EUV Source Workshop Summary and EUV Source Technology Status

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EUV Source Workshop Summary and EUV Source Technology Status

- EUV Source Requirement Status
- Meeting Highlights
- Industry status
- EUV Source Power and Critical Component Life-time Status
- Paths for EUV Sources to Enable 100 WPH EUV Steppers
- Source Critical Issues
- Acknowledgment

EUV Source Requirements Update*

Source Cleanliness Defined

For Optics after IMF, Relative Reflectivity ≥ 90% after 30,000 light-on hours

Vacuum chamber

Vacuum chamber

Source

Filter

Collector

Debris mitigation

Gas
Debris

Aperture (IF)

Optics after IF

Relative Reflectivity ≥ 90%
after 30,000 light-on hours

*** ASML/Cannon/Nikon Presentation**

EUV Source Requirements Update

ASML/Cannon/Nikon Presentation

- Joint requirements have been stable since the last EUV Source workshop
- It is confirmed that source cleanliness is defined as a lifetime of optics after IMF and is related to gas and debris flow through an aperture at IMF
- Source cleanliness doesn't require any lifetime of source components, i.e., components before IMF
- Source suppliers need to provide proposals about measurement method of source component lifetime and CoO of EUV sources

EUV Source Requirements Update

ASML/Cannon/Nikon Presentation

- **Cost of ownership will determine critical component life-time requirements**
- The MTBF, MTTR, scheduled down time for routine maintenance and the maintenance cost for the EUV source should be about the same as or an extension of those of present lithography sources.
- The exchange time and cost of electrode, collector, debris mitigation and spectral purity filter should be contained in the total maintenance time and cost.
- **Source suppliers need to provide proposals about measurement method of source component lifetime and CoO.**

Meeting Highlights: Supplier Presentations

- Concerted efforts to produce reliable high power lasers
- More GDPP suppliers showed results with Sn: Cymer, PLEX
- Cymer : Demonstrated 25 kW thermal load mitigation and added LPP to their source development program
- EUVA: Fast ion mitigation by magnetic field and GDPP optics ready
- EXULITE: Progress on laser and collector for LPP
- JMAR: Presented a closed target concept to address debris issue
- PLEX: Modeling of Erosion of surfaces via sputtering
- Philips: No loss of reflectivity after 500 M pulses for Xe! 5M shots life-time for collector for Sn source
- PowerLase: 1kW laser demonstrated with plans to multiplexed to produce 3.6 kW within a year (with previously demonstrated scheme)
- Xtreme technologies: Improvement in Debris Mitigation

Meeting Highlights : Sessions

- **Fundamental Data**
  - Good agreement on wavelength comparison
  - Need Cross-section data (Electron impact ionization, excitation, and recombination are most important)
  - Need benchmarking on EBIT to validate models –modeling comparison workshop proposed as part of EUV Source Modeling Workshop
- **Modeling**
  - Detailed modeling of EUV emission for PE, Cymer and Xtreme source (Up to 3000 lines used for generating models)
  - Modeling of electrode heating – may give us lead for reducing electrode erosion
- **Consortium Research Programs**
  - More Moore Program in Europe

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Break-out Sessions Highlights

- **EUV Source Metrology**
  - We need to better understand the EUV Source Metrology requirements
  - IMF Metrology needed
- **GDPP vs. LPP**
  - Comments on LPP
    - CE of 3% has been achieved for Sn LPP (Nishihara)
    - Cooling requirements are 100 x for LPP as compared to GDPP
    - For LPP large collection angle is possible
    - Small Size for LPP
    - Upto 50% collection possible
    - Erosion rate is comparable to GDPP
    - Increase the drive-power in
    - More Complex and more expensive by a factor of 3-5.
    - LPP seems to be lagging behind due to withdrawal of two LPP suppliers in 2003 for business and not technical reasons - Less power for LPP (2 W vs 150 W)

Break-out sessions Highlights

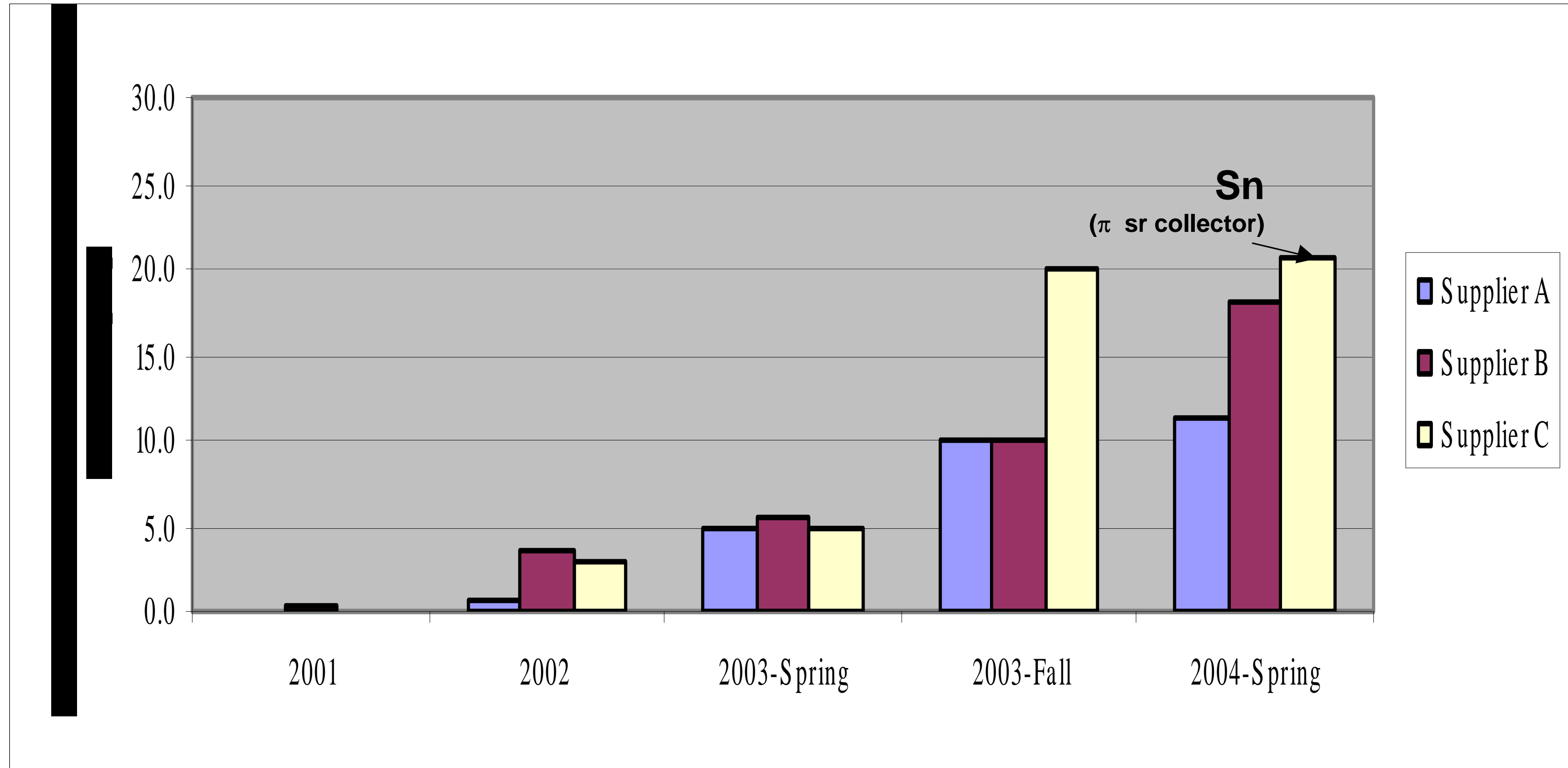
- **High power Source Feasibility**
  - Two major decisions
    - Xe vs Sn
    - LPP vs GDPP
  - Issues
    - Power scaling
    - Collector lifetime
    - System affordability
    - Multiplexing
      - DPP need temporal multiplexing with moving mirrors or sources
      - Due to smaller size more feasible for LPP

EUV Source Industry Status

- **Strong supplier commitment with roadmap to deliver 115 W by 2009**
  - Five Suppliers and two consortium are actively developing High Power EUV sources
  - Worldwide funding of EUV source development
    - US: Intel, International SEMATECH, DARPA, NSF, SRC
    - Europe: MEDEA+, More Moore
    - Japan: EUVA
  - Source for MET tool and alpha level stepper have been delivered
  - EUVL on roadmap for 2009 implementation

Source Power Continues to increase

Source power has increased by a factor of 2 to 4 in the last one year



All suppliers are for GDPP sources for Xe Sources, except for Supplier C (with π sr collector)
No Spectral purity filter loss is assumed
For Supplier B, output is expected to be in 10-20 W range (2003 Fall)
Data from ISMT source workshops

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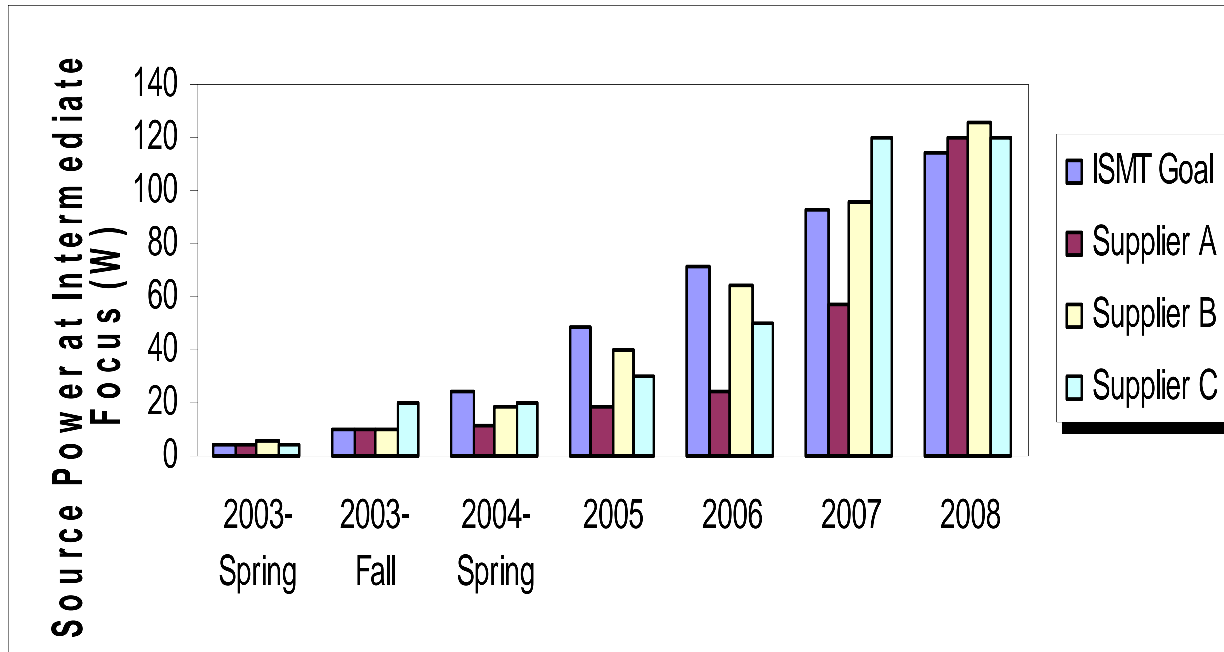
Large improvement in the Source Power Needed
20 W to 115 W



All suppliers are for GDPP
Reported Data from ISMT source workshops
Future Plans from September 2003 Workshop

- **Source Power Measurements at IMF are needed to verify the assumptions made to convert the source power and better understand the source performance**

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Order of Magnitude Improvement is needed in Critical Component Life-time (electrode and collector)

CCLT has improved and suppliers expect reasonable life-time in 1-2 years

1E8 pulses at 1 kHz is ~ 28 hours at 1 kHz and ~ 4 Hours at 7 kHz
1E9 pulses at 1 kHz is ~ 11 days at 1 kHz and ~ 1.5 day at 7kHz
1E10 pulses at 1 kHz is ~ 4 months at 1 kHz and ~0. 5 months at 7kHz

						Today				
			2001	2002	2003	**2004**	2005	2006	2007	REQUIREMENTS
1	**ISMT Goal**	**Collector (GDPP)**			**1.00E+08**	**1.00E+09**	**1.00E+10**	**1.00E+11**	**2.50E+11**	7.56E+11
		Collector (LPP)			**1.00E+10**	**5.00E+10**	**1.00E+11**	**2.50E+11**	**2.50E+11**	7.56E+11
		Electrode			**5.00E+08**	**1.00E+09**	**1.00E+10**	**1.00E+11**	**2.50E+11**	7.56E+11
2	A	Collector	5.E+05	5.E+07	5.E+07	5.E+07	1.E+10	5.E+10	1.E+11	7.56E+11
		Electrode	1.E+06	2.E+06	1.E+07	5.E+07	1.E+08	1.E+09	1.E+10	7.56E+11
3	B	Collector		4.E+07	5.E+07	1.E+08	1.E+09	1.E+09	1.E+11	7.56E+11
		Electrode		1.E+08	1.E+08	1.E+08	5.E+08	5.E+09	1.E+11	7.56E+11
4	C	Collector			1.E+08	5.E+08			1.E+11	7.56E+11
		Electrode			1.E+08	5.E+08			1.E+11	7.56E+11
5	D	Electrode			1.E+09	1.E+09			1.E+10	7.56E+11

EUV Source Technology Status

- **GDPP**
  - Current leading technology with estimates EUV power ~ 20 W at IMF
  - More power is achieved through increasing the operation frequency
  - Concerns on scalability to achieve 115 W at the intermediate focus due to Electrode erosion and thermal load. This issue may be addressed by
    - Switching to Sn (reduce input power requirements)
    - innovative electrode design (For example Star Pinch)
    - Innovative cooling mechanism (Liquid metal cooling)
    - New Electrode materials
- **LPP**
  - Small plasma size allows multiplexing (reduce requirements by 50%)
  - Cryogenic Xenon sources have solved nozzle cooling issues
  - Need reliable high power lasers

Paths for EUV Sources to Enable 100 WPH EUV Steppers

- **Generate More EUV Power**
  - Address Electrode issue (GDPP)
    - Innovative designs to reduce thermal load on electrodes
    - New thermal management technologies
    - New electrode materials
  - Maximize conversion efficiency or energy per pulse (GDPP, LPP)
  - Choose material (Sn) with higher CE (GDPP, LPP)
  - Increase Laser power (LPP)

Paths for EUV Sources to Enable 100 WPH EUV Steppers

- **Collect more EUV Power**
  - Improve Collectors
    - New designs for collector (GDPP, LPP)
    - What is the upper limit of etendue requirements? (GDPP)
    - New collector materials with higher reflectivity (GDPP, LPP)
  - Reduce light loss in mechanical foil traps (GDPP, LPP)
    - Non-mechanical debris mitigation
  - Spectral purity filters (GDPP, LPP)
    - Achieve SPF with close to 0% loss

Paths for EUV Sources to Enable 100 WPH EUV Steppers

- **Reduce Power Requirements**
  - Increase peak optics reflectivity (67% to >70%)
    - Factor of 1.56 for eleven mirror system
  - Can we develop a system with less than eleven mirrors?
  - Reduce the stepper overhead time
    - Present model assumes 27 s for overhead time and 9 s for exposure time (10% reduction in overhead time is 25 % reduction for power0
  - Can we develop more sensitive EUV resists?
    - Present model assumes 5 mJ/ cm2
- **Develop Requirements in terms of Cost of Ownership**
  - Develop Cost of ownership model for source and for EUVL steppers

EUV Source Critical Issues

- **Source Power (GDPP and LPP)**
- **Electrode life-time and thermal management (GDPP)**
- **Debris reduction (to increase the condenser and optics life-time) (GDPP and LPP)**
- **Reliable High Power Laser Sources (LPP)**
- **Source Stability (GDPP and LPP)**
- **Need to focus industry resources by making technology choices in the near future**
  - Source technology :GDPP or LPP
  - Source material: Xe or Sn
- **Industry co-ordination**
  – Source requirements clarification, metrology for source performance & life-time measurements, pre-competitive research

Announcements

- Thanks to Presenters, Chairpersons, Breakout session co-chairs, EUV Source Workshop Organization Committee, ISMT meeting services, Darlyne Harlan, and Judy Behr
- There will be a half day source modeling workshop on November 4, 2004 in Miyazaki, Japan
- Next EUV Source Workshop will be help on Sunday, November 5, 2004 in Miyazaki, Japan