Part 2

"Industry Needs in Semiconductor EHS Assessment - Summary of Survey Results"

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Purpose of Survey

1. To understand what companies' needs are, and where the requirements of integrated ESH assessment are
   - To ensure that our work is aligned with their issues and addresses their ESH concerns.
2. To then present a short summary of our proposed methodology and tools
   - At ERC Review
   - At this forum
3. Get feedback from the companies on our directions, through follow-up discussion and questions

Methodology

- Identified several key individuals at different semiconductor companies
  - Who are active in ESH decision making
  - Mostly ESH experts, some process, equipment, and chemical experts.
- Interviewed:
  - Chip manufacturers (AMD, Intel, Motorola, TI, etc.)
  - Chemical suppliers (3M, Air Products, DuPont, etc.)
  - Equipment manufacturers (ATMI, Applied Materials, BOC Edwards, Novellus, TEL, etc.)
  - Consortia (SEMATECH, SEMI)

Questionnaire

- Decision making around product development
  - Time frame of development
  - Lifetime of processes and equipment
  - Chemical handling
    - Scope of checklists? Exceeding regulations? Level of Automation?
  - Criteria in choosing chemicals and equipment
    - How do/have ESH and COO issues affect product development
    - How do you make tradeoffs?
    - Use of chemical property estimation tools: QSAR, group contribution method
- ESH considerations in decision making
  - System boundary of ESH analysis (fab-wide, downstream, upstream)
  - Motivations of environmental analysis
  - Roles of safety, worker health, and environment in decision making
  - Barriers
    - Largest datagaps (processes/byproducts/etc.)

Questionnaires (contd.)

- Uncertainty and risk
  - Missing or uncertain data
  - Allocate resources to tackle risk?
    - Value of information
    - How would you like to see this problem addressed
- Existing ESH tools
  - CARRI®
  - Chemical Data Matrix
  - Cost Analysis Tool
- Communicating ESH Issues and Achievements
  - Do process engineers and R&D personnel estimate ESH impacts of chemicals
  - Do you see ESH issues as a competitive advantage?
  - Conflict between proprietary information and the need to provide ESH information to your customers?

Common Findings

- Product Development
  - "Performance is always the key."
  - "ESH enhancement cannot compromise performance."
  - Regulation is still the biggest driving factor
    - Hard to comply with different requirements from different customers and regions.
- ESH Evaluations
  - Companies all have chemical review and approval process.
  - The system boundary for most of the companies is around the fab.
  - The mindset for environmental protection is end-of-pipe type of downstream treatment.
  - Most companies are focused on one or a few environmental impacts.
  - Rule of thumb: "ESH COO is only important if the total abatement costs for the module is equivalent to the cost of one process tool"
  - "R&D personnel and process engineers (of the tool suppliers and IC manufacturers) rely on ESH people to do the (ESH) evaluation."

Findings (cont.)

- Uncertainty
  - Due to the large data gap and uncertainty in data, there is a need for decision support at early chemical screening stage.
  - Limited awareness of the value of information and matching decision context with required data quality.
  - Even with chemical data present, may still have a hard time in translating these data into decisions
- Opportunity for change
  - "It is easier to incorporate ESH considerations during technology inflection."
- **Findings from IC manufacturers**
  - "We (IC manufacturers) often rely on suggestions from suppliers on what chemicals to test in the fab."
  - "Our customers usually care more about the environmental performance of their products and less on the manufacturing process."
  - "Environmental issues with product content have started to become a concern."

Findings (contd.)

- **Findings from tool suppliers**
  - The burden of safety, emission qualification and abatement is largely on tool suppliers.
- **Common findings from IC mfg and equipment suppliers**
  - Short and Long Term contributions
    - Understanding EHS issues related to facilitization of new processes/tools, capacity limitations and COO is the most pressing need for the industry
    - Understanding the environmental impacts of the chemicals used and processes is more forward looking

Findings (contd.)

- **Findings from Chemical Suppliers**
  - The burden of understanding the ESH properties of chemicals is largely on chemical suppliers.
  - "We have a good understanding of safety control, worker protection, ESH properties of chemicals, such as toxicity."
    - "But we don't always know how chemicals are handled in the fab"
    - These constrain the chemical suppliers from better providing safety control recommendations
    - Estimating the COO of the processes/tools that use their chemicals.
  - If a chemical has already been used in other applications, it is much faster to introduce it to a new application
    - "The most time consuming part in chemical development is to find the right chemical for a certain application"
    - "EHS screening and global registration constitutes a good fraction of ramp-up time and may cost a lot (~$500k)

Summary

	Broad Areas	Semiconductor Manufacturers	Chemical Suppliers	Equipment Suppliers	Specific Research Topics	Other Challenges
1	**New Chemicals**					
	Screening at Early Stages	Yes (Also, need to know and predict regulations)	Maybe (They have some resources to do this already)	Maybe (more concerned with emissions)	(i) How can this be done - QSAR+tox studies+Experts;(ii) Predict and Track Regulations; (iii) Decision Making	Confidentiality and Data Sharing
	EHS Impacts during Ramp Up and High Vol. Mfg.(HVM)	Yes	Maybe (Did not lay stress on this)	Concerned about emissions during HVM	(i) Filling data gaps;(ii) Decision Making	Data Sharing
2	**Life-cycle issues**					
	Downstream Issues	Yes	Yes (But hard since do not know how chemicals are used)	Yes	(i) Emissions measurements (ii) Modeling treatment systems	
	Product Content	Yes (but more on packing)	No	Somewhat (with content in equipment at end of life)		
	Upstream LCA	Are beginning work, but not so much interest.	Maybe (Have some resources in this area)	Maybe (But generally not that interested. Acknowledge that this is where the industry should be going)	(i) Data gaps (ii) Uncertainty (iii) Rate of change in the industry	Need to use this perspective to make environmental decisions

Summary (contd.)

	Broad Areas	Semiconductor Manufacturers	Chemical Suppliers	Equipment Suppliers	Specific Research Topics	Other Challenges
3	**Equipment and Facility Infrastructure**					
	COO	Some use SEMATECH Model, Others don't. EHS COO sometimes considered too small to bother, in chem decisions	Yes	Yes	(i) Std. model, integrating environmental components including facility infrastructure (ii) Include effects of downtime of infrastructure (abatement equipment, piping) on mfg	
	Bulk Chemicals/Resources	Maybe (some mfg already know this well)	Maybe	Yes	(i) Integrate tracking these, with process databases/manufacturing software? (ii) Expand to overall LCI	
	Predict waste streams, capacity requirements with scale up to HVM	Maybe (some mfg already know this well)	Yes (emissions and interactions)	Yes		
4	**Training**					
	EHS Assessment to Process Engineers	Maybe (some companies teams work well together). SEMATECH developing seminar of env assessments for process engineers	Yes (They already do this)	Maybe (some companies already have some programs, but scope for growth)	Developing training modules	Encouraging increased communication and cooperation between groups

Summary Contd.

	Broad Areas	Semiconductor Manufacturers	Chemical Suppliers	Equipment Suppliers
5	**Case Studies**			
		Supercritical CO_2 (2)	Spin on Vs. CVD low k	**(i) Look at past changes, eg: NF3 remote cleaning**
		Copper CMP and copper waste	**POU F_2 generation**	(ii) Then Rank different chemistries for etch
		PFC	Cu CVD Vs. Cu Plating	Analyze materials that are banned
		NF_3 vs. ClF_3 (3)	Biometrics (DNA on chip)	**Replacement solvents with supercritical CO2**
		NF_3 Vs. F_2 (including economies of scale)	SAR (focus on PBT)	PFOS
		Focus on major transformations such as phase out of lead	Case Studies in litho or dep with potential for multiple exposures	PFC Replacements
		Generate Tech Tr. Documents		Projects in the ERC Center
6	**Other Recommendations**			
		Look at EHS decision making 3-4 years before large technology inflection	Partner with trade associations	Facility Models to be developed: clean room air, inert gases, UPW, etc.
		Need to look at emerging issues 6-8 years ahead		Pyrophoric, HAPs, haz waste, etc. And routes of exposure through breath, skin, etc.

Summarizing Research Ideas

- Shorter Term
  - Focus on
    - Providing a systematic approach to technology assessment with multiple criteria
      - Decision process for alternative technologies under uncertainty
    - How to deal with missing, inaccurate or uncertain data
    - Transparent environmental evaluation process
    - Develop and populate databases describing EHS issues related to
      - Equipment and facilities infrastructure and COO
    - Include life cycle issues
  - Pick a few industrially relevant case studies
    - Work through them in detail
    - Illustrate information needed at each stage and how should one use approximation
    - Generate a tech transfer type report
- Longer Term Focus on
  - Designing a screening process for early stage of chemicals introduction
    - Use of SAR, other screening technologies
- Brief training on ESH for process engineers

Feedback Questions

- Do the findings reflect your EHS Assessment Needs
- Do the research topics outlined address these needs?
- Additional comments/feedback
- We will put also together a more detailed proposal and would appreciate feedback on that