International Technology Roadmap for Semiconductors

2000 Update

Lithography

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LITHOGRAPHY WORKING GROUP 2000 UPDATE

SUMMARY

In preparing the update for year 2000, the Lithography ITWG could not reach consensus on the Technology Node Timing and the resulting Lithography Requirement. Three proposals were made since the July 11th ITRS meeting:

1. The IRC proposal (ORTC Revision 1 ke, 7/28/00) in the August 18th e-Bulletin.
2. The US Lithography TWG proposal in John Canning's email of 9/1/00
3. The Japan Lithography TWG proposal in Sasago-san's email of 9/28/00

To resolve this issue, the Lithography ITWGs were asked to recommend one of the three proposals. The resulting vote was: two votes for proposal #2, one vote for proposal #3, and two abstentions. The following Lithography Requirements (Tables 39, 40, and 41) are based on proposal #2. Although we did not reach consensus for year 2000, the possibility of achieving consensus for year 2001 is much greater, since proposals #2 and #3 are identical as the starting point of the 2001 ITRS Update process.

The Lithography Requirements in tables 39, 40, and 41 are based on the primary nodes given in proposal #1 (180nm/1999, 130nm/2001, 90nm/2004, 65nm/2007, 45nm/2010, and 33nm/2013). The methodology used was to derive all key lithography parameters from the DRAM half-pitch, since it is the most difficult lithography parameter.

1. The input frm our chip maker companies indicates that the MPU half-pitch should lag the DRAM half-pitch by only one year, not two years as proposed in Rev 1 ke.
2. The MPU gate length in resist has traditionally been 70% of the DRAM half-pitch. 1999 was an exception (~65%) when we could not accelerate the DRAM half-pitch. We went back to the 70% value across the entire time frame and not the 80% values as in Rev 1 ke.
3. The MPU physical gate length (post-etch) should lead the MPU gate-length in resist by one year.
4. For our use in the Lithography Tables 39a and 39b we will target contacts for both DRAM and MPU to lag the DRAM half-pitch by one year (or equal to the MPU half-pitch).

For Minimum Field Size the requirement was reduced from 800mm squared (25x32) to 572mm squared (22x26) starting in year 2004. This change allows the stepper suppliers the option of using larger magnification (5x vs. 4x) in the design of the optical lens. The 572mm squared field size is large enough for two production (year 4) DRAM chips. It should be understood that this requirement is for <u>minimum</u> field sizes. Larger field sizes with possible greater productivity are, of course, highly desirable.

The Mask Requirements were changed consistent with the timing acceleration and the 5x magnification option. Also, the mask error factor (MEF) increases very rapidly at duty ratios below 1:1.5, requiring a much tighter CD uniformity for dense lines in optical masks.

In summary, the key challenges facing Lithography for the ITRS 2000 Update are:

1. The impact of the technology node acceleration on lithography exposure technology and mask making capability.
2. Gate CD control and overlay improvements.
3. The ever tightening mask requirements, especially CD uniformity and image placement.
4. The return on investment (ROI) for lithography suppliers, especially for single node solutions below 90nm.

2000 Update										
Year of Production Technology Node (1999 ITRS)	1999 180 nm	2000	2001	2002 130 nm	2003	2004	2005 100 nm	2008 70 nm	2011 50 nm	2014 35 nm
Year of Production Technology Node (Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)	1999 180 nm	2000	2001 130 nm	2002	2003	2004 90nm	2005	2008 [60 nm]	2011 [40 nm]	2014 [30 nm]

2000 Update Tables

Table 39a Lithography Technology Requirements—Near Term

Year Technology Node	1999 ITRS Sc. 2.0 1999 ITRS Sc. 2.0	1999 1999 180 nm 180 nm	2000 2000	2001 2001 130 nm	2002 2002 130 nm	2003 2003	2004 2004 90 nm	2005 2005 100 nm
DRAM								
Half pitch (nm)	1999 ITRS	180	165	150	130	120	110	100
Half pitch (nm)	Sc. 2.0	180	150	130	115	100	90	80
Contacts (nm)	1999 ITRS	200	185	170	150	145	140	130
Contacts (nm)	Sc. 2.0	200	180	150	130	115	100	90
Overlay (nm, mean + 3 sigma)	1999 ITRS	65	58	52	45	42	38	35
Overlay (nm, mean + 3 sigma)	Sc. 2.0	65	52	45	40	35	31	28
CD control (nm, 3 sigma, post-etch)	1999 ITRS	18	17	15	13	12	11	10
CD control (nm, 3 sigma, post-etch)	Sc. 2.0	18	15	13	11	10	9	8
MPU/ASIC								
Half pitch	1999 ITRS	230	210	180	160	145	130	115
Half pitch	Sc. 2.0	230	180	150	130	115	100	90
Gate length (nm, in resist)	1999 ITRS	140	120	100	90	80	70	65
Gate length (nm, in resist)	Sc. 2.0	140	105	90	80	70	60	55
Gate length (nm, post-etch)	1999 ITRS	140	120	100	90	80	70	65
Gate length (nm, post-etch)	Sc. 2.0	120	90	80	70	60	55	50
Contacts (nm, in resist)	1999 ITRS	230	210	180	160	145	130	115
Contacts (nm, in resist)	Sc. 2.0	230	180	150	130	115	100	90
Gate CD control (nm, 3 sigma, post-etch)	1999 ITRS	14	12	10	9	8	7	6
Gate CD control (nm, 3 sigma, post-etch)	Sc. 2.0	12	9	8	7	6	6	5
Chip Size								
DRAM								
Introduction	1999 ITRS	400	—	438	—	480	—	526
Introduction	Sc. 2.0	400	—	390	—	485	—	454
Production (+4 years)	1999 ITRS	132	—	145	—	159	—	174
Production (+4 years)	Sc. 2.0	131	—	127	—	157	—	147
MPU Cost Performance								
Introduction	1999 ITRS	340	—	340	—	372	—	408
Introduction	Sc. 2.0	340	340	340	356	372	390	408
Production (+ 2 years)	1999 ITRS	170	—	170	—	214	—	235
Production (+ 2 years)	Sc. 2.0	170	170	170	178	186	195	204
MPU High Performance								
Production (+2 years)	1999 ITRS	450	—	450	—	567	—	622
Production (+2 years)	Sc. 2.0	310	310	310	325	340	356	372
ASIC/SoC								
Dependent on design up to the maximum field size at ramp	1999 ITRS	800	800	800	800	800	800	800
Dependent on design up to the maximum field size at ramp	Sc. 2.0	800	800	800	800	800	572	572

** In response to the observed acceleration of the Technology Nodes (TN) represented by DRAM half-pitch, the IRC proposes a new TN called Scenario 2 (SC. 2.0) for the year 2001 Renewal. The subsequent contents of this Table have been tied to update so as to reflect the new TN.*

All the items and/or numericals modified from the 1999 ITRS are highlighted in bold blue text.

2000 Update										
Year of Production *Technology Node* *(1999 ITRS)*	*1999* *180 nm*	*2000*	*2001*	*2002* *130 nm*	*2003*	*2004*	*2005* *100 nm*	*2008* *70 nm*	*2011* *50 nm*	*2014* *35 nm*
Year of Production *Technology Node* ***(Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)***	*1999* *180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 nm]**	2011 **[40 nm]**	2014 **[30 nm]**

Table 39a Lithography Technology Requirements—Near Term (continued)

Year *Technology Node*	***1999 ITRS*** ***SC. 2.0*** ***1999 ITRS*** ***SC. 2.0***	*1999* *1999* *180 nm* *180 nm*	*2000* *2000*	*2001* *2001* *130 nm*	*2002* *2002* *130 nm*	*2003* *2003*	*2004* *2004* *90 nm*	*2005* *2005* *100 nm*
Additional Requirements								
Minimum feature size for development (nm)	**1999 ITRS**	**90**	**80**	**70**	**65**	**55**	**50**	**45**
Minimum feature size for development (nm)	***SC. 2.0***	**90**	***70***	***60***	***55***	***50***	***45***	***40***
Minimum field area (mm^2) DRAM introduction (1 chip)	**1999 ITRS**	**400**	—	**438**	—	**480**	—	**526**
Minimum field area (mm^2) DRAM introduction (1 chip)	***SC. 2.0***	**400**	—	***390***	—	***485***	—	***454***
Minimum field area (mm^2) DRAM production (year 4, 2 chips)	**1999 ITRS**	**264**	—	**290**	—	**318**	—	**348**
Minimum field area (mm^2) DRAM production (year 4, 2 chips)	***SC. 2.0***	***262***	—	***254***	—	***314***	—	***294***
Minimum field area (mm^2) MPU (1 chip)	**1999 ITRS**	**450**	—	**450**	—	**567**	—	**622**
Minimum field size (mm x mm)	***SC. 2.0***	***25 x 32***	***25 x 32***	***25 x 32***	***25 x 32***	***25 x 32***	***22 x 26***	***22 x 26***
Depth of focus (μm)	**1999 ITRS**	**0.7**	**0.7**	**0.7**	**0.6**	**0.6**	**0.6**	**0.5**
Depth of focus (μm)	***SC. 2.0***	**0.7**	**0.7**	***0.6***	**0.6**	***0.5***	***0.5***	**0.5**
Mask size (mm, square optical/diameter non-optical)	**1999 ITRS**	**152**	**152**	**152**	**152**	**152**	**152**	**152/200**
Mask blank size (mm, square) (mm, diameter)	***SC. 2.0***	**152**	**152**	**152**	**152**	**152**	***152***	***152*** ***200***
Wafer size (mm, diameter)	**1999 ITRS**	**200**	**200**	**300**	**300**	**300**	**300**	**300**
Wafer size (mm, diameter)	***SC. 2.0***	**200**	**200**	**300**	**300**	**300**	**300**	**300**

Note: The dates in this table are the year of first product shipment of integrated circuits from a manufacturing site with volume exceeding 10,000 units. Exposure tools, resists and masks for manufacturing must be available one year earlier. Development capability must be available 2–3 years earlier.

Manufacturable Solutions Exist (white) *Manufacturable Solutions Are Known* (yellow) *Manufacturable Solutions Are Not Known* (red)

** In response to the observed acceleration of the Technology Nodes (TN) represented by DRAM half-pitch, the IRC proposes a new TN called Scenario 2 (SC. 2.0) for the year 2001 Renewal. The subsequent contents of this Table have been tied to update so as to reflect the new TN.*

All the items and/or numericals modified from the 1999 ITRS are highlighted in bold blue text.

2000 Update										
Year of Production Technology Node (1999 ITRS)	1999 180 nm	2000	2001	2002 130 nm	2003	2004	2005 100 nm	2008 70 nm	2011 50 nm	2014 35 nm
Year of Production Technology Node (Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)	1999 180 nm	2000	2001 130 nm	2002	2003	2004 90nm	2005	2008 [60 nm]	2011 [40 nm]	2014 [30 nm]

Table 39b Lithography Technology Requirements—Long Term*

Year Technology Node	1999 ITRS Sc. 2.0 1999 ITRS Sc. 2.0	2008 2007 70 nm 65 nm	2011 2010 50 nm 45 nm	2014 2013 35 nm 33 nm
DRAM				
Half pitch (nm)	1999 ITRS	70	50	35
Half pitch (nm)	Sc. 2.0	65	45	33
Contacts (nm)	1999 ITRS	100	70	50
Contacts (nm)	Sc. 2.0	70	50	35
Overlay (nm, mean + 3 sigma)	1999 ITRS	25	20	15
Overlay (nm, mean + 3 sigma)	Sc. 2.0	26	18	13
CD control (nm, 3 sigma, post-etch)	1999 ITRS	7	5	4
CD control (nm, 3 sigma, post-etch)	Sc. 2.0	7	5	3
MPU/ASIC				
Half pitch	1999 ITRS	80	55	40
Half pitch	Sc. 2.0	70	50	35
Gate length (nm, in resist)	1999 ITRS	45	30	20
Gate length (nm, in resist)	Sc. 2.0	45	32	23
Gate length (nm, post-etch)	1999 ITRS	40	30	20
Gate length (nm, post-etch)	Sc. 2.0	40	28	20
Contacts (nm, in resist)	1999 ITRS	80	55	40
Contacts (nm, in resist)	Sc. 2.0	70	50	35
Gate CD control (nm, 3 sigma, post-etch)	1999 ITRS	4	3	2
Gate CD control (nm, 3 sigma, post-etch)	Sc. 2.0	4	3	2
Chip Size (mm^2)				
DRAM				
Introduction	1999 ITRS	—	691	—
Introduction	Sc. 2.0	494	563	429
Production (+4 years)	1999 ITRS	—	229	—
Production (+4 years)	Sc. 2.0	183	256	239
MPU Cost Performance				
Introduction	1999 ITRS	—	536	—
Introduction	Sc. 2.0	447	512	588
Production (+2 years)	1999 ITRS	—	308	—
Production (+2 years)	Sc. 2.0	223	256	294
MPU High Performance				
Production (+2 years)	1999 ITRS	---	817	---
Production (+2 years)	Sc. 2.0	408	467	536
ASIC/SoC				
Dependent on design up to the maximum field size at ramp	1999 ITRS	800	800	800
Dependent on design up to the maximum field size at ramp	Sc. 2.0	572	572	572

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All the items and/or numericals modified from the 1999 ITRS are highlighted in bold blue text.

2000 Update										
Year of Production *Technology Node* (1999 ITRS)	1999 180 nm	2000	2001	2002 130 nm	2003	2004	2005 100 nm	2008 70 nm	2011 50 nm	2014 35 nm
Year of Production *Technology Node* (Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)	1999 180 nm	2000	2001 130 nm	2002	2003	2004 90nm	2005	2008 [60 nm]	2011 [40 nm]	2014 [30 nm]

*Table 39b Lithography Technology Requirements—Long Term (continued)**

Year ***Technology Node***	**1999 ITRS** **Sc. 2.0** **1999 ITRS** **Sc. 2.0**	**2008** **2007** **70 nm** **65 nm**	**2011** **2010** **50 nm** **45 nm**	**2014** **2013** **35 nm** **33 nm**
Additional Requirements				
Minimum feature size for development (nm)	1999 ITRS	33	22	16
Minimum feature size for development (nm)	Sc. 2.0	32	23	16
Minimum field area (mm^2) DRAM introduction (1 chip)	1999 ITRS	---	691	---
Minimum field area (mm^2) DRAM introduction (1 chip)	Sc. 2.0	494	563	429
Minimum field area (mm^2) DRAM production (year 4, 2 chips)	1999 ITRS	---	458	---
Minimum field area (mm^2) DRAM production (year 4, 2 chips)	Sc. 2.0	366	512	478
Minimum field area (mm^2) MPU (1 chip)	1999 ITRS	---	817	---
Minimum field size (mm x mm)	Sc. 2.0	22 x 26	22 x 26	22 x 26
Depth of focus (µm)	1999 ITRS	0.5	0.5	0.5
Depth of focus (µm)	Sc. 2.0	0.5	0.5	0.5
Mask size (mm, square optical/diameter non-optical)	1999 ITRS	152/200	152/200	152/200
Mask blank size (mm, square) (mm, diameter)	Sc. 2.0	152 200	152 200	152 200
Wafer size (mm, diameter)	1999 ITRS	300	450	450
Wafer size (mm, diameter)	Sc. 2.0	300	450	450

Note: The dates in this table are the year of first product shipment of integrated circuits from a manufacturing site with volume exceeding 10,000 units. Exposure tools, resists and masks for manufacturing must be available one year earlier. Development capability must be available 2–3 years earlier.

Manufacturable Solutions Exist (white) *Manufacturable Solutions Are Known* (yellow) *Manufacturable Solutions Are Not Known* (red)

** In response to the observed acceleration of the Technology Nodes (TN) represented by DRAM half-pitch, the IRC proposes a new TN called Scenario 2 (SC. 2.0) for the year 2001 Renewal. The subsequent contents of this Table have been tied to update so as to reflect the new TN.*

All the items and/or numericals modified from the 1999 ITRS are highlighted in bold blue text.

2000 Update										
Year of Production *Technology Node* *(1999 ITRS)*	*1999* *180 nm*	*2000*	*2001*	*2002* *130 nm*	*2003*	*2004*	*2005* *100 nm*	*2008* *70 nm*	*2011* *50 nm*	*2014* *35 nm*
Year of Production *Technology Node* ***(Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)***	*1999* *180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 nm]**	2011 **[40 nm]**	2014 **[30 nm]**

*Table 40a Resist Requirements—Near Term**

Year ***Technology Node***	***1999 ITRS*** ***Sc. 2.0*** ***1999 ITRS*** ***Sc. 2.0***	***1999*** ***1999*** ***180 nm*** ***180 nm***	***2000*** ***2000***	***2001*** ***2001*** ***130 nm***	***2002*** ***2002*** ***130 nm***	***2003*** ***2003***	***2004*** ***2004*** ***90 nm***	***2005*** ***2005*** ***100 nm***
Resist meets lithography requirements for resolution and CD control (nm, 3 sigma)	1999 ITRS	13	11	9	8	7	7	6
Resist meets lithography requirements for resolution and CD control (nm, 3 sigma)	*Sc. 2.0*	*12*	*9*	*8*	*7*	*6*	*6*	*5*
Resist thickness (μm, imaging	1999 ITRS	0.54-0.72	0.50-0.66	0.45-0.60	0.39-0.52	0.36-0.48	0.33-0.44	0.3-0.4
Resist thickness (μm, imaging	*Sc. 2.0*	0.54–0.72	*0.45-0.60*	*0.39-0.52*	*0.35-0.46*	*0.30-0.40*	*0.27-0.36*	*0.24-0.32*
Ultra thin resist thickness	1999 ITRS	—	—	—	—	0.15–0.10	0.15–0.10	0.15–0.10
Ultra thin resist thickness	*Sc. 2.0*					0.15–0.10	0.15–0.10	0.15–0.10
Post-exposure bake sensitivity	1999 ITRS	5	4	4	3	3	2	2
Post-exposure bake sensitivity	*Sc. 2.0*	5	4	4	*3*	3	2	2
Backside particles (particles/m^2 @ critical size, nm)	1999 ITRS	3000 @ 200	3000 @ 200	2500 @ 200	2000 @ 200	2000 @ 200	2000 @ 200	2000 @ 100
Backside particles (particles/m^2 @ critical size, nm)	*Sc. 2.0*	3000 @ 200	3000 @ 200	*2500 @ 200*	2000 @ 200	2000 @ 200	2000 @ 200	2000 @ 100
Other requirements	- Need for positive or negative resist will depend on the critical feature density - Slope should be 90 +0–2 degrees - Thermal stability should be in the range of 130–150ºC - Etch selectivity should be comparable to or exceed polyhydroxystyrene (PHOST) - Strippability with no detectable residues - Airborne amine contamination ≤ 1000 pptM - Ionic/metal contaminants ≤ 5 ppb							

** In response to the observed acceleration of the Technology Nodes (TN) represented by DRAM half-pitch, the IRC proposes a new TN called Scenario 2 (SC. 2.0) for the year 2001 Renewal. The subsequent contents of this Table have been tied to update so as to reflect the new TN.*

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2000 Update										
Year of Production *Technology Node* *(1999 ITRS)*	*1999* *180 nm*	*2000*	*2001*	*2002* *130 nm*	*2003*	*2004*	*2005* *100 nm*	*2008* *70 nm*	*2011* *50 nm*	*2014* *35 nm*
Year of Production *Technology Node* ***(Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)***	*1999* *180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 nm]**	2011 **[40 nm]**	2014 **[30 nm]**

*Table 40b Resist Requirements—Long Term**

Year ***Technology Node***	***1999 ITRS*** ***Sc. 2.0*** ***1999 ITRS*** ***Sc. 2.0***	***2008*** ***2007*** ***70 nm*** ***65 nm***	***2011*** ***2010*** ***50 nm*** ***45 nm***	***2014*** ***2013*** ***35 nm*** ***33 nm***
Resist meets lithography requirements for resolution and CD control (nm, 3 sigma)	1999 ITRS	4	3	2
Resist meets lithography requirements for resolution and CD control	*Sc. 2.0*	4	3	2
Resist thickness (µm, imaging layer)*	1999 ITRS	0.21–0.28	0.15–0.20	0.11–0.14
Resist thickness (µm, imaging layer)*	*Sc. 2.0*	*0.20-0.26*	*0.14-0.18*	*0.10-0.13*
Ultra thin resist thickness (µm)**	1999 ITRS	0.15–0.10	0.15–0.10	0.15–0.10
Ultra thin resist thickness (µm)**	*Sc. 2.0*	0.15–0.10	0.15–0.10	0.15–0.10
Post-exposure bake sensitivity (nm/°C)	1999 ITRS	2	1	1
Post-exposure bake sensitivity (nm/°C)	*Sc. 2.0*	2	1	1
Backside particles (particles/m² @ critical size, nm)	1999 ITRS	2000 @ 100	2000 @ 100	2000 @ 100
Backside particles (particles/m² @ critical size, nm)	*Sc. 2.0*	2000 @ 100	2000 @ 100	2000 @ 100
Other Requirements	- Need for positive or negative resist will depend on the critical feature density - Slope should be 90 +0–2 degrees - Thermal stability should be in the range of 130–150ºC - Etch selectivity should be comparable to or exceed polyhydroxystyrene (PHOST) - Strippability with no detectable residues - Airborne amine contamination ≤ 1000 pptM - Ionic/metal contaminants ≤ 5 ppb			

Manufacturable Solutions Exist [white] *Manufacturable Solutions Are Known* [yellow] *Manufacturable Solutions Are Not Known* [red]

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Year of Production *Technology Node* ***(Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)***	*1999* *180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 NM]**	2011 **[40 NM]**	2014 **[30 NM]**

*Tables 40 a & b(continued)**

Exposure Dependent Requirements

Exposure technology	***STATUS***	***Sensitivity***
248 nm	**1999 ITRS**	**20–50 mJ/cm²**
248 nm	***SC. 2.0***	**20–50 mJ/cm²**
193 nm	**1999 ITRS**	**10-20 mJ/cm²**
193 nm	***SC. 2.0***	***10-20 mJ/cm²***
157 nm	**1999 ITRS**	**- 10 mJ/cm2**
157 nm	***SC. 2.0***	***5-10 mJ/cm²***
X-Ray	**1999 ITRS**	**50 mJ/cm²**
X-Ray	***SC. 2.0***	***50 mJ/cm²***
Extreme ultraviolet	**1999 ITRS**	**5–10 mJ/cm2**
Extreme ultraviolet	***SC. 2.0***	***5-10 mJ/cm²***
E-beam projection	**1999 ITRS**	**5–10 µC/cm² @ 100 kV*****
E-beam projection	***SC. 2.0***	***5-10 µC/cm² @ 100 kV******
E-beam direct write	**1999 ITRS**	**1–5 µC/cm² @ 50 kV*****
E-beam direct write	***SC. 2.0***	***1-5 µC/cm² @ 50 kV******
Ion-beam projection	**1999 ITRS**	**0.2–2.0 µC/cm²**
Ion-beam projection	***SC. 2.0***	**0.2–2.0 µC/cm²**

* *Resist thickness determined by aspect ratio range of 3:1 to 4:1.*
** *Lower limit for ultra thin resist (UTR) determined by opacity to exposure source.*
*** *Linked with resolution.*

Manufacturable Solutions Exist (white) *Manufacturable Solutions Are Known* (yellow) *Manufacturable Solutions Are Not Known* (red)

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2000 Update										
Year of Production *Technology Node* ***(1999 ITRS)***	*1999* *180 nm*	*2000*	*2001*	*2002* *130 nm*	*2003*	*2004*	*2005* *100 nm*	*2008* *70 nm*	*2011* *50 nm*	*2014* *35 nm*
Year of Production *Technology Node* ***(Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)***	*1999* *180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 nm]**	2011 **[40 nm]**	2014 **[30 nm]**

*Table 41a Mask Requirements—Near Term**

Year ***Technology Node***	***1999 ITRS*** ***SC. 2.0*** ***1999 ITRS*** ***SC. 2.0***	***1999*** ***1999*** ***180 nm*** ***180 nm***	***2000*** ***2000***	***2001*** ***2001*** ***130 nm***	***2002*** ***2002*** ***130 nm***	***2003*** ***2003***	***2004*** ***2004*** ***90 nm***	***2005*** ***2005*** ***100 nm***			
Wafer minimum half pitch (nm) [A]	1999 ITRS	180	165	150	130	120	110	100			
Wafer minimum half pitch (nm) [A]	***SC. 2.0***	180	***150***	***130***	***115***	***100***	***90***	***80***			
Wafer minimum isolated line (nm, in resist) (A)	1999 ITRS	140	120	100	90	80	70	65			
Wafer minimum isolated line (nm, in resist) (A)	***SC. 2.0***	140	***105***	***90***	***80***	***70***	***60***	***55***			
Wafer minimum contact hole (nm, in resist)	1999 ITRS	200	185	170	150	145	130	115			
Wafer minimum contact hole (nm, in resist)	***SC. 2.0***	200	***180***	***150***	***130***	***115***	***100***	***90***			
Wafer overlay (nm, mean + 3 sigma)	1999 ITRS	65	58	52	45	42	38	35			
Wafer overlay (nm, mean + 3 sigma)	***SC. 2.0***	65	***52***	***45***	***40***	***35***	***31***	***28***			
Lithography technology		Optical	Optical	Optical	Optical	Optical	Optical	Optical		NGL	XRL
Magnification [B]	1999 ITRS	4	4	4	4	4	4	≥4		≥4	1
Magnification [B]	***SC. 2.0***	4	4	4	4	4	4	***4***	***5***	≥4	1
Mask minimum image size (nm) [C]	1999 ITRS	560	480	400	360	320	280	260		260	65
Mask minimum image size (nm) [C]	***SC. 2.0***	560	***420***	***360***	***320***	***280***	***240***	***220***	***275***	***220***	***55***
Mask OPC feature size (nm) [D]	1999 ITRS	280	240	200	180	160	140	130		---	---
Mask OPC feature size (nm) [D]	***SC. 2.0***	***360***	***300***	***260***	***230***	***200***	***180***	***160***	***200***	—	---
Image placement (nm, multi-point) [E]	1999 ITRS	39	35	31	27	25	23	21		21	10
Image placement (nm, multi-point) [E]	***SC. 2.0***	39	***31***	***27***	***24***	***21***	***19***	***17***	***21***	***17***	***12***

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All the items and/or numericals modified from the 1999 ITRS are highlighted in bold blue text.

2000 Update										
Year of Production *Technology Node* (1999 ITRS)	*1999* *180 nm*	*2000*	*2001*	*2002* *130 nm*	*2003*	*2004*	*2005* *100 nm*	*2008* *70 nm*	*2011* *50 nm*	*2014* *35 nm*
Year of Production *Technology Node* (Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)	*1999* *180 nm*	*2000*	*2001* **130 nm**	*2002*	*2003*	*2004* **90nm**	*2005*	2008 **[60 nm]**	2011 **[40 nm]**	2014 **[30 nm]**

*Table 41a Mask Requirements—Near Term (continued)**

Year ***Technology Node***	***1999 ITRS*** ***Sc. 2.0*** ***1999 ITRS*** ***Sc. 2.0***	***1999*** ***1999*** ***180 nm*** ***180 nm***	***2000*** ***2000***	***2001*** ***2001*** ***130 nm***	***2002*** ***2002*** ***130 nm***	***2003*** ***2003***	***2004*** ***2004*** ***90 nm***	***2005*** ***2005*** ***100 nm***			
CD uniformity (nm, 3 sigma) [F]											
Isolated lines (MPU gates)	1999 ITRS	16	14	12	10/20*	9/18*	8/16*	7/14*		10	6
Isolated lines (MPU gates)	Sc. 2.0	16	12	10 20*	9 18*	8 16*	7 14*	6 12*	7 14*	10	6
Dense lines (DRAM half pitch)	1999 ITRS	24	21	17	13/26*	12/24*	11/22*	10/20*		16	8
Dense lines (DRAM half pitch)	Sc. 2.0	24	17	13	11	10	9	8	10	13	10
Contact/vias	1999 ITRS	24	21	17	14	13	12	11		18	9
Contact/vias	Sc. 2.0	24	17	14	13	12	11	10	12	14	8
Linearity (nm) [G]	1999 ITRS	28	26	23	20	18	16	14		14	6
Linearity (nm) [G]	Sc. 2.0	27	23	20	17	15	14	12	15	12	5
CD mean to target (nm) [H]	1999 ITRS	14	13	12	10	9	9	8			3
CD mean to target (nm) [H]	Sc. 2.0	14	12	10	9	8	7	6	8	6	3
Defect size (nm) [I]	1999 ITRS	144	132	120	104	96	88	80			26
Defect size (nm) [I]	Sc. 2.0	144	120	104	92	80	72	64	80	64	25
Data volume (GB) [J]	1999 ITRS	16	24	40	64	100	160	256			129
Data volume (GB) [J]	Sc. 2.0	16	32	64	96	144	216	324	324	216	64
Mask design grid (nm) [K]	1999 ITRS	10	10	10	8	8	8	4			1
Mask design grid (nm) [K]	Sc. 2.0	10	10	8	8	4	4	4			1

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All the items and/or numericals modified from the 1999 ITRS are highlighted in bold blue text.

2000 Update										
Year of Production *Technology Node* *(1999 ITRS)*	*1999* *180 nm*	*2000*	*2001*	*2002* *130 nm*	*2003*	*2004*	*2005* *100 nm*	*2008* *70 nm*	*2011* *50 nm*	*2014* *35 nm*
Year of Production *Technology Node* ***(Proposed Node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)***	*1999* *180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 nm]**	2011 **[40 nm]**	2014 **[30 nm]**

*Table 41a Mask Requirements—Near Term (continued)**

Year ***Technology Node***	***1999 ITRS*** ***Sc. 2.0*** ***1999 ITRS*** ***Sc. 2.0***	***1999*** ***1999*** ***180 nm*** ***180 nm***	***2000*** ***2000***	***2001*** ***2001*** ***130 nm***	***2002*** ***2002*** ***130 nm***	***2003*** ***2003***	***2004*** ***2004*** ***90 nm***	***2005*** ***2005*** ***100 nm***		
Lithography technology		Optical	Optical	Optical	Optical	Optical	Optical	Optical	NGL	XRL
Attenuated PSM transmission mean Deviation from target (+/– % of target) [L]	1999 ITRS	6	6	5	5	5	5	5	—	---
Attenuated PSM transmission mean Deviation from target (+/– % of target) [L]	***Sc. 2.0***	6	***5***	5	5	5	5	5	---	---
Attenuated PSM transmission uniformity (+/– % of target) [M]	1999 ITRS	4	4	4	4	4	4	4	—	---
Attenuated PSM transmission uniformity (+/– % of target) [M]	***Sc. 2.0***	4	4	***4***	4	4	4	4	---	---
Attenuated PSM phase mean deviation from 180° (+/– degree)	1999 ITRS	5	5	5	5	4	4	3	—	
Attenuated PSM phase mean deviation from 180° (+/– degree)	***Sc. 2.0***	5	5	***4***	***4***	***3***	***3***	3	---	---
Attenuated PSM phase uniformity (+/– degree)	1999 ITRS	2	2	2	2	2	2	2	—	
Attenuated PSM phase uniformity (+/– degree)	***Sc. 2.0***	2	2	***2***	2	2	2	2	---	---
Alternating PSM phase mean deviation from 180° (+/– degree)	1999 ITRS	—	—	—	2	2	2	2	—	
Alternating PSM phase mean deviation from 180° (+/– degree)	***Sc. 2.0***	---	---	***2***	2	2	2	2	---	---
Alternating PSM phase uniformity (+/– degree)	1999 ITRS	—	—	—	2	2	2	2	—	
Alternating PSM phase uniformity (+/– degree)	***Sc. 2.0***	---	---	***2***	2	2	2	2	---	---
Mask materials and substrates (Exposure tool dependent)		**Optical** - Absorber on fused silica, except for 157 nm optical which will be absorber on modified fused silica square with pellicles - Primary PSM choices are attenuated shifter and alternating aperture **X-Ray** - Refactory metal on Si Carbide Membrane (100 mm diameter) - "Pellicle" definition required **E-Beam Projection** - Refractory metal scatterer on strutted SiN_x membrane (200 mm diameter) - "Pellicle" definition required **EUV** - Absorber on multilayer reflector substrate (152 mm square) - "Pellicle" definition required **Ion Projection** - Carbon coated silicon membrane stencil mask (200 mm diameter) - "Pellicle" definition required								

Note: The requirements are for critical layers at defined year. Early volumes are assumed to be relatively small and difficult to produce.
** The second number applies to alternating PSM only. Delta between NGL and Optical is due to optical MEF at low k*

Manufacturable Solutions Exist [white] *Manufacturable Solutions Are Known* [yellow] *Manufacturable Solutions Are Not Known* [red]

** In response to the observed acceleration of the Technology Nodes (TN) represented by DRAM half-pitch, the IRC proposes a new TN called Scenario 2 (SC. 2.0) for the year 2001 Renewal. The subsequent contents of this Table have been tied to update so as to reflect the new TN.*

All the items and/or numericals modified from the 1999 ITRS are highlighted in bold blue text.

2000 Update										
Year of Production *Technology Node* ***(1999 ITRS)***	*1999* *180 nm*	*2000*	*2001*	*2002* *130 nm*	*2003*	*2004*	*2005* *100 nm*	*2008* *70 nm*	*2011* *50 nm*	*2014* *35 nm*
Year of Production *Technology Node* ***(Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)***	*1999* *180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 nm]**	2011 **[40 nm]**	2014 **[30 nm]**

*Table 41b Mask Requirements—Long Term**

Year ***Technology Node***	***1999 ITRS*** ***Sc. 2.0*** ***1999 ITRS*** ***Sc. 2.0***	***2008*** ***2007*** ***70 nm*** ***65 nm***				***2011*** ***2010*** ***50 nm*** ***45 nm***	***2014*** ***2013*** ***35 nm*** ***33 nm***
Wafer minimum half pitch (nm) [A]	1999 ITRS	70				50	35
Wafer minimum half pitch (nm) [A]	*Sc. 2.0*	*65*				*45*	*33*
Wafer minimum isolated line (nm, in resist) [A]	1999 ITRS	45				30	20
Wafer minimum isolated line (nm, in resist) [A]	*Sc. 2.0*	45				*32*	*23*
Wafer minimum contact hole (nm, in resist)	1999 ITRS	80				55	40
Wafer minimum contact hole (nm, in resist)	*Sc. 2.0*	*70*				*50*	*35*
Wafer overlay (nm, mean + 3 sigma)	1999 ITRS	25				20	15
Wafer overlay (nm, mean + 3 sigma)	*Sc. 2.0*	*26*				*18*	*13*
Lithography technology		Optical		NGL	NGL	NGL	NGL
Magnification [B]	1999 ITRS	≥4		≥4	1	≥4	≥4
Magnification [B]	*Sc. 2.0*	*4*	*5*	≥4	1	≥4	≥4
Mask minimum image size (nm) [C]	1999 ITRS	180		180	45	120	80
Mask minimum image size (nm) [C]	*Sc. 2.0*	*180*	*225*	180	45	*128*	*92*
Mask OPC feature size (nm) [D]	1999 ITRS	90		---	---	---	---
Mask OPC feature size (nm) [D]	*Sc. 2.0*	*130*	*163*	—	---	—	—
Image placement (nm, multi-point) [E]	1999 ITRS	15		15	10	12	9
Image placement (nm, multi-point) [E]7	*Sc. 2.0*	*15*	*19*	15	10	*11*	*8*
CD uniformity (nm, 3 sigma) [F]							
Isolated lines (MPU gates)	1999 ITRS	10*		7	6	5	3
Isolated lines (MPU gates)	*Sc. 2.0*	*9**	*11**	7	*5*	5	*4*
Dense lines (DRAM half pitch)	1999 ITRS	14*		11	8	8	5.6
Dense lines (DRAM half pitch)	*Sc. 2.0*	*6*	*8*	*10*	*9*	*7*	*5*
Contact/vias	1999 ITRS	8		12	9	9	6.4
Contact/vias	*Sc. 2.0*	*7*	*9*	*11*	*6*	*8*	*6*
Linearity (nm) [G]	1999 ITRS	10			6	7	5
Linearity (nm) [G]	*Sc. 2.0*	*10*	*12*	*10*	*4*	7	5
CD mean to target (nm) [H]	1999 ITRS	6			3	5	4
CD mean to target (nm) [H]	*Sc. 2.0*	*5*	*7*	*5*	*2*	*4*	*3*
Defect size (nm) [I]	1999 ITRS	55			20	40	28
Defect size (nm) [I]	*Sc. 2.0*	*52*	*65*	*52*	20	*36*	*26*
Data volume (GB) [J]	1999 ITRS	1024			128	2048	8196
Data volume (GB) [J]	*Sc. 2.0*	*729*	*729*	*486*	*256*	*2460*	*8304*
Mask design grid (nm) [K]	1999 ITRS	4			1	4	4
Mask design grid (nm) [K]	*Sc. 2.0*	*4*	*5*	*4*	1	4	4

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All the items and/or numericals modified from the 1999 ITRS are highlighted in bold blue text.

2000 Update										
Year of Production Technology Node (1999 ITRS)	1999 180 nm	2000	2001	2002 130 nm	2003	2004	2005 100 nm	2008 70 nm	2011 50 nm	2014 35 nm
Year of Production Technology Node (Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)	1999 180 nm	2000	2001 **130 nm**	2002	2003	2004 **90nm**	2005	2008 **[60 nm]**	2011 **[40 nm]**	2014 **[30 nm]**

*Table 41b Mask Requirements—Long Term (continued)**

Year *Technology Node*	*1999 ITRS* *Sc. 2.0* *1999 ITRS* *Sc. 2.0*	*2008* *2007* *70 nm* *65 nm*			*2011* *2010* *50 nm* *45 nm*	*2014* *2013* *35 nm* *33 nm*
Lithography technology		Optical 4X	Optical 5X	NGL	NGL	NGL
Attenuated PSM transmission mean deviation from target (+/− % of target) [L]	1999 ITRS	4		---	—	—
Attenuated PSM transmission mean deviation from target (+/− % of target) [L]	Sc. 2.0	4	4	---	---	---
Attenuated PSM transmission uniformity (+/− % of target) [M]	1999 ITRS	4		---	—	—
Attenuated PSM transmission uniformity (+/− % of target) [M]	Sc. 2.0	4	4	---		
Attenuated PSM phase mean deviation from 180° (+/− degree)	1999 ITRS	3		---	—	—
Attenuated PSM phase mean deviation from 180° (+/− degree)	Sc. 2.0	3	3	---	---	---
Attenuated PSM phase uniformity (+/− degree)	1999 ITRS	2		---	—	—
Attenuated PSM phase uniformity (+/− degree)	Sc. 2.0	2	2	---	---	---
Alternating PSM phase mean deviation from 180° (+/− degree)	1999 ITRS	1		---	—	—
Alternating PSM phase mean deviation from 180° (+/− degree)	Sc. 2.0	1	1	---	---	---
Alternating PSM phase uniformity (+/− degree)	1999 ITRS	1		---	—	—
Alternating PSM phase uniformity (+/− degree)	Sc. 2.0	1	1	---	---	---

Mask materials and substrates (exposure tool dependent)		
	Optical	- Absorber on fused silica, except for 157 nm optical which will be absorber on modified fused silica square with pellicles - Primary PSM choices are attenuated shifter and alternating aperture
	X-Ray	- Refactory metal on Si Carbide Membrane (100 mm diameter) - "Pellicle" definition required
	E-Beam Projection	- Refractory metal scatterer on strutted SiN_x membrane (200 mm diameter) - "Pellicle" definition required
	EUV	- Absorber on multilayer reflector substrate (152 mm square) - "Pellicle" definition required
	Ion Projection	- Carbon coated silicon membrane stencil mask (200 mm diameter) - "Pellicle" definition required

Note: The requirements are for critical layers at defined year. Early volumes are assumed to be relatively small and difficult to produce.

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