eBeam
Initiative

Impact of Mask Writer Throughput on Optical Lithography for 22 nm and 14 nm

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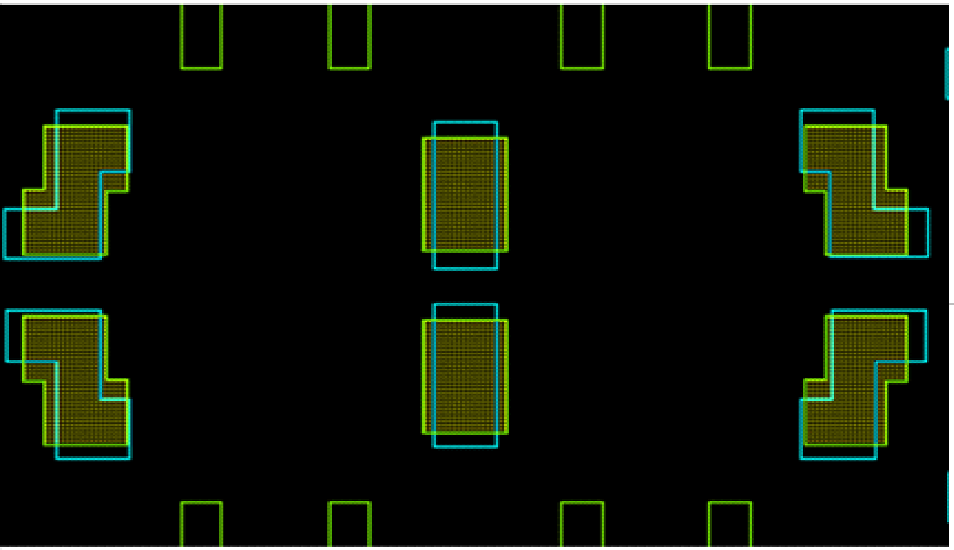
Introduction

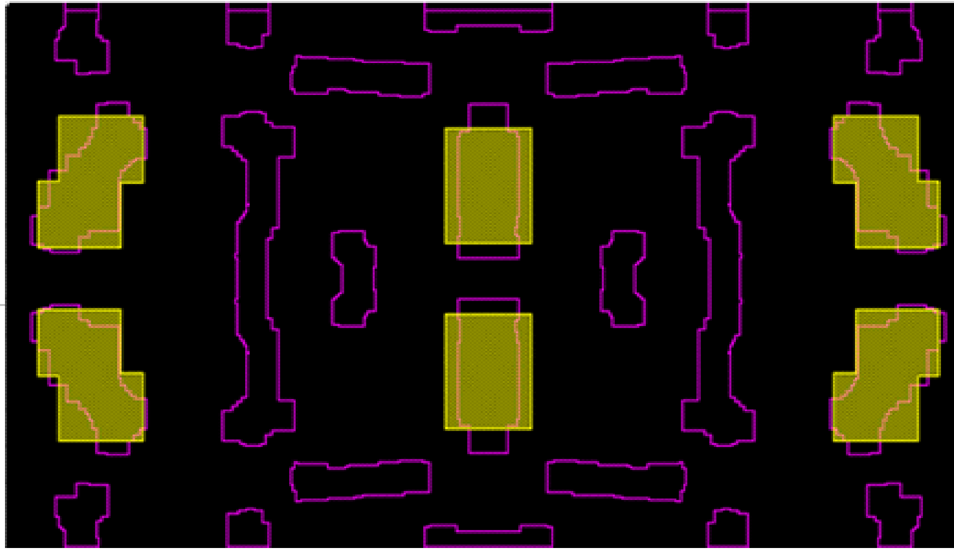
- Huge Optical Lithography Challenges at 22 nm and 14 nm Nodes
  - No significant immersion stepper improvements for enabling smaller features
  - Requires use of combination of design rule restrictions, double patterning, and enhanced computational lithography techniques.
- Alternative EUV lithography option not ready for 22 nm and early 14 nm production.
  - 22 nm production = 2012
  - 14 nm early production = 2014

Effect of Inverse Lithography

- Impact of Inverse Lithography Techniques on Shot Count
  - Inverse lithography techniques required to achieve acceptable process window at 22 nm and 14 nm nodes.
  - Inverse lithography approach drives large increase in mask pattern complexity and e-beam shot count that results in non-manufacturable mask.



Normal OPC Approach for 22 nm contact level



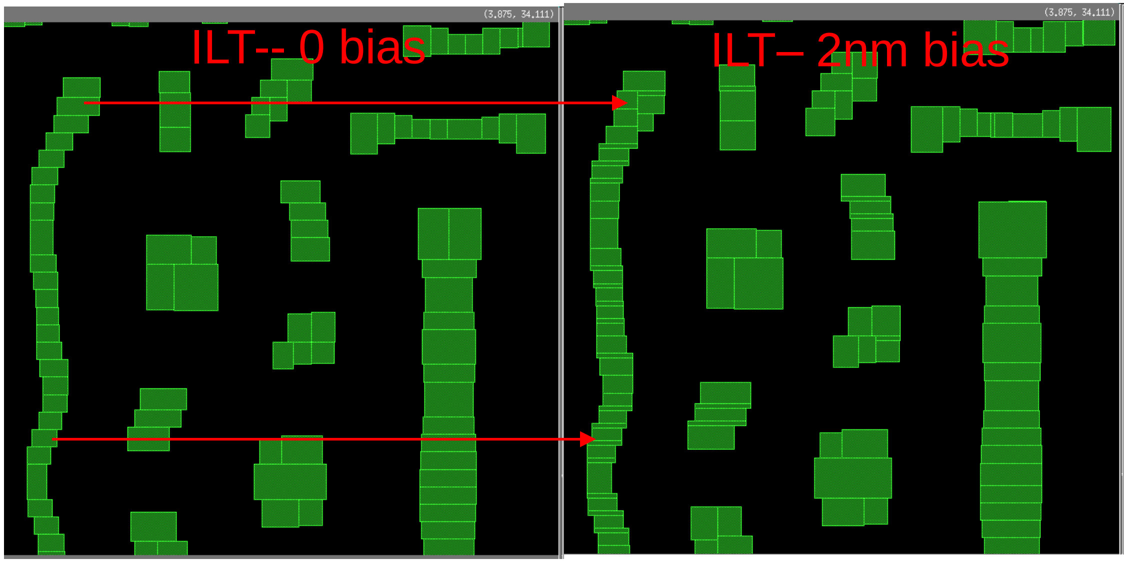
Generic ILT Approach for 22 nm contact level

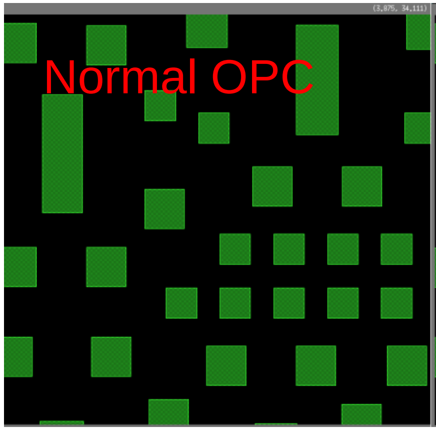
Mshot/cm²	410
E-beam Print Time (70A/cm2)	5.2 Hrs
Max PV Dev	22.75nm

Mshot/cm²	7229
E-beam Print Time (70A/cm2)	79.7 Hrs
Max PV Dev	13.25nm

Additional Impact of Mask Process Bias

- Fracture with 0 bias shows 6x increase in shot count for ILT.
- When 2 nm mask process bias applied, 8x increase seen
  - Opposing jogs shifted opposite directions on curvilinear shapes
- Normal opc has little bias effect
  → all rectangular shapes





	ILT	Normal OPC	Multiplier
0 bias Shotcount	14198	2341	***6.1***
2nm bias shotcount	18656	2351	***7.9***
Mulitplier	***1.3***	***1.0***	

E-beam Shot Count Projections for 22 nm and 14 nm

- Key Variables
  - Density scaling per node (2x)
  - Impact of normal OPC (1.5x)
    - Increase use of SRAFs, jogs
  - Impact of inverse lithography techniques (3x-10x)
    - Heavy use of “ideal” curvilinear shapes
    - Manhattenization of curvilinear shapes leads to huge increase in shot count.
  - Impact of double patterning:
    - Impact on shot count will be very small (10% or less).
  - E-beam resist sensitivity:
    - Higher dose e-beam resists may be needed to meet mask CD uniformity , resolution, and pattern fidelity reqts.
    - Shot count will double if e-beam resist dose reqt. is too large (2 pass→ 4 pass print)

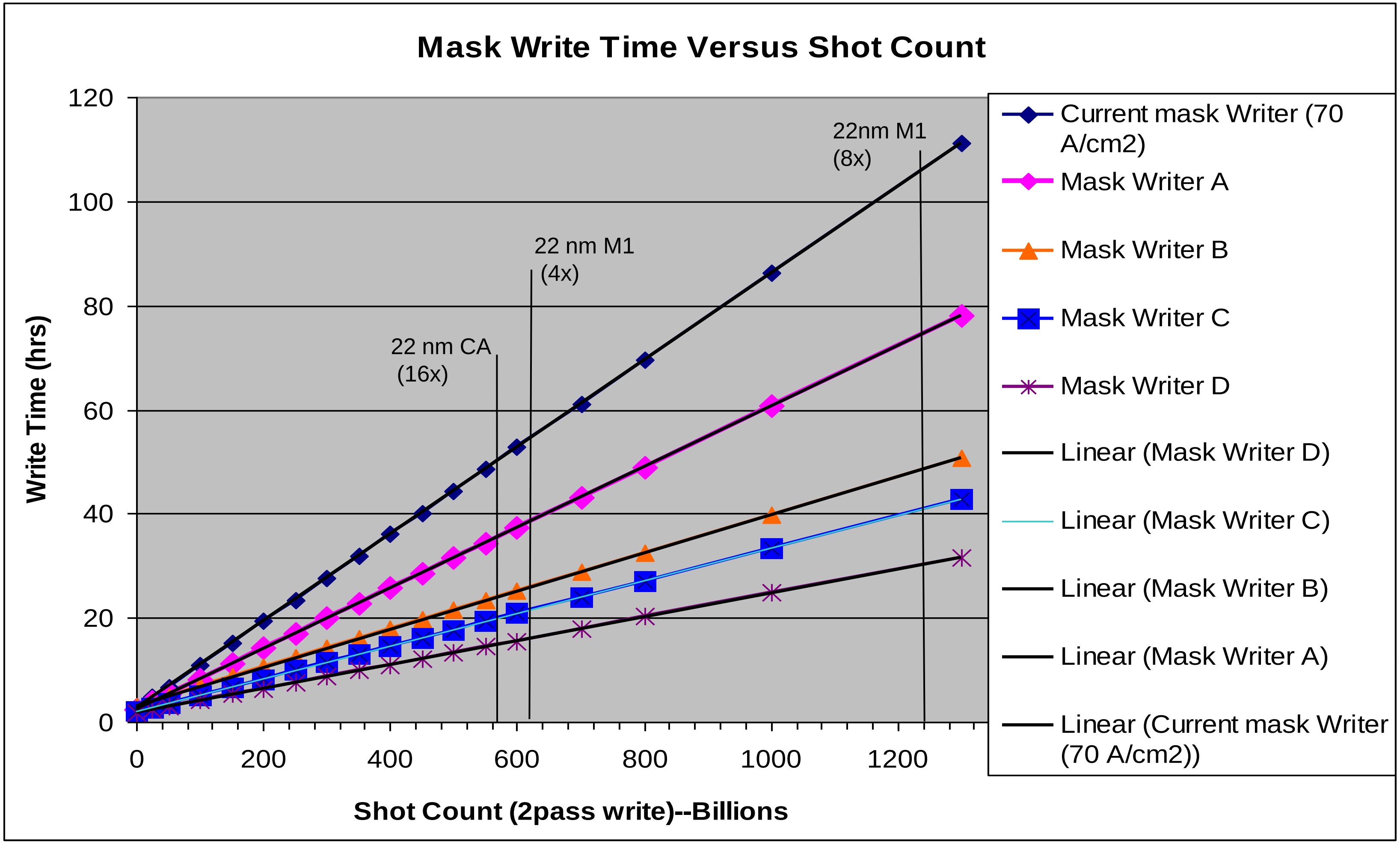
E-beam Shot Count Estimates by Node
(note: all shot count numbers = billions)

Node	M1 actual	M1 (2x scaling per node)	M1 (4x)	M1 (8x)
14		620	2480	9920
22		310	620	1240
32	155			
45	70			

Node	CA actual	CA (2x scaling)	CA (8x)	CA (16x)
14		142	2272	9088
22		71	284	568
32	35.5			
45	7.3			

E-beam Write Time Projections for 22 nm and 14 nm

- Throughput of Advanced E-beam Writers (2 pass e-beam write)
  - Write times exceeding 24 hours will occur even on the most advanced writers.
  - Many 22 nm and 14 nm masks will have write times of 18 hrs.
    - Current 32 nm mask set write times = 4-5 hrs for contact/via masks and 10 hours for metal masks.
  - Further improvement in mask writer thruput is needed for 22 nm and 14 nm manufacturing.

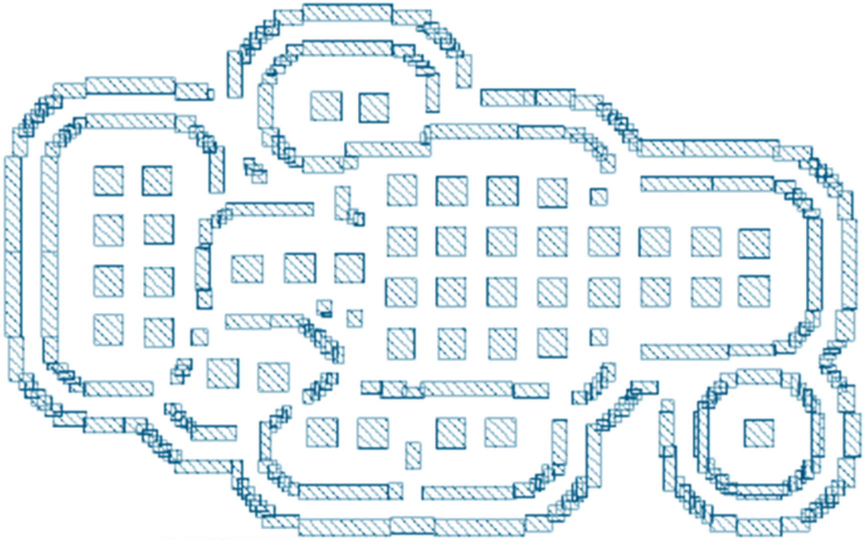


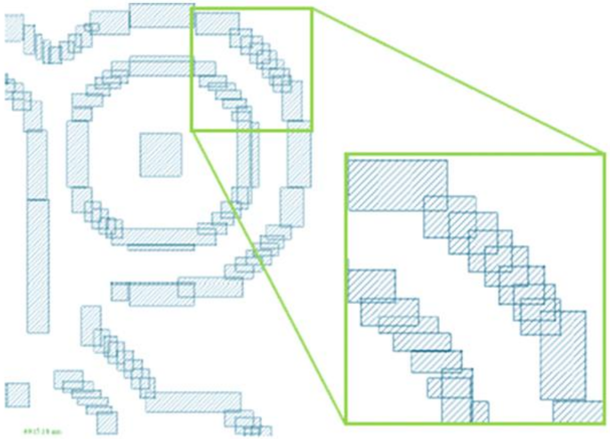
Methods to Reduce Write Time: Software Approaches

- Changes to Mask data prep to enable improved write time required:
  - Mask data prep needs to match OPC intent.
    - Need freedom to move vertices → historically this has not been permitted.
    - Analogous to how OPC shifts vertices but matches design intent.
  - New approaches proposed by D2S, Mentor , and others rely on moving vertices in mask data prep but result in final mask that matches intent of OPC.
  - E-beam tool makers need to support new mask data prep approaches:
    - Overlapping shots
    - Dose modulation per shot.
    - Different exposure pattern per pass.
    - Curvilinear shapes
      - Circular, L shot, triangular apertures.

Methods to Reduce Write Time: Software Approaches

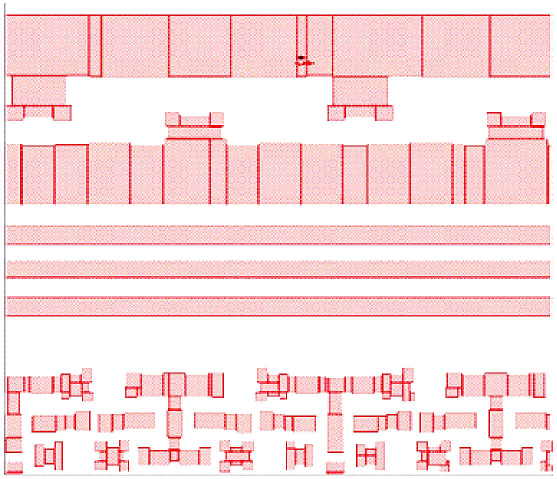
- D2S
  - Model -based mask data prep[1]
    - Conventional fracture= 620 shots
    - D2S MB-MDP= 402 shots



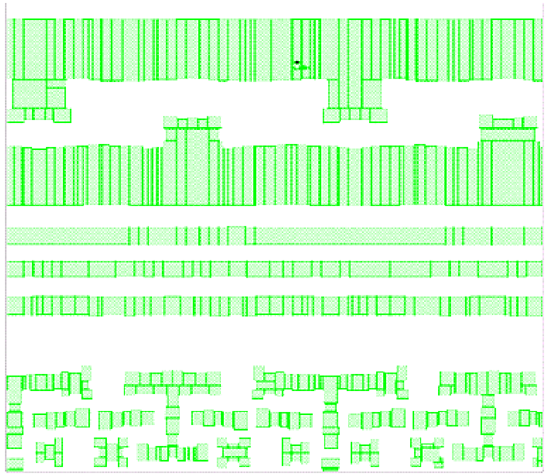


1.. A. Fujimura et al. “Writing 32 nm-hp Contacts with Curvilinear Assist Features”, Proc. SPIE, 7823 (2010)”

- Mentor
  - Multiresolution mask data prep[2]
    - Different shot count complexity per write pass.



Core



Detail

2. E. Sahouria, “Multiresolution Mask Writing “, EMLC 2011”

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