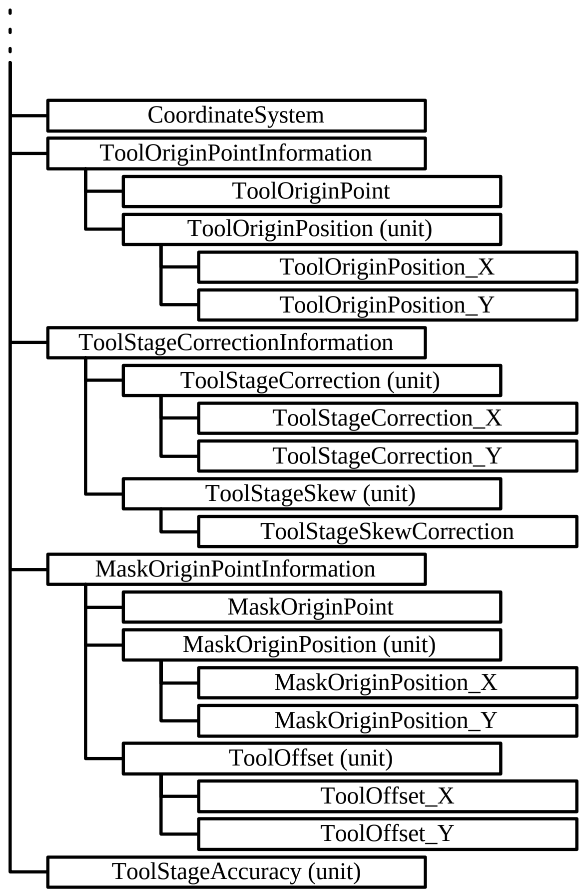

Figure 5
Structure of Tool Coordinate Section

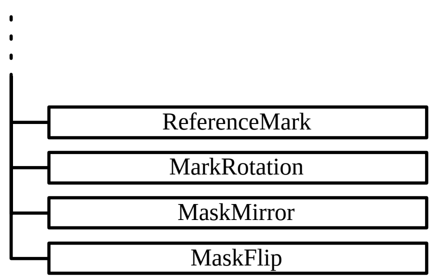

Figure 6
Structure of Mask Direction Information Section

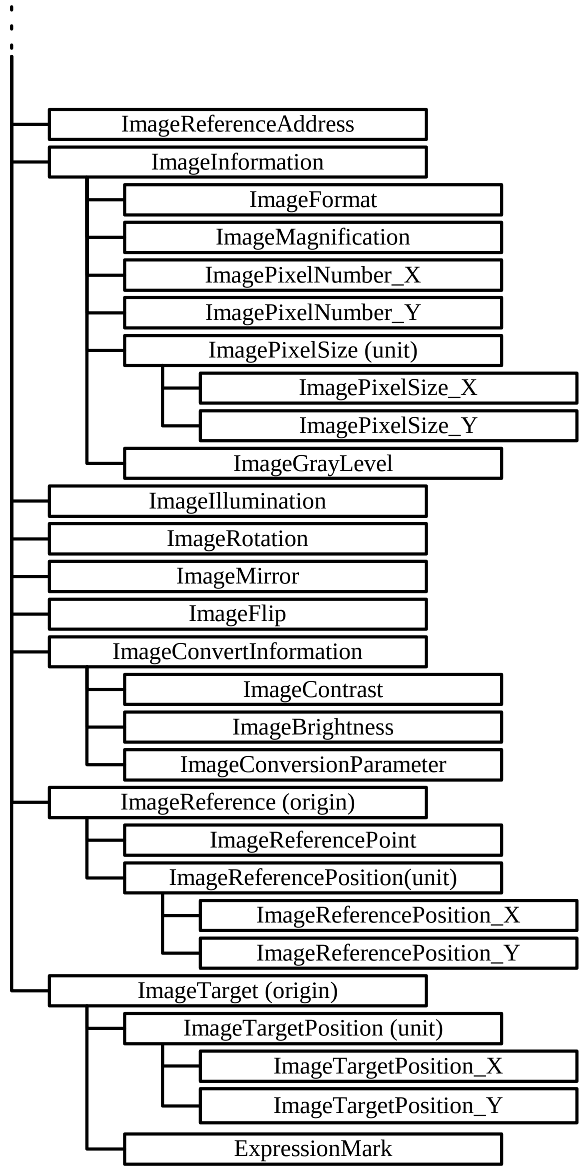

Figure 7
Structure of Image Data Section

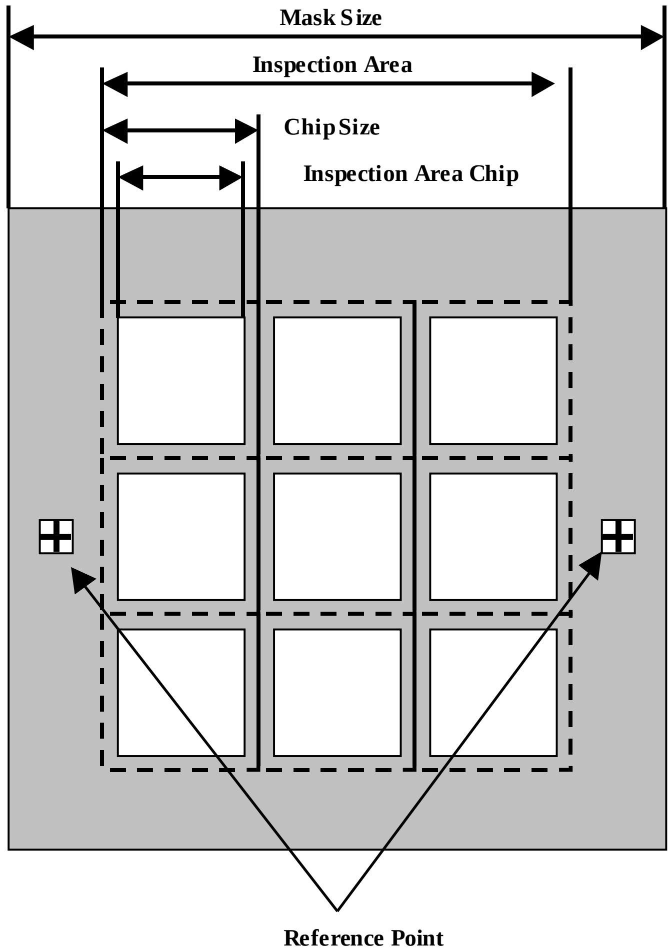

Figure 8
Inspection Area

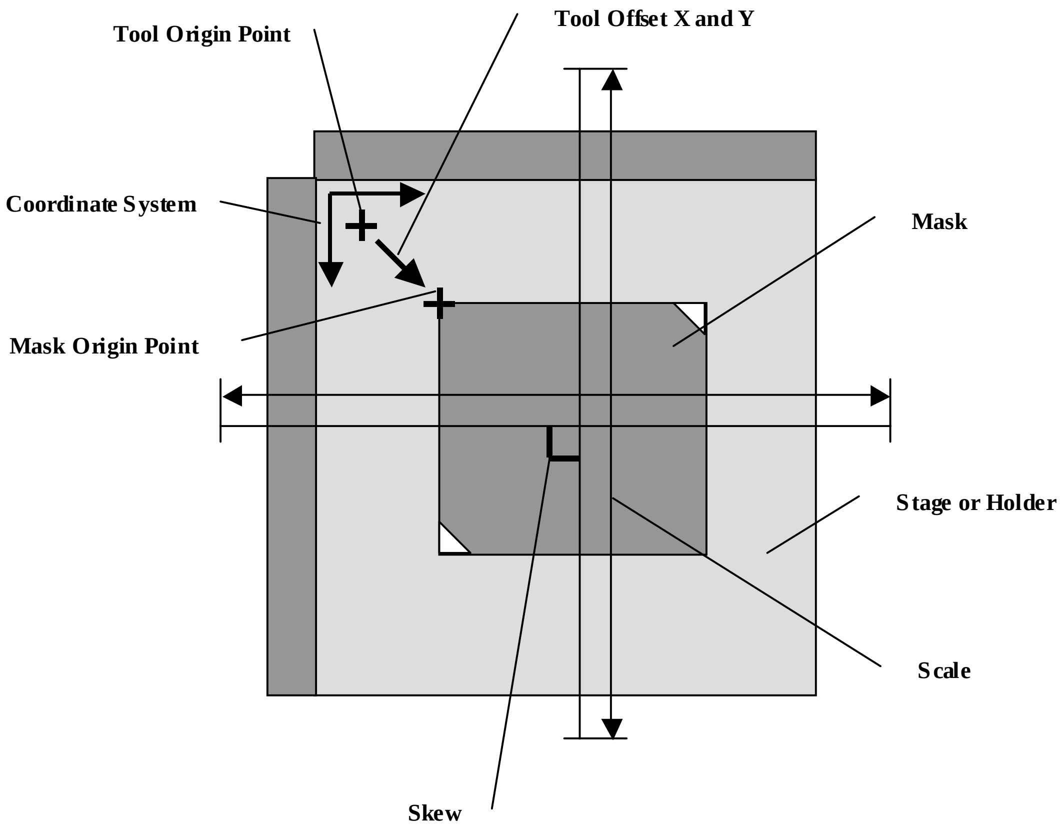

Figure 9
Tool Coordinate

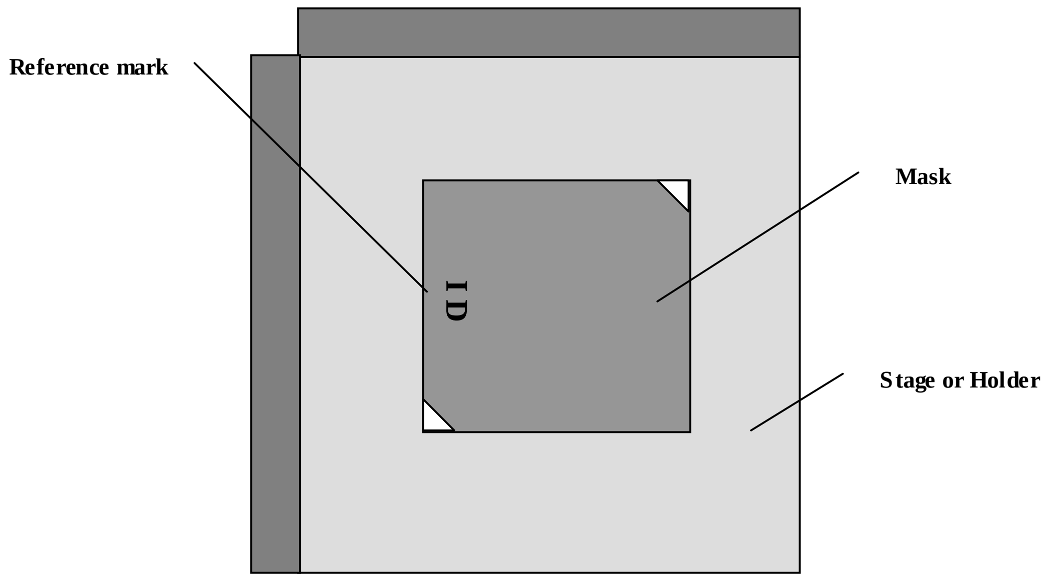

Figure 10
Direction

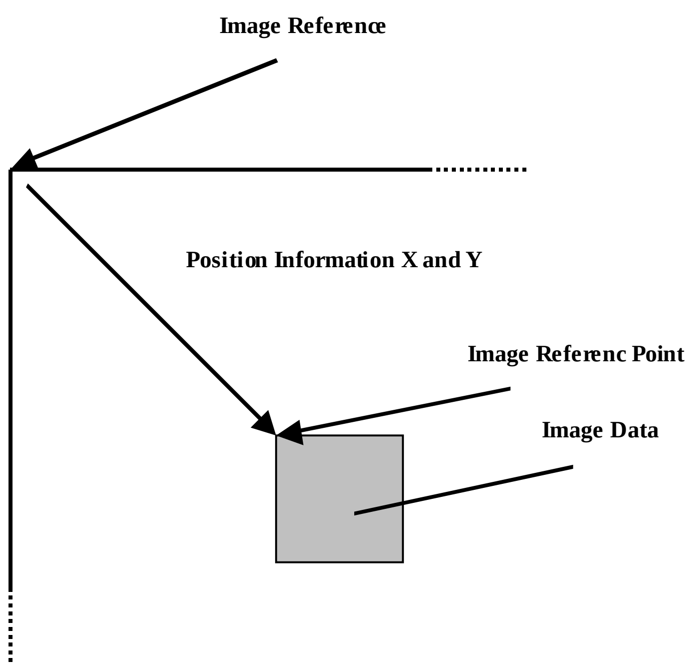

Figure 11
Image Reference

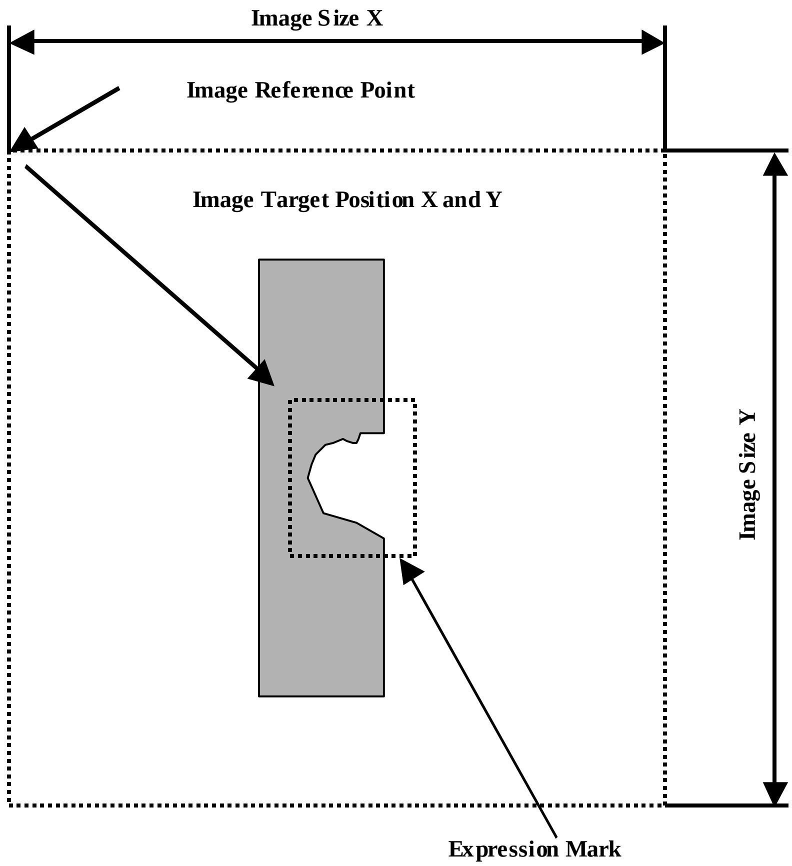

Figure 12
Image Target

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RELATED INFORMATION 1
APPLICATION NOTES

NOTICE: This related information is not an official part of SEMI P41 and was derived from the work of the originating task force. This related information was approved for publication by full letter ballot procedures on January 9, 2004.

R1-1 EXAMPLE OF AN XML FILE


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      <ImageGrayLevel>256</ImageGrayLevel>
    </ImageInformation>
    <ImageIllumination>transmission</ImageIllumination>
    <ImageRotation>none</ImageRotation>
    <ImageMirror>y-mirror</ImageMirror>
    <ImageFlip>none</ImageFlip>
    <ImageConvertInformation>
      <ImageContrast>230/256</ImageContrast>
      <ImageBrightness>230/256</ImageBrightness>
      <ImageConversionParameter>convert 8bit from 12bit</ImageConversionParameter>
    </ImageConvertInformation>
```

```
      &lt;ImageReference origin = "mask origin"&gt;
        &lt;ImageReferencePoint&gt;center&lt;/ImageReferencePoint&gt;
        &lt;ImageReferencePosition unit = "micron"&gt;
          &lt;ImageReferencePosition_X&gt;86200&lt;/ImageReferencePosition_X&gt;
          &lt;ImageReferencePosition_Y&gt;76200&lt;/ImageReferencePosition_Y&gt;
        &lt;/ImageReferencePosition&gt;
      &lt;/ImageReference&gt;
      &lt;ImageTarget origin = "LeftTop"&gt;
        &lt;ImageTargetPosition unit = "pixel"&gt;
          &lt;ImageTargetPosition_X&gt;1024&lt;/ImageTargetPosition_X&gt;
          &lt;ImageTargetPosition_Y&gt;1024&lt;/ImageTargetPosition_Y&gt;
        &lt;/ImageTargetPosition&gt;
        &lt;ExpressionMark&gt;square box&lt;/ExpressionMark&gt;
      &lt;/ImageTarget&gt;
    &lt;/ImageData&gt;
  &lt;/DefectEvaluate&gt;
 &lt;/Defect&gt;
&lt;/InspectionResut&gt;
&lt;/MDML&gt;
```

SEMI P42-0304
SPECIFICATION OF RETICLE DATA FOR AUTOMATIC RECIPE TRANSFER TO WAFER EXPOSURE SYSTEM

This specification was technically approved by the Global Micropatterning Committee and is the direct responsibility of the Japanese Micropatterning Committee. Current edition approved by the Japanese Regional Standards Committee on January 9, 2004. Initially available at www.semi.org February 2004; to be published March 2004.

1 Purpose

1.1 This specification defines a common data interface, which consists of frame information of reticle data, in order to prepare recipes for wafer exposure tools. By utilizing this interface, it becomes possible to carry out data handling between design and wafer manufacture so that the data can be reused during recipe making of wafer exposure tools. This standard is intended to assist automatic recipe generation of wafer exposure tools.

2 Scope

2.1 This standard details frame information in automatic recipe preparation for wafer exposure equipment. This standard focuses on communication interface in work flow of design, mask manufacturing, and wafer manufacturing processes.

2.1.1 This standard defines the items of the required and common design information at a reticle design and a recipe preparation for wafer exposure equipment.

2.1.2 This standard defines a data interface, which can be commonly used independently to the suppliers and models of exposure equipment.

NOTICE: This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This data interface is expandable (an item addition and a user definition are enabled) instead of fixed, and serves as a form with flexibility.

3.2 This standard uses the current XML standard to describe a reticle data interface.

3.3 This standard does not provide the definition of the handling interface of device design data. Only the data interface specific to frame data information is defined.

3.4 The wafer map information by reticle frame data and the wafer, which exposure equipment uses, are defined in this standard.

3.5 This standard includes the handling items of the related information for reticle exposure and a mark formation process (reticle) required for automatic recipe preparation.

3.6 Recipe preparation is shown in Figure 1. This document focuses on reticle data management (RDM) interface (IF) as indicated in Figure 1.

4 Referenced Standards

4.1 *JEITA Documents*[1]

Reticle Data Management Guideline Ver.1.0 (2001) — (http://jeita-smtc.elisasp.net/)

4.2 *World Wide Web Consortium Documents*[2]

Extensible Markup Language (XML) 1.0 (Second Edition) — W3C,6 October 2000 (http://www.w3.org/TR/2000/REC-xml-20001006)

Extensible Markup Language (XML) 1.1 — W3C,15 October 2002 (http://www.w3.org/TR/2002/CR-xml11-20021015)

Extensible Markup Language (XML) 1.1 — 15 October 2002, John Cowan (http://www.w3.org/TR/2002/CR-xml-names11-20021218/)

Namespaces in XML — W3C, 14 January 1999 (http://www.w3.org/TR/1999/REC-xml-names-19990114/)

XML Schema Part 0: Primer — W3C, 2 May 2001 (http://www/w3/org/TR/xmlschema-0/)

XML Schema Part 1: Structures — W3C, 2 May 2001 (http://www/w3/org/TR/xmlschema-1/)

XML Schema Part 2: Datatypes — W3C, 2 May 2001 (http://www/w3/org/TR/xmlschema-2/)

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1 Japanese Electronic and Information Technology Industries Association, Tokyo Chamber of Commerce and Industry Bldg. 2-2, Marunouchi 3-chome, Chiyoda-ku, Tokyo 100-0005, Japan. Website: http://www.jeita.or.jp

2 *World Wide Web Consortium (W3C),* ,Website: http://www.w3c.org

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Definitions*

5.1.1 *alignment mark design* — the information related to wafer alignment marks placed on the reticle for exposure on the wafer.

5.1.2 *alignment mark ID* — identifier for each wafer alignment mark.

5.1.3 *alignment mark information* — information related to alignment marks.

5.1.4 *alignment USE Mark* — information of alignment marks in the layer used for wafer alignment.

5.1.5 *barcode* — the barcode that is used for identification of reticle.

5.1.6 *edge clearance* — the area that cannot be used for production. It is expressed by the distance from a Wafer edge. The value reduces the effective exposure area of wafer radius (half of diameter).

5.1.7 *formulation information* — information related to the reticle frame design data.

5.1.8 *frame information* — the CAD design information of a reticle. It includes information about the part that does not depend on circuit figures of a chip, the frame of a rectangular area, and alignment marks and barcode, and the information of the marks of all layers.

5.1.9 *group* — character string used for grouping alignment marks if required.

5.1.10 *machine type information* — target machines for using the reticle frame design information.

5.1.11 *mark use rule* — name of the file containing the wafer alignment mark selection rule to be applied for the subject layer.

5.1.12 *projection magnification* — projection magnification of a reticle.

5.1.13 *reticle design* — reticle design information.

5.1.14 *reticle ID* — identifier for each reticle.

5.1.15 *reticle information* — information related to reticles.

5.1.16 *reticle mark* — mark used for alignment of a reticle

5.1.17 *reticle mark ID* — identifier for each reticle alignment mark.

5.1.18 *reticle mark type* — type of reticle alignment mark.

5.1.19 *reticle name* — names for reticle identification.

5.1.20 *reticle projection magnification* — magnification of projection lens used by the exposure tool.

5.1.21 *reticle size* — size of reticle blank.

5.1.22 *reticle type* — type of reticle.

5.1.23 *shot* — an area exposed by a lithography system on a wafer with a single flash or scan.

5.1.24 *shot area* — an area divided with masking blades on reticle. It is exposed as a single shot.

5.1.25 *shot area ID* — identifier for identifying shot areas.

5.1.26 *shot area information* — information related to the rectangular area used for exposure at a time.

5.1.27 *shot area position shift* — shifting measure of the reference position of a shot area with the reference position of a shot on a wafer.

5.1.28 *shot area shift* — a coordinate of a reference position of the shot area, relative to a reference position of a frame.

5.1.29 *shot area size* — size of an area of a rectangle used as a shot area. It is expressed with size of X and Y directions.

5.1.30 *shot ID* — identifier for each shot.

5.1.31 *shot information* — information related to shots.

5.1.32 *shot location* — the coordinate of the shot expressed based on the matrix arrangement for a shot on a wafer.

5.1.33 *shot map* — information related to shots exposed on a wafer.

5.1.34 *shot map array* — maximum number of shots for the matrix arrangement. It will be expressed as the number of shots in the X and Y directions.

5.1.35 *shot map information* — information related to shot arrays on a wafer.

5.1.36 *shot map offset* — translational offset for a shot arrangement on wafer relative to a reference position on the wafer.

5.1.37 *shot position* — the coordinate of a reference position of the shot relative to a reference position of the wafer.

5.1.38 *step pitch* — a pitch of matrix arrangement for a shot. The pitch for the X and Y directions can be different.

5.1.39 *use exposure machine* — information related to equipment used for exposure.

5.1.40 *wafer information* — information related to the target wafer for processing.

5.1.41 *wafer mark* — a mark formed on a wafer for the purpose of wafer alignment. It can be used to align the wafer, where reticle image will be projected.

5.1.42 *wafer mark position* — the mark coordinate origin as defined by the equipment. It is expressed as coordinate relative to a reference position of the shot that exposes a wafer mark or a wafer reference position.

5.1.43 *wafer mark type* — type of wafer alignment mark.

5.1.44 *wafer rotation* — the direction of wafer rotation. It is defined by exposure tool.

5.1.45 *wafer size* — the diameter of a wafer.

5.1.46 *wafer thickness* — thickness of the target wafer for processing.

5.1.47 *wafer type* — the identification to use notch or OF (orientation flat) as a base for the direction of wafer rotation.

5.2 Figure 2 explains the terminology. Figure 2 is an example and shall be treated as a supplement data.

6 Reticle Frame Data

6.1 Reticle frame data is correlated with a hierarchic configuration as shown in Table 1. The item that defines the ID in this table can have several pieces of data. This table is used to generate one recipe of the exposure equipment. The unit of "µm" in this table is transcribed as "um", which can be used as the entry in XML files.

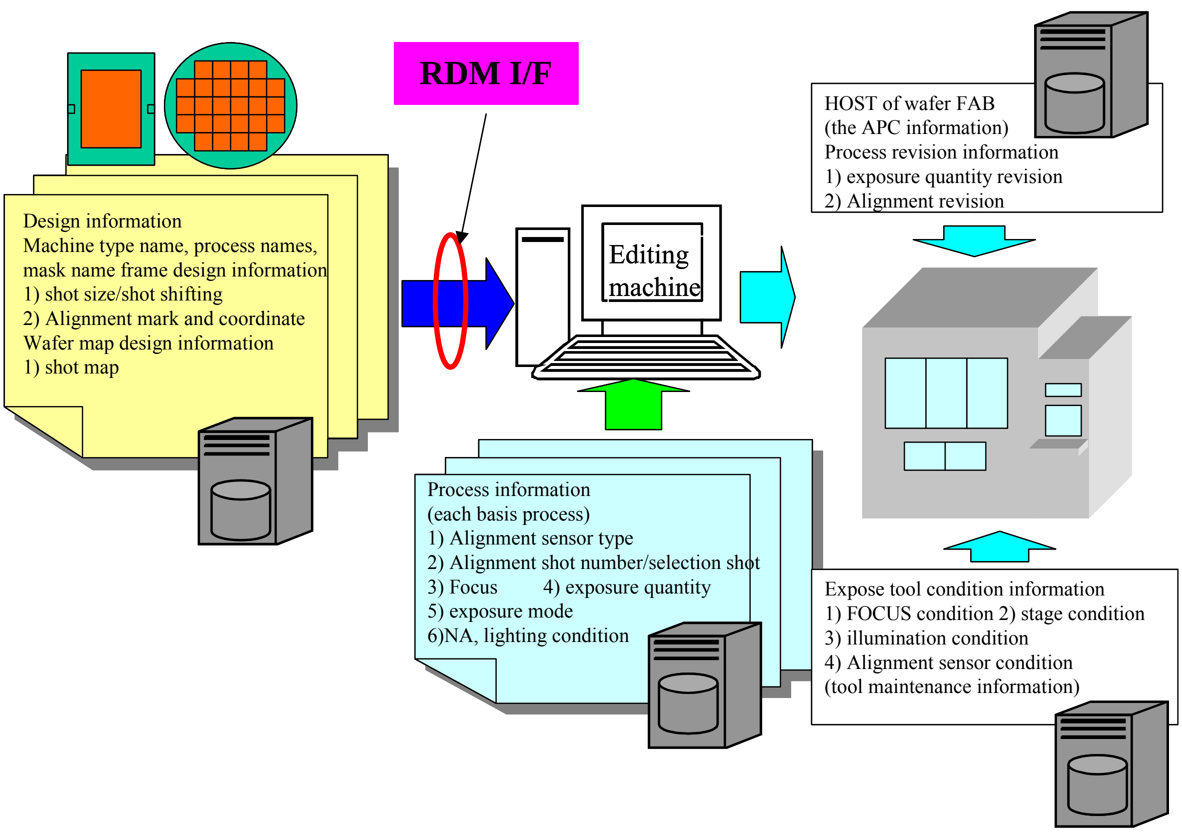

Figure 1
Recipe Preparation of Exposure Machine

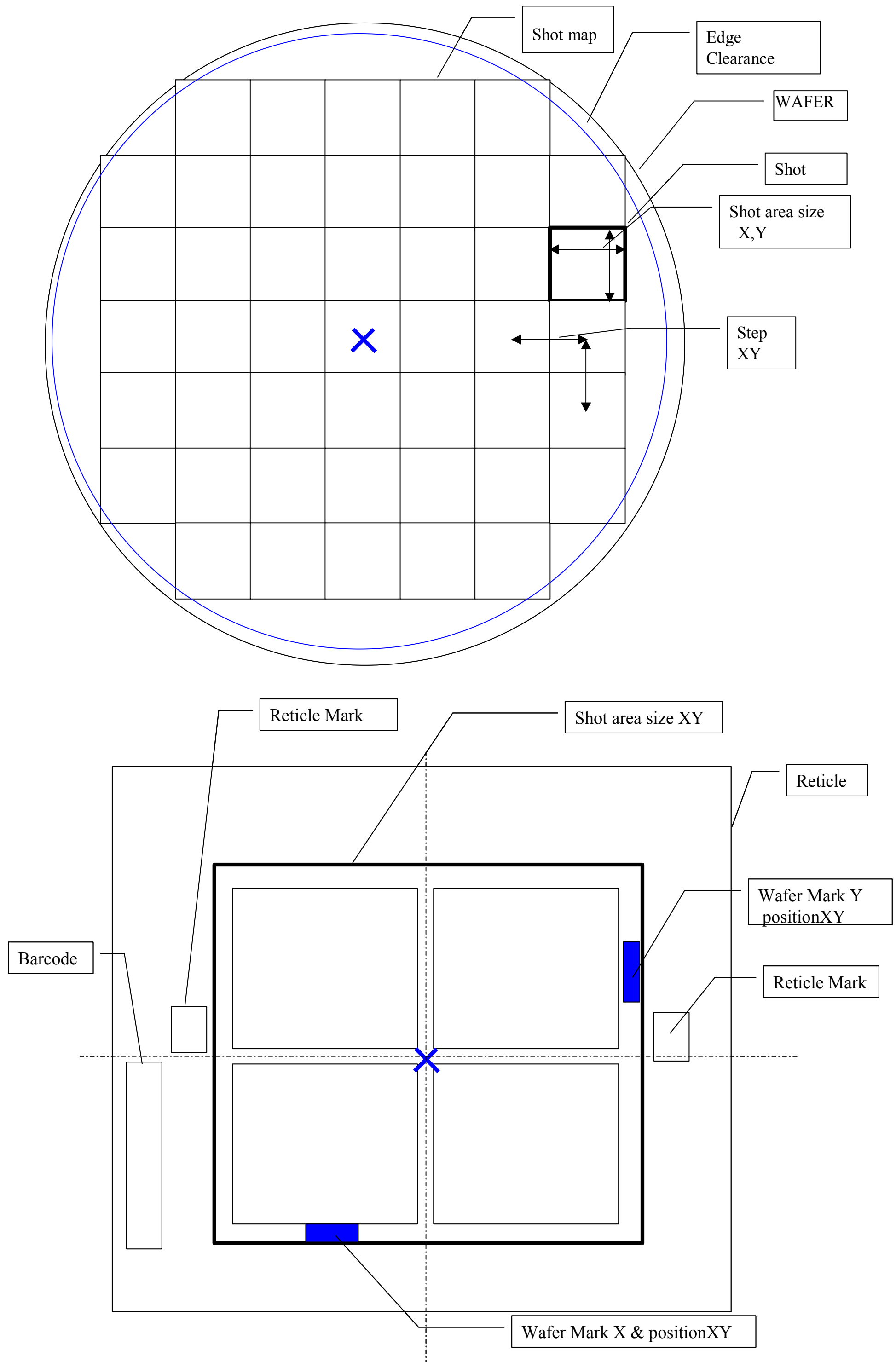

Figure 2
Explanation for Terminology

Table 1 Reticle Frame Data

Item				*Data type*	*Unit*	*the entry example*
Formulation information	Date			Date Time	----	1999-05-31T13:20+08:00
	Person			string	----	HIGASHINO
Use exposure machine	Machine type information (1 – ∞)			string	----	
Shot map	Wafer information	Wafer type		string	----	SEMI,JEIDA,OF,notch
		Wafer size	Size	unsignedInt	----	150,200,300,5,6,8,12
			UnitType	string	mm/um/inch	mm,inch
		Edge Clearance	Clearance	Double	----	3.0
			UnitType	string	mm/um/inch	mm
		Wafer thickness	Thickness	unsignedInt	----	725
			UnitType	string	mm/um/inch	um
		Wafer Rotation		unsignedInt	deg	0,90,180,270,xxx
	Shot Map information	Step Pitch	X	Double	----	X size
			Y	Double	----	Y size
			UnitType	string	mm/um/inch	
		Shot Map array	C	unsignedInt	----	Col
			R	unsignedInt	----	Row
		Shot Map offset	X	Double	----	X offset
			Y	Double	----	Y offset
			UnitType	string	mm/um/inch	
	Shot area information (1 – ∞)	Shot area ID		ID	----	Uniqueness ID
		Reticle ID		string	----	Reticle information Reticle ID
		Shot area size	X	Double	----	X size
			Y	Double	----	Y size
			UnitType	string	mm/um/inch	
		Shot area shift	X	Double	----	X shift
			Y	Double	----	Y shift
			UnitType	string	mm/um/inch	
		Shot area position shift	X	Double	----	X position
			Y	Double	----	Y position
			UnitType	string	mm/um/inch	
	Shot information (1 – ∞)	Shot ID		ID	----	Uniqueness ID
		Shot area ID		string	----	Shot area information Shot area ID
		Shot Location	C	unsignedInt	----	Column
			R	unsignedInt	----	Row
		Shot position	X	Double	----	X position
			Y	Double	----	Y position
			UnitType	string	mm/um/inch	

Item					*Data type*	*Unit*	*the entry example*
Reticle design	Reticle information (1 – ∞)	Reticle ID			ID	----	Uniqueness ID
		Reticle name			string	----	
		Bar code			string	----	ex. Code39
		Reticle size	Size		unsignedInt	----	230,5,6
			UnitType		string	mm/um/inch	mm,inch
		Reticle Type			string	----	Cr,ArCr,Att.PSM, EAPSM,….
		Reticle Mark ID			string	----	
		Reticle Mark Type			string	----	STD
		Projection Magnification			unsignedInt	----	1,2,4,5………
Alignment Mark design	Alignment Mark information (0 – ∞)	Alignment Mark ID			ID	----	Uniqueness ID
		Group			string	----	
		Wafer mark type			string	----	P1,P2,…,F1,F2…
		Wafer mark position	X-Mark	X	Double	----	X-Mark X position
				Y	Double	----	X-Mark Y position
			Y-Mark	X	Double	----	Y-Mark X position
				Y	Double	----	Y-Mark Y position
				UnitType	string	mm/um/inch	
		Comment			string	----	
	Mark use rule	FileName			string	----	
Alignment USE Mark	Alignment Mark information (0 – ∞)	Alignment Mark ID			ID		Uniqueness ID
		Group			string		
		Wafer mark type					TYPE=P1,P2,…,F1,F2…
		Wafer mark position	X-Mark	X	Double	----	X-Mark X position
				Y	Double	----	X-Mark Y position
			Y-Mark	X	Double	----	Y-Mark X position
				Y	Double	----	Y-Mark Y position
				UnitType	string	mm/um/inch	
		Comment			string	----	

7 XML Description (Schema)

XML description defined from Table 1 is as follows.

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema targetNamespace="file://XML\SEMI_Samples\SemiSEMI"
xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:rfd="file://XML\SEMI_Samples\SemiSEMI">
	<!-- ================= Reticle frame design data infomation Table ======================= -->
	<xsd:element name="rdm" type="rfd:rdmType"/>
	<xsd:complexType name="rdmType">
		<xsd:sequence>
			<xsd:element name="FormulationInformation"
type="rfd:FormulationInformationType"/>
			<xsd:element name="UseExposureMachine" type="rfd:UseExposureMachineType"/>
			<xsd:element name="ShotMap" type="rfd:ShotMapType"/>
			<xsd:element name="ReticleDesign" type="rfd:ReticleDesignType"/>
			<xsd:element name="AlignmentMarkDesign" type="rfd:AlignmentMarkDesignType"/>
			<xsd:element name="AlignmentUSEMark" type="rfd:AlignmentUSEMarkType"/>
		</xsd:sequence>
	</xsd:complexType>
	<!-- ====================== FormulationInformation ============================ -->
```

```
	<xsd:complexType name="FormulationInformationType">
		<xsd:sequence>
			<xsd:element name="Date" type="xsd:dateTime"/>
			<xsd:element name="Person" type="xsd:string"/>
		</xsd:sequence>
	</xsd:complexType>
	<!-- ======================== UseExposureMachine ============================== -->
	<xsd:complexType name="UseExposureMachineType">
		<xsd:sequence>
			<xsd:element name="MachineTypeInformation" type="xsd:string"
maxOccurs="unbounded"/>
		</xsd:sequence>
	</xsd:complexType>
	<!-- ============================== ShotMap =================================== -->
	<xsd:complexType name="ShotMapType">
		<xsd:sequence>
			<xsd:element name="WaferInformation" type="rfd:WaferInformationType"/>
			<xsd:element name="ShotMapInformation" type="rfd:ShotMapInformationType"/>
			<xsd:element name="ShotAreaInformation" type="rfd:ShotAreaInformationType"
maxOccurs="unbounded"/>
			<xsd:element name="ShotInformation" type="rfd:ShotInformationType"
maxOccurs="unbounded"/>
		</xsd:sequence>
	</xsd:complexType>
	<!-- ========================================================================= -->
	<xsd:complexType name="WaferInformationType">
		<xsd:sequence>
			<xsd:element name="WaferType" type="xsd:string"/>
			<xsd:element name="WaferSize" type="rfd:WaferSizeType"/>
			<xsd:element name="EdgeClearance" type="rfd:EdgeClearanceType"/>
			<xsd:element name="WaferThickness" type="rfd:WaferThicknessType"/>
			<xsd:element name="WaferRotation" type="xsd:unsignedInt"/>
		</xsd:sequence>
	</xsd:complexType>
	<xsd:complexType name="ShotMapInformationType">
		<xsd:sequence>
			<xsd:element name="StepPitch" type="rfd:XYCodeType"/>
			<xsd:element name="ShotMapArray" type="rfd:CRUnitType"/>
			<xsd:element name="ShotMapOffset" type="rfd:XYCodeType"/>
		</xsd:sequence>
	</xsd:complexType>
	<xsd:complexType name="ShotAreaInformationType">
		<xsd:sequence>
			<xsd:element name="ShotAreaID" type="xsd:ID"/>
			<xsd:element name="ReticleID" type="xsd:string"/>
			<xsd:element name="ShotAreaSize" type="rfd:XYCodeType"/>
			<xsd:element name="ShotAreaShift" type="rfd:XYCodeType"/>
			<xsd:element name="ShotAreaPositionShift" type="rfd:XYCodeType"/>
		</xsd:sequence>
	</xsd:complexType>
	<xsd:complexType name="ShotInformationType">
		<xsd:sequence>
			<xsd:element name="ShotID" type="xsd:ID"/>
			<xsd:element name="ShotAreaID" type="xsd:string"/>
			<xsd:element name="ShotLocation" type="rfd:CRUnitType"/>
			<xsd:element name="ShotPosition" type="rfd:XYCodeType"/>
```

```
        </xsd:sequence>
    </xsd:complexType>
    <!-- ====================================================================== -->
    <xsd:complexType name="WaferSizeType">
        <xsd:sequence>
            <xsd:element name="Size" type="xsd:unsignedInt"/>
            <xsd:element name="UnitType" type="rfd:UnitTypeType"/>
        </xsd:sequence>
    </xsd:complexType>
    <xsd:complexType name="EdgeClearanceType">
        <xsd:sequence>
            <xsd:element name="Clearance" type="xsd:double"/>
            <xsd:element name="UnitType" type="rfd:UnitTypeType"/>
        </xsd:sequence>
    </xsd:complexType>
    <xsd:complexType name="WaferThicknessType">
        <xsd:sequence>
            <xsd:element name="Thickness" type="xsd:unsignedInt"/>
            <xsd:element name="UnitType" type="rfd:UnitTypeType"/>
        </xsd:sequence>
    </xsd:complexType>
    <xsd:complexType name="CRUnitType">
        <xsd:sequence>
            <xsd:element name="C" type="xsd:unsignedInt"/>
            <xsd:element name="R" type="xsd:unsignedInt"/>
        </xsd:sequence>
    </xsd:complexType>
    <!-- ======================== ReticleDesign =============================== -->
    <xsd:complexType name="ReticleDesignType">
        <xsd:sequence>
            <xsd:element name="ReticleInformation" type="rfd:ReticleInformationType"
maxOccurs="unbounded"/>
        </xsd:sequence>
    </xsd:complexType>
    <!-- ====================================================================== -->
    <xsd:complexType name="ReticleInformationType">
        <xsd:sequence>
            <xsd:element name="ReticleID" type="xsd:ID"/>
            <xsd:element name="ReticleName" type="xsd:string"/>
            <xsd:element name="BarCode" type="xsd:string"/>
            <xsd:element name="ReticleSize" type="rfd:ReticleSizeType"/>
            <xsd:element name="ReticleType" type="xsd:string"/>
            <xsd:element name="ReticleMarkID" type="xsd:string"/>
            <xsd:element name="ReticleMarkType" type="xsd:string"/>
            <xsd:element name="ProjectionMagnification" type="xsd:unsignedInt"/>
        </xsd:sequence>
    </xsd:complexType>
    <!-- ====================================================================== -->
    <xsd:complexType name="ReticleSizeType">
        <xsd:sequence>
            <xsd:element name="Size" type="xsd:unsignedInt"/>
            <xsd:element name="UnitType" type="rfd:UnitTypeType"/>
        </xsd:sequence>
    </xsd:complexType>
    <!-- ===================== AlignmentMarkDesign ========================== -->
    <xsd:complexType name="AlignmentMarkDesignType">
```

```
			<xsd:sequence>
				<xsd:element name="AlignmentMarkInformation"
type="rfd:AlignmentMarkInformationType" minOccurs="0" maxOccurs="unbounded"/>
				<xsd:element name="MarkUseRule" type="rfd:MarkUseRuleType"/>
			</xsd:sequence>
		</xsd:complexType>
		<!-- ============================================================================ -->
		<xsd:complexType name="AlignmentMarkInformationType">
			<xsd:sequence>
				<xsd:element name="AlignmentMarkID" type="xsd:ID"/>
				<xsd:element name="Group" type="xsd:string"/>
				<xsd:element name="WaferMarkType" type="xsd:string"/>
				<xsd:element name="WaferMarkPosition" type="rfd:WaferMarkPositionType"/>
				<xsd:element name="Comment" type="xsd:string"/>
			</xsd:sequence>
		</xsd:complexType>
		<xsd:complexType name="MarkUseRuleType">
			<xsd:sequence>
				<xsd:element name="FileName" type="xsd:string"/>
			</xsd:sequence>
		</xsd:complexType>
		<!-- ============================================================================ -->
		<xsd:complexType name="WaferMarkPositionType">
			<xsd:sequence>
				<xsd:element name="X-Mark" type="rfd:XYUnitType"/>
				<xsd:element name="Y-Mark" type="rfd:XYUnitType"/>
				<xsd:element name="UnitType" type="rfd:UnitTypeType"/>
			</xsd:sequence>
		</xsd:complexType>
		<!-- ======================== AlignmentUSEMark ============================== -->
		<xsd:complexType name="AlignmentUSEMarkType">
			<xsd:sequence>
				<xsd:element name="AlignmentMarkInformation"
type="rfd:AlignmentMarkInformationType" minOccurs="0" maxOccurs="unbounded"/>
			</xsd:sequence>
		</xsd:complexType>
		<!-- ============================== Common ==================================== -->
		<!-- ============================XYUnitType==================================== -->
		<xsd:complexType name="XYUnitType">
			<xsd:sequence>
				<xsd:element name="X" type="xsd:double"/>
				<xsd:element name="Y" type="xsd:double"/>
			</xsd:sequence>
		</xsd:complexType>
		<!-- ============================XYCodeType==================================== -->
		<xsd:complexType name="XYCodeType">
			<xsd:sequence>
				<xsd:element name="X" type="xsd:double"/>
				<xsd:element name="Y" type="xsd:double"/>
				<xsd:element name="UnitType" type="rfd:UnitTypeType"/>
			</xsd:sequence>
		</xsd:complexType>
		<!-- =====================UnitTypeType========================================== -->
		<xsd:simpleType name="UnitTypeType">
			<xsd:restriction base="xsd:string">
				<xsd:enumeration value="mm"/>
```

```
                &lt;xsd:enumeration value="um"/&gt;
                &lt;xsd:enumeration value="inch"/&gt;
            &lt;/xsd:restriction&gt;
    &lt;/xsd:simpleType&gt;
&lt;/xsd:schema&gt;
```

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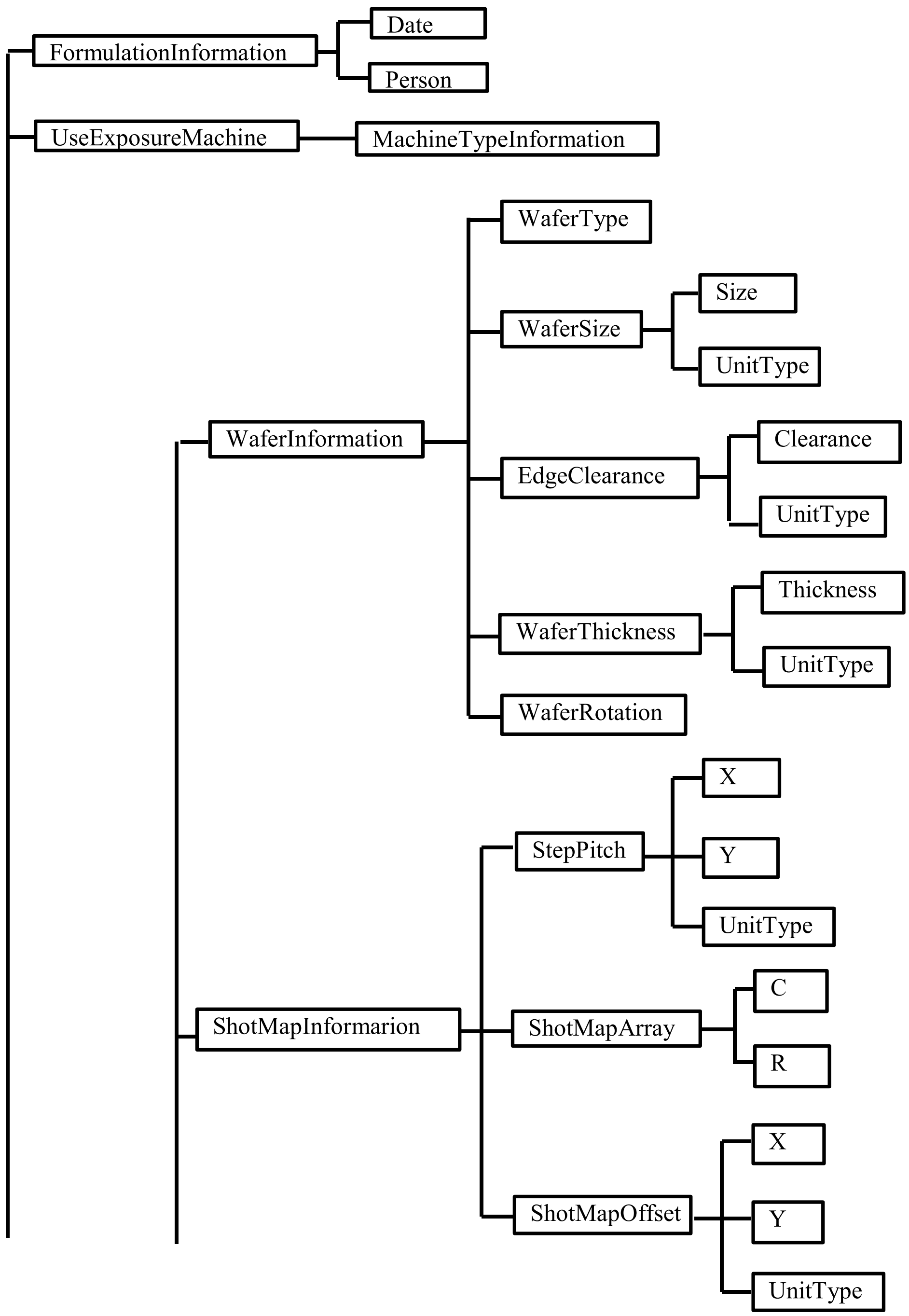
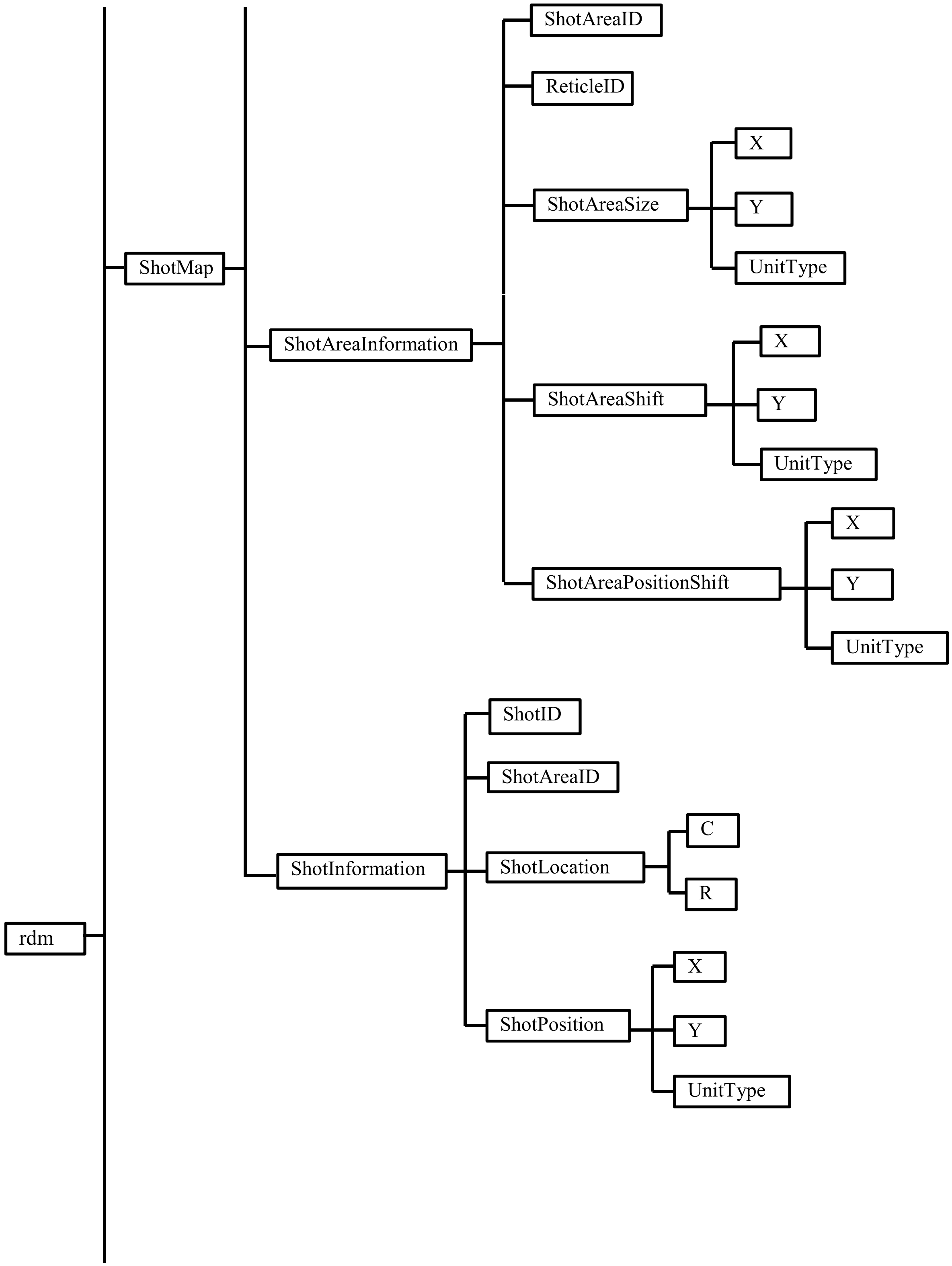
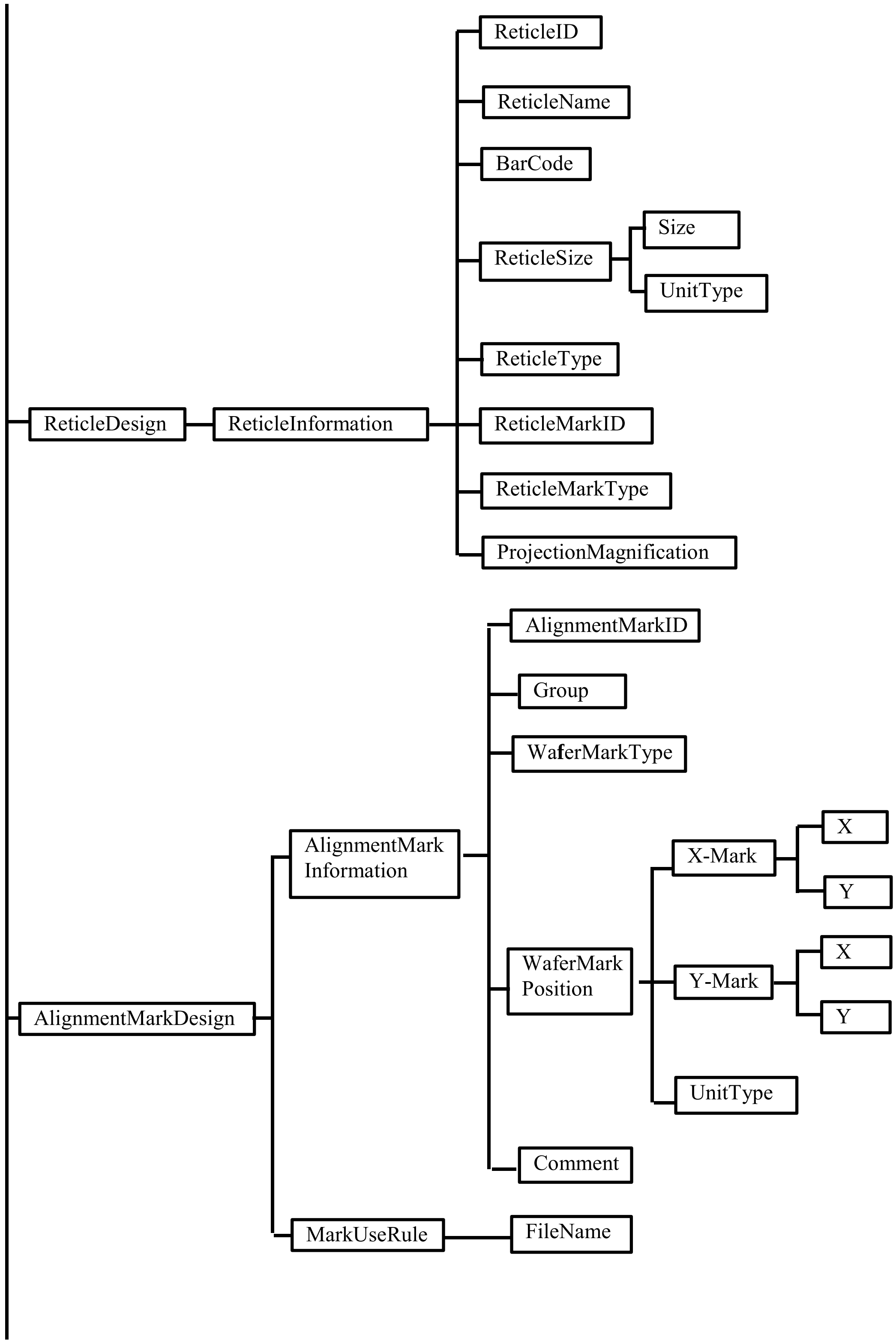
RELATED INFORMATION 1
APPLICATION NOTES

NOTICE: This related information is not an official part of SEMI P42 and was derived from work by the originating task force. This related information was approved for publication by full letter ballot procedures on January 9, 2004.

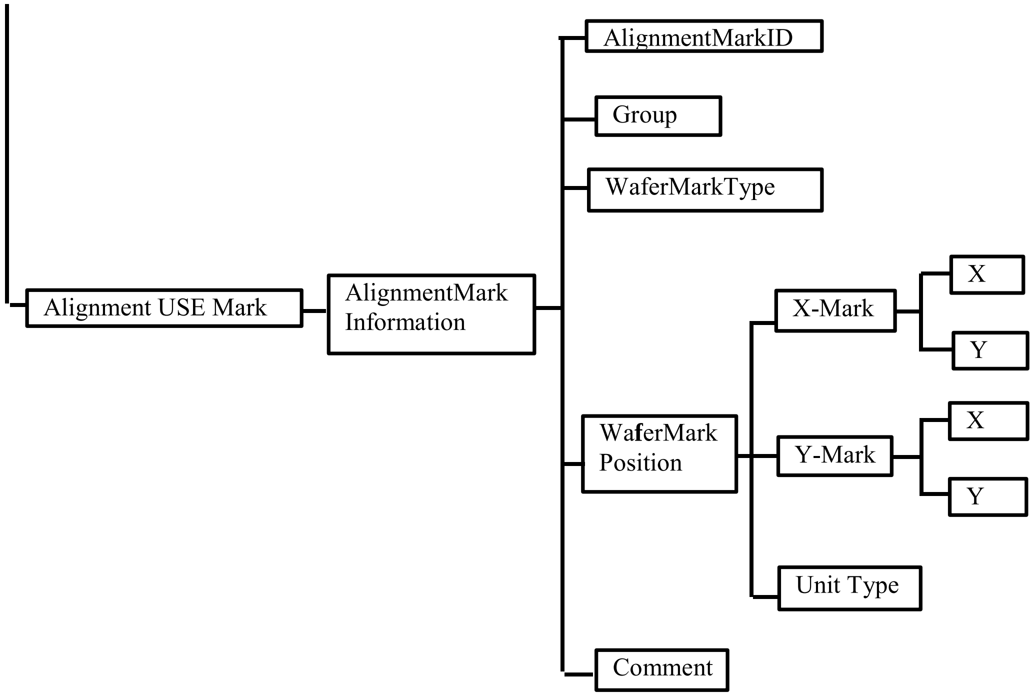
R1-1 Diagram Sample of Reticle Frame Data




rdm
ShotMap
ShotAreaInformation
ShotAreaID
ReticleID
ShotAreaSize
X
Y
UnitType
ShotAreaShift
X
Y
UnitType
ShotAreaPositionShift
X
Y
UnitType
ShotInformation
ShotID
ShotAreaID
ShotLocation
C
R
ShotPosition
X
Y
UnitType



ReticleID
ReticleName
BarCode
Size
ReticleSize
UnitType
ReticleType
ReticleDesign
ReticleInformation
ReticleMarkID
ReticleMarkType
ProjectionMagnification
AlignmentMarkID
Group
WaferMarkType
X
AlignmentMark Information
X-Mark
Y
X
WaferMark Position
Y-Mark
AlignmentMarkDesign
Y
UnitType
Comment
MarkUseRule
FileName



R1-2 XML Description Sample

This sample is provided with the repetitive description of <ShotID>S76 from <ShotID>S9 not repeated.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SEMI P43-0304
PHOTOMASK QUALIFICATION TERMINOLOGY

This terminology was technically approved by the Global Micropatterning Committee and is the direct responsibility of the European Micropatterning Committee. Current edition approved by the European Regional Standards Committee on January 9, 2004. Initially available at www.semi.org February 2004; to be published March 2004. This document replaces SEMI PR7-0302 in its entirety.

1 Purpose

1.1 This standard defines a unique language in the field of specification for, and qualification of, photomasks for use in optical lithography within the semiconductor industry.

2 Scope

2.1 At present only the International Technology Roadmap for Semiconductors (ITRS) serves as a universally accepted working document on how to specify photomasks, however the definitions used are subject to interpretation. Different tool makers, mask makers and mask users are hindered in the communication with each other, as they first need to know and understand each others terminology. The lack of a common terminology complicates comparison of tools. A uniformly used, and universally accepted terminology, with a minimum of ambiguity, is required.

2.2 The definitions listed are for mask qualification, incorporating 3 possible types of value for a given qualification parameter:

- **<*(true) qualification parameter*>,** which would be the result of an ideal measurement of the total population of features of interest[1].
- **<*measured qualification parameter*>,** the result of a given population of measurements. It is hereby mentioned that a measured value (for example the mean, the standard deviation, the range) is always subject to the sample size of the measured population and the measurement method. Therefore both the sample size and the measurement method are mandatory information.
- **<*qualification parameter spec(ification)*>,** the maximum or minimum value that may not be exceeded for the selected population of measurements which must be defined as mandatory information.

2.2.1 The first two types of value for a given parameter, the true and measured qualification parameters, will be defined in the present document.

2.2.2 The third parameter type, the parameter specification, will not be discussed here, since it is subject to the agreement between the individual parties of the mask qualification process.

2.3 In order to assist users, the major differences in recommended default values between this standard and the ITRS mask table definitions are noted where applicable.

NOTICE: This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This document is restricted to dimensional metrology aspects. Other conventional mask qualification aspects, including those related to materials, overlay and defectivity, are not considered within the scope of this version.

3.2 The definitions listed are specific to state-of-the-art photomasks, with a focus on reduction reticles. They may therefore overrule any related terminology in other standards, with a more general scope. Application to other types of masks, e.g., for next generation lithography, may be feasible, but is not within the scope of the present document.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI P10 — Specification of Data Structures for Photomask Orders

SEMI P19 — Specification for Metrology Pattern Cells for Integrated Circuit Manufacture

SEMI P21 — Guidelines for Precision and Accuracy Expression For Mask Writing Equipment

SEMI P22 — Guideline for Photomask Defect Classification and Size Definition

SEMI P24 — CD Metrology Procedures

SEMI P35 — Terminology for Microlithography Metrology

1 See reference document in Section 4.2.

SEMI Compilation of Terms

4.2 *ISO Standards* [2]

International Vocabulary of Basic and General Terms in Metrology

4.3 *Other Standards*

International Technology Roadmap for Semiconductors (ITRS) [3]

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Interpretation of Related General Terminology

NOTE 1: This paragraph includes general terms, as a basis for the specific mask related terminology, which is the main subject of this document.

5.1 *feature* — as defined in SEMI P35.

5.2 *proximity range* — distance over which a feature influences another significantly (criterion to be stated). This term applies to mask fabrication, mask metrology and/or printed wafer image, defining 3 types of proximity range (for example *mask fabrication proximity range*). It is mandatory to state which of the 3 types is referred to.

NOTE 2: Within this document *proximity range* will refer by DEFAULT to the first type mentioned.

5.3 *line* — a clear field, dark feature of quasi-infinite length (>> *proximity range*) determined by its width. A *line* is an example of a 1D feature (see Figure 1).

5.4 *space* — in analogy to line, but a clear feature in a dark field (see Figure 1).

5.5 *contact* — a clear feature in a dark field with length:width ratio ranging from 0.5 (1 is default) to 2 maximum (see Figure 1). The width of such feature may be measured as if it were a 1D feature, but for enhanced relevance it requires 2D assessment such as an area measurement. A large contact can be called a *window*.

5.6 *dot* — in analogy to contact, but a dark feature in a clear field (see Figure 1). A large dot can be called a *pad*.

5.7 *isolated feature* — feature that has no neighbors that are within a distance smaller than the proximity range to any edge of the feature.

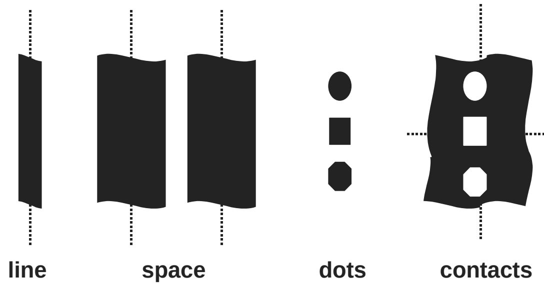


Figure 1
Nomenclature for Feature Types (as Designed)
Default contact (dot) is square.

5.8 *dense features* — features that influence each other (i.e., features that are not isolated). Clarification is required to describe the proximity, either by detailing the feature pitch and number of lines, for regular arrays (pitch = design values of line width and space width added), or by describing the surrounding area (see Section 7). In absence of such clarification dense is regarded by default as equal lines and spaces in a semi-infinite array size, insofar that the feature width does not exceed the proximity range.

5.9 *nominal feature* — feature as it is intended. This usually corresponds to the data used for mask making, including any pre-compensation to overcome process biases of the wafer process (e.g., subresolution features such as hammerheads and serifs), but excluding any pre-compensation that is purely done to deal with mask process limitations (e.g., chrome etch bias). In the simplest case it corresponds to the original design itself.

5.10 *actual feature* — feature as it is on the mask. In practical cases this will include deviations in feature widths, lengths, shape and position from the nominal feature.

NOTE 3: A feature, whether actual or nominal, may contain holes, as shown in Figure 2.

Figure 2
Example of Features Containing Holes
(left: nominal; right: actual)

5.11 *pattern* — subset of a layout containing one or more features.

2 International Organization for Standardization 1, rue de Varembé Case Postale 56 CH-1211 Genève 20 Switzerland

3 International Technology Roadmap for Semiconductors, organized by International SEMATECH, 2706 Montopolis Drive, Austin, Texas 78741, see itrs.org

NOTE 4: It is possible that some features are only included in part, see *clipped feature.*

5.12 *region of interest* (ROI) — circumscribed section of a pattern that contains (parts of) the features considered for measurement.

NOTE 5: It is recommended to make the ROI as small as possible without affecting the obtained result.

5.13 *clipped (nominal/actual) feature* — the part of the (nominal/actual) feature lying within the region of interest (Figure 7).

5.14 *feature (or Pattern) alignment* — positioning of nominal and actual feature (or pattern) relative to each-other (see Section 8.4).

6 Coordinate System

6.1 The coordinate system XYZ for this document is defined in Figure 3. It is defined with patterned mask side upwards and mask orientation as it was patterned. XY determines the mask plane. Z is the direction perpendicular to it. $z = 0$ at the absorber–substrate interface and $z < 0$ to the substrate side. Absorber is for example chrome or embedded material. $(x,y) = (0,0)$ is tool or application specific.

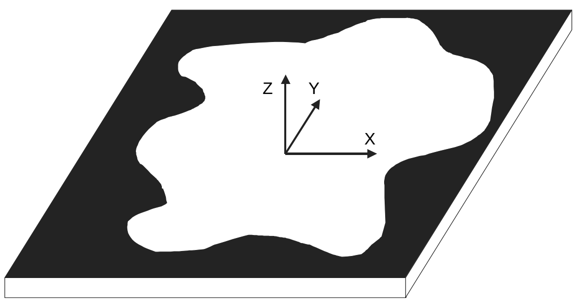


Figure 3
Mask Coordinate System

6.2 Features are called vertical when their length is along Y. Feature width is then measured in X. This corresponds to Figure 2 of SEMI P35. Horizontal features have their length along X. Feature width is then measured in Y. See Figure 4.

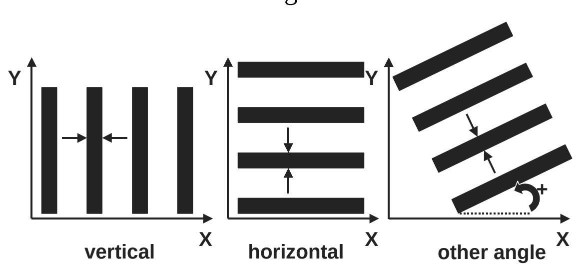


Figure 4
Orientation of Mask Features

7 1D Mask Qualification Terminology

7.1 *feature width* — width of a cross section of a mask feature at a certain height defined by an appropriate bounding box model as described in SEMI P35 (see Figure 5). The bounding box model must be stated as mandatory information, as well as the z height of the measurement. DEFAULT is at $z = 0$.

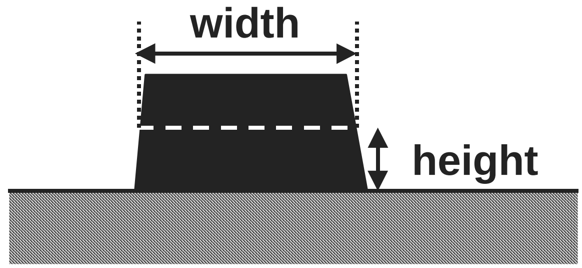


Figure 5
Cross Section of a Mask Feature

7.2 *measured feature width* — width determined from the measured signal obtained on the mask feature. For example, the width may be determined at a certain level of the measured signal. To be stated as mandatory information:

- region of interest. For 1D features this corresponds to the specified line segment (SEMI P35),
- measurement method used (SEM, optical reflection, optical transmission, AFM, etc.),
- calibration and/or correlation used,
- precision (SEMI P24),

and as optional information:

- measurement tool (vendor, model or any tool specific options), and
- measurement algorithm used.

NOTE 6: The bounding box could be infinitely short as in the special situation of a measurement of a *feature* using a cross-section.

7.3 *feature width deviation (from target)* — difference between actual and nominal feature width.

7.4 *measured feature width deviation (from target)* — difference between measured and nominal feature width.

7.5 *feature edge* — position of the material boundary of a mask feature at a certain height of the physical cross section (see Figure 2 of SEMI P35), to be stated as mandatory information. DEFAULT is feature/substrate interface.

7.6 *measured feature edge* — position determined from the measured signal obtained on the mask feature edge. For example position determined at a certain level of the signal, as defined by the bounding box model of SEMI P35. The same mandatory/optional information must be stated as for *measured feature width.*

7.7 *critical dimension (abbreviated to CD)* — a user defined feature width of interest, mainly used for further qualification. The critical dimension can be plural. DEFAULT CD is one width and one pitch. Mandatory information is the nominal feature width and pitch.

NOTE 7: The ITRS mask table assumes multiple pitches.

7.8 *feature width uniformity* — the spread of the distribution of the width of all mask features of a given design size, selected as detailed hereafter. To be stated as mandatory information:

- its targeted feature width,
- the criterion used (range, 3-sigma, maximum deviation, etc.), where sigma stands for standard deviation. Recommendation: before 3-sigma is relevant, the distribution needs to be "normal" or "near normal", and the number of measurements should be > 30,
- type and tone of features considered (line, contact, space, etc. as defined in SEMI P19),

  NOTE 8: Several types and/or tones of features could be combined, but the recommendation is one tone and one type, DEFAULT is lines for clearfield, spaces for darkfield).

- all orientations considered (adopting a pre-determined mask orientation, based on the coordinate system in Section 6), for example horizontal and vertical together, horizontal only, vertical only, including other angles, horizontal-and-vertical separately, etc. DEFAULT is horizontal and vertical together,
- the pitch of the feature (or in general: a description of the surrounding area, see further), e.g., equal lines and spaces, isolated line, etc., or (if wished, but not recommended) an interval of pitches, and

  NOTE 9: In case of multiple pitches the defined *feature width uniformity* would not be proximity free. DEFAULT is one fixed pitch, to be mentioned. (The ITRS mask table assumes multiple pitches.)

- The considered area of interest on the mask.

7.9 *measured feature width uniformity* — measured value of *feature width uniformity,* stating as mandatory information in addition to that of *measured feature width* and *feature width uniformity*:

- the number of measurement points used,
- the measured area on the mask,

and as optional information:

- the spatial distribution of measurement locations, e.g., by their coordinates. DEFAULT is spread evenly over the measurement area.

7.10 *(measured) CD uniformity* — the special case of *feature width uniformity* where the selected feature is the *critical dimension.*

7.11 *feature mean-to-target* — the difference between the mean width of features, selected as detailed, and the targeted feature width, stating the same information as for *feature width uniformity*. (DEFAULT: selecting the same information and values as for *feature width uniformity.*)

7.12 *measured feature mean-to-target* — the difference between the mean of measured feature widths and the targeted feature width, stating the same information as for *measured feature width uniformity*. (DEFAULT: selecting the same values as selected for *measured feature width uniformity.*)

7.13 *(measured) CD mean-to-target* — the special case of *(measured) feature mean-to-target* where the selected feature is the *critical dimension.*

7.14 *maximum feature width deviation from target* — maximum deviation of the width of a *feature* from its target width in the total population of features considered, stating the same information as in *feature width uniformity*. (DEFAULT: selecting the same information and values as used for *feature width uniformity.*)

7.15 *measured maximum feature width deviation from target* — maximum deviation of the measured width of a *feature* from its target width in the population of measurements, stating the same information as in *measured feature width uniformity.* (DEFAULT: selecting the same values as used for *measured feature width uniformity.*)

NOTE 10: *(Measured) maximum feature width deviation from target* combines *(measured) feature width uniformity* and *(measured) mean-to-target.*

7.16 *mean X-Y deviation* — the difference between the mean of considered feature widths in X and Y directions (horizontal and vertical direction), stating the same information as *feature width uniformity*. (DEFAULT: selecting the same values as used for *feature width uniformity.*)

7.17 *measured mean X-Y deviation* — the difference between the mean values of measured feature widths in X and Y directions, stating the same information as for *measured feature width uniformity* (DEFAULT: selecting the same values as used for *measured feature width uniformity.*)

7.18 *X-Y deviation uniformity* — the spread of the distribution of the difference between the width of all considered feature widths in X and Y directions (horizontal and vertical direction), stating the same information as *feature width uniformity*. (DEFAULT: selecting the same values as used for *feature width uniformity*.)

NOTE 11: For such purpose X and Y feature width measurement locations should be as close as practically possible.

7.19 *measured X-Y deviation uniformity* — the spread of the distribution of the difference between the width of the measured feature widths in X and Y directions (horizontal and vertical direction), including/stating the same information as *measured feature width uniformity*. (DEFAULT: selecting the same values as used for *measured feature width uniformity.*)

7.20 *feature linearity error* — total range of the deviations between the mask feature width and the respective target width on a range of feature widths (see Figure 6a), stating as mandatory information:

- the range of feature widths used (at mask level). (DEFAULT is the interval from the critical dimension to 5 times this value.)

  NOTE 12: The ITRS uses a wider interval.

- all types and tones of features considered, e.g., line, contact, space, etc. (see in Section 5 for definitions of these terms). It is a strong recommendation to fix on 1 tone and 1 type to reach a useful number. DEFAULT is on lines ("*line linearity error*"). Contacts may be more challenging *("contact linearity error*").

- all orientations considered, e.g., horizontal and vertical together, horizontal only, vertical only, including other angles, horizontal-and-vertical separately, etc.

- the pitch of the feature (or in general: a description of the surround(ing mask area), see further), e.g., equal lines and spaces, isolated line, etc., or (if wished, but not recommended) an interval of pitches. DEFAULT is isolated features only, which is defined as *feature intra-proximity error.*

  NOTE 13: If a range of pitches is included, the resulting definition will include (inter)proximity effects. (The ITRS mask table assumes multiple pitches.)

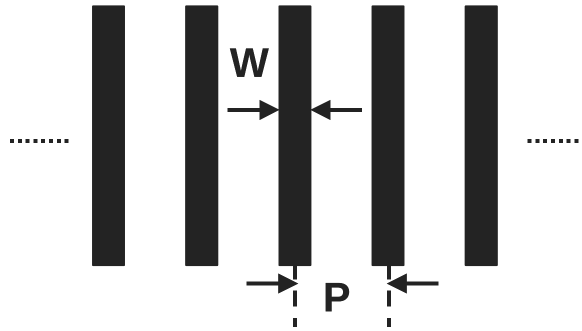


Figure 6
Choice of width (W) and pitch (P) in an array of features (here shown for lines) for the determination of a) feature linearity: varying W and P fixed; b) feature interproximity: fixed W and varying P; c) feature proximity: W and P BOTH varying.

7.21 *measured feature linearity error* — measured value of *feature linearity error*, stating as mandatory information in addition to that of *measured feature width* and *feature linearity error*:

- the number of measurement points per feature width (which is recommended to be more than one measurement per feature width). If more than one measurement per feature is taken, then the mean value for each feature width is used.

and as optional information:

- the measured area.
- the spatial distribution of measurement locations.

7.22 *feature inter-proximity error* — range of the deviations between the mask feature width of a given size and the respective target width, on a variation of local pattern density and configuration (i.e., of the surround) (see Figure 6b), stating as mandatory info:

- the nominal feature width at mask level.

- all types and tones of features considered, e.g., line, contact, space, etc. (see in Section 5 for definitions of these terms). It is a strong recommendation to fix on 1 tone/ 1 type to reach a useful number. DEFAULT is on lines (*line inter-proximity error).*

- all orientations considered, e.g., horizontal and vertical together, horizontal only, vertical only, including other angles, horizontal-and-vertical separately, etc.

- range of feature pitches. DEFAULT is equal lines-and-spaces to isolated features. If only equal lines-and-spaces and isolated features themselves (and nothing in-between) are used, the term *iso-dense deviation* can also be used. In more general cases an alternative detailed description of the surround(ing mask area), preferably clarified with a drawing, will replace the pitch information.

7.23 *measured feature inter-proximity error* — measured value of *feature inter-proximity error*, stating as mandatory information in addition to that of *measured feature width* and *feature inter-proximity error*:

- the number of measurement points used per pitch or surrounding mask area (to be more than one measurement per pitch). If more than one measurement per pitch is taken, then the mean value for each pitch is used.

and as optional information:

- the measured area on the mask.
- the spatial distribution of measurement locations.

7.24 *feature proximity error* — total range of the deviations between the mask feature width and the respective target width on a range of feature widths and on a variation of local pattern density and configuration (i.e., of the surround) (see Figure 6c), stating as mandatory info:

- the range of feature widths used (at mask level). (DEFAULT is the interval from the critical dimension to 5 times this value.)

  NOTE 14: The ITRS uses a wider interval.

- all types and tones of features considered, e.g., line, contact, space, etc. (see in Section 5 for definitions of these terms). It is a strong recommendation to fix on 1 tone and 1 type to reach a useful number. DEFAULT is on lines ("*line proximity error*").
- all orientations considered, e.g., horizontal and vertical together, horizontal only, vertical only, including other angles, horizontal-and-vertical separately, etc.
- range of feature pitches. In more general cases an alternative detailed description of the surround(ing mask area), preferably clarified with a drawing, will replace the pitch information.

7.25 *measured feature proximity error* — measured value of *feature proximity error*, stating as mandatory information in addition to that of *measured feature width* and *feature proximity error*:

- the number of measurement points used per pitch or surrounding mask area (recommendation is > 1. Then the mean value is used).

and as optional information:

- the measured area on the mask.
- the spatial distribution of measurement locations.

8 2D Mask Qualification Terminology

8.1 *Introductory Remarks*

8.1.1 The 2D terminology adds onto the 1D terminology (Section 7). The 1D errors are an inherent part of, and affect, the 2D qualification. Section 8.2 treats 2D-qualification without considering the impact of 1D control (Section 7). Section 8.3 will suggest how to include consequences of feature width deviation.

8.1.2 Most 2D definitions are based on a comparison of a nominal and an actual feature/pattern. Where relevant, appropriate alignment of nominal and actual feature/pattern is assumed. This will be treated in detail in Section 8.4.

8.2 *True Values*

NOTE 15: Reminder: The meaning of *true* is described in Section 2.2. An ideal measurement then includes the idea of perfect alignment of nominal and actual feature (see Section 8.4).

8.2.1 *feature contour* — shape formed by all edges of a feature, including external and internal edges (see Note 3 in Section 5.10). If the feature considered is clipped, then the edge(s) clipped by the region of interest serve as the edge(s) of the clipped feature (Figure 7).

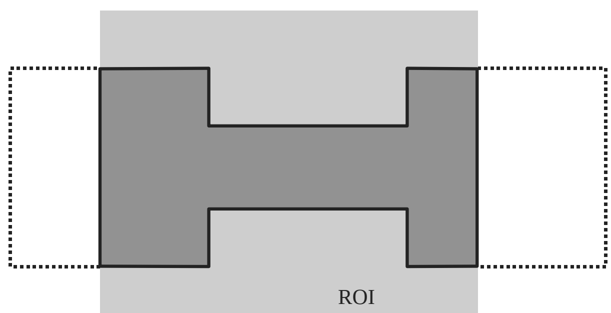


Figure 7
Contour (for definition see Section 8.2.1, shown as a full line,) of a clipped feature (region of interest in light grey; the dotted line shows the feature contour outside ROI)

8.2.2 *General Approach, Based on Area*

8.2.2.1 *(clipped) feature area* — enclosed area defined by the edges of the (*clipped)* feature, i.e., area in the (*clipped) feature contour*, mentioning as mandatory information:

- description of the nominal feature including type, dimensional information, tone, surrounding area, and orientation relative to the coordinate system (described in Section 6).

- additionally if clipped: region of interest, clipping details.

8.2.2.2 *(clipped) feature area gain* — area in the actual (clipped) feature contour outside of the nominal (clipped) feature (see Figure 8). Additional mandatory information:

- relative position of actual and nominal feature (see Section 8.4).

8.2.2.2.1 Note that the value of the *(clipped) feature area gain* is always positive.

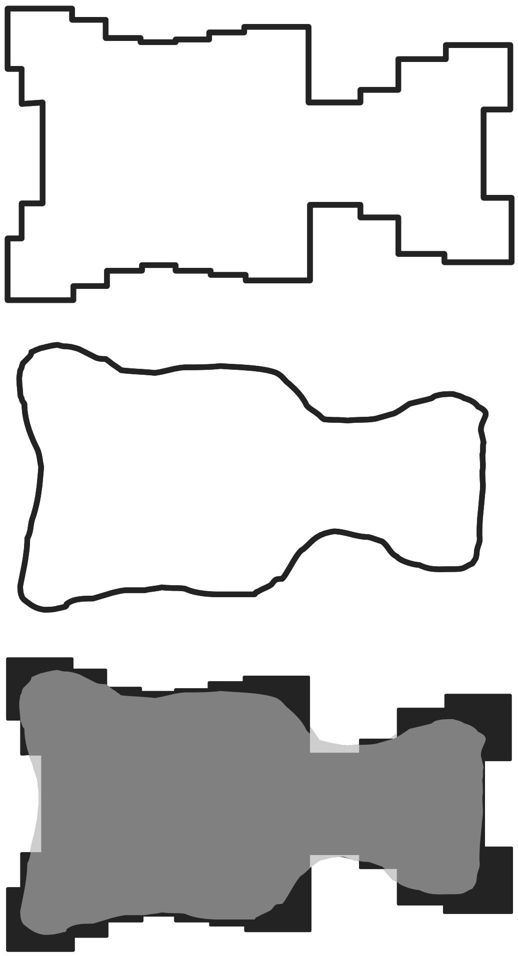
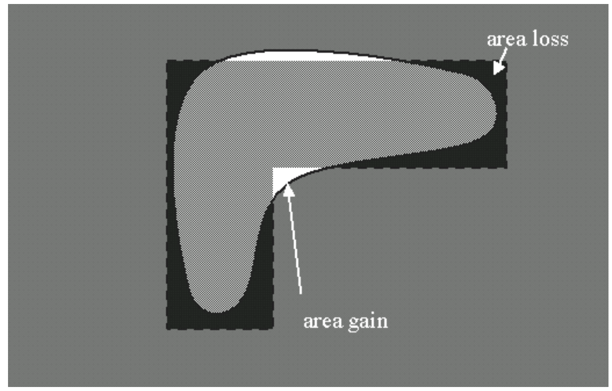


Figure 8
Illustration of feature area (top: nominal feature, center: actual feature) and bottom: feature area gain (light gray), feature area loss (black) and overlapping area (medium gray)

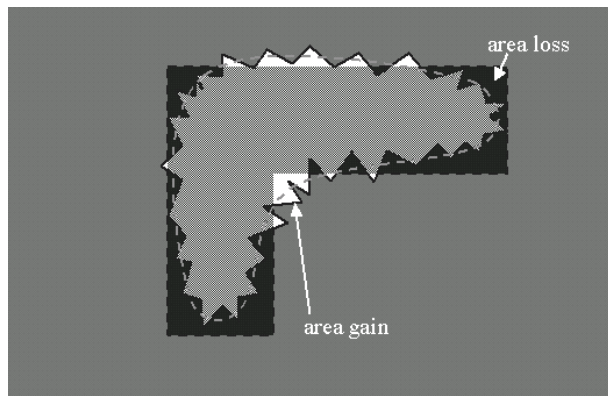
8.2.2.3 *(clipped) feature area loss* — (clipped) area outside of the actual feature, still inside of the nominal feature (see Figure 8).

8.2.2.3.1 Same mandatory information as in *(clipped) feature area gain*.

8.2.2.3.2 Note that the value of the *(clipped) feature area loss* is always positive.



(a)



(b)

Figure 9
Illustration that edge roughness can influence feature area deviation, unlike feature area difference.
(a) without edge roughness (or with severe smoothing)
(b) with edge roughness: area gain and area loss are larger than in case (a), but can compensate each-other when using feature area difference

8.2.2.4 *(clipped) feature area difference* — (clipped) feature area gain minus (clipped) feature area loss. This is also equal to the (clipped) feature area of the actual feature minus the (clipped) feature area of the nominal feature. The value of the (clipped) feature area difference may be positive or negative accordingly. Same mandatory information as in *(clipped) feature area gain.*

NOTE 16: This qualification parameter is recommended for contacts or dots, because in these cases it is of relatively minor importance where the gain and loss are situated.

8.2.2.5 *absolute (clipped) feature area deviation* — the sum of the values of *(clipped) feature area gain* and *(clipped) feature area loss*. Note that the value of the *absolute (clipped) feature area deviation* is always positive. Same mandatory information as in *(clipped) feature area gain.*

NOTE 17: This qualification parameter is recommended for features for which it does matter where the gain and loss are situated.

NOTE 18: This reasoning could be extended to *Pattern area gain /loss /difference /deviation* if several features are present in the region of interest.

NOTE 19: Edge roughness may influence *feature area deviation,* unlike *feature area difference,* in which the effect of edge roughness is filtered out by allowing the resulting area gain and area loss to cancel out (see Figure 9).

NOTE 20: *Normalized feature area, normalized feature area gain, normalized feature area loss, normalized feature area difference* and *normalized feature area deviation* are defined as the ratio between the actual value of the considered parameter and the nominal feature area.

8.2.3 *Specific Case of Corner Rounding (CR)*

8.2.3.1 *corner rounding* — deviation of an actual feature corner from the nominal one.

8.2.3.1.1 The definition above is qualitative, and can be quantified in all practical cases by treating it as a special case of feature area difference (see further in Sections 8.2.3.2–7). Quantitative determination requires as mandatory information:

- the designed angle (see Figure 10), DEFAULT angle is 90 degrees.
- feature tone: dark vs. clear.
- corner type: outer vs. inner. Corner type is ambiguous without feature tone specified (see Figure 11).
- other features or feature corners within the proximity range from the corner of interest, DEFAULT is an isolated corner.
- orientation of the corner (determined by the 2 linear sections, e.g., 90^ 180, 160^ 210,.., (see Figure 10). DEFAULT is all 4 orientations with linear sections along X- and Y-axes (Figure 12) for both dark and clear feature tone.

NOTE 21: The purpose of the default corners is to help the user of this document to select representative features to qualify, for example, the corner rounding fingerprint of a mask making process.

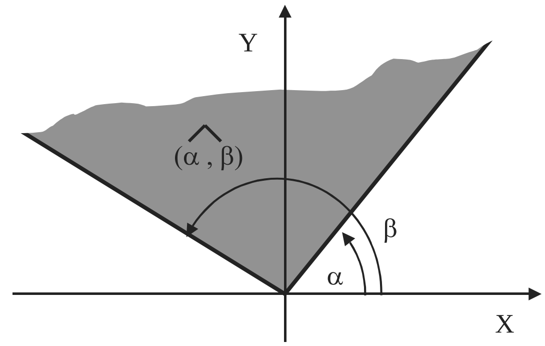
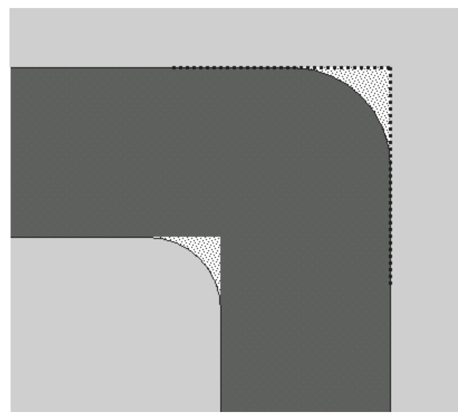


Figure 10
Nomenclature of Feature Corners by the Angles of Their Linear Sections



(a)

(b)

Figure 11
Illustration of nomenclature used for feature corners (elbow as example)
(a) dark feature; (b) clear feature;
bottom left in each sub-figure: inner corner;
top right in each sub-figure: outer corner.

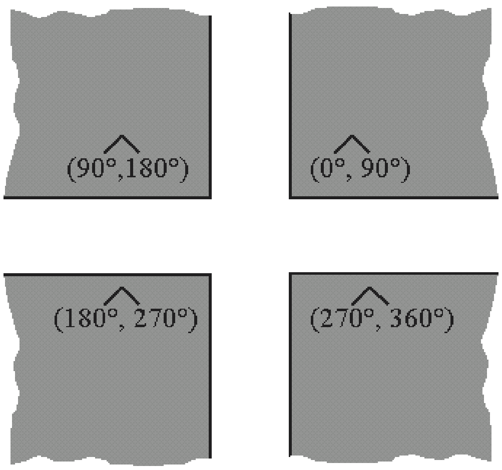


Figure 12
The 4 Default Orientations of a 90º Corner

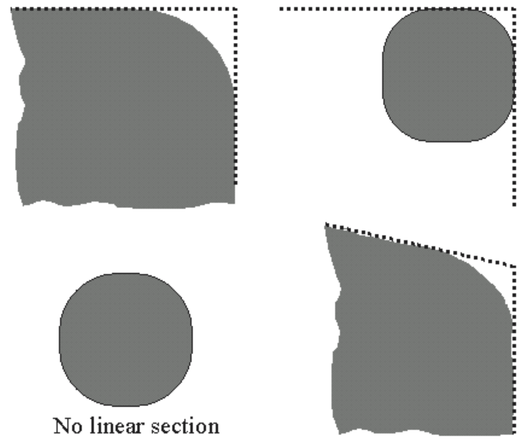


Figure 13
Corner Rounding Determination by Extrapolation of the Linear Sections of the Actual Feature Contour

8.2.3.2 *corner area gain* — special case of *clipped feature area gain*, in which the region of interest contains one corner of a feature.

8.2.3.3 *corner area loss* — special case of *clipped feature area loss*, in which the region of interest contains one corner of a feature.

NOTE 22: In non-corrected isolated cases normally there is **only** a loss for outer corners and a gain for inner corners. In other cases (i.e., corrected corners) there may be a loss and a gain, which makes it necessary to also define the difference and deviation, as done below.

8.2.3.4 *corner area difference* — *corner area gain* minus *corner area loss*. As such it is a special case of *clipped feature area difference*, in which the *region of interest* contains one corner of a feature.

8.2.3.5 *corner area deviation* — the sum of *corner area gain* and *corner area loss*. As such it is a special case of *clipped feature area deviation*, in which the *region of interest* contains one corner of a feature.

NOTE 23: As the corner shape is expected not to be decisive for its printability (at least for an isolated corner), but rather the balance between area gain and loss, it is recommended to use *area difference* for corner qualification rather than *area deviation*.

NOTE 24: Certain features with non-isolated corners, such as line-ends and contacts, have specific definitions listed in Sections 8.2.4 and beyond.

8.2.3.6 In present practice, corner rounding quantification is done without comparison to the nominal corner. However, this is only valid if the corner is isolated, non-corrected, and its area gain is negligible. Typically it is done based on the determination of a reference corner which is obtained by the extrapolation of the linear sections of the corner, if present (Figure 13).

8.2.3.7 *equivalent corner rounding radius* (ECRR) — an equivalent, effective corner rounding radius calculated from the area difference. It assumes that the corner is a circular arc. The ECRR is calculated as

ECRR = sqrt(4 * corner area difference / (π - 4)), for a 90 degree corner.

8.2.3.7.1 The ECRR is defined only for negative corner area differences, i.e., where the *corner area loss* is larger than the *corner area gain*.

NOTE 25: This definition actually gives a 1D representation for a 2D quality assessement, but it is found useful when comparing mask quality to wafer printing results, which are typically characterized by 1D measurements, such that a dimensionless MEEF (mask error enhancement factor) can be used. As with area based assessment, also this term disregards the shape at the feature corner.

NOTE 26: Current methods to determine a corner rounding radius based on fitting a circle to an actual corner have been experimentally shown to deliver unreliable results and are therefore strongly discouraged.

8.2.3.8 *corner pull-back* (CPB) — the distance between the reference corner and the actual feature contour. This may be based on the minimum distance (*minimum CPB*) or that determined along the bisectric (*bisectric CPB*) (see Figure 14). The choice of CPB technique is mandatory information.

NOTE 27: Edge roughness may have an important influence on the *corner pull-back*, such that contour averaging may be necessary to produce a meaningful result. The method of contour averaging is mandatory information for corner pull-back, if used.