SOLUTIONS INNOVATION STAGE

Geopolitics & Supply Chain:

Strategic Materials for Thermal Management

How shifting geopolitics are disrupting access to h-BN, alumina, and graphene—
and what TIM ecosystem players must do about it.

SPEAKERS

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09:30 – 09:50 AM

TODAY'S AGENDA

The TIM Risk Story in 15 Minutes

01

Why TIM Supply Chains Are Exposed

Demand surge meets geopolitical fracture

02

Three Materials, Three Fault Lines

h-BN · Alumina · Graphene

03

The Three-Legged Stool

Diversification · Substitution · Filler Recovery

04

Strategic Frameworks & Call to Action

Scenario planning, multi-region sourcing, next steps

RISK MITIGATION PHILOSOPHY

Diversify. Anticipate. Adapt.

Proactive, multi-layered defense across every link in the TIM value chain for manufactures operations

Supply Chain

- Multi-region sourcing for h-BN, alumina & graphene precursors
- Safety stock & dual-qualification programs at every tier
- Continuous supplier audits (ISO 9001 / IATF 16949)

Regulatory & Compliance

- PFAS phase-out readiness (REACH 2.0, EU restriction by 2027)
- RoHS / SVHC substance tracking & disclosure protocols
- Proactive reformulation pipeline for restricted chemistries

Geopolitical & Trade

- Tariff exposure mapping (Section 301 / 232 duties up to 35%)
- China export-control scenario planning for graphite & boron
- Nearshoring & friendshoring to reduce single-country dependency

Operational

- Manufacturing redundancy across multiple production sites
- Quality consistency & full batch traceability protocols
- Workforce development & critical-skills retention programs

Competitive & Technology

- R&D investment in next-gen TIM formulations & composites
- IP protection & patent portfolio management
- Continuous market intelligence on rival material advances

The Guiding Principle **No single-source dependency. No unmonitored regulation. No unhedged trade exposure. Every TIM manufacturer must build resilience across all five pillars simultaneously—a failure in any one domain cascades across the entire thermal materials value chain.**

01

Why TIM Supply Chains Are Exposed

$6.2B

TIM market by 2030

~12% CAGR driven by AI, EVs & 5G

85%+

AI chip heat densities rising

Next-gen GPUs demand 5–20× more thermal management

3×

Supply risk amplification

Each material has ≥1 critical geopolitical chokepoint

The Perfect Storm

The TIM industry sits at the intersection of three megatrends: exploding AI/EV demand, intensifying US-China tech rivalry, and resource nationalism from key mineral-producing nations. The materials that make TIMs work—h-BN, alumina, and graphene—all have critical supply vulnerabilities. This is no longer a theoretical risk; it is operational reality in 2025.

02

Three Materials, Three Fault Lines

h-BN

Hexagonal Boron Nitride

THERMAL CONDUCTIVITY

~300 W/m·K (in-plane)

SUPPLY RISK

Boron precursor concentration: 75% from just 3 countries

Price volatility >25% annually

HIGH RISK

Al_2O_3

Alumina

THERMAL CONDUCTIVITY

~30–35 W/m·K

SUPPLY RISK

Bauxite reserves: Guinea/Brazil/ Australia control 75%

Prices surged >70% YoY in 2024

MODERATE-HIGH

Graphene

Graphene / Graphite

THERMAL CONDUCTIVITY

~1,500–3,000 W/m·K (in-plane)

SUPPLY RISK

China controls ~75% of natural graphite; export controls active

30–90 day permit delays, Q4'25

CRITICAL RISK

MATERIAL DEEP DIVE · h-BN

Hexagonal Boron Nitride: "White Graphene" Under Pressure

Boron Precursor Concentration

75% of boron raw material production concentrated in just 3 countries — creating acute single-point-of-failure risk.

Price Volatility

Export restrictions and geopolitical tensions drive >25% annual price swings, complicating long-term contracts.

Long Lead Times

Specialized synthesis reactors have lead times exceeding 18 months — meaning supply cannot flex quickly.

China's Growing Role

China holds ~27% of global h-BN market share and is expanding lower-cost standard-grade (SG) production, creating dependency risk.

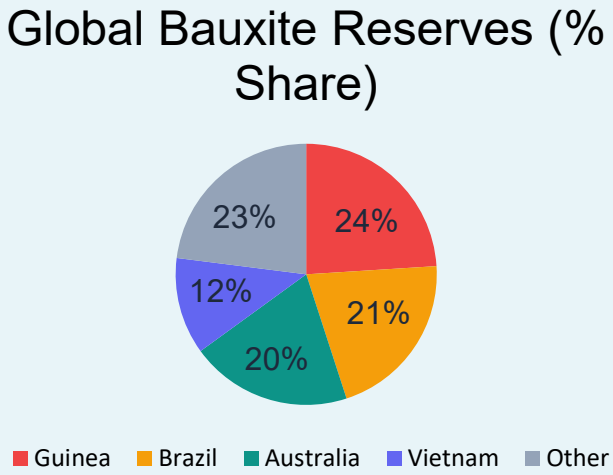
MARKET SNAPSHOT

2024 Market Value	**$296M**
2032 Projected	**$440M**
CAGR	**6.7%**
Top 4 firms' share	**>40%**
SG grade market share	**>70%**
2025 tariff impact	**High**

Key players: Momentive, Saint-Gobain, 3M, H.C.Starck

MATERIAL DEEP DIVE · ALUMINA

Alumina: The Workhorse With a Hidden Fragility



70%+ Price Spike

Australia's 2024 production disruptions (Rio Tinto, South32) caused alumina prices to surge >70% year-over-year.

Asia-Pacific Dominates

Asia-Pacific commands >65% global market share. China alone represents $29B. New capacity from Indonesia adds further concentration.

2025 Tariff Shock

New US tariffs introduced complexity into spherical alumina supply chains, elevating landed costs and driving strategic stockpiling.

Spherical Grade Gap

High-purity spherical alumina for advanced TIMs has limited Western production — qualifying alternatives takes 6–9 months.

MATERIAL DEEP DIVE · GRAPHENE / GRAPHITE

Graphene: Exceptional Performance, Exceptional Concentration Risk

ESCALATION TIMELINE

Oct 2023 — China imposes graphite export licensing requirements — first shot in critical minerals trade war

Oct 2025 — MOFCOM expands controls to artificial graphite anode materials; export licence now required

Nov 2025 — China temporarily suspends enhanced controls to US through Nov 2026 — analysts call it a 'geopolitical bear trap'

Q4 2025 — Spot prices spike 25–35%; permit processing extends to 30–90 days

Nov 2026 — ⚠ Suspension expires — structural risk resurfaces unless Western alternatives are qualified

CHINA'S GRAPHITE GRIP

~75%
of natural graphite production globally

~80%
of spherical graphite processing capacity

8–12 wks
typical Western graphite inventory buffer

>18 mo
to permit & build a new Western mine

03

The Three-Legged Stool

A resilient TIM supply strategy requires all three legs — remove one and the whole structure collapses.

LEG 1

Supply Diversification

→ Multi-region sourcing models (US, EU, Japan, Australia)

→ Qualify ≥2 suppliers per critical filler

→ Long-term supply agreements with price corridors

→ 'Friendshoring' toward geopolitically stable jurisdictions

→ Strategic inventory buffers beyond 8–12 week norms

LEG 2

Material Substitution

→ Qualify alternative fillers: AlN, ZnO, MgO as h-BN bridge

→ Ternary filler systems (h-BN + Al_2O_3 + MWCNT) for resilience

→ Evaluate synthetic graphene vs. natural graphite sourcing

→ Invest in drop-in substitution qualification programs

→ Monitor NIST AI/materials risk frameworks for guidance

LEG 3

Filler Recovery

→ Design TIM formulations for reworkability and filler reclaim

→ Recyclable matrices, like silicone, reduce virgin demand

→ End-of-life TIM recovery programs from EV/data center teardowns

→ Closed-loop supply chains cut exposure to spot market volatility

→ Circular model as strategic hedge, not just ESG initiative

LEG 3 — DEEP DIVE

Filler Recovery: From Cost Center to Strategic Hedge

The Economic Case

h-BN filler costs significantly more than the polymer matrix — making it the primary cost driver in advanced TIM formulations. Graphene is even more expensive. Recovery of these fillers from end-of-life products and manufacturing scrap is economically compelling AND decouples a portion of supply demand from geopolitically exposed primary production.

Reversable Binder Design

Engineer TIM recovery processes (silicone based) that allow disassembly and filler reclaim without degradation of the filler particles.

End-of-Life Recovery Programs

Partner with EV OEMs and data center operators to recover TIMs at service/teardown. Battery-pack disassembly and GPU replacements are natural collection points.

In-Process Scrap Recovery

Implement closed-loop manufacturing processes to capture filler-rich trim/scrap. This is particularly suitable for pad and film formats where edge waste is significant.

IP is retained In-House.

BGSU FURGAL LAB — REAL RESULTS

Silicone TIM Filler Recovery



METHOD

Fluoride depolymerization in ethyl acetate (1:5 ratio) dissolves silicone matrix within hours — filler recovered intact by centrifugation, solvent distilled.

Ni-graphite + fumed silica

Magnetically separated post-recovery. FTIR confirms recovered silica retains hydrophobic surface treatment.

Graphite/silica blend

TGA: 87.7% graphite + 12.3% silica. Hydrophobic functionalization fully preserved — no re-treatment needed.

Patent: PCT/US22/14500 · Int'l filed July 2023

04

Strategic Frameworks & Call to Action

NOW (0–6 months)

✓ Audit all TIM formulations for single-source filler exposure

✓ Map Tier 2/3 suppliers — identify China-origin materials

✓ Begin qualification of ≥1 alternate supplier per critical filler

NEAR-TERM (6–18 months)

✓ Build strategic inventory buffers (target 6–9 months for h-BN, graphene)

✓ Launch recovered TIM formulation R&D program

✓ Engage EV/data center customers on filler recovery partnerships

LONG-TERM (18 months+)

✓ Establish multi-region supplier contracts with price corridors

✓ Deploy closed-loop filler recovery at scale

✓ Invest in/partner with Western graphite & boron mineral development

THE BOTTOM LINE

The TIM industry cannot afford a single-source strategy.

1

The risk is real and accelerating

h-BN, alumina, and graphene all face active geopolitical pressure — not theoretical future risk.

2

The three-legged stool is your framework

Diversification + substitution + filler recovery must be pursued simultaneously — not sequentially.

3

Filler recovery is undervalued

Circular economy approaches reduce virgin material demand, buffer price volatility, and build long-term resilience.

Q & A — Thank You

Joseph Furgal · Bowling Green State University | Charles Olsen · CTO, Sciencey Products Inc.