrosilylation explosion-proof, nitrogen oxygen isolation, vacuum negative pressure and light-proof clean systems; screening of stock trimethoxysilane, allyl glycidyl ether and platinum catalyst, reject deteriorated raw materials with excessive water, peroxide and chlorine impurities.

If you require more professional and in-depth analysis regarding process troubleshooting or product consultation of 3 Glycidoxypropyltrimethoxysilane, please contact HiSiaddi customer service or visit our official website www.hisiaddi.com

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