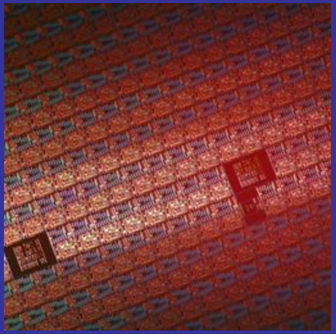
Accelerating the next technology revolution

IEUVI Mask TWG
Defect Reduction Program

Frank Goodwin

Defect Reduction Program

27 Feb, 2010



Outline

- 2010 Defect Reduction Accomplishments
- Roadmap and gaps
- Defect size distributions
- Summary

2010 Defect Reduction Achievements

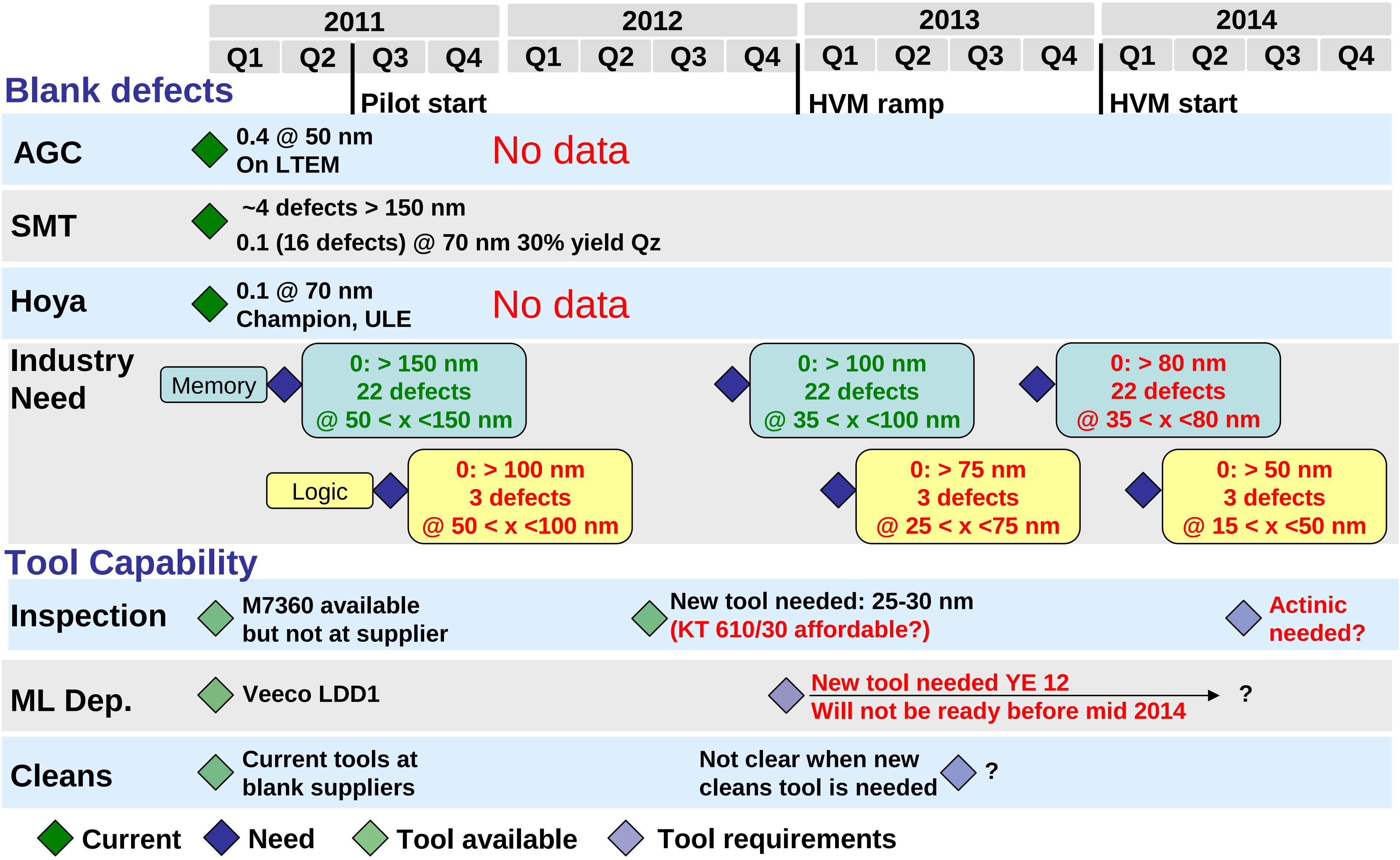
- Mask blank defect reduction
  - Achieved 60% reduction in total mask blank defects at 70nm size and at a 30% process yields (44 defects/MB to 16 defects/MB)
    - Includes defects from substrate and ML deposition
  - New Champion mask blank at 6 total defects
    - 4 particles and 2 pits
  - Demonstrated ability to eliminate Si type defects
    - Pursuing 2 patents on shield cleaning process and surface treatments
- M7360 defect detection
  - Tool is now operational and a sensitivity better than 40nm on quartz and 45mn on ML
  - Defect printability - developed punch marking process supporting AIT imaging of native defects
- FE Dual Pod Design
  - Published Engineering design of a dual pod front-end concept for deposition tool

2010 FA Accomplishments

- TEM
  - Compositional analysis of sub-70nm defects
  - Characterization of ML film growth over substrate pit and particle defects – smoothing
  - FA support for defect printability
  - Two trained engineers covering two shifts
  - Sample yield at > 60% from 0% in Feb 2010
- Auger
  - Incorporated AES for sub-100nm defect composition analysis
  - Demonstrated analysis of sub-50nm defects on a substrate
  - Demonstrated analysis of 30 nm C
  - Develop process for defect analysis on a non-conductive substrate
  - Two trained engineers covering two shifts
- FIB/SEM
  - Working with FEI established automated scripts for TEM sample prep
  - New milling technique development for sub-100nm defects
  - 7X24 support with two engineers and four technicians

Roadmap and gaps

Defect Reduction Roadmap Gaps



Blank defects

AGC ◆ 0.4 @ 50 nm
On LTEM
No data

SMT ◆ ~4 defects > 150 nm
0.1 (16 defects) @ 70 nm 30% yield Qz

Hoya ◆ 0.1 @ 70 nm
Champion, ULE
No data

Industry Need

Memory ◆
0: > 150 nm
22 defects
@ 50 < x <150 nm

◆
0: > 100 nm
22 defects
@ 35 < x <100 nm

◆
0: > 80 nm
22 defects
@ 35 < x <80 nm

Logic ◆
0: > 100 nm
3 defects
@ 50 < x <100 nm

◆
0: > 75 nm
3 defects
@ 25 < x <75 nm

◆
0: > 50 nm
3 defects
@ 15 < x <50 nm

Tool Capability

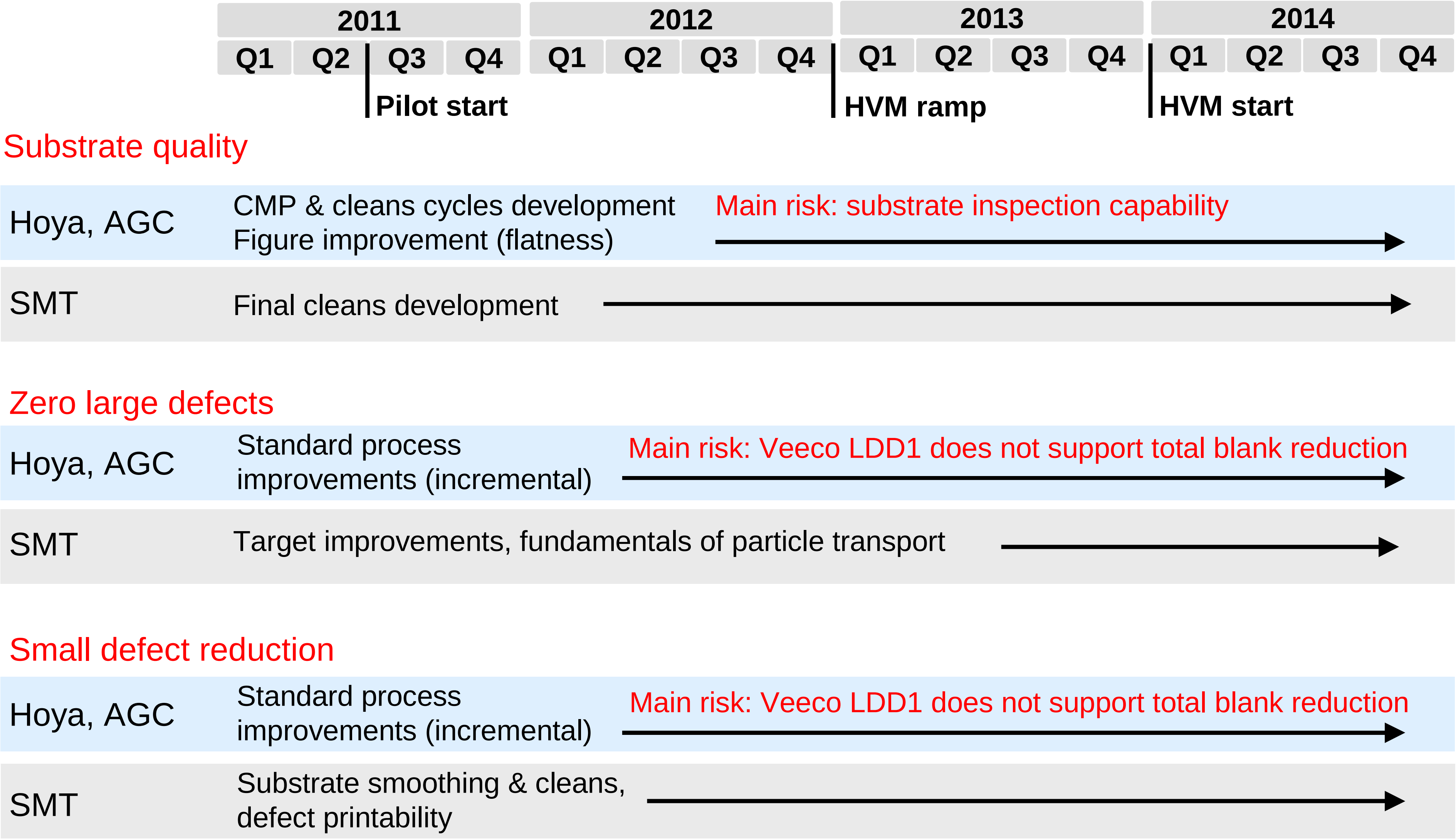
Inspection ◇ M7360 available
but not at supplier
◇ New tool needed: 25-30 nm
(KT 610/30 affordable?)
◇ Actinic
needed?

ML Dep. ◇ Veeco LDD1
◇ New tool needed YE 12
Will not be ready before mid 2014 → ?

Cleans ◇ Current tools at
blank suppliers
Not clear when new
cleans tool is needed ◇ ?

◆ Current ◆ Need ◇ Tool available ◇ Tool requirements

Showstoppers



Substrate quality

Hoya, AGC — CMP & cleans cycles development; Figure improvement (flatness) — Main risk: substrate inspection capability

SMT — Final cleans development

Zero large defects

Hoya, AGC — Standard process improvements (incremental) — Main risk: Veeco LDD1 does not support total blank reduction

SMT — Target improvements, fundamentals of particle transport

Small defect reduction

Hoya, AGC — Standard process improvements (incremental) — Main risk: Veeco LDD1 does not support total blank reduction

SMT — Substrate smoothing & cleans, defect printability

Tool Gaps

2011				2012				2013				2014			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		Pilot start						**HVM ramp**				**HVM start**			

Substrate inspection

AGC / Hoya	**Current capability ends at 35 nm**
NewCo	**NewCo has no plans for a substrate inspection tool.**
SMT	**EMI has no plans for a substrate inspection tool.**

Blank inspection

AGC / Hoya	**Current capability ends at 45 nm. KT610/630 could provide 22 nm hp capability.**
NewCo	**NewCo actinic Lasertec tool available early 2014, tool late for 22 nm hp development.**
SMT	**EMI path still being explored (work with NewCo or support alternative).**

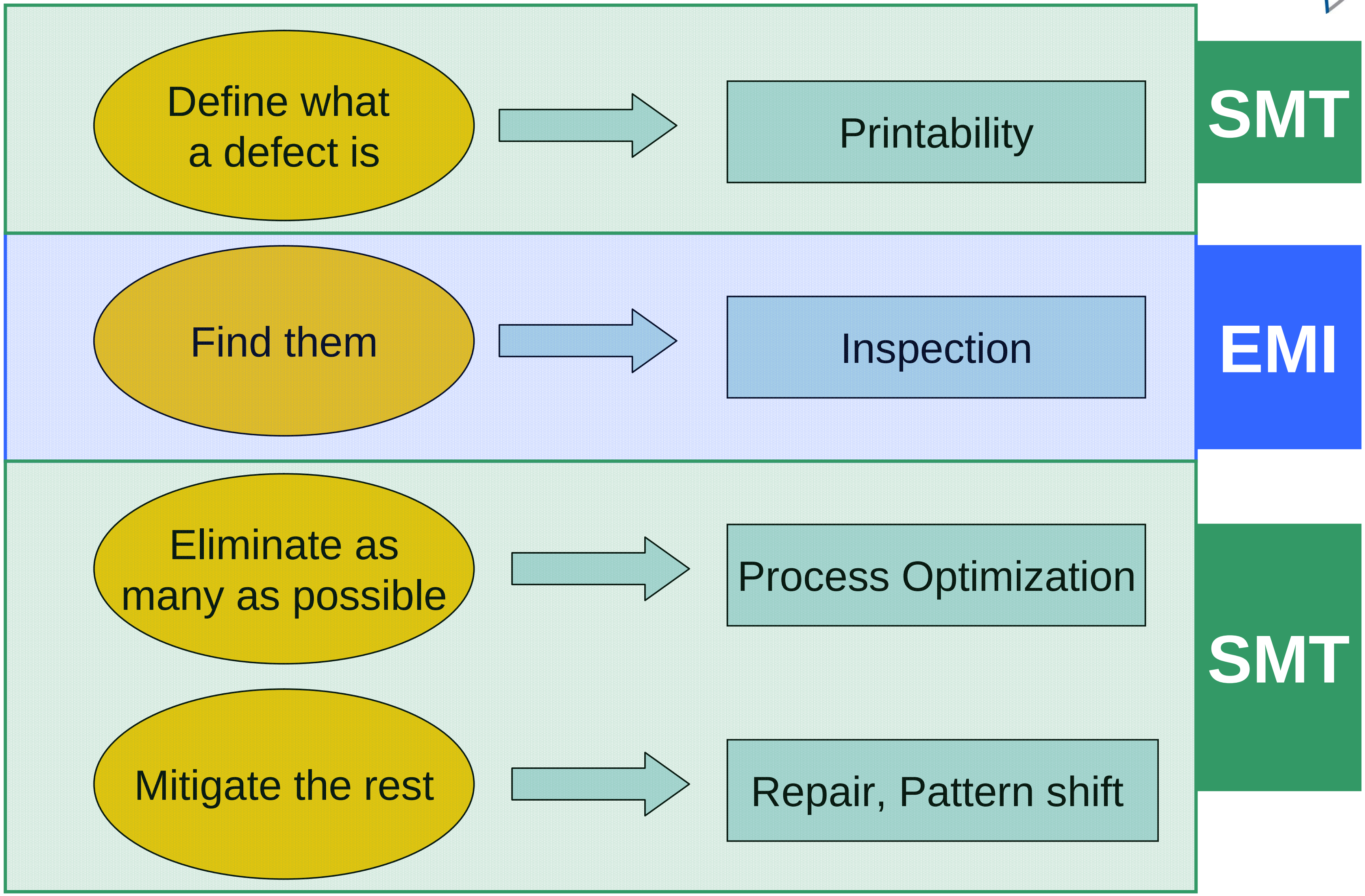
ML dep. tool

AGC / Hoya	**Current capability ends at 22 nm pilot line.**
NewCo	**NewCo has no plans to enable new deposition tool.**
SMT	**Enables new tool design but development and build currently not funded.**

Cleans tool

AGC / Hoya / SMT	**New tool need not clear yet.**

EUV Defect-free Mask Strategy Concept



Define what a defect is → Printability

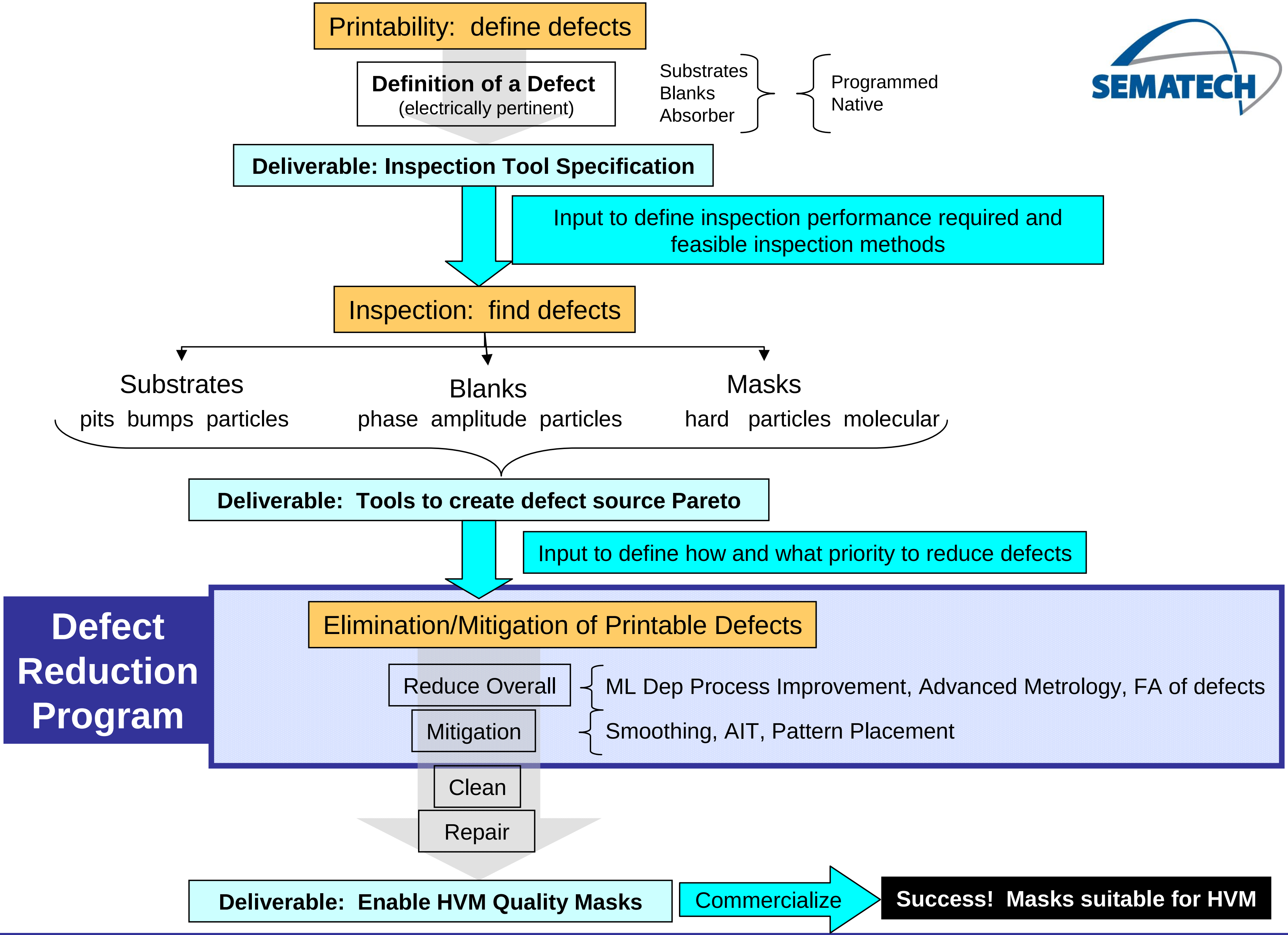
Find them → Inspection

Eliminate as many as possible → Process Optimization

Mitigate the rest → Repair, Pattern shift

Courtesy of Kurt Kimmel

SEMATECH



Printability: define defects

Definition of a Defect
(electrically pertinent)

Substrates
Blanks
Absorber

Programmed
Native

Deliverable: Inspection Tool Specification

Input to define inspection performance required and feasible inspection methods

Inspection: find defects

Substrates
pits bumps particles

Blanks
phase amplitude particles

Masks
hard particles molecular

Deliverable: Tools to create defect source Pareto

Input to define how and what priority to reduce defects

Defect Reduction Program

Elimination/Mitigation of Printable Defects

Reduce Overall – ML Dep Process Improvement, Advanced Metrology, FA of defects

Mitigation – Smoothing, AIT, Pattern Placement

Clean

Repair

Deliverable: Enable HVM Quality Masks

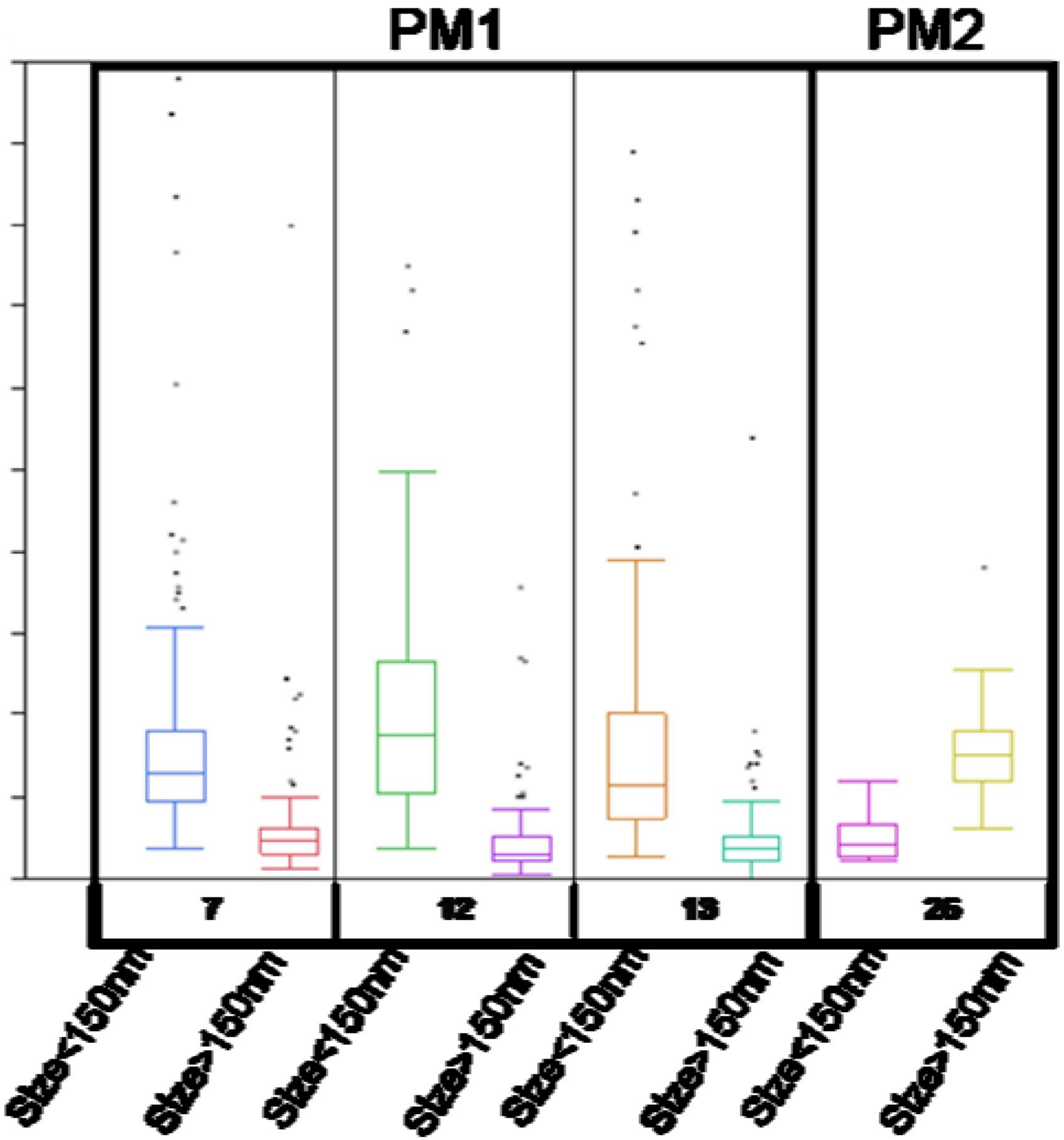
Commercialize

Success! Masks suitable for HVM

Courtesy of Kurt Kimmel

Defect size distribution

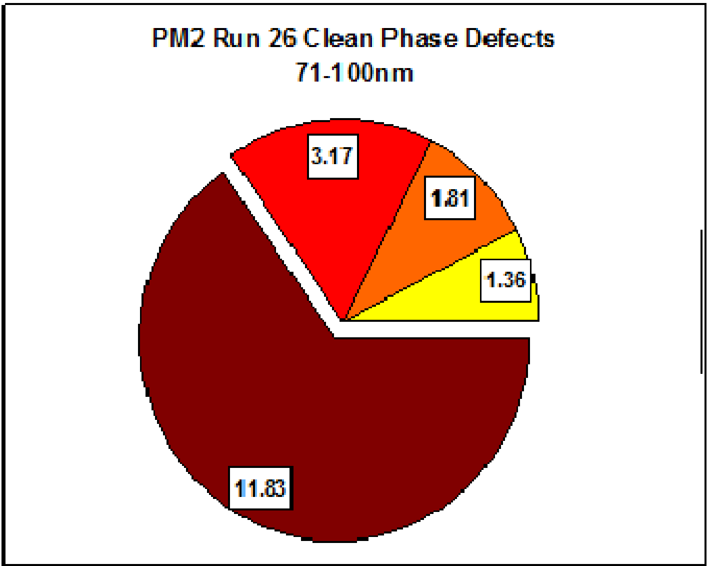
Defect Counts per MB by Size

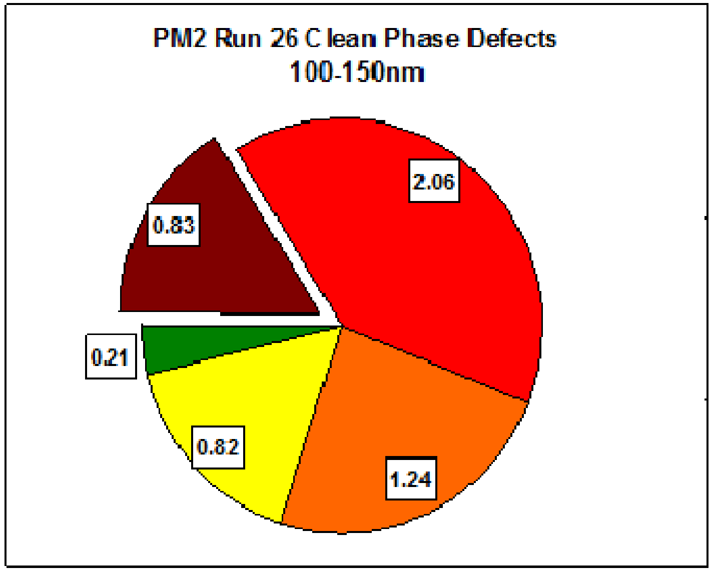


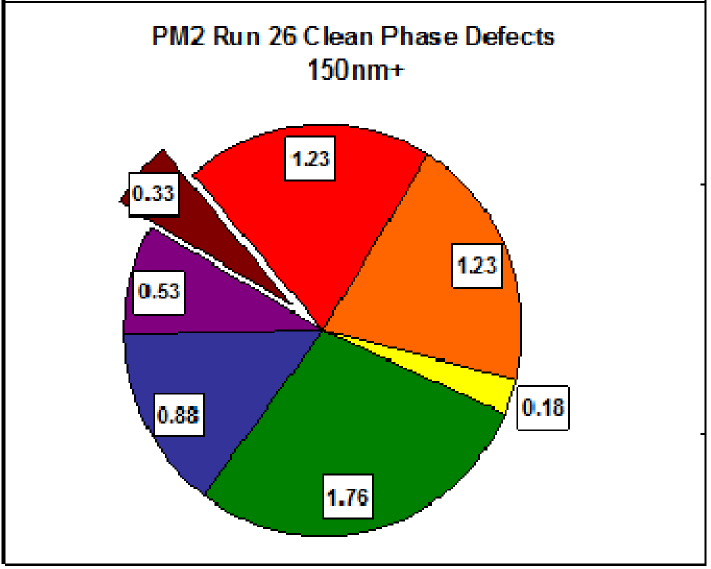
- Defects per mask blank
- Two different signatures per tool
  - PM1 defects <150nm dominate
  - PM2 defects > 150nm dominate
    - Larger chamber (door)
    - FE maintenance

ML deposition from PM2

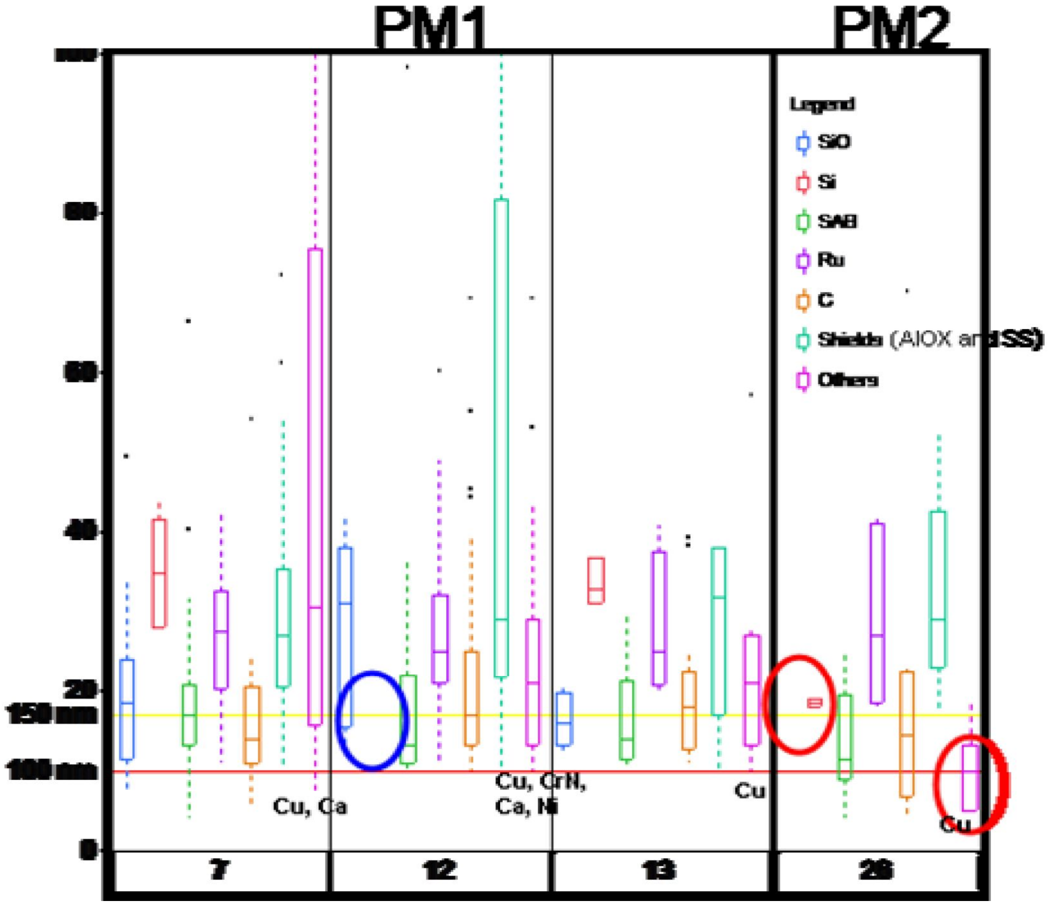
- Defects coming from shield treatments make up most of the larger sized defects (SS, AlOx) as well as porous C, SAB (Mo/Si), and Ru


PM2 Run 26 Clean Phase Defects
71-100nm


PM2 Run 26 Clean Phase Defects
100-150nm


PM2 Run 26 Clean Phase Defects
150nm+

Size Distribution by Type: Clean Phase (not counts per MB)



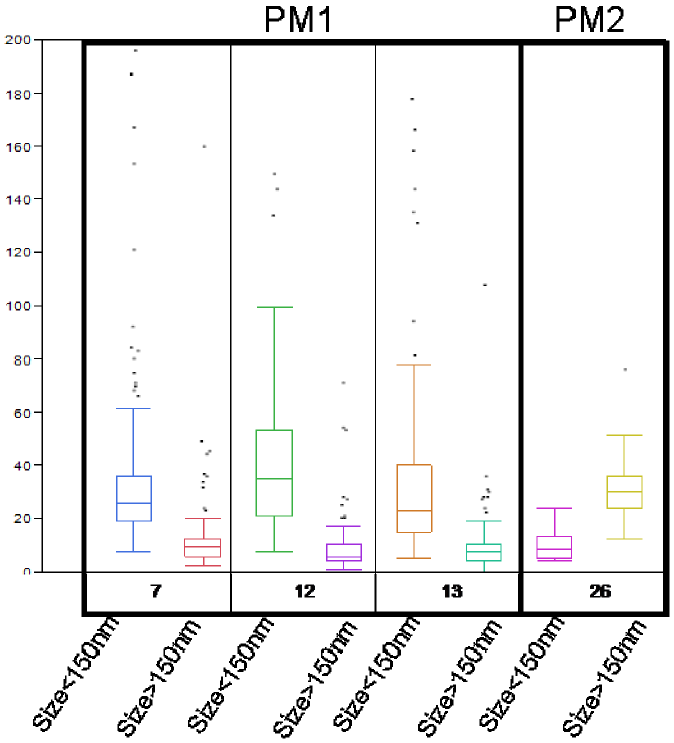
PM2 FA Results

- No SiO defects: aligner was removed from FE handling
- Low Si defects: improved shield coating with high roughness (>500uin)
- Other defects (Cu): small size distribution

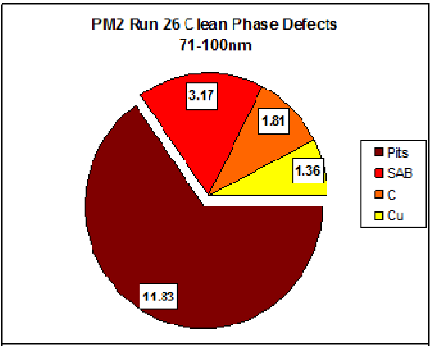
M12 on PM1

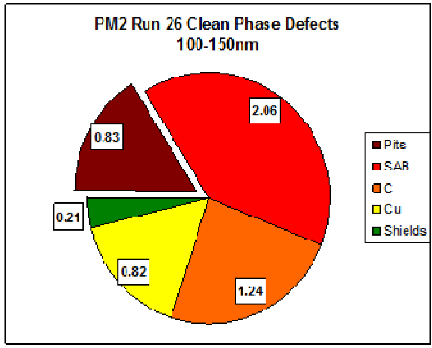
- No Si defects: improved shield coating

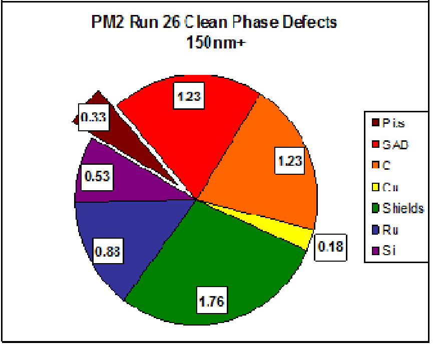
Near term focus



- Defect Counts per MB by Size Defects per mask blank:
  - Large (killer) defects: >150nm
    - Elimination
  - Small defects: 50nm to 150nm
    - Reduction and Mitigation
- Objective:
  - Enable manufacture of for usable EUV mask Pilot Line and HVM







Summary

Summary

- Mask blank defect performance
  - 60% reduction in total mask blank defects with demonstrated process yield and new champion data
  - Demonstrated elimination of Si type defects
- M7360
  - Now operational with improved sensitivity
  - Supporting AIT of native defects for printability studies
- FE Dual Pod Engineering Concept published
- FA
  - TEM and Auger sample prep processes created
    - Adds significant capability in analysis of defect composition and isolating defect sources
  - FIB/SEM
    - Added efficiency in TEM sample prep with auto scripting work and milling optimization
- EUV Mask Blank Deposition Process
  - No longer solely focusing on complete elimination of defects
  - Elimination of large (killer) defects
    - Size threshold different for memory and logic
    - Threshold will need to match technology node
  - Reduction of small defects
    - Defects which can be mitigated or potentially repaired
    - Defect density targets different for memory and logic
      - Requirements for logic are challenging