TROY TECHNICAL

ADHESIVES & SEALANTS
WEEKLY REPORT

October 24 - October 30, 2026 | Issue 2026-W43

Bond-line performance, cure process, durability and cross-industry qualification

11	10
ANALYZED ARTICLES	PRIORITY THEMES

Issued 2026-10-30 | English edition | fixed approved cover artwork



Adhesives & Sealants: the boundary moved from isolated claims to qualification evidence

11 English articles were reviewed independently from the Japanese edition. Ten themes are retained for management decisions.

SIGNAL 01 | CHEMISTRY

Henkel: AI Chip Adhesive Production and 2027 R&D Roadmap

Henkel is leveraging its Songdo, South Korea facility to produce advanced semiconductor adhesives required for AI chip packaging.

SIGNAL 02 | FORMULATION

Tokuyama: Aluminum Nitride Heat Dissipation Material Timeline

Tokuyama is expanding its production capacity for semiconductor heat dissipation materials by 50% with a new facility in Yanai City.

SIGNAL 03 | APPLICATION & CURE

Loctite AA-series: Henkel's EU-MDR compliant light-cure adhesives

Henkel has launched five Loctite light-cure adhesives (AA 3914, AA 3915, AA 3917, AA 3937, and AA 3964) designed for medical device assembly.

SIGNAL 04 | QUALIFIED PRODUCT

SK Ecoplant Materials and Furukawa Electric: AI Material MOU

SK Ecoplant Materials and Furukawa Electric have signed a Memorandum of Understanding (MOU) to expand high-performance materials for semiconductor and AI data center markets.

DECISION

Focus this week's management attention on bond-line performance, cure process, durability and cross-industry qualification. Move only when the linked evidence can be reproduced under your own operating conditions.

THREE MANAGEMENT MOVES

1. Buyers: evaluate the complete joint or sealed system under process and lifetime conditions.
2. Suppliers: provide substrate preparation, cure window, rework, aging and failure-analysis evidence.
3. Executives: track adhesion aging, cure variability, outgassing, regulation, repair and scale.

EVIDENCE DISCIPLINE

FACT states what the collected English source reports. BUSINESS READ and ACTION are editorial interpretations. UNKNOWN lists information that the source file does not establish. A linked article is not treated as independent confirmation of every claim.

Five numbers or evidence anchors that require conditions

50%
A09

SOURCE-BOUND CONDITION
Tokuyama is expanding its production capacity for semiconductor heat dissipation materials by 50% with a new facility in Yanai City.

0.1%
A06

SOURCE-BOUND CONDITION
These formulations contain less than 0.1% by weight of CMR, ED, and TPO-related content to align with EU MDR 2017/745 Section 10.4.

23.3%
A11

SOURCE-BOUND CONDITION
The optimized formulation increased tensile strength by 23.3% over unfilled baselines, resolving the traditional trade-off between flame retardancy and structural integrity.

P04
A10

SOURCE-BOUND CONDITION
SK Ecoplant Materials and Furukawa Electric have signed a Memorandum of Understanding (MOU) to expand high-performance materials for semiconductor and AI data center markets.

P05
A04

SOURCE-BOUND CONDITION
Researchers utilized principal component analysis (PCA) to link the complex spectral fingerprints of degrading filler-containing epoxy adhesives to the loss of mechanical strength.

HOW TO USE THESE NUMBERS
Each value is shown with the condition stated in the collected English article. Do not compare values across different test methods, device sizes, operating temperatures or commercial stages without normalizing those conditions.

Where the value chain moved

Each stage combines one leading theme and one supporting theme. The report treats handoffs as evidence transfers, not decorative arrows.

1

Chemistry

P01/P06

Henkel is leveraging its Songdo, South Korea facility to produce advanced semiconductor adhesives required for AI chip.

2

Formulation

P02/P07

Tokuyama is expanding its production capacity for semiconductor heat dissipation materials by 50% with a new facility in.

3

Application & cure

P03/P08

Henkel has launched five Loctite light-cure adhesives (AA 3914, AA 3915, AA 3917, AA 3937, and AA 3964) designed for medical.

4

Qualified product

P04/P09

SK Ecoplant Materials and Furukawa Electric have signed a Memorandum of Understanding (MOU) to expand high-perfor mance.

5

Repair & circularity

P05/P10

Researchers utilized principal component analysis (PCA) to link the complex spectral fingerprints of degrading.

EVIDENCE REQUIRED AT EACH HANDOFF

Chemistry to Formulation	Transfer test conditions, acceptance criteria, failure data, owner and decision date. Recheck adhesion aging, cure variability, outgassing, regulation, repair and scale.
Formulation to Application & cure	Transfer test conditions, acceptance criteria, failure data, owner and decision date. Recheck adhesion aging, cure variability, outgassing, regulation, repair and scale.
Application & cure to Qualified product	Transfer test conditions, acceptance criteria, failure data, owner and decision date. Recheck adhesion aging, cure variability, outgassing, regulation, repair and scale.
Qualified product to Repair & circularity	Transfer test conditions, acceptance criteria, failure data, owner and decision date. Recheck adhesion aging, cure variability, outgassing, regulation, repair and scale.

COMMON CONTROL POINT

No theme moves to a commercial commitment until a named owner has reproduced the relevant evidence and documented adhesion aging, cure variability, outgassing, regulation, repair and scale.

Priority map: maturity and next decision locus



P01	Henkel: AI Chip Adhesive Production and 2027 R&D Roadmap System / adoption | cue: integration
P02	Tokuyama: Aluminum Nitride Heat Dissipation Material Timeline Business / rules | cue: capacity
P03	Loctite AA-series: Henkel's EU-MDR compliant light-cure adhesives Business / rules | cue: regulatory
P04	SK Ecoplant Materials and Furukawa Electric: AI Material MOU Business / rules | cue: infrastructure
P05	Epoxy Degradation Analysis: PCA-Based Spectral Mapping of 3 Curing Agents Tech / process | cue: no system/business cue
P06	Plasma Surface Activation: Argon vs Nitrogen for Plastic Bonding Tech / process | cue: no system/business cue
P07	Boron Nitride Composites: Tuning Heat Flow via MSLA 3D Printing Tech / process | cue: no system/business cue
P08	Polysulfide Sealants: Cotton Fibers and Silane for 60-Min Fire Resistance Business / rules | cue: fid
P09	Qnity Thermal Solutions: AI Data Center Cooling for DDR5 DIMMs Tech / process | cue: no system/business cue
P10	Nano-silver Sintering: Reliability on Cyanate Ester Composites System / adoption | cue: integrating

REPRODUCIBLE POSITIONING RULE

Horizontal position uses five discrete stages: Research, Prototype, Joint evaluation, Product adoption and Scale. The vertical bands classify the next decision locus: Tech / process, System / adoption, or Business / rules (including supply systems). Article-title cues take precedence; the overview is used only when the title is silent. These are categories, not impact ranks. Bubble diameter reflects the editorial score.

FACT is source-bound. BUSINESS READ, ACTION and UNKNOWN are explicit editorial layers.

P01 Henkel: AI Chip Adhesive Production and 2027 R&D Roadmap

A05 | Chemistry | Product adoption

Date not stated

FACT

Henkel is leveraging its Songdo, South Korea facility to produce advanced semiconductor adhesives required for AI chip packaging. The company plans to expand its research capabilities with a new technical center in March 2027 to address thermal management and integration challenges.

WHY IT MATTERS

The decision relevance is bond-line performance, cure process, durability and cross-industry qualification. The signal should be tested at the application and operating-system level, not accepted from a headline alone.

BUSINESS READ

For operating companies, compare the reported change with current qualification, sourcing and product-roadmap assumptions. For suppliers, provide substrate preparation, cure window, rework, aging and failure-analysis evidence.

ACTION

Within 30 days, evaluate the complete joint or sealed system under process and lifetime conditions; record the evidence and owner against P01.

UNKNOWN

Still unproven or incompletely stated: adhesion aging, cure variability, outgassing, regulation, repair and scale.

EDITORIAL SCORE 21/25 | MATURITY 4/5 | DECISION LOCUS: SYSTEM / ADOPTION

P02 Tokuyama: Aluminum Nitride Heat Dissipation Material Timeline

A09 | Formulation | Product adoption

Date not stated

FACT

Tokuyama is expanding its production capacity for semiconductor heat dissipation materials by 50% with a new facility in Yanai City. The investment targets the production of aluminum nitride granules to meet rising demand for high-performance semiconductors, with operations scheduled to begin in February 2028.

WHY IT MATTERS

The decision relevance is bond-line performance, cure process, durability and cross-industry qualification. The signal should be tested at the application and operating-system level, not accepted from a headline alone.

BUSINESS READ

For operating companies, compare the reported change with current qualification, sourcing and product-roadmap assumptions. For suppliers, provide substrate preparation, cure window, rework, aging and failure-analysis evidence.

ACTION

Within 30 days, evaluate the complete joint or sealed system under process and lifetime conditions; record the evidence and owner against P02.

UNKNOWN

Still unproven or incompletely stated: adhesion aging, cure variability, outgassing, regulation, repair and scale.

EDITORIAL SCORE 21/25 | MATURITY 4/5 | DECISION LOCUS: BUSINESS / RULES

FACT is source-bound. BUSINESS READ, ACTION and UNKNOWN are explicit editorial layers.

P03 Loctite AA-series: Henkel's EU-MDR compliant light-cure adhesives

A06 | Application & cure | Research

Date not stated

FACT

Henkel has launched five Loctite light-cure adhesives (AA 3914, AA 3915, AA 3917, AA 3937, and AA 3964) designed for medical device assembly. These formulations contain less than 0.1% by weight of CMR, ED, and TPO-related content to align with EU MDR 2017/745 Section 10.4. This release enables medical device manufacturers to maintain high-performance bonding while meeting evolving European regulatory requirements.

WHY IT MATTERS

The decision relevance is bond-line performance, cure process, durability and cross-industry qualification. The signal should be tested at the application and operating-system level, not accepted from a headline alone.

BUSINESS READ

For operating companies, compare the reported change with current qualification, sourcing and product-roadmap assumptions. For suppliers, provide substrate preparation, cure window, rework, aging and failure-analysis evidence.

ACTION

Within 30 days, evaluate the complete joint or sealed system under process and lifetime conditions; record the evidence and owner against P03.

UNKNOWN

Still unproven or incompletely stated: adhesion aging, cure variability, outgassing, regulation, repair and scale.

EDITORIAL SCORE 20/25 | MATURITY 1/5 | DECISION LOCUS: BUSINESS / RULES

P04 SK Ecoplant Materials and Furukawa Electric: AI Material MOU

A10 | Qualified product | Joint evaluation

Date not stated

FACT

SK Ecoplant Materials and Furukawa Electric have signed a Memorandum of Understanding (MOU) to expand high-performance materials for semiconductor and AI data center markets. The partnership focuses on integrating technical capabilities to develop materials for packaging, heat dissipation, insulation, and communication infrastructure.

WHY IT MATTERS

The decision relevance is bond-line performance, cure process, durability and cross-industry qualification. The signal should be tested at the application and operating-system level, not accepted from a headline alone.

BUSINESS READ

For operating companies, compare the reported change with current qualification, sourcing and product-roadmap assumptions. For suppliers, provide substrate preparation, cure window, rework, aging and failure-analysis evidence.

ACTION

Within 30 days, evaluate the complete joint or sealed system under process and lifetime conditions; record the evidence and owner against P04.

UNKNOWN

Still unproven or incompletely stated: adhesion aging, cure variability, outgassing, regulation, repair and scale.

EDITORIAL SCORE 20/25 | MATURITY 3/5 | DECISION LOCUS: BUSINESS / RULES

FACT is source-bound. BUSINESS READ, ACTION and UNKNOWN are explicit editorial layers.

P05 Epoxy Degradation Analysis: PCA-Based Spectral Mapping of 3 Curing Agents

A04 | Repair & circularity | Pilot

Date not stated

FACT

Researchers utilized principal component analysis (PCA) to link the complex spectral fingerprints of degrading filler-containing epoxy adhesives to the loss of mechanical strength. The study reveals that degradation behavior varies significantly based on the curing agent used, with some systems showing non-monotonic strength changes.

WHY IT MATTERS

The decision relevance is bond-line performance, cure process, durability and cross-industry qualification. The signal should be tested at the application and operating-system level, not accepted from a headline alone.

BUSINESS READ

For operating companies, compare the reported change with current qualification, sourcing and product-roadmap assumptions. For suppliers, provide substrate preparation, cure window, rework, aging and failure-analysis evidence.

ACTION

Within 30 days, evaluate the complete joint or sealed system under process and lifetime conditions; record the evidence and owner against P05.

UNKNOWN

Still unproven or incompletely stated: adhesion aging, cure variability, outgassing, regulation, repair and scale.

EDITORIAL SCORE 20/25 | MATURITY 2/5 | DECISION LOCUS: TECH / PROCESS

P06 Plasma Surface Activation: Argon vs Nitrogen for Plastic Bonding

A03 | Chemistry | Research

Date not stated

FACT

Nitrogen and argon atmospheric-pressure plasma significantly increase the lap-shear strength of engineering plastics, with nitrogen boosting PVC and PP adhesion by up to six-fold. However, research indicates that the lowest water contact angle does not always correlate with the strongest bond, suggesting that wettability alone is an insufficient predictor of adhesion.

WHY IT MATTERS

The decision relevance is bond-line performance, cure process, durability and cross-industry qualification. The signal should be tested at the application and operating-system level, not accepted from a headline alone.

BUSINESS READ

For operating companies, compare the reported change with current qualification, sourcing and product-roadmap assumptions. For suppliers, provide substrate preparation, cure window, rework, aging and failure-analysis evidence.

ACTION

Within 30 days, evaluate the complete joint or sealed system under process and lifetime conditions; record the evidence and owner against P06.

UNKNOWN

Still unproven or incompletely stated: adhesion aging, cure variability, outgassing, regulation, repair and scale.

EDITORIAL SCORE 19/25 | MATURITY 1/5 | DECISION LOCUS: TECH / PROCESS

FACT is source-bound. BUSINESS READ, ACTION and UNKNOWN are explicit editorial layers.

P07 Boron Nitride Composites: Tuning Heat Flow via MSLA 3D Printing

A02 | Formulation | Pilot

Date not stated

FACT

Researchers have demonstrated that masked stereolithography (MSLA) 3D printing can control the orientation of hexagonal boron nitride (h-BN) platelets to tune thermal conductivity. By adjusting platelet size and layer thickness, the team achieved high basal-plane alignment, overcoming the inherent anisotropy of the material.

WHY IT MATTERS

The decision relevance is bond-line performance, cure process, durability and cross-industry qualification. The signal should be tested at the application and operating-system level, not accepted from a headline alone.

BUSINESS READ

For operating companies, compare the reported change with current qualification, sourcing and product-roadmap assumptions. For suppliers, provide substrate preparation, cure window, rework, aging and failure-analysis evidence.

ACTION

Within 30 days, evaluate the complete joint or sealed system under process and lifetime conditions; record the evidence and owner against P07.

UNKNOWN

Still unproven or incompletely stated: adhesion aging, cure variability, outgassing, regulation, repair and scale.

EDITORIAL SCORE 19/25 | MATURITY 2/5 | DECISION LOCUS: TECH / PROCESS

P08 Polysulfide Sealants: Cotton Fibers and Silane for 60-Min Fire Resistance

A11 | Application & cure | Research

Date not stated

FACT

A new formulation strategy using surface-treated cotton fibers and silane coupling agents allows two-component polysulfide sealants to maintain mechanical strength while passing a 60-minute fire resistance test. The optimized formulation increased tensile strength by 23.3% over unfilled baselines, resolving the traditional trade-off between flame retardancy and structural integrity.

WHY IT MATTERS

The decision relevance is bond-line performance, cure process, durability and cross-industry qualification. The signal should be tested at the application and operating-system level, not accepted from a headline alone.

BUSINESS READ

For operating companies, compare the reported change with current qualification, sourcing and product-roadmap assumptions. For suppliers, provide substrate preparation, cure window, rework, aging and failure-analysis evidence.

ACTION

Within 30 days, evaluate the complete joint or sealed system under process and lifetime conditions; record the evidence and owner against P08.

UNKNOWN

Still unproven or incompletely stated: adhesion aging, cure variability, outgassing, regulation, repair and scale.

EDITORIAL SCORE 19/25 | MATURITY 1/5 | DECISION LOCUS: BUSINESS / RULES

FACT is source-bound. BUSINESS READ, ACTION and UNKNOWN are explicit editorial layers.

P09 Qnity Thermal Solutions: AI Data Center Cooling for DDR5 DIMMs

A08 | Qualified product | Product adoption

Date not stated

FACT

Qnity Electronics Inc. has expanded its semiconductor materials portfolio with two new thermal management products targeting high-density AI data centers. These solutions address the heat loads generated by modern server platforms that can accommodate up to 48 DDR5 memory modules.

WHY IT MATTERS

The decision relevance is bond-line performance, cure process, durability and cross-industry qualification. The signal should be tested at the application and operating-system level, not accepted from a headline alone.

BUSINESS READ

For operating companies, compare the reported change with current qualification, sourcing and product-roadmap assumptions. For suppliers, provide substrate preparation, cure window, rework, aging and failure-analysis evidence.

ACTION

Within 30 days, evaluate the complete joint or sealed system under process and lifetime conditions; record the evidence and owner against P09.

UNKNOWN

Still unproven or incompletely stated: adhesion aging, cure variability, outgassing, regulation, repair and scale.

EDITORIAL SCORE 19/25 | MATURITY 4/5 | DECISION LOCUS: TECH / PROCESS

P10 Nano-silver Sintering: Reliability on Cyanate Ester Composites

A01 | Repair & circularity | Research

Date not stated

FACT

Low-temperature nano-silver sintering enables the direct bonding of power chips to fiber-reinforced cyanate ester composite substrates with a maximum shear strength of 11.5 MPa. The joints maintain 9.3 MPa strength after 600 h of high-temperature aging, identifying substrate thermal degradation as the primary reliability limit. This method provides a route for integrating power electronics with lightweight, thermally stable, and low-dielectric polymer composites.

WHY IT MATTERS

The decision relevance is bond-line performance, cure process, durability and cross-industry qualification. The signal should be tested at the application and operating-system level, not accepted from a headline alone.

BUSINESS READ

For operating companies, compare the reported change with current qualification, sourcing and product-roadmap assumptions. For suppliers, provide substrate preparation, cure window, rework, aging and failure-analysis evidence.

ACTION

Within 30 days, evaluate the complete joint or sealed system under process and lifetime conditions; record the evidence and owner against P10.

UNKNOWN

Still unproven or incompletely stated: adhesion aging, cure variability, outgassing, regulation, repair and scale.

EDITORIAL SCORE 19/25 | MATURITY 1/5 | DECISION LOCUS: SYSTEM / ADOPTION

Playbook and 0-5 year roadmap

STAKEHOLDER	NOW | 0-30 DAYS	NEXT | 1-12 MONTHS	LATER | 1-5 YEARS
Operating companies	evaluate the complete joint or sealed system under process and lifetime conditions	Run production-like qualification with explicit acceptance and stop criteria.	Build a portfolio and architecture that can absorb technology and supplier changes.
Materials, equipment and technology suppliers	provide substrate preparation, cure window, rework, aging and failure-analysis evidence	Create shared reliability, process-window and failure-analysis data with customers.	Standardize interfaces, traceability, lifecycle support and recovery services.
Trading, investment and legal teams	Map adhesion aging, cure variability, outgassing, regulation, repair and scale.	Contract for capacity, quality, change notice, liability, alternatives and exit.	Diversify regional, technical and customer concentration risk.

ROADMAP

NOW | 0-30 DAYS
Evidence ledger
Owner: Strategy + quality
Deliverable: claim, source, condition, owner

NOW | 0-30 DAYS
Risk screen
Owner: Procurement + legal
Deliverable: unknowns, alternatives, stop

NEXT | 1-12 MONTHS
Joint qualification
Owner: R&D + supplier
Deliverable: process window and failure data

NEXT | 1-12 MONTHS
Commercial gate
Owner: Business + finance
Deliverable: unit economics and capacity

LATER | 1-5 YEARS
Platform strategy
Owner: Executive team
Deliverable: portfolio and interface roadmap

LATER | 1-5 YEARS
Service layer
Owner: Operations + channel
Deliverable: monitoring, maintenance and recovery

GO / NO-GO GATES

GATE	OWNER	REQUIRED EVIDENCE	NO-GO CONDITION
G1 Evidence	**Quality**	Source, test conditions and reproducibility	No traceable evidence
G2 Integration	**R&D**	Interface, process window and failure analysis	Cannot meet system conditions
G3 Commercial	**Business**	Capacity, total cost, contract and alternatives	Economics or supply cannot be supported
G4 Lifecycle	**Operations**	Monitoring, maintenance, change notice and exit	No accountable operating plan

ANALYZED ARTICLES | ITEMS 01-12

Every title and URL is displayed in full. URLs wrap without shortening and remain clickable. A verified-reference label means the translated HTML did not retain its original source URL.

ID	FULL ARTICLE TITLE	FULL SOURCE / VERIFIED REFERENCE URL - CLICKABLE
A01	Nano-silver Sintering: Reliability on Cyanate Ester Composites	https://doi.org/10.21203/rs.3.rs-11259596/v1
A02	Boron Nitride Composites: Tuning Heat Flow via MSLA 3D Printing	https://bioengineer.org/3d-printed-boron-nitride-composites-tune-heat-flow-through-platelet-alignment/
A03	Plasma Surface Activation: Argon vs Nitrogen for Plastic Bonding	https://bioengineer.org/argon-and-nitrogen-plasma-boost-plastic-adhesion-but-lowest-contact-angle-is-not-always-best/
A04	Epoxy Degradation Analysis: PCA-Based Spectral Mapping of 3 Curing Agents	https://bioengineer.org/research-report-unsupervised-learning-based-analysis-of-degradation-behavior-in-filler-containing-amine-cured-epoxy-formulations/
A05	Henkel: AI Chip Adhesive Production and 2027 R&D Roadmap	https://www.koreaherald.com/article/10915087
A06	Loctite AA-series: Henkel's EU-MDR compliant light-cure adhesives	https://news.europawire.eu/henkel-launches-five-loctite-light-cure-adhesives-for-eu-mdr-focused-medical-device-assembly/eu-press-release/2026/10/26/18/53/03/184491/
A08	Qnity Thermal Solutions: AI Data Center Cooling for DDR5 DIMMs	https://www.mychesco.com/a/news/regional/qnity-expands-ai-data-center-cooling-portfolio/
A09	Tokuyama: Aluminum Nitride Heat Dissipation Material Timeline	https://www.yomiuri.co.jp/local/kyushu/20261030-GYS1T00005/
A10	SK Ecoplant Materials and Furukawa Electric: AI Material MOU	https://japan.cnet.com/release/31218996/
A11	Polysulfide Sealants: Cotton Fibers and Silane for 60-Min Fire Resistance	https://bioengineer.org/cotton-fibers-and-silane-coupling-restore-strength-in-fire-resistant-sealants/
A12	POSTECH Bio-Adhesive: Mussel-Inspired Underwater Bonding Mechanism	https://www.newsis.com/view/NISX20261028_0003844655

Adhesives_Sealants — Selected Articles

Date: 2026-10-31

Articles: 11

Table of Contents

#01 Nano-silver Sintering: Reliability on Cyanate Ester Composites

#02 Boron Nitride Composites: Tuning Heat Flow via MSLA 3D Printing

#03 Plasma Surface Activation: Argon vs Nitrogen for Plastic Bonding

#04 Epoxy Degradation Analysis: PCA-Based Spectral Mapping of 3 Curing Agents

#05 Henkel: AI Chip Adhesive Production and 2027 R&D Roadmap

#06 Loctite AA-series: Henkel's EU-MDR compliant light-cure adhesives

#08 Qnity Thermal Solutions: AI Data Center Cooling for DDR5 DIMMs

#09 Tokuyama: Aluminum Nitride Heat Dissipation Material Timeline

#10 SK Ecoplant Materials and Furukawa Electric: AI Material MOU

#11 Polysulfide Sealants: Cotton Fibers and Silane for 60-Min Fire Resistance

#12 POSTECH Bio-Adhesive: Mussel-Inspired Underwater Bonding Mechanism

#01 Nano-silver Sintering: Reliability on Cyanate Ester Composites

Published October 23, 2026　Research Square（プレプリント）

OVERVIEW

Low-temperature nano-silver sintering enables the direct bonding of power chips to fiber-reinforced cyanate ester composite substrates with a maximum shear strength of 11.5 MPa. The joints maintain 9.3 MPa strength after 600 h of high-temperature aging, identifying substrate thermal degradation as the primary reliability limit. This method provides a route for integrating power electronics with lightweight, thermally stable, and low-dielectric polymer composites.

IN DEPTH

Key Findings

Direct nano-silver sintering on non-metallized cyanate ester composite substrates achieves a maximum shear strength of 11.5 MPa. Following 600 h of high-temperature aging, the shear strength remained at 9.3 MPa, which represents a decrease of approximately 19%.

Technical Details

The bonding process involves the coalescence of Ag particles on the composite surface to form a mechanically bonded heterogeneous interface. The study analyzed the impact of pressure on the porosity of the sintered Ag layer:

- Sintering at 15 MPa for 15 min resulted in a porosity of 10.1%.
- Increasing the pressure to 20 MPa decreased the porosity to 6.5%.

Analysis of failure modes revealed a progressive shift during the aging process. Initial failures occurred at the Ag/composite interface, but later shifted toward cracking and delamination within the composite substrate itself.

Background & Context

The integration of power chips with polymer composites is driven by the need for materials that are lightweight, thermally stable, and possess low-dielectric properties. Cyanate ester composite substrates serve as the base for this integration, and nano-silver sintering is utilized as a low-temperature bonding method to avoid damaging the polymer matrix.

Significance & Outlook

The results demonstrate that low-temperature nano-silver bonding is feasible for non-metallized cyanate ester composites. While the joints show high stability after 600 h of aging, the shift in failure mode indicates that the thermal degradation of the substrate, rather than the silver joint itself, is the principal limitation on long-term reliability.

Source: https://doi.org/10.21203/rs.3.rs-11259596/v1

Collected: October 31, 2026 | Automated Research System (AI)

#02 Boron Nitride Composites: Tuning Heat Flow via MSLA 3D Printing

Published October 27, 2026　Bioengineer.org（Journal of Materials Science の研究紹介）
USA

OVERVIEW

Researchers have demonstrated that masked stereolithography (MSLA) 3D printing can control the orientation of hexagonal boron nitride (h-BN) platelets to tune thermal conductivity. By adjusting platelet size and layer thickness, the team achieved high basal-plane alignment, overcoming the inherent anisotropy of the material.

IN DEPTH

Key Findings

The study establishes that the alignment of hexagonal boron nitride (h-BN) platelets in 3D-printed composites is primarily governed by the relationship between platelet size and layer thickness. The strongest basal-plane alignment occurs when using the largest platelets (BN45) combined with the thinnest layer thickness (10 micrometers). Conversely, smaller platelets (BN0.9) remain largely randomly oriented due to greater rotational freedom within the printing layers.

Technical Details

The research team dispersed three grades of h-BN microplatelets—with average lateral sizes of 0.9, 12, and 45 micrometers (BN0.9, BN12, and BN45)—into Anycubic Standard Resin+ at weight loadings of 5 to 20 percent. Printing was performed using an MSLA printer with a 405 nanometer light source and layer thicknesses ranging from 10 to 50 micrometers. Post-processing included isopropanol washing and curing under a 450-watt UV system.

- **Rheology:** All formulations showed shear-thinning. Viscosity increased with higher loadings and smaller platelets; the 20 percent BN0.9 formulation was too viscous for reliable measurement and was excluded.
- **Density:** Archimedes principle measurements showed density rose consistently with filler loading, tracking theoretical rule-of-mixtures values within approximately 2 percent.
- **Orientation Analysis:** X-ray diffraction (XRD) and optical microscopy confirmed that decreasing layer thickness from 50 to 10 micrometers increased the alignment function for BN45 composites at 15 percent loading.

Background & Context

Hexagonal boron nitride is prized for its high thermal conductivity along its basal planes and its electrical insulation. However, its anisotropic nature means that randomly oriented fillers in a composite waste much of the material's thermal potential. While extrusion methods rely on nozzle-induced shear, MSLA relies more heavily on geometric confinement to press platelets flat during the resin recoating process.

Significance & Outlook

By utilizing "control knobs" of platelet size and layer thickness, engineers can now precisely tune heat flow in 3D-printed insulating components. This method allows for the creation of composites with low porosity and high directional thermal performance without requiring high-shear extrusion.

Source: https://bioengineer.org/3d-printed-boron-nitride-composites-tune-heat-flow-through-platelet-alignment/

Collected: October 31, 2026 | Automated Research System (AI)

#03 Plasma Surface Activation: Argon vs Nitrogen for Plastic Bonding

Published October 29, 2026　Bioengineer.org（Discover Mechanical Engineering の研究紹介）

OVERVIEW

Nitrogen and argon atmospheric-pressure plasma significantly increase the lap-shear strength of engineering plastics, with nitrogen boosting PVC and PP adhesion by up to six-fold. However, research indicates that the lowest water contact angle does not always correlate with the strongest bond, suggesting that wettability alone is an insufficient predictor of adhesion.

IN DEPTH

Key Findings

Nitrogen plasma treatment provides the most dramatic increases in lap-shear strength for certain materials. When using a two-component epoxy, nitrogen plasma increased the bond strength of PVC from 2.1 ± 0.3 MPa to 12.8 ± 2.3 MPa and PP from 0.5 ± 0.1 MPa to 11.6 ± 0.7 MPa, resulting in substrate failure in both cases. While nitrogen plasma achieved lower water contact angles than argon, the study found that the lowest contact angle did not reliably predict the strongest joint. For example, argon plasma yielded higher bond strengths than nitrogen for PP using Soudal Fix All Flexi (0.8 MPa vs 0.3 ± 0.05 MPa) and for PET using Loctite 4860 (2.4 ± 0.5 MPa vs 2.0 ± 0.1 MPa).

Technical Details

The study tested five plastics: polypropylene (PP), high-impact polystyrene (HIPS), poly(vinyl chloride) (PVC), polycarbonate (PC), and polyethylene terephthalate (PET). Treatments were applied using a FARI PM-G13A atmospheric rotating cold plasma head at 529 ± 1 W with gases at 3.5 bar. Head speeds ranged from 100 to 2000 mm/min, with a nozzle-to-surface distance of 5 mm. Nitrogen plasma caused visible surface degradation, such as burning, at speeds below 500 mm/min for PP and 250 mm/min for PVC and HIPS. Argon plasma produced higher contact angles than nitrogen but caused no visible surface damage across the investigated range.

Background and Context

Engineering thermoplastics are often difficult to bond due to chemically inert, low-energy surfaces. Untreated PP is particularly challenging, with a surface free energy of 29–31 mJ/m^2 and a water contact angle of 95–105°. The research compared argon and nitrogen plasma to determine how different activation mechanisms—ion bombardment and etching for argon versus chemical functionalization for nitrogen—affect real-world lap-shear strength according to ISO 4587 standards.

Significance and Outlook

The results demonstrate that while plasma treatment is essential for structural adhesive applications on low-energy plastics, the choice of gas depends on the specific polymer and adhesive. The discrepancy between wettability and bond strength suggests that complex plasma mechanisms, which a single water contact angle cannot disentangle, dictate final adhesion quality.

Source: https://bioengineer.org/argon-and-nitrogen-plasma-boost-plastic-adhesion-but-lowest-contact-angle-is-not-always-best/

Collected: October 31, 2026 | Automated Research System (AI)

#04 Epoxy Degradation Analysis: PCA-Based Spectral Mapping of 3 Curing Agents

Published October 28, 2026　Bioengineer.org（Results in Chemistry の研究紹介）　USA

OVERVIEW

Researchers utilized principal component analysis (PCA) to link the complex spectral fingerprints of degrading filler-containing epoxy adhesives to the loss of mechanical strength. The study reveals that degradation behavior varies significantly based on the curing agent used, with some systems showing non-monotonic strength changes.

IN DEPTH

Key Findings

The study demonstrates that unsupervised machine learning via PCA can systematically organize spectral data from degrading epoxy adhesives to identify dominant degradation themes. The analysis identified three primary spectral components: moisture-related variations (3000 to 3600 per centimeter), oxidation-associated processes (near 1700 and 1100 per centimeter), and filler-phase features related to calcium carbonate (near 700, 900, and 1400 per centimeter). Notably, the AMAM system exhibited a non-monotonic tensile strength profile, where strength initially dropped, partially recovered, and then fell again.

Technical Details

The researchers tested three curing agents mixed into a common base resin from Cemedine Co., Ltd. containing epoxy resin, CTBN-modified epoxy, silica, calcium carbonate, and calcium oxide:

- TETA (aliphatic polyamine): Cured at 100 °C for one hour.
- MDA (aromatic diamine): Cured at 160 °C for one hour.
- AMAM (commercial amidoamine): Cured at 100 °C for 30 minutes.

Accelerated aging was conducted via water immersion at 63 °C and 87 °C, and humid air exposure at 120 °C (100 percent relative humidity). The 120 °C tests were terminated after one week due to rapid degradation. Data was collected using a handheld FTIR spectrometer with the attenuated total reflection method on 0.3-millimeter-thick specimens.

Background & Context

To ensure raw variations were captured, spectra were left unprocessed except for common offset adjustments. PCA was applied with mean centering but no variance scaling, with the first three components capturing approximately 90 percent of the variance. Bootstrap resampling with 100 iterations confirmed the robustness of loading patterns, with Pearson correlation coefficients between 0.923 and 0.999.

Significance & Outlook

The method's sensitivity allowed the detection of anomalies, such as 168-hour observations in the AMAM system that deviated from temporal trajectories. The findings suggest that while initial strength loss is consistent with plasticization, later stages of degradation—particularly in the AMAM system—may involve network relaxation or filler-interfacial changes.

Source: https://bioengineer.org/research-report-unsupervised-learning-based-analysis-of-degradation-behavior-in-filler-containing-amine-cured-epoxy-formulations/

Collected: October 31, 2026 | Automated Research System (AI)

#05 Henkel: AI Chip Adhesive Production and 2027 R&D Roadmap

Published October 26, 2026 The Korea Herald South Korea

OVERVIEW

Henkel is leveraging its Songdo, South Korea facility to produce advanced semiconductor adhesives required for AI chip packaging. The company plans to expand its research capabilities with a new technical center in March 2027 to address thermal management and integration challenges.

IN DEPTH

Key Findings

Henkel has established a strategic semiconductor materials hub in Songdo, Incheon, to meet the rising demand for advanced packaging driven by AI. The 10,144-square-meter facility, completed in 2022 with an investment of approximately 35 million euro ($39.2 million), is the company's only Korean plant dedicated to semiconductor adhesives and represents its largest single investment in the country, excluding acquisitions.

Technical Details

The Songdo plant has an annual production capacity of up to 250 metric tons of semiconductor adhesives. The manufacturing process consists of seven stages: raw material inspection and weighing, mixing, milling additives, finished product testing, and filling into piston-operated syringes. To ensure consistency, the facility utilizes Class 10,000 cleanrooms and statistical process controls to monitor production data.

Henkel's broader portfolio includes over 500 adhesive solutions, specifically:

- Die-attach materials for bonding chips to surfaces.
- Underfills for reinforcing connections beneath chips.
- Encapsulants for component protection.
- The Loctite Ablestik CDF900 series of thermally conductive die-attach films for AI and high-performance computing.

Technical requirements are shifting toward adhesives that flow more readily and form thinner bonding layers to accommodate shrinking components and tighter spaces within packages.

Background & Context

The location in Songdo provides proximity to major memory manufacturers Samsung Electronics and SK hynix. Additionally, the site's proximity to Incheon International Airport allows for efficient air transport to overseas customers via competitive cargo rates. Henkel's Adhesive Technologies division is a primary business driver, generating 10.7 billion euros in sales last year.

Significance & Outlook

To address increasingly difficult thermal management and mechanical stress in complex AI packaging, Henkel plans to open a new technical center in Seoul's Gasan Digital Complex in March 2027. This center will expand existing R&D operations and work in tandem with the Songdo production site to develop materials that meet the demanding specifications of next-generation AI and high-performance computing processors.

Source: https://www.koreaherald.com/article/10915087

Collected: October 31, 2026 | Automated Research System (AI)

#06 Loctite AA-series: Henkel's EU-MDR compliant light-cure adhesives

Published October 26, 2026　Europa Wire（Henkel プレスリリース）　Germany

OVERVIEW

Henkel has launched five Loctite light-cure adhesives (AA 3914, AA 3915, AA 3917, AA 3937, and AA 3964) designed for medical device assembly. These formulations contain less than 0.1% by weight of CMR, ED, and TPO-related content to align with EU MDR 2017/745 Section 10.4. This release enables medical device manufacturers to maintain high-performance bonding while meeting evolving European regulatory requirements.

IN DEPTH

Key Findings

Henkel Adhesive Technologies has introduced five next-generation Loctite light-cure adhesives: Loctite AA 3914, AA 3915, AA 3917, AA 3937, and AA 3964. These products are specifically formulated to address the regulatory thresholds defined in the Medical Device Regulation (EU MDR 2017/745), specifically Section 10.4.

Technical Details

The new AA-series adhesives are engineered with the following technical specifications and improvements:

- **Chemical Composition:** Formulations contain less than 0.1% by weight of carcinogenic, mutagenic or toxic for reproduction (CMR) substances, endocrine disruptors (ED), and Trimethylbenzoyl Diphenylphosphine Oxide (TPO).
- **Testing Protocols:** The products were tested according to Henkel protocols based on ISO 10993.
- **Visual Inspection:** The grades feature enhanced fluorescence stability both before and after curing to facilitate in-line visual inspection.
- **Durability:** The adhesives demonstrate improved strength retention in accelerated aging tests, supporting long-term device performance and validation.

Background and Context

The development of these adhesives responds to the EU MDR 2017/745, which places increased emphasis on the restriction of CMR substances and endocrine disruptors. This regulatory environment has forced medical device manufacturers to reassess existing material choices to ensure future compliance. Henkel's approach focuses on providing validated materials that reduce risk during the product development and manufacturing process.

Significance and Outlook

The launch allows manufacturers to navigate complex regulatory shifts without sacrificing manufacturing efficiency or bonding reliability. Henkel will demonstrate the portfolio at two upcoming industry events: MD&M Midwest in Minneapolis on 28–29 October 2026, and COMPAMED in Düsseldorf on 16–19 November 2026. While the products are designed for these regulatory thresholds, Henkel advises customers to conduct their own suitability testing for specific applications.

Source: https://news.europawire.eu/henkel-launches-five-loctite-light-cure-adhesives-for-eu-mdr-focused-medical-device-assembly/eu-press-release/2026/10/26/18/53/03/184491/

Collected: October 31, 2026 | Automated Research System (AI)

#08 Qnity Thermal Solutions: AI Data Center Cooling for DDR5 DIMMs

Published October 25, 2026 MyChesCo USA

OVERVIEW

Qnity Electronics Inc. has expanded its semiconductor materials portfolio with two new thermal management products targeting high-density AI data centers. These solutions address the heat loads generated by modern server platforms that can accommodate up to 48 DDR5 memory modules.

IN DEPTH

Key Findings

Qnity Electronics Inc. (NYSE: Q) has introduced Graphite-over-Foam (GOF) and Thermal Interface Material (TIM) solutions specifically engineered for high-density memory modules. These products are designed to mitigate rising heat loads in artificial intelligence (AI) data centers and high-performance computing systems, where dense server memory configurations increase cooling demands.

Technical Details

The new thermal management materials are optimized for Double Data Rate 5 Dual In-line Memory Modules (DDR5 DIMMs). According to Qnity, modern server platforms may utilize as many as 48 DDR5 memory modules in tightly packed configurations. The GOF and TIM solutions are engineered to:

- Improve heat transfer across components.
- Accommodate variations in manufacturing tolerances and component dimensions.
- Address assembly requirements and serviceability within compact server configurations.
- Ensure more consistent thermal performance and long-term reliability.

These materials were developed by extending Qnity's existing Laird thermal interface and gap-filling technologies into high-density server memory applications.

Background & Context

The development of these products is driven by the increasing memory bandwidth, capacity, and speed required by AI workloads. As power consumption and memory capacity rise, thermal management becomes a critical factor in sustaining system performance and reliability. Chuck Xu, president of Qnity’s Interconnect Solutions business, noted that keeping memory modules cool is essential for maintaining these performance standards.

Significance & Outlook

By expanding its portfolio, Qnity is positioned to supply thermal management materials to manufacturers of AI infrastructure. The company's focus on simplifying assembly and improving maintenance access addresses the logistical challenges of managing heat in densely arranged memory components. This expansion targets the broader trend of increasing computing demands and the subsequent need for enhanced heat dissipation throughout next-generation server systems.

Source: https://www.mychesco.com/a/news/regional/qnity-expands-ai-data-center-cooling-portfolio/

Collected: October 31, 2026 | Automated Research System (AI)

#09 Tokuyama: Aluminum Nitride Heat Dissipation Material Timeline

Published October 30, 2026 読売新聞 Japan

OVERVIEW

Tokuyama is expanding its production capacity for semiconductor heat dissipation materials by 50% with a new facility in Yanai City. The investment targets the production of aluminum nitride granules to meet rising demand for high-performance semiconductors, with operations scheduled to begin in February 2028.

IN DEPTH

Key Findings

Tokuyama has announced the construction of a new production facility for semiconductor-grade heat dissipation materials at its site in Yanai City, Yamaguchi Prefecture. The company intends to increase its total production capacity by 50% across its various sites to address the growing demand driven by the increasing performance of semiconductors. The facility is targeted to begin commercial operations in February 2028.

Technical Details

The new investment, valued at several billion yen, focuses specifically on the production of aluminum nitride granules. These granules will be produced at the "Advanced Technology Commercialization Center" in Yanai City. The resulting materials are designed to ensure the stable operation of semiconductor manufacturing equipment by providing efficient heat dissipation.

Background & Context

Tokuyama currently holds the top global market share for aluminum nitride powder, which serves as the raw material for the granules. To create a fully integrated production system, the company previously announced in September the installation of new aluminum nitride powder production equipment at the same Advanced Technology Commercialization Center. This latest move to add granule production completes the internal supply chain from powder to granules.

Financial Performance

Concurrent with the facility announcement, Tokuyama revised its consolidated earnings forecast for the fiscal year ending March 2027. The company increased its projected final profit by 20.5 billion yen compared to the July estimate, bringing the total to 46.5 billion yen. This upward revision is attributed to the gain from the sale of its domestic cement sales business to Taiheiyo Cement. The projected net sales remain unchanged at 392 billion yen.

Source: https://www.yomiuri.co.jp/local/kyushu/20261030-GYS1T00005/

Collected: October 31, 2026 | Automated Research System (AI)

#10 SK Ecoplant Materials and Furukawa Electric: AI Material MOU

Published October 28, 2026　CNET Japan（古河電気工業リリース）　Japan

OVERVIEW

SK Ecoplant Materials and Furukawa Electric have signed a Memorandum of Understanding (MOU) to expand high-performance materials for semiconductor and AI data center markets. The partnership focuses on integrating technical capabilities to develop materials for packaging, heat dissipation, insulation, and communication infrastructure.

IN DEPTH

Key Findings

SK Ecoplant Materials and Furukawa Electric have entered into a strategic partnership via a Memorandum of Understanding (MOU) to target the growing demand for high-performance materials in the AI data center and semiconductor sectors. The collaboration aims to create new business opportunities in the South Korean market by aligning the companies' product portfolios with specific customer needs.

Technical Details

The partnership focuses on several critical technical domains necessitated by the advancement of AI semiconductors and the expansion of data centers, including:

- Packaging materials
- Heat dissipation and insulation solutions
- Communication infrastructure materials

Under the terms of the MOU, Furukawa Electric will lead the development of new products for semiconductors and data centers, while SK Ecoplant Materials will be responsible for evaluating these products to facilitate their application and expansion within the Korean market. To maintain technical alignment, the two companies are establishing a working group for regular technical exchanges and business consultations.

Background & Context

SK Ecoplant Materials operates a group of four subsidiaries specializing in semiconductor materials, including photoresists, precursors, etching gases, and packaging materials, as well as blue dopant materials for OLEDs. Furukawa Electric leverages four core technologies—metal, polymer, photonics, and high-frequency—across business areas such as optical solutions, information components, energy infrastructure, automotive electronic systems, and metal solutions.

Significance & Outlook

The collaboration addresses the increasing complexity of material requirements in the semiconductor industry, which Furukawa Electric notes has become difficult for single material manufacturers to resolve independently. By combining their respective technical bases, the companies intend to move beyond simple supply chains to provide a collaborative model that supports technical innovation and product competitiveness for their end customers.

Source: https://japan.cnet.com/release/31218996/

Collected: October 31, 2026 | Automated Research System (AI)

#11 Polysulfide Sealants: Cotton Fibers and Silane for 60-Min Fire Resistance

Published October 28, 2026 BIOENGINEER.ORG USA

OVERVIEW

A new formulation strategy using surface-treated cotton fibers and silane coupling agents allows two-component polysulfide sealants to maintain mechanical strength while passing a 60-minute fire resistance test. The optimized formulation increased tensile strength by 23.3% over unfilled baselines, resolving the traditional trade-off between flame retardancy and structural integrity.

IN DEPTH

Key Findings

The complete formulation (Group 4), incorporating surface-flame-retardant-treated cotton fiber powder, achieved an average tensile strength of 37 kgf per square centimeter (3.63 megapascals), a 23.3% improvement over the control group's 30 kgf per square centimeter (2.94 megapascals). Regarding adhesion, Group 2 (using an amino-silane coupling agent) showed the highest average strength at 31 kgf per square centimeter (3.04 megapascals), a 24.0% increase over the control. Group 4 also showed a 20.87% improvement in adhesion strength, reaching 30 kgf per square centimeter.

Technical Details

Researchers tested five groups based on 100 parts by weight of base polysulfide polymer with a 10:1 matrix-to-curing agent ratio. The experimental groups added components in stages:

- Group 1: Magnesium hydroxide, aluminum hydroxide, and expanded graphite.
- Group 2: Added an amino-silane-based adhesion promoter.
- Group 3: Added zinc stannate with inorganic nanofibers.
- Group 4: Added high aspect ratio surface-flame-retardant-treated cotton fiber powder.

Fire performance was validated via KS F 2845:2013 vertical furnace tests using triple-pane tempered glass assemblies with a 7-millimeter sealant layer. While the control group failed quickly due to decomposition and detachment, Groups 1 through 4 all passed the 60-minute requirement without flame penetration or structural collapse.

Background & Context

Traditional fire-resistant sealants use high loads of inorganic flame retardants, which typically disrupt the polymer matrix's cross-linking network and weaken tensile strength and glass adhesion. This study addresses this by using a layered defense: magnesium and aluminum hydroxides provide endothermic cooling, expanded graphite forms a porous char barrier, and zinc stannate stabilizes this char to resist convective airflow.

Significance & Outlook

The integration of cotton fibers with an aspect ratio exceeding 50 creates three-dimensional stress transfer pathways that bridge disconnected polymer segments. This physical reinforcement, combined with chemical siloxane cross-links, allows the sealant to carry structural loads at room temperature while maintaining the integrity of fire compartments during high-temperature exposure.

Source: https://bioengineer.org/cotton-fibers-and-silane-coupling-restore-strength-in-fire-resistant-sealants/

Collected: October 31, 2026 | Automated Research System (AI)

#12 POSTECH Bio-Adhesive: Mussel-Inspired Underwater Bonding Mechanism

Published October 28, 2026 NEWSIS South Korea

OVERVIEW

Researchers from POSTECH and Kangwon National University have developed a next-generation bio-adhesive by mimicking the charge arrangement of mussel adhesive proteins. The team successfully identified the molecular-level mechanisms of phase separation fluidity and nano-interface adhesion that enable strong bonding in underwater environments.

IN DEPTH

Key Findings

A joint research team led by Professor Cha Hyung-jun of POSTECH (Department of Chemical Engineering and Graduate School of Convergence) and Professor Jung Young-mi of Kangwon National University (Department of Chemistry) has designed a new adhesive protein. The research identifies the molecular principles that allow this protein to maintain strong adhesion in water, specifically focusing on the charge arrangement of mussel adhesive proteins.

Technical Details

The development centers on the following technical mechanisms:

- **Charge Patterning:** The team utilized zwitterionic charge patterning to control the phase change of the underwater adhesive protein.
- **Adhesion Mechanism:** The research simultaneously clarified the mechanisms of phase separation fluidity and nano-interface adhesion.
- **Molecular Design:** By mimicking the specific charge arrangement found in natural mussel proteins, the synthetic protein achieves enhanced surface adhesion in aqueous environments.

Background & Context

The project was a collaborative effort involving multiple researchers. From POSTECH, the team included Professor Cha Hyung-jun, Dr. Yoon Tae-hee, Professors Lee Sang-min and Kim Young-ki, and Master's student Shin Ji-soo. From Kangwon National University, the team included Professor Jung Young-mi and Dr. Park Yeon-ju.

Significance & Outlook

The ability to regulate phase changes and strengthen surface adhesion at the nano-interface opens new possibilities for bio-medical applications. The researchers highlight that this technology is particularly applicable for the development of hemostatic agents (blood-stopping agents) and the adhesion of biological tissues, where maintaining bond strength in wet environments is critical.

Source: https://www.newsis.com/view/NISX20261028_0003844655

Collected: October 31, 2026 | Automated Research System (AI)