Manufacturing With EUV ?

Peter Silverman
Intel
Lithography Capital Equipment Development

EUVL Workshop
October 2000

The Questions:

① When is EUVL needed? (Will it ever be needed?)

② What EUVL performance is required for successful insertion into high volume manufacturing?

③ Can EUVL meet high volume manufacturing requirements? (If EUVL can't, then what?)

The Market Drives Lithography

① Scale pitch at 0.70X per generation ➜ Cost
- Lower cost increases the total market size

② Scale gates at 0.70X per generation ➜ Speed
- Higher speed drives the upgrade market

③ Maintain a two year technology cycle
- Competitive position

Technology requirements are Market Driven

Technology Insertion Timing

- Industry history over the past 20+ years is empirical “proof” that the technology roadmap will be met by driving optical lithography to shorter wavelengths and high NA.
  - 436nm ➡ 365nm ➡ 248nm ➡ 193nm ➡ 157nm ➡ 13nm
  - 0.35 ➡ 0.45 ➡ 0.50 ➡ 0.60 ➡ 0.68 ➡ 0.75 ➡ 0.80 (?) ➡ 0.85 (?)

- Improvements in resist technology, OPC, CMP, etc. have allowed each generation of optical technology to achieve a lower ultimate k_1
  - k_1 = ~1.0 ➡ 0.50 ➡ 0.40 (?) with binary masks and OPC

Meeting The Technology Roadmap

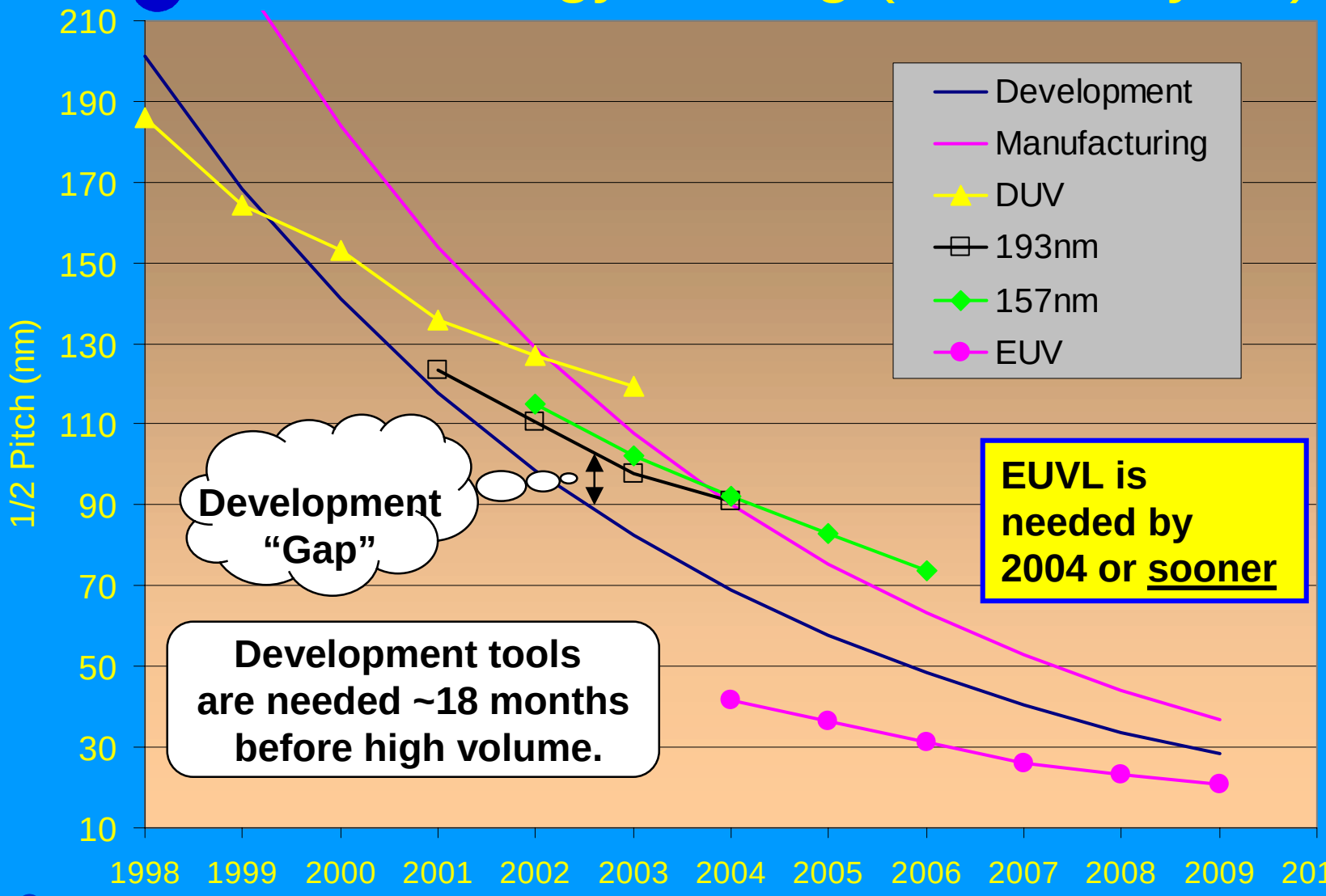
Assertion:

New technologies will only be inserted when there is no other choice.

For example:

- $k_1 \leq 0.4$ Probable limit for binary masks
- Strong Phase Shift Masks required on multiple layers
- “Overwhelming” OPC requirements, leading to very high reticle cost

Technology Timing (2 Year Cycle)



The Questions:

① When is EUVL needed? (Will it ever be needed?)

➔ EUVL is needed by 2004 or sooner!

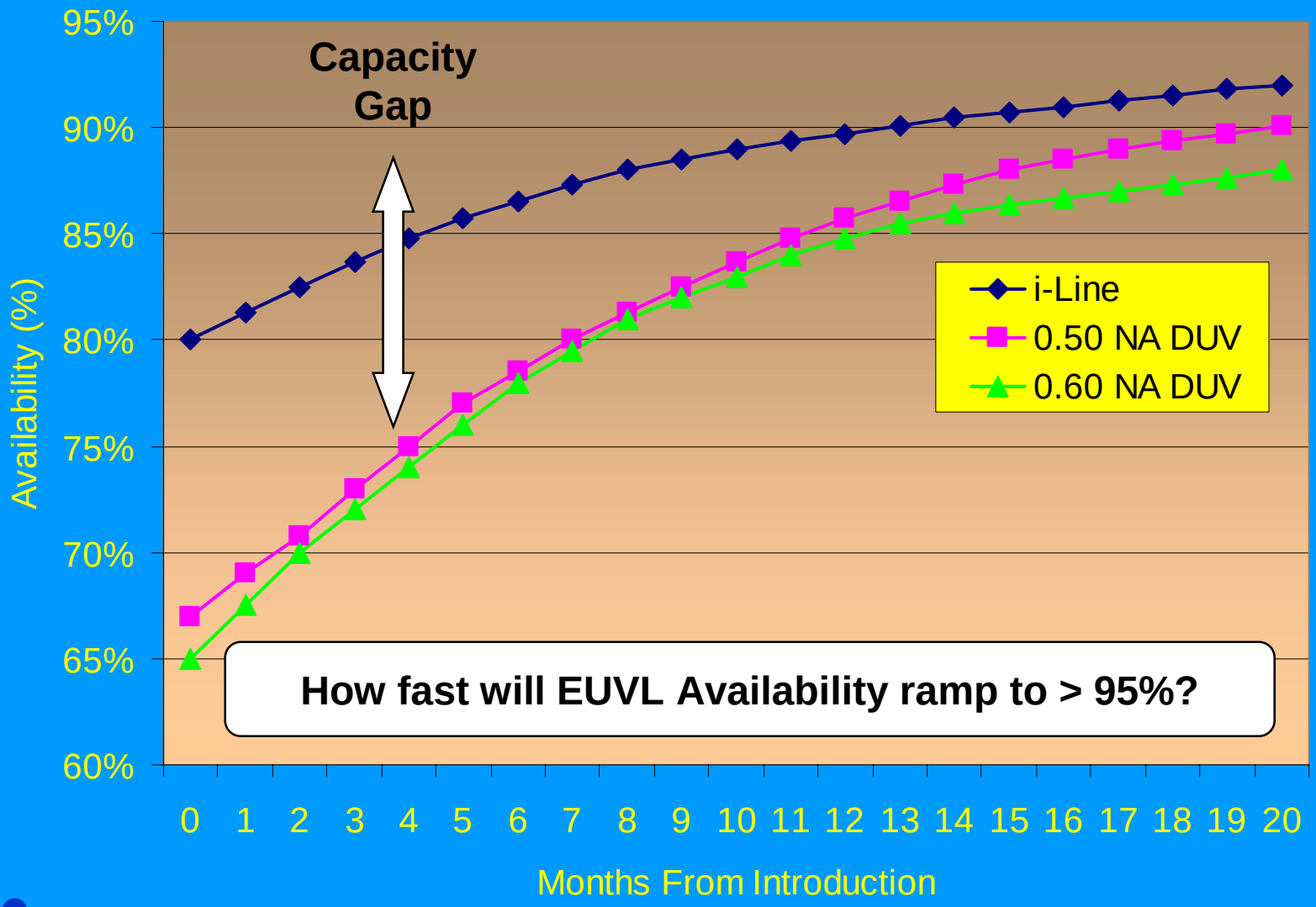
② What EUVL performance is required for successful insertion into high volume manufacturing?

③ Can EUVL meet high volume manufacturing requirements? (If EUVL can't, then what?)

Manufacturing Requirements

- High **Availability** → Cost/Capacity
  - Trend: ~90% → > 95%
- "Reuse" of Equipment and Knowledge Base → Cost/Time
  - Trend: 3+ generations
- Simplicity → Cost/Time
  - Trend: Optical lithography with wavelength and NA scaling
- Simple, Cheap (?) Reticles → Cost/Time
  - Trend: Binary masks + OPC where necessary; avoid complex Phase Shift Masks
- High Output → Cost/Capacity
  - Trend: 30 WPH → 50 WPH → 80 WPH → >100 WPH

Availability Learning



Manufacturing Requirements

- High Availability → **Cost**/Capacity
  - Trend: ~90% → > 95%
- "Reuse" of Equipment and Knowledge Base → **Cost**/Time
  - Trend: 3+ generations
- Simplicity → **Cost**/Time
  - Trend: Optical lithography with wavelength and NA scaling
- Simple, Cheap (?) Reticles → **Cost**/Time
  - Trend: Binary masks + OPC where necessary; avoid complex Phase Shift Masks
- High Output → **Cost**/Capacity
  - Trend: 30 WPH → 50 WPH → 80 WPH → >100 WPH

Challenges For EUV Insertion

	Status
◆ Meet the technology requirements:	
● Pitch and Gate	**Capable**
● Extendibility (2 year cycle)	**Capable**
◆ Meet the manufacturing requirements:	
● High Availability	**"Optical-Like"**
● Knowledge Reuse	**"Optical-Like"**
● **Simplicity (Binary Masks)**	**Commercial Masks**
● **High Output: 80 WPH**	**Source**
● **CoO**	**Source**
● **Capacity (Avoid material limitations; e.g. CaF_2)**	**Commercialization**
◆ **Be ready when needed for process development.**	**Commercial β Tools**

Challenge #1: Commercialization

- Semiconductor Equipment Manufacturers will not/can not take the risk to commercialize any "NGL" technology until a full field "alpha" tool has been demonstrated.

  The EUV LLC Engineering Test System must provide the necessary technology demonstration to catalyze the commercialization process.

- Good News: Suppliers *are* well positioned to commercialize EUVL once the technology is demonstrated.
  - EUVL platforms build on existing optical technology: polishing, coatings, alignment systems, platform configuration
  - Photoresists are available which meet early development needs.
  - Development reticles can be produced by the EUV LLC.

- Tool development schedules are marginal for 70nm but easily meet 50nm.

- Is is time to place bets. Are IC manufacturers ready to place orders?

Challenge #2: Source

- The EUV source is the primary technical risk for EUVL.
- Source power determines run rate (and CoO).
- Good News: The current Laser Plasma Source is suitable for β tools.
  - EUV does not have the synchrotron insertion problem which gated X-Ray
- There are 5- 10 candidate EUV sources for high volume. It is not clear if any of the sources can produce the power required for 80 WPH operation.
- In the near future (6-9 months) the industry must select an EUV source for first generation manufacturing tools.
- Cooperation will be essential to ensure a good decision.

Challenge #3: Masks

- The semiconductor industry knows how to make binary masks on rigid substrates (and doesn't seem to know how to make anything else).
  - XRL never solved the mask problem
  - Strong Shifter PSMs are still not in high volume manufacturing (and may never get there due to high cost and high complexity).
- Good News: EUVL uses rigid masks which can be produced by commercial mask suppliers with existing equipment. Commercialization is probably not a big issue.
- At current substrate yields the cost of EUVL masks is well above worst case estimates for Alt PSM reticles.
- If defect reduction continues at the present rate, EUVL mask substrates have the potential of meeting all cost and availability requirements.

Will EUVL Be Used In Manufacturing?

If:

- Beta tools are available in time.
- CoO is below 157nm with Alt PSM.
- An affordable, high reliability source is available soon.
- Masks stay on their current trend to lower costs.

Then EUVL will be used in manufacturing