Supply Chain Resilience: Sustainability Strategy and Challenges for Next Generation Semiconductor Nodes' Ecosystem

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Agenda

- Introduction: Perspective
- Intel RISE 2030 Goals
- Reimagining Supply Chain: Resilience
- Supply Chain Challenges: Next Generation Thinking
- Need for “Smart” Industry Collaboration and Joint Responsibility

Disruptive Technologies for Advanced Nodes: Proactive, Predictive Yield And Quality Management are Must

- Nontraditional Scaling, 2D-3D mixed architectural changes
  - New "Material Challenges" being added
  - Increasing design innovation, integration challenges w/increased process steps, process sensitivity, complexity & fab infrastructure need
  - Shrinking feature size adds to increased susceptibility to defects

- Complex Chemistry, Equipment, Recipes and Processes: "Interactive" Compatibility Issues
  - More defects, new defect types/sources, increase defect sensitivity
  - Need unprecedented purity at process maturity: Materials & Systems

- Analytics and Metrology techniques of all types are challenged:
  - Pushing fundamental limits of physics & chemistry → Innovation R&D ROI is Challenged for HVM
  - Supplier Infrastructures still lacking "Cost Effective and Proactive" defect detection & *characterization*

- Challenge of HVM Drivers: Defectivity Vs. Cost Vs. Yield

- Challenges regarding Global Complexity: Economical and Geopolitical Disruptions, Environmental Sustainability

- Semiconductor Ecosystem needs to "Strategically Collaborate" and put "Unified" Effort to
  - Develop resilient and sustainable supply chain solutions across the GLOBE
  - Mitigate such disruptive challenges for next generation business need

Reimagining Supply Chain

Intel's global supply chain strategy is to drive a resilient, diverse, and responsible supply chain

We continue to collaborate extensively with supply chain-related organizations—including the Responsible Business Alliance (RBA) and its Mineral and Labor Initiatives, the Semiconductor Industry Association, and SEMI—to help set

Electronics industry-wide standards	Develop audit processes	Respect Human Rights	Address third-party anti-corruption issues	Responsible Mineral sourcing	Supplier Diversity and Inclusion	Sustainable Manufacturing and Chemistry

These engagements are an important part of the foundation of many of our programs in pursuit of our Global Supply Chain Strategy

Intel's RISE Goals

2030 Goal

Responsible

Employee Health, Safety, and Wellness. Ensure that more than 90% of our employees believe that Intel has a strong safety culture and that 50% participate in our global wellness program.

Supply Chain Human Rights. Scale our supplier responsibility programs to ensure respect for human rights across 100% of our tier 1 contracted suppliers and higher risk tier 2 suppliers.[1]

Inclusive

Workforce Inclusion.
- Double the number of women and underrepresented minorities in senior leadership roles.
- Exceed 40% representation of women in technical positions.
- Advance accessibility and increase the percentage of employees who self-identify as having a disability to 10% of our workforce.
- Ensure that inclusive leadership practices and accountability are embedded in our culture globally by creating and adopting an inclusive leader certification program.

Supplier Diversity. Increase global annual spending with diverse suppliers[2] by 100% to reach $2 billion in annual spending by 2030.

Sustainable

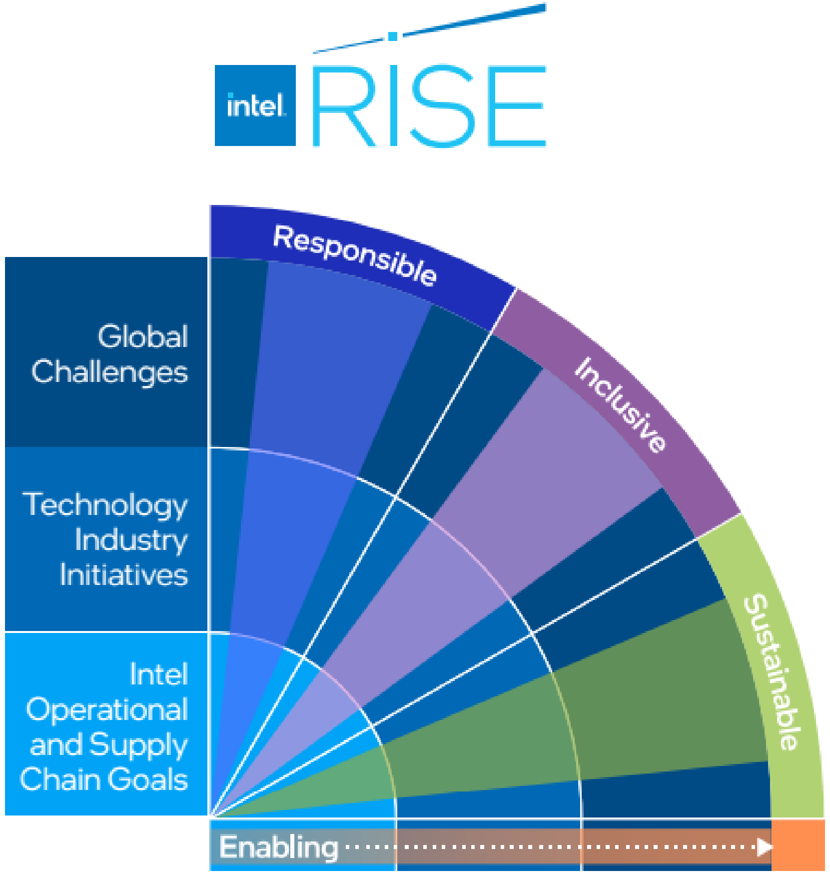
Climate and Energy.
- Achieve 100% renewable energy use across our global manufacturing operations.
- Conserve 4 billion kWh of energy.
- Drive a 10% reduction in our absolute Scope 1 and 2 carbon emissions as we grow, informed by climate science.
- Increase product energy efficiency 10x for Intel client and server microprocessors to reduce our Scope 3 emissions.

Net Zero Water. Achieve net positive water use by conserving 60 billion gallons of water and funding external water restoration projects.

Zero Waste[3]/Circular Economy. Achieve zero total waste to landfill and implement circular economy strategies for 60% of our manufacturing waste streams in partnership with our suppliers.

Enabling

Community Impact. Deliver 10 million volunteer hours to improve our local communities, including an increase in skills-based volunteerism.



“Modern” Supply Chain

Modern Supply chain needs to be

- ❖Collaborative
- ❖Resilient
- ❖More flexible

“Modern” Supply Chain: Big Data Transformation

Big Data Transformation, Modeling and Simulation Brings:

- Improved Collaboration with Ecosystem
- Increased E2E Supply Chain Visibility
- Improved Business Processes Via Predictability
- Proactive Vs Reactive Impacts
- Increased Sensitivity for Early Detection & Prevention
- Efficient and Improved Operations
- Cost Reduction

Intel Role Modeling

- **Supplier Program to Accelerate Responsibility and Commitment (SPARC) Program:**

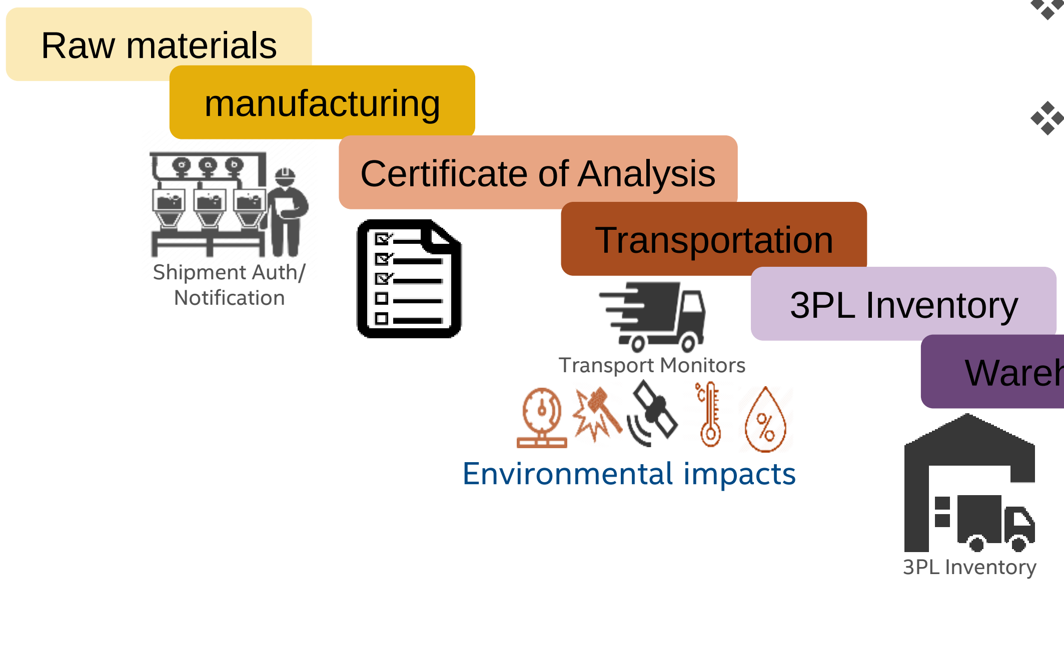
This collaborative and proactive initiative brings focus on corporate responsibility through rigorous annual commitments to compliance, transparency, and capability-building.

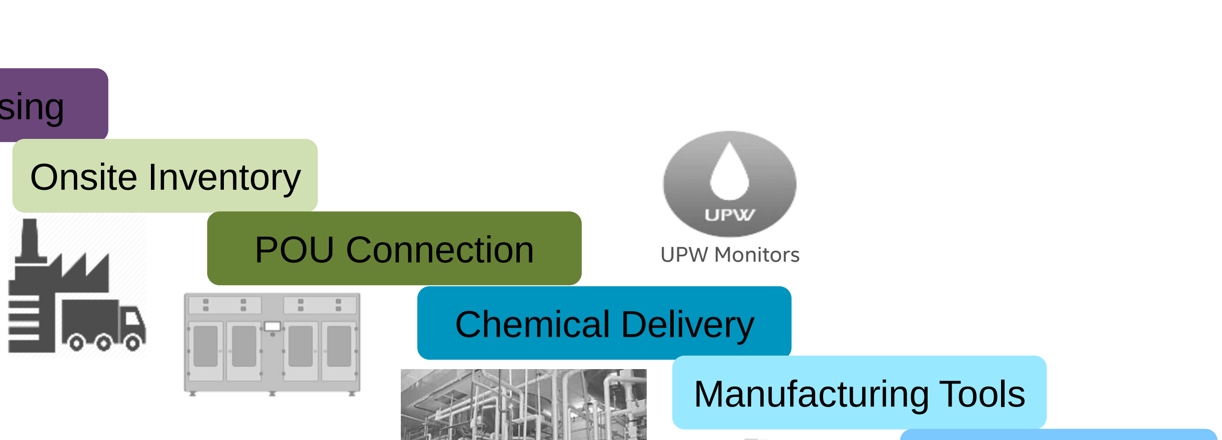
- **We decrease the greenhouse gas (GHG) emissions related to our transportation and logistics network:**
  - by optimizing packaging to reduce the quantity and weight of shipments,
  - by increasing local sourcing
  - Intel is at the forefront of standardizing transportation CO2 reporting within the industry through collaboration with organizations such as the Global Logistics Emissions Council.

- **Sustainable chemistry involves designing chemical products and processes in ways that minimize the use and creation of hazardous materials:**
  - Intel published a process with our suppliers to complete green chemistry screening and alternative assessments on high-volume manufacturing chemicals that met certain hazard criteria.
  - eliminate exposure to toxic chemicals in the supply chain through use of safer alternatives where feasible, and on developing tools to understand and further control chemical risks

Challenge: E2E Visibility in Supply Chain

Materials Journey





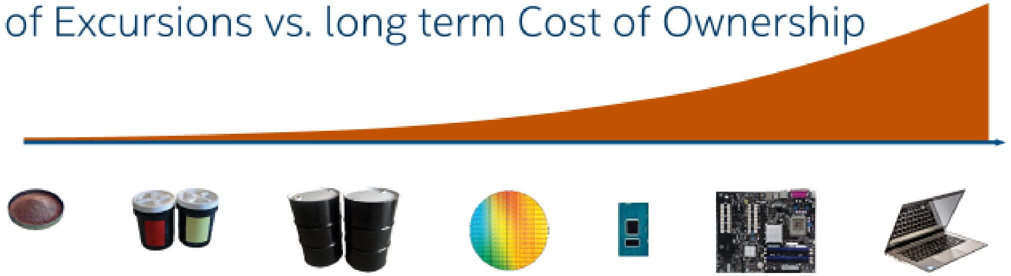
- Materials E2E lifecycle is critical to understand
- Materials prone to many interactive defects in life cycle
- We are blind to interactive interaction during chemical life cycle

- Packaging, Transportation, Warehousing, PCD/BCD facilities effects, along with Environmental (Temp, light, vibration, humidity, etc.) and Age of chemical play role in quality of final chemical

Wafer Environment is Redefined Encompassing the Whole of Supply Chain

- ❖ New "**Interactive and Untraced**" Defects: from complex chemical-component-process interactions
- ❖ More possible defects and **"Lower"** defect tolerance
- ❖ Nanoparticles becoming more **"Detectable**" with advanced SCANS at "End Users"
- ❖ Gap in "**Advanced Metrology"**: Cannot detect or stop "**Dissolved**" contamination, that ends up on wafer
- ❖ **"Purity"** is a relative term which now needs meeting beyond CofA requirement

Co$t of Excursions vs. long term Cost of Ownership



- Excursions are expensive for everyone
- Contaminated raw material impacts finished goods' quality
- Factory uses material for several weeks before detection
- Earlier Detection → Lowers Impact to Finished Goods

Small problems not prevented early increase exponentially in impact as value is added in the supply chain.

For End Users: One issue can have a very large financial impact

Process Yield: Cost vs Defectivity Control
Need to track lifetime of a chemical, gas, AMC, chemical and gas delivery system and tool parts

Early Detection, Proactive Contamination Control Via Collaboration saves $$ and Proves Cost Effective Return of Investment (ROI) for Entire Ecosystem

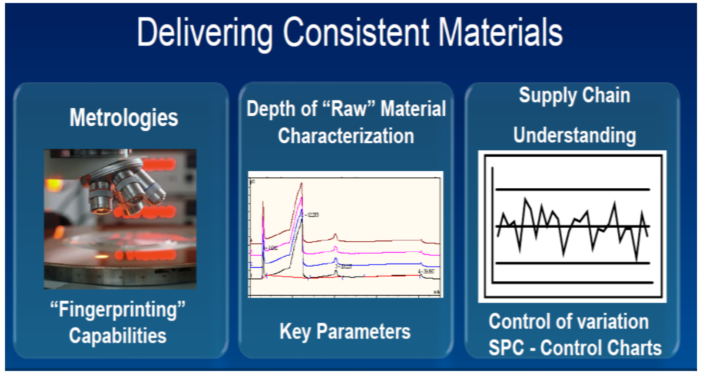
Next Generation Collaborative Thinking: Practical and Economical

- **Enhanced Quality Control: Think Smart** on **where to look** to prevent "Excursion": Nothing is inert: Look for weakest link, look beyond CofA
  - Behavior of Material Reactivity @High Volume Use (including environmental factors): to set up limits/key vs control parameters
  - Advanced characterization needed (ppq level)?: Meaningful and cost-effective solutions for entire supply chain?

- **Identify Critical Manufacturing Steps and Relevant Matrices at Suppliers' and at IDM** to "Measure, Monitor, Maintain and Control" **(**as enhanced possible)

- Proactive Detection, Identification and Elimination defect source across supply Line are major keys for HMV yield improvement and keeping cost/transistor down:
  - **Need P**ractical, economically viable **C**ollaborative Advanced Materials/Process Learning and right "**Methodology**" Development

- Process Control & Role of Critical Analytical Metrology in IC Industry is changing: Collaboration is Must
  - Nature of R&D and Pathfinding Technology development
  - Out of the Box thinking: Alternative from outside of IC industry?



Supply Chain Responsibility: Example

SILICON SOLUTIONS

Material:
a) Raw Material (Incoming Chemical)
b) Handling Materials (Tubing, Valve, Tanks, Pumps, etc.)
c) Filtration related Materials (Housing, Filters, etc.)
d) Transportation Related Materials (Containers, Drums, etc.)

Manufacturing:
a) Unit operations – are they optimized?
b) Do diluent streams need to be optimized? (Example: Water for bases, acids)

Methodology:
a) Understand how contamination forms – e.g., **WHAT**: Hydrocarbon is observed; **WHEN?.....**; **WHERE?.....**; **WHY?......**; **HOW**: is the HC formed? Can it be measured? Can it be Controlled?

Electronic Grade Chemical Manufacturing & Packaging

Metrology: Characterize
a) Incoming Chemical, Chemical post each unit operation, Final Chemical
b) Existing Filter & its Performance
c) Interaction between Handling, Transportation materials and Chemical (E.g., Extractables)

Modeling (and Simulation):
a) How should the filtration scheme be arranged (pore size, membrane, modification, etc.)
b) Mode of operation : Single Pass, Recirculation (if so, how many turns) etc.

ULTRAPURE MICRO

Slide Borrowed: Acknowledgement: Ashutosh Bhabhe, UPM June 2023

Call For Action: Advanced Analytical Measurement and Metrology Enabling Leading Edge Semiconductor Manufacturing

- **Work Together to Establish a National Center for Advanced Analytical Measurement & Metrology for Semiconductor Fabrication**
- The CHiPS and Science Act was enacted to be transformative for the domestic semiconductor industry and the CHIPS Act Funding presents a significant opportunity for collaboration of SEMI Ecosystem.
- The effective application and continued development of next generation metrology systems and techniques in the semiconductor industry is critical to enable the continued development of future semiconductor technologies for both advanced logic and memory devices.
- The establishment of a National Center for Semiconductor Metrology will benefit industry participants across the entire supply chain including semiconductor device producers, wafer fab equipment suppliers, key component suppliers, and chemical and materials suppliers. Such a center can leverage existing government (NIST) capabilities and networks and be the basis novel government-industry partnership models into the future.
- SEMI Foundation, NIST could be strategic partners to work together towards such endeavor: establishing such a center under the CHIPS Workforce Development Guide.
- An initial White Paper is published to NIST, SEMI and Other Industry Platform Partners for consideration: Need Active Participation, and Collaboration Across Ecosystem

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Additional contributors of thoughts: Mark Bohr, Bob McIntosh. A larger team is being built: Please Join the Effort

Use of SEMI_IRDS_SECC_SCIS Platforms: Global Collaboration and Learning with Industry Technology Community

- ❖ Evolution of Business Drivers, Market Trends & Research Breakthroughs Influence Next Cycle
- ❖ The Overall Roadmap Technology Characteristics (ORTC) and System Characteristics (ORSC: System Trends: Systems and Architectures, Application Benchmarking)
- ❖ Next Generation Semi Standard Modification, Addition and Development: Use Industry Research, Adopt and Update Roadmap
- ❖ Address shared Challenges & Disruptors through Collaboration
- ❖ Regulatory Efforts →

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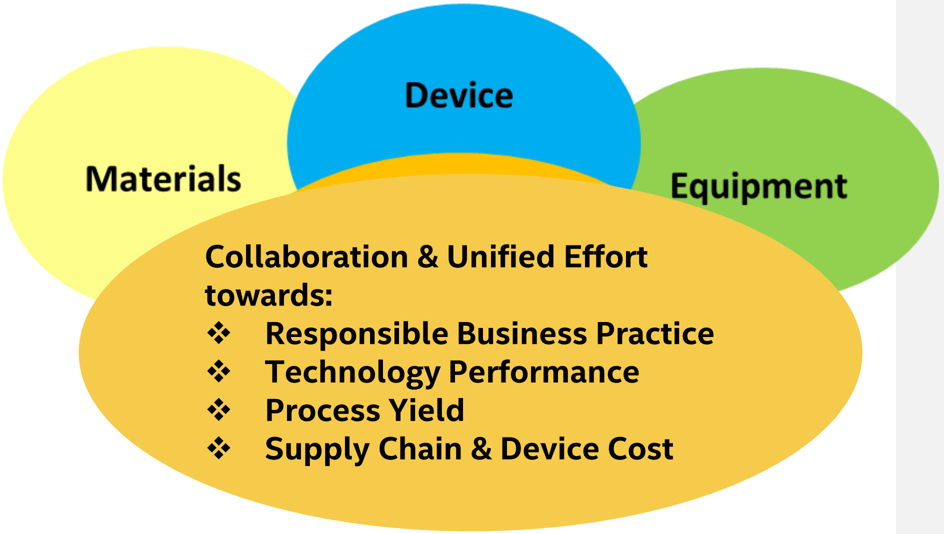
SEMI PFAS Regulatory Efforts

- The SEMI PFAS Working Group, composed of industry technologists and gov't affairs staff from SEMI member companies across the global semiconductor manufacturing supply chain, meets on a regular basis to share intelligence and develop strategies to earn exemptions and/or extensions from regulators to enable the industry to continue manufacturing using PFAS until effective alternatives are found.
- Current focus is on proposed legislation in the EU and USA (at both the EPA and state levels)
  - US EPA TSCA (Toxic Substances Control Act)
  - EU REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals)
  - Maine, Minnesota, New England Waste Management Officials' Association
- The Working Group is also developing a "PFAS Explainer" for the SEMI Web site
- SEMI is aligned with other groups to maximize the industry's influence: Semiconductor PFAS Consortium, SIA, ESIA
- To get involved, contact ehs@semi.org

Slide borrowed and content reference:
MTI AmeriTAC 141, June 2023, Bob McIntosh, SEMI IRDS

Semiconductor Ecosystem Resilience: Call for actions

- ❖ Future of SEMICONDUCTOR Manufacturing Success Depends on All Partners: MUST Work Together to establish:
- ❖ Safe, Healthy and responsible business practices across global manufacturing operations
- ❖ Environmentally sustainable solutions including chemical footprint and green-house gas emission reduction, renewable electricity, C-neutral computing, global recycling, water and chemical waste reduction
- ❖ Diversity, Equity and Inclusion: Encourage skill building
- ❖ Smart Cost-Effective Comprehensive Solutions for Global Operational Sustainability
- ❖ Proactive, Preventative Quality Control
- ❖ Across the Globe Business Continuity to Lower Supply Chain "Risk and Operational Cost"
- ❖ **Commitment to creating a better world through the power of collaboration, next gen technology, expertise and resilience of SEMI Industry Ecosystem: Together we WIN**



Thank you!
Question & Answer

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