SEMI® INTERNATIONAL STANDARDS

New Edge Profile Specification Format in SEMI M1

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semi

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Introduction (1)

- SEMI M1 was the first SEMI standard generated in the 1970‘s
- It was revised repeatedly in parallel to the progressing design rules for semiconductor devices and Si wafers
- In the past ~10 years specifications for edges or near edge regions of wafers got increasing attention

Introduction (2)

- This was driven by realizing that
  - several IC manufacturing processes are sensitive to specific edge profile (EP) parameters, and
  - variations of the shape of the edge profile may have a major impact on process yield of IC's

Current SEMI M1

- Two formats for specifying EP
  - Template-Coordinate based specification („Old“ Template)
  - Profile-Parameter based specifications
    - Parameters +/- tolerances: P&T
    - „New“ Template: NT

Template-Coordinate Based Specification

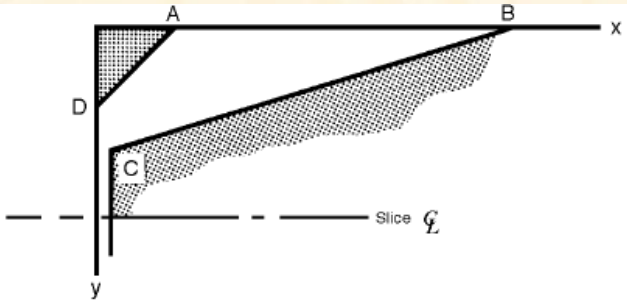


Figure 6
SEMI Wafer Edge Profile Template

Table 3 Wafer Edge Profile Template Coordinates (See Figure 6)

T/3 Wafer Edge Profile Template

Point	$x^{\#1}$		$y^{\#1}$	
A	0.0030 in.	76 µm	0.00 in.	0 µm
B	0.0200 in.	508 µm	0.00 in.	0 µm
C	0.0020 in.	50 µm	T/3[#2]	
D	0.00 in.	0 µm	0.0030 in.	76 µm

T/4 Wafer Edge Profile Template

Point	$x^{\#1}$		$y^{\#1}$	
A	0.0047 in.	120 µm	0.00 in.	0 µm
B	0.0200 in.	508 µm	0.00 in.	0 µm
C	0.0040 in.	100 µm	T/4[#2]	
D	0.00 in.	0 µm	0.0020 in.	50 µm

#1 For referee purposes, U.S. Customary units are to be used for 2 and 3 in. diameter wafers SI units are to be used for all other wafers.
#2 For the value of this coordinate, see the specifications for the appropriate wafer category in Tables 4–9.

Template-Coordinate Based Specification

acceptable

acceptable

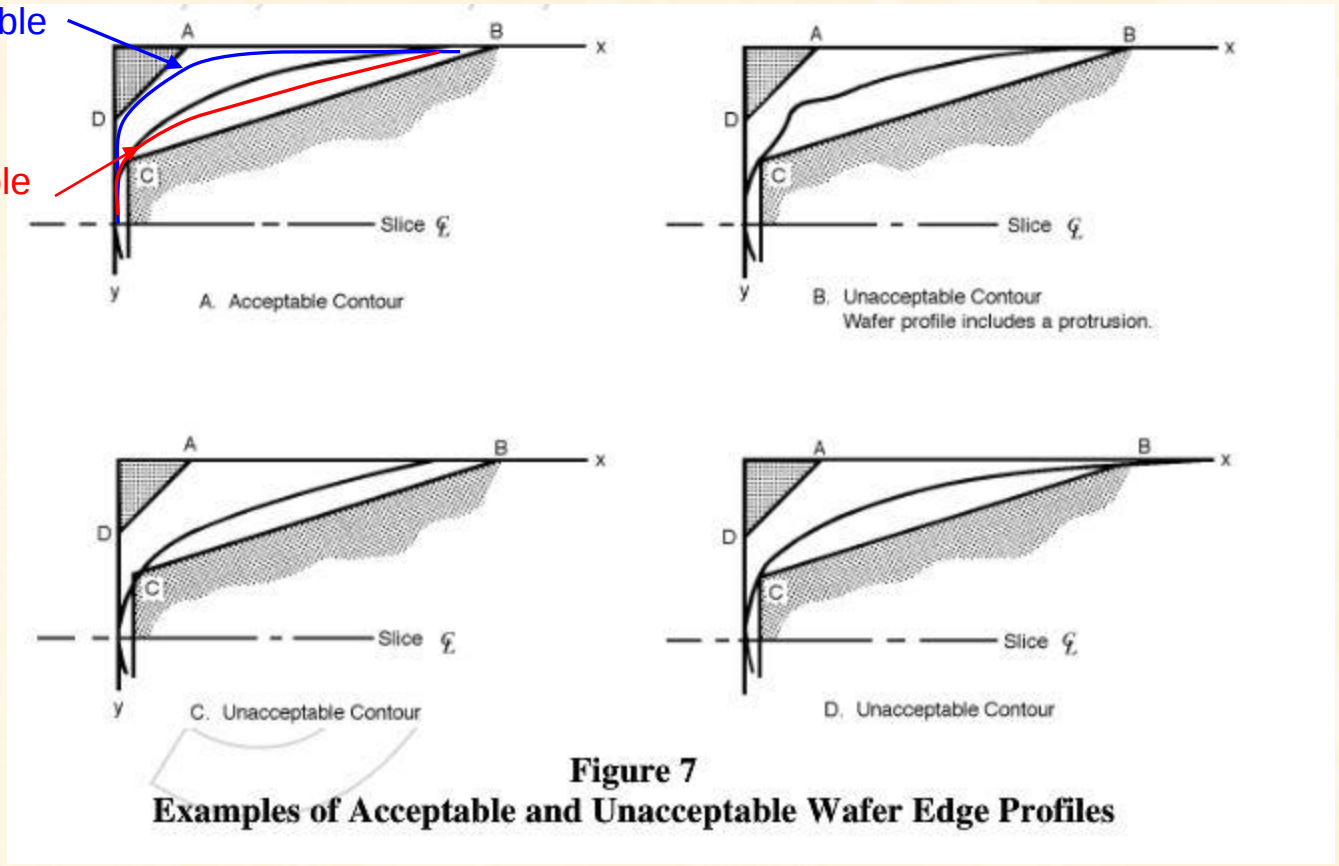


Figure 7
Examples of Acceptable and Unacceptable Wafer Edge Profiles

→Template is much too wide for advanced technology generations

Profile-Parameter Based Specifications (1)

- Different approach
- EP is now defined by a set of characteristic EP parameters
- EP is specified by assigning values to these parameters, and
  - by specifying tolerances for these parameters (P&T), or
  - by specifying a template into which a measured profile must fit (NT)

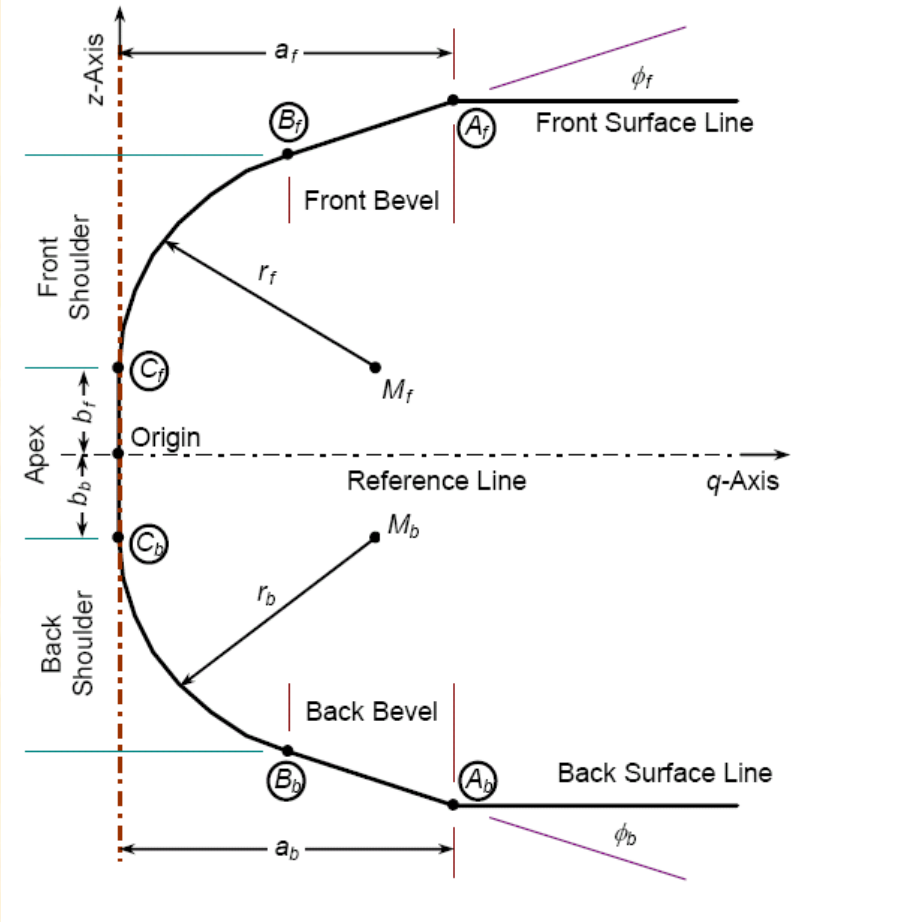
Profile-Parameter Based Specifications (2)

- EP PARAMETERS

  - front edge width a_f
  - front bevel angle Φ_f
  - front shoulder radius r_f
  - apex length front b_f

  - thickness t

  - back edge width a_b
  - back bevel angle Φ_{bb}
  - back shoulder radius r_b
  - apex length back b_b



Profile-Parameter Based Specifications (3)

- Parameters are not independent of each other

$$t/2 = b_i + r_i \cos\Phi_i - [a_i - r_i(1-\sin\Phi_i)]\tan\Phi_i$$

- This allows easily designing and drawing of a target EP

Profile-Parameter Based Specifications (4)

Table A3-2 Coordinates of Target Edge Profile Reference Points and Shoulder Circle Center Points

Point	*Description (Moving Counterclockwise Around the Edge)*	*q-coordinate*	*z-coordinate*
A_f	Starting point of front bevel.	a_f	$t/2$
B_f	Ending point of front bevel, starting point of front shoulder.	$r_f(1-\sin\phi_f)$	$b_f + r_f\cos\phi_f$
M_f	Center point of front shoulder circular arc.	r_f	b_f
C_f	Ending point of front shoulder, starting point of front apex.	0	b_f
Origin	Origin of q-z coordinate system	0	0
C_b	Back point of apex, starting point of back shoulder.	0	$-b_b$
M_b	Center point of back shoulder circular arc.	r_b	$-b_b$
B_b	Ending point of back shoulder, starting point of back bevel.	$r_b(1-\sin\phi_b)$	$-(b_b + r_b\cos\phi_b)$
A_b	Ending point of back bevel.	a_b	$-t/2$

Profile-Parameter Based Specifications: P&T

Table 4 Parameters for Use with Profile-Parameter Based Edge Profile Specifications

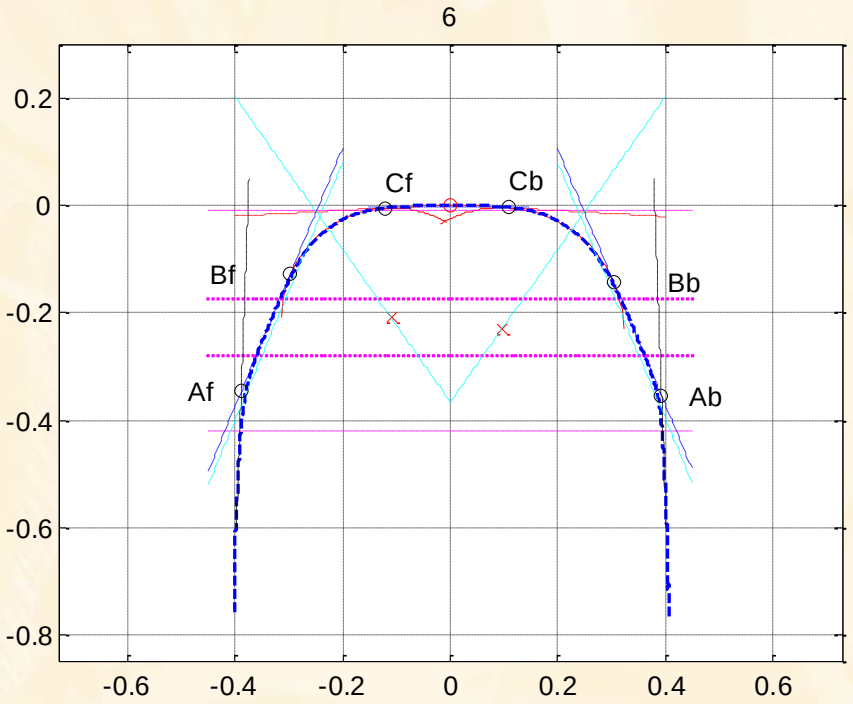
Parameter Name	*Symbol*	*Value ± Tolerance*	*Unit*
Front edge width	a_f		µm
Front bevel angle	ϕ_f		°
Front shoulder radius	r_f		µm
Back shoulder radius	r_b		µm
Back bevel angle	ϕ_b		°
Back edge width	a_b		µm
Thickness[#1]	t		µm

#1 Thickness is that which is specified for the wafer on which the edge profile is being generated; it is not separately specified for the edge profile specification.

Specifications are verified by test methods according to SEMI M73, see next presentation

Examples P&T (1)

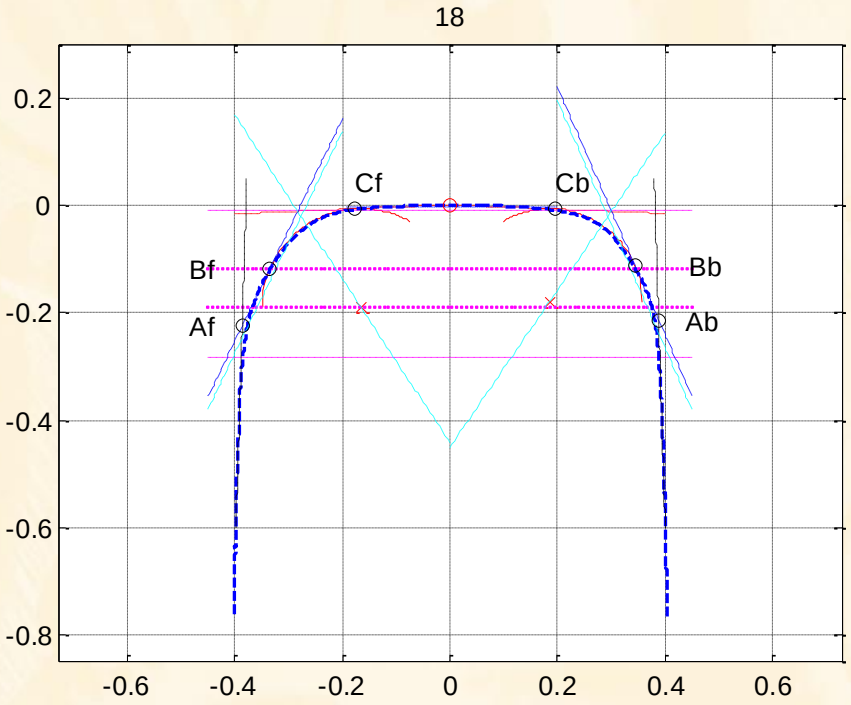
- EP PARAMETERS
  - front edge width a_f: *0.346 mm*
  - front bevel angle Φ_f: *22.6 deg*
  - front shoulder radius r_f: *0.20 mm*
  - apex length front b_f: *0.123 mm*
  - thickness *t : 0.782 mm*
  - back edge width a_b : *0.354 mm*
  - back bevel angle Φ_b : *22.8 deg*
  - back shoulder radius r_b : *0.23 mm*
  - apex length back b_b : *0.129 mm*



Measured EP: dashed blue line

Examples P&T (2)

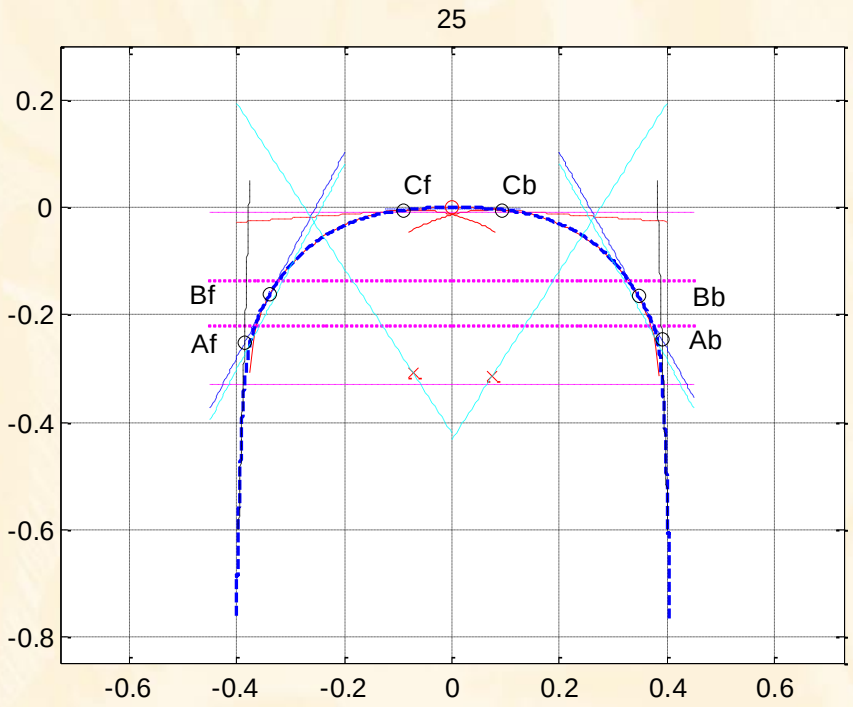
- EP PARAMETERS
  - front edge width a_f: *0.224 mm*
  - front bevel angle Φ_f: *25.8 deg*
  - front shoulder radius r_f: *0.184 mm*
  - apex length front b_f: *0.177 mm*
  - thickness *t : 0.775 mm*
  - back edge width a_b : *0.213 mm*
  - back bevel angle Φ_b : *23.5 deg*
  - back shoulder radius r_b : *0.173 mm*
  - apex length back b_b : *0.196 mm*



Measured EP: dashed blue line

Examples P&T (3)

- EP PARAMETERS
  - front edge width a_f: *0.252 mm*
  - front bevel angle Φ_f: *27.7 deg*
  - front shoulder radius r_f: *0.303 mm*
  - apex length front b_f: *0.091 mm*
  - thickness *t : 0.777 mm*
  - back edge width a_b : *0.246 mm*
  - back bevel angle Φ_b : *28.8 deg*
  - back shoulder radius r_b : *0.309 mm*
  - apex length back b_b : *0.094 mm*



Measured EP: dashed blue line

Profile-Parameter Based Specifications: NT

- Parameters for target EP are specified
- A tolerance range on both sides of the target profile is specified instead of specifying tolerances for the individual parameters
- This tolerance range defines a template into which a measured profile has to fall

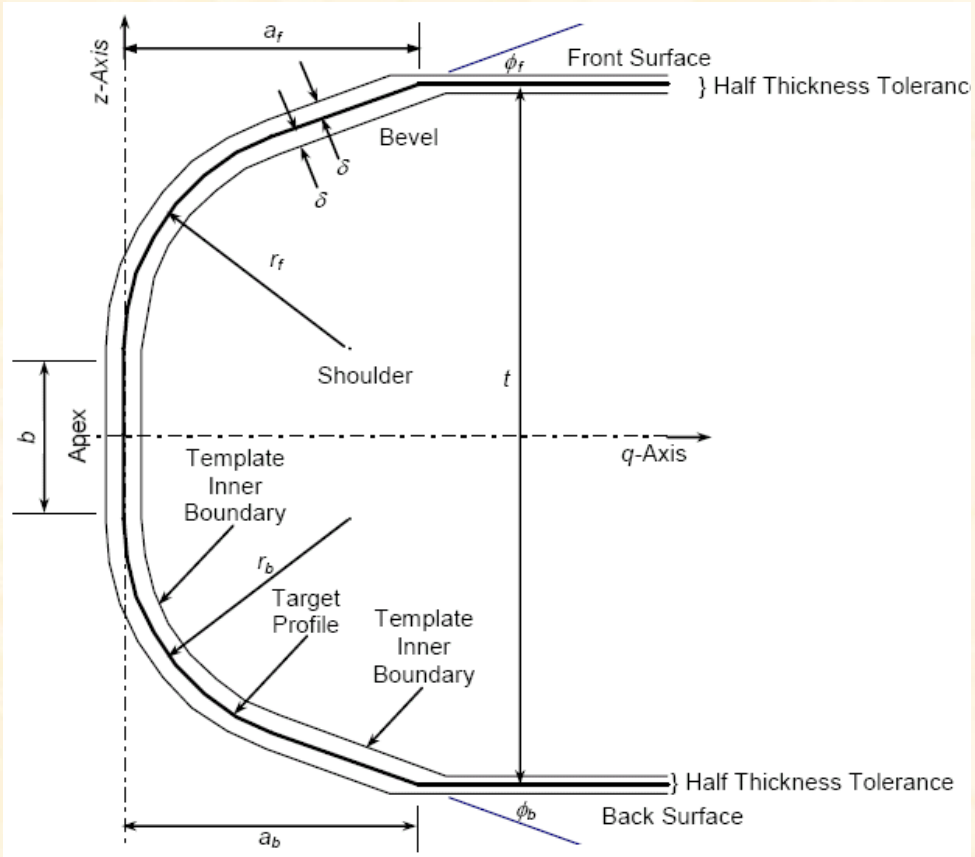


Figure A3-1
Example of Parameter-Based Template

Profile-Parameter Based Specifications: NT

Table A3-1 Coordinates of Target Edge Profile Reference Points and Shoulder Circle Center Points

Parameter Name	*Symbol*	*Value of Parameter*	*Unit*
Front edge width	a_f		µm
Front bevel angle	ϕ_f		°
Front shoulder radius	r_f		µm
Back shoulder radius	r_b		µm
Back bevel angle	ϕ_b		°
Back edge width	a_b		µm
Thickness[#1]	t		µm
Common Tolerance[#2]	δ		µm

#1 Thickness is that which is specified for the wafer on which the edge profile is being generated; it is not separately specified for the edge profile specification.

#2 The common tolerance is used instead of individual parameter tolerances when a restricted target-based template is used. Construction of this template is described in § A3-3.

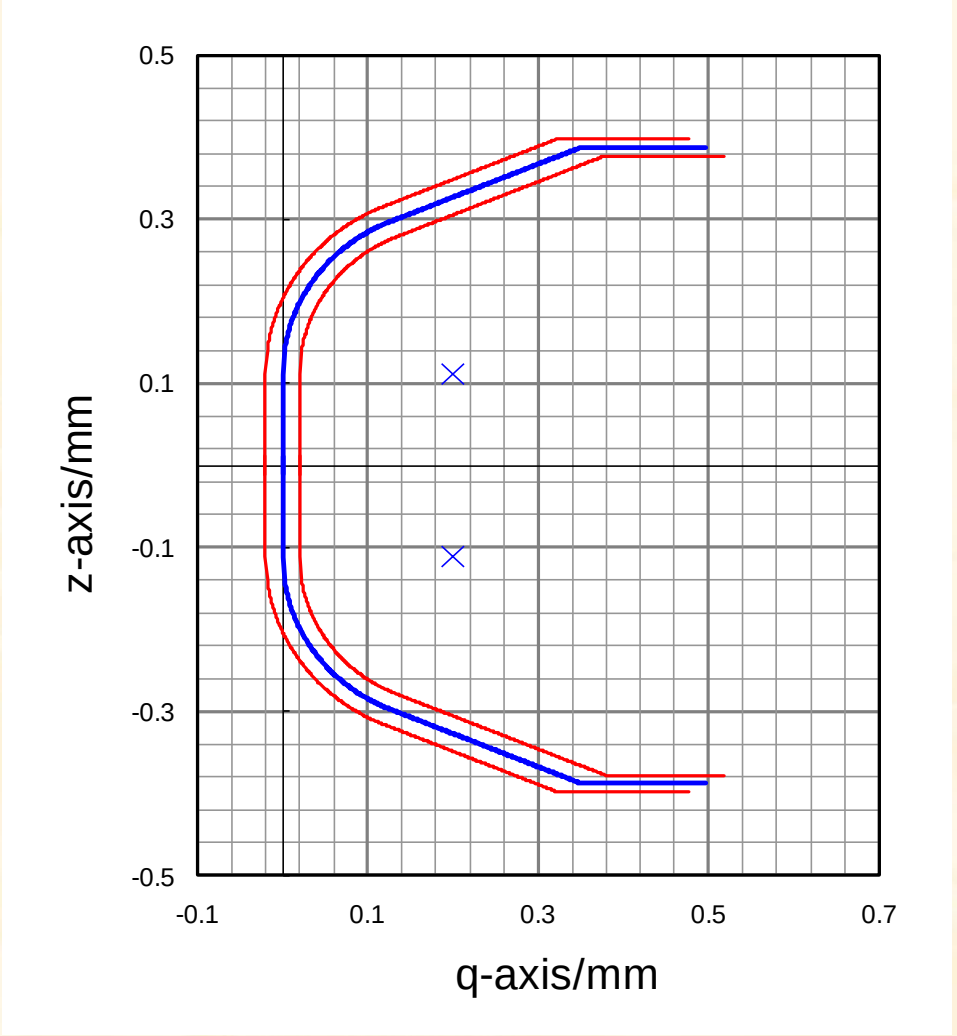
Construction of NT

Table A3-3 Coordinates of Reference Points for Outer and Inner Boundaries of Parameter-Based Template

Template Outer Boundary			*Template Inner Boundary*		
Point	*q-coordinate*	*z-coordinate*	*Point*	*q-coordinate*	*z-coordinate*
A_f	$a_f - ((\delta/\cos\phi_f) - 10)/\tan\phi_f$	$t/2 + 10$	A_f	$a_f + ((\delta/\cos\phi_f) - 10)/\tan\phi_f$	$t/2 - 10$
B_f	$r_f(1-\sin\phi_f) - \delta\sin\phi_f$	$b_f + r_f\cos\phi_f + \delta\cos\phi_f$	B_f	$r_f(1-\sin\phi_f) + \delta\sin\phi_f$	$b_f + r_f\cos\phi_f - \delta\cos\phi_f$
M_f	r_f	b_f	M_f	r_f	b_f
C_f	$-\delta$	b_f	C_f	δ	b_f
C_b	$-\delta$	b_b	C_b	δ	$-b_b$
M_b	r_b	b_b	M_b	r_b	$-b_b$
B_b	$r_b(1-\sin\phi_b) - \delta\sin\phi_b$	$-(b_b + r_b\cos\phi_b) - \delta\cos\phi_b$	B_b	$r_b(1-\sin\phi_b) + \delta\sin\phi_b$	$-(b_b + r_b\cos\phi_b) + \delta\cos\phi_b$
A_b	$a_b - ((\delta/\cos\phi_b - 10)/\tan\phi_b$	$-t/2 - 10$	A_b	$a_b + ((\delta/\cos\phi_b - 10)/\tan\phi_b$	$-t/2 + 10$

Examples NT (1)

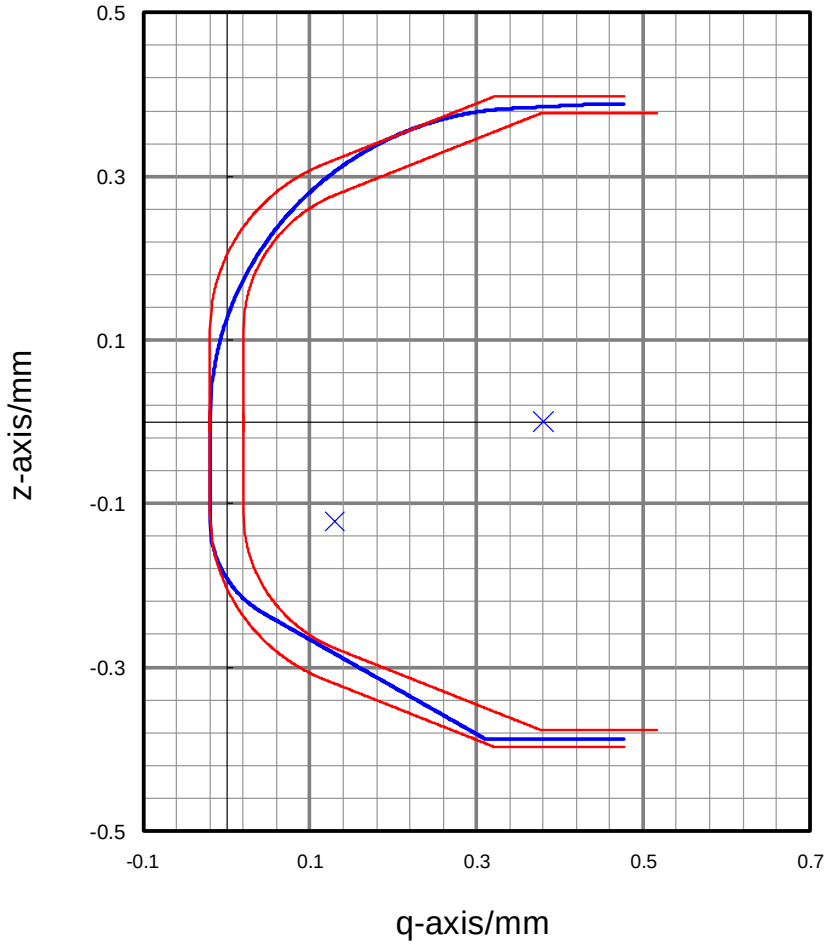
- Blue line: Specified edge profile
- Red lines: Template boundaries = specified EP +/- tolerance



Examples NT (2)

	As is	Target	
fron edge width	0.45	0.35	mm
front bevel angle	5	22	deg
front shoulder radius	0.38	0.2	mm
back shoulder radius	0.13	0.2	mm
back bevel angle	30	22	deg
back edge width	0.33	0.35	mm
thickness	0.775	0.775	mm
offset	0.02		mm
thickness tolerance	0.02	0.02	mm
template tolerance		0.02	mm
apex length front	0.000	0.111	mm
apex length back	0.122	0.111	mm

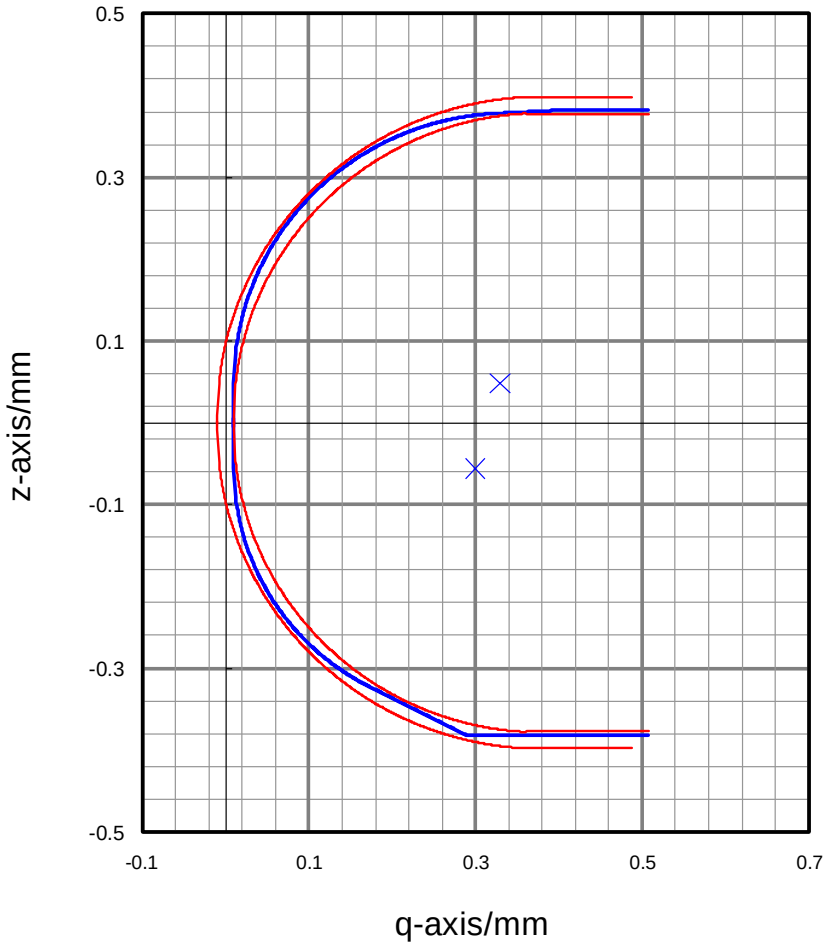
Blue line: simulated EP that would meet specification



Examples NT (3)

	As is	Target	
fron edge width	0.4	0.35	mm
front bevel angle	3	3	deg
front shoulder radius	0.33	0.38	mm
back shoulder radius	0.3	0.38	mm
back bevel angle	27	3	deg
back edge width	0.28	0.35	mm
thickness	0.765	0.775	mm
offset	-0.01		mm
thickness tolerance	0.02	0.02	mm
template tolerance		0.01	mm
apex length front	0.048	0.009	mm
apex length back	0.056	0.009	mm

Blue line: simulated EP that would meet specification



Conclusions (1)

- Templates were appropriate for older technology generations and up to 200 mm wafers
- The tolerances of templates are much too wide for advanced technology generations
- Customers could get wafers with edge profiles that significantly deviate from the specified profile

Conclusions (2)

- Templates do not provide sufficiently detailed information for process engineers in case of claims
- Examples shown did not take in account tilt of profile, up and down shift of profile, and apex angle → even more variation possible
- There is no standardized test method available for NT→ decision on compliance with spec depends on operator

Conclusions (3)

- P&T provides detailed information about EP and clear criteria for verifying the specifications
- Standardized test methods (SEMI M73) allow repeatable measurement and common understanding of the results

Thank you for your kind attention !