Reticle Handbook

A UNIT OF GENERAL SIGNAL **GS**

●●▲ GCA

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Section 1 - Overview

Introduction

The reticle plays an important role in the transfer of the circuit image from the reticle to the wafer in the wafer stepper system. The quality of the reticle circuit pattern is a key factor in keeping the reticle defect density at a minimum. The future of the semiconductor lithography depends upon keeping reticle defects at an absolute minimum.

This reticle handbook has been written for the users of the GCA AUTOSTEP 200, LASERSTEP and 8000 series wafer stepper systems which require the creation of 5X reduction reticle technology. The handbook is designed to explain the basic system operation of the global alignment, local alignment, and reticle management sub-systems of the wafer stepper systems, as well as the information needed to layout and create a reticle. The information required for CAD layout such as; reticle configuration, wafer alignment targets, and reticle alignment window position is also discussed.

Handbook Organization

The reticle handbook is organized to explain the the general wafer stepper sub-system operation to make the user understand what role the reticle plays in the operation of these sub-systems. Chapters 2 - 4 explain the sub-systems in the order in which they operate, reticle alignment, global wafer alignment, and local die alignment. The layout and creation of the reticle is explained in the subsequent chapters.

The table of contents provides a listing of all sections of this manual. The table and illustrations listing also provides a handy refernce for the various tables and illustrations contained in this manual.

Section 2 - Reticle Management System (RMS)

RMS Reticle Alignment Windows

The 5600 RMS alignment windows are used to align the reticle to the platen chuck, and to the X and Y-axis stages of the wafer stepper system The alignment windows are typically located in the center of the reticle, or offset 11mm from the center position to eliminate possible pattern generation interference as shown in Figure 2-1.
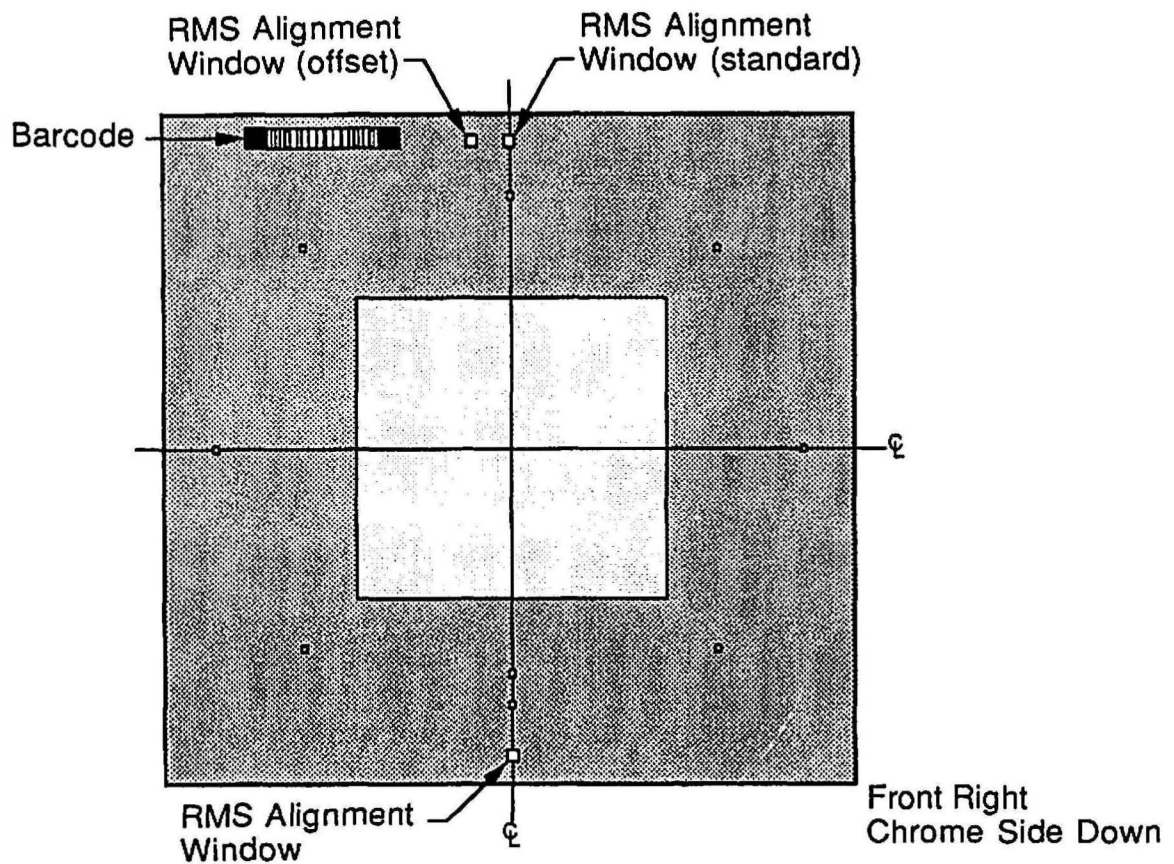
Figure 2-1
Typical Alignment Window Location

Alignment Window Phase and Position

The industry standard reticle phase, and the alignment window is negative. A negative phase indicates that the alignment window is a clear opening in the chrome background of a reticle as shown in Figure 2-2.

Negative Phase Reticle

Positive Phase Reticle

Alignment Window

Alignment Window
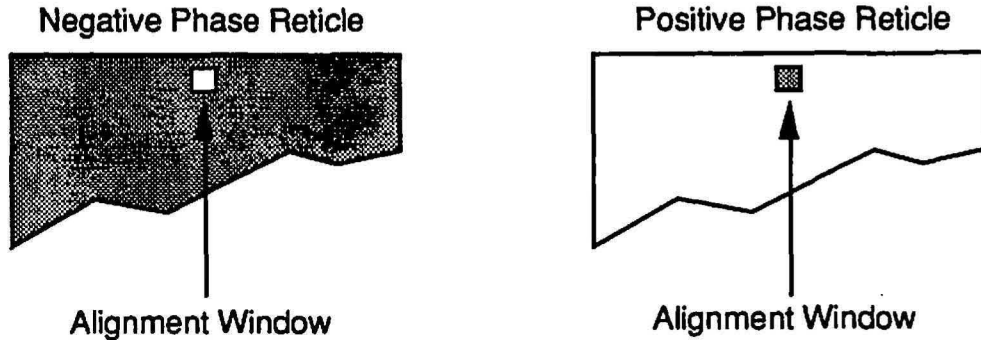
TP-6988

Figure 2-2
Reticle Window Phases

Positive phase reticles exist, however, they are not commonly used. The RMS is capable of being calibrated to align either positive or negative phase reticles.

The position of the negative phase alignment window corresponds to RMS aligner detectors. The detector observes the position of the window, with respect to the aligner fiducial. When the aligner detector assembly photo-diodes generate a voltage of 0.65vDC or less, the reticle is aligned.

Refer to **Section 5 - Alignment Target CAD Layout** for more information on alignment windows and their location on reticles for use with the GCA wafer stepper system.

Bar Code Identification

The RMS can identify a reticle by reading a barcode that is printed on the reticle. A bar code reader is positioned on the A fork side of the turntable as shown in Figure 2-3.

A Fork

Reticle
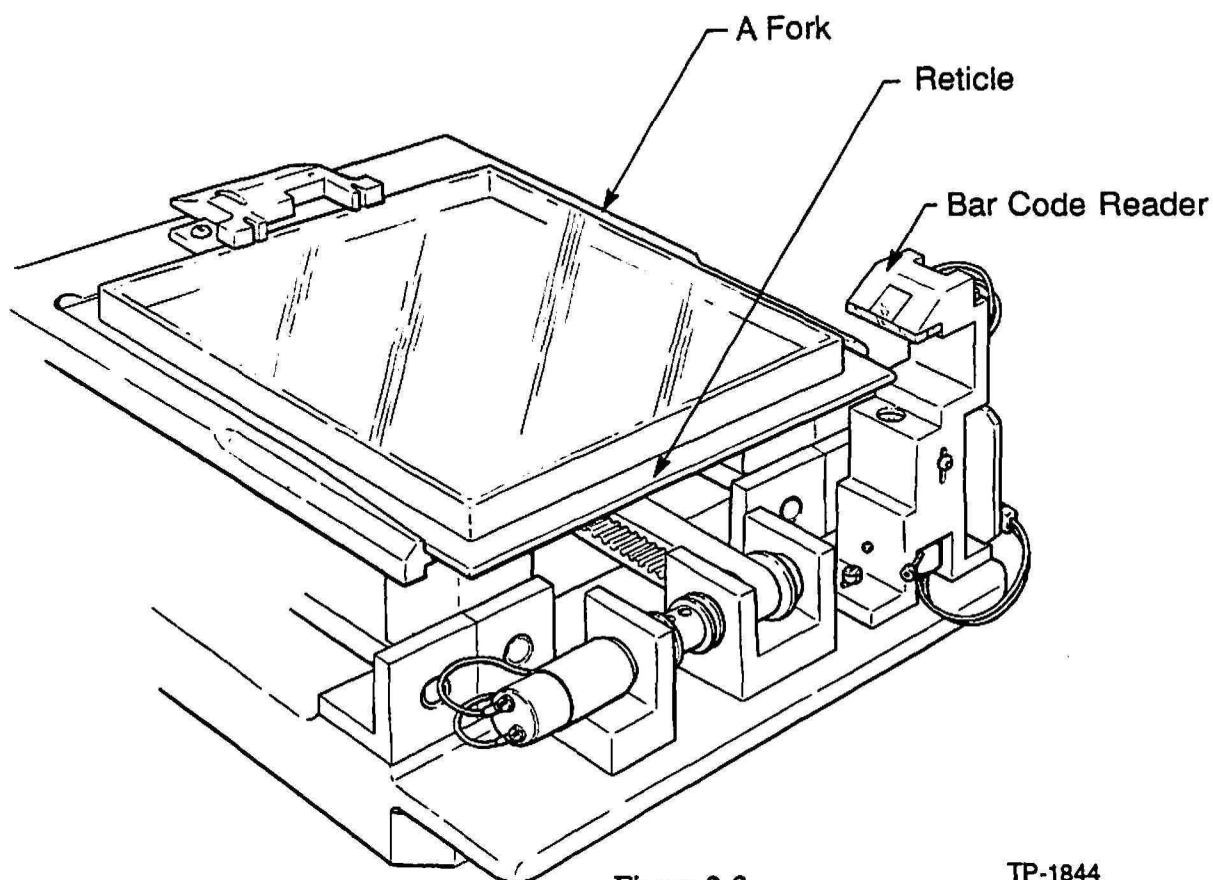
Bar Code Reader

Figure 2-3
Bar Code Reader Assembly

TP-1844

The bar code reader consists of two circuit boards; the sensor board and the main board. The sensor board contains the circuitry to power an infrared emitter (IR) and circuitry for receiving signals from a photovoltaic detector. The output signals of the sensor board go to the main board in the RMS control chassis where the logic, the counter, the First-In-First-Out (FIFO) memory, and the micro computer interface circuitries are located.

To ensure reticle matching to a job specification, the bar code reader reads the bar code of each reticle for identification when removing it from the cassette and verifies that it is the correct reticle

Refer to **Section 5 - Alignment Target CAD Layout** for more information on bar codes and their location on reticles for use with the GCA wafer stepper system.

Aperture Blade Opening and Specifications

The aperture blades are designed to be independently adjustable in 0.127mm steps to a position certainty of ±0.25mm. They are able to reach any position within 3 seconds, regardless of starting position. Their range is 100mm to 10mm, measured at the reticle. The fully open 100mm position is calibrated by software. The aperture control subassembly consists of a metal base or frame which includes the blade/drive apparatus, and serves as mount (pivot plate) for the MAXIMUS light source and its optics (Figure 14-53).

Four blades in pairs define the X and Y dimensions of the aperture through which the reticle pattern is transmitted. All other patterns are blocked by the blades.

Each blade has a 100mm range of travel equal to half the full field. The minimal addressable increment for each blade is 0.63mm [0.025 in]. Blade setting precision is ±0.25mm [0.010 in.] per blade. The home position for the blades is open.

The aperture control assembly is positioned over the platen chuck precisely for the correct portion of the reticle artwork to be defined and exposed at any time.

The user may select and set the position of each particular aperture blade to the position defined in the pass parameters. Less operator intervention is therefore needed, and a higher degree of repeatability achieved. Motion of the blades is controlled by small stepper motors . The positioning of the blades is monitored by optical sensors within the subassembly housing.

Operation of the aperture control assembly involves no pneumatics. All control is electrical and derived from the RMS patch box.

Pellicles

The 5600 RMS has the capability to store, load, and unload reticles which have a pellicle installed. The typical pellicle size which is used with the RMS is approximately 104.585mm square. The installation position of the pellicle is very important because none of the alignment or barcode geometries can be blocked.

Section 3 - Global Alignment System

Introduction

Global alignment is an important first step in aligning the entire wafer to the wafer stepper system for exposure of additional levels. Alignment between each exposure level (overlay or registration) is extremely important in todays IC production environment.

Global alignment can be performed by one of 2 methods, by the operator, or automatically by the Automatic Wafer Aligner/Digital. The AWA/D performs automatic global alignment in a more consistent, faster, and reliable method than the typical operator. Figure 3-1 shows the general global alignment system configuration on the wafer stepper system.
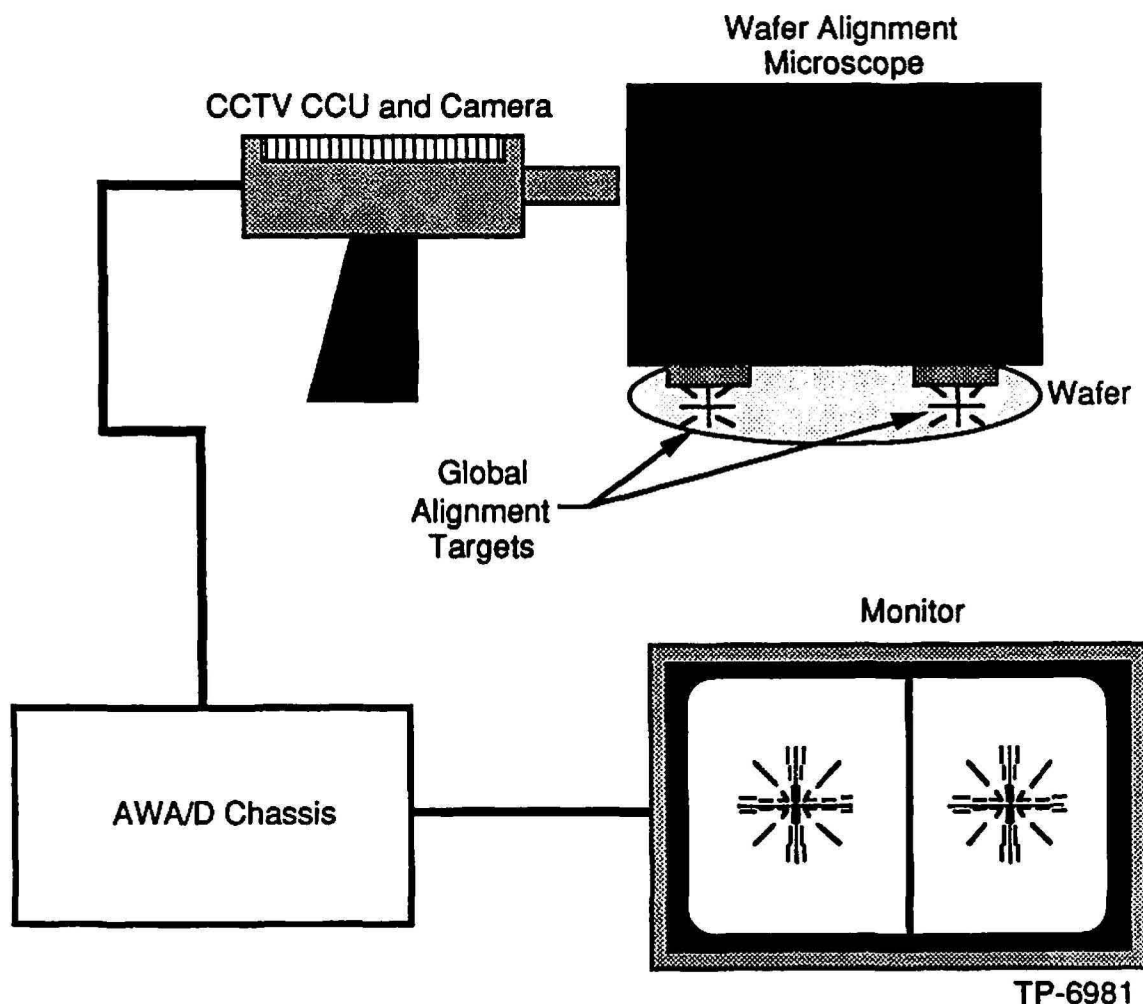
Figure 3-1
Global Alignment System Example

AWA/D Theory

The AWA/D provides accurate global alignment of a wafer on the DSW system. A proper understanding of AWA/D operation is required because of the software calibration that is required to set up the AWA/D. The flowchart shown in Figure 3-4 demonstrates the process which the AWA/D implements to perform global alignment of a wafer.

Global Scan

A global scan of the AWA/D, in conjunction with a global mask (mathematical algorithm), is used to determine the general location of the wafer alignment mark by scanning the whole digitized video image searching for the 45° and 135° components of the wafer alignment mark. The wafer alignment mark is shown in Figure 3-2.
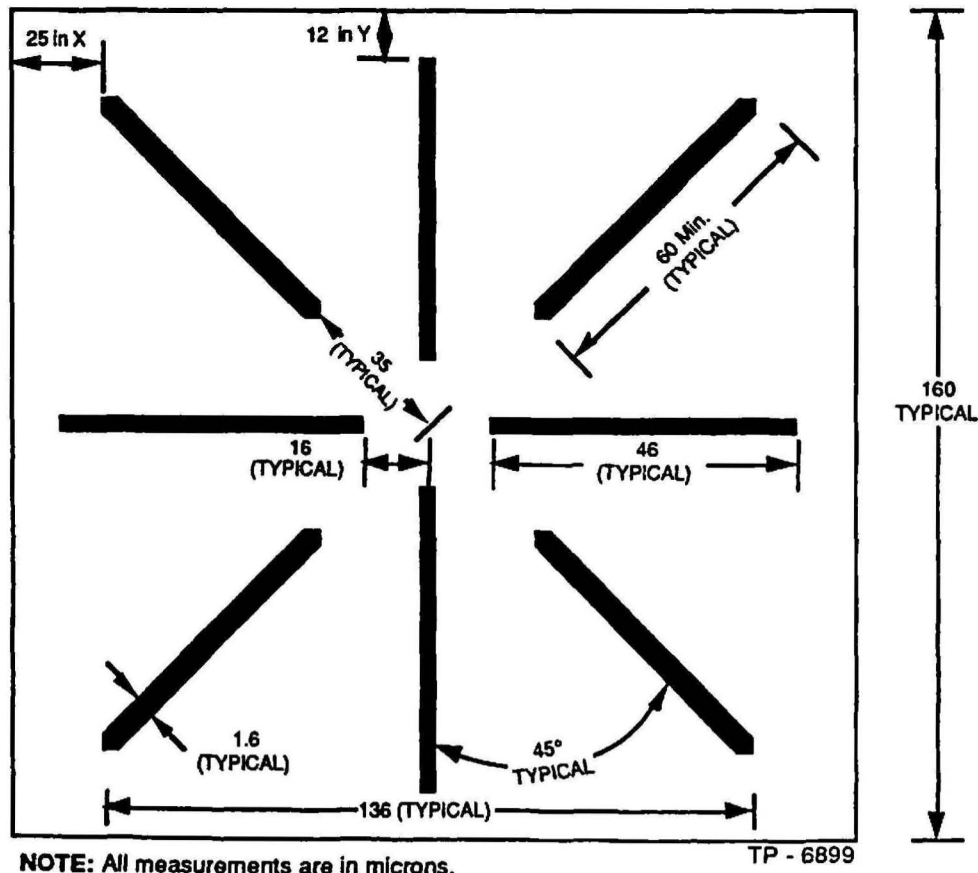
NOTE: All measurements are in microns.

NOTE: Minimum separation distances of 25 microns in the X-axis, and 12 microns in the Y-axis between the ends of the target lines and any other geometries.

Figure 3-2
Typical Wafer Alignment Mark for AWA/D

Reference Scan

A reference scan of the AWA/D, in conjunction with a reference mask (mathematical algorithm), is used to determine the precise location of the center of the wafer alignment microscope reference mark within the digitized video image. The wafer alignment microscope reference marks are located on a reticle within the wafer alignment microscope as shown in Figure 3-3.
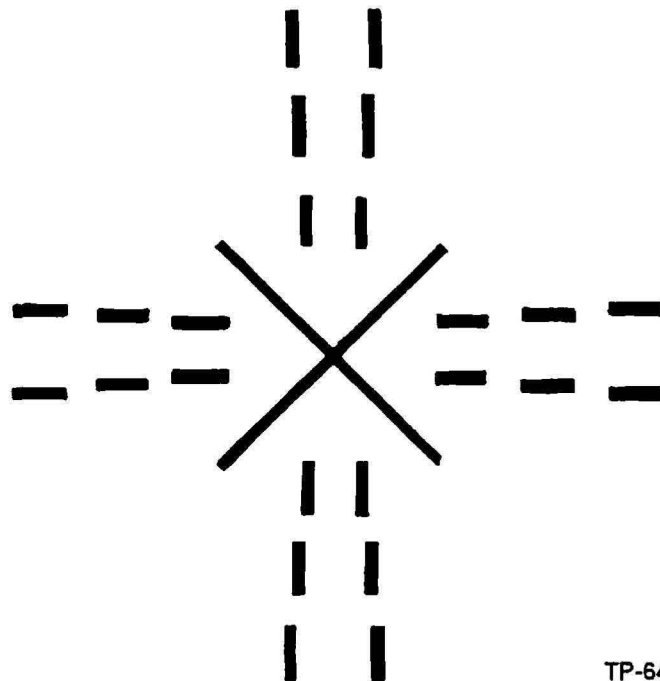
TP-6486

Figure 3-3
Wafer Alignment Microscope Reference Mark

Fine Scan

A fine scan of the AWA/D, in conjunction with a fine mask (mathematical algorithm), is used to determine the precise location of the wafer alignment mark and the wafer alignment microscope reference mark by scanning the video image within two regions about the center of the alignment area. The wafer alignment microscope reference mark and the wafer alignment mark should be aligned well to each other after a successful fine scan, as shown in Figure 3-4.

TP-6486
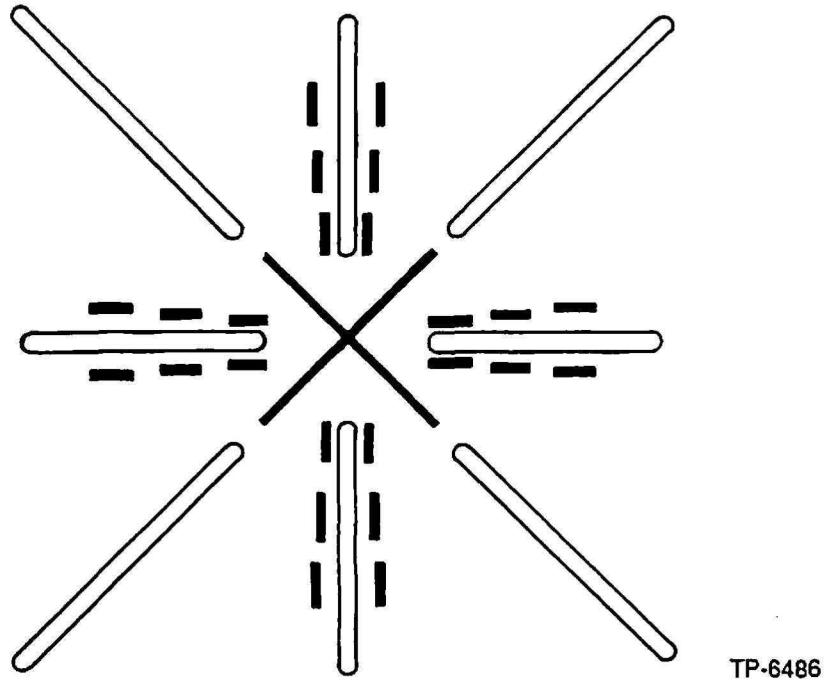
Figure 3-4
Wafer Alignment Mark and Wafer Alignment Microscope
Reference Mark Aligned after Fine Scan

System Flowchart

The flowchart in Figure 3-5 describes the operation of the AWA/D system. The flowchart shows the global, reference, and fine scans in the order in which they are used, as well as other important events that occur during the automatic global alignment process.
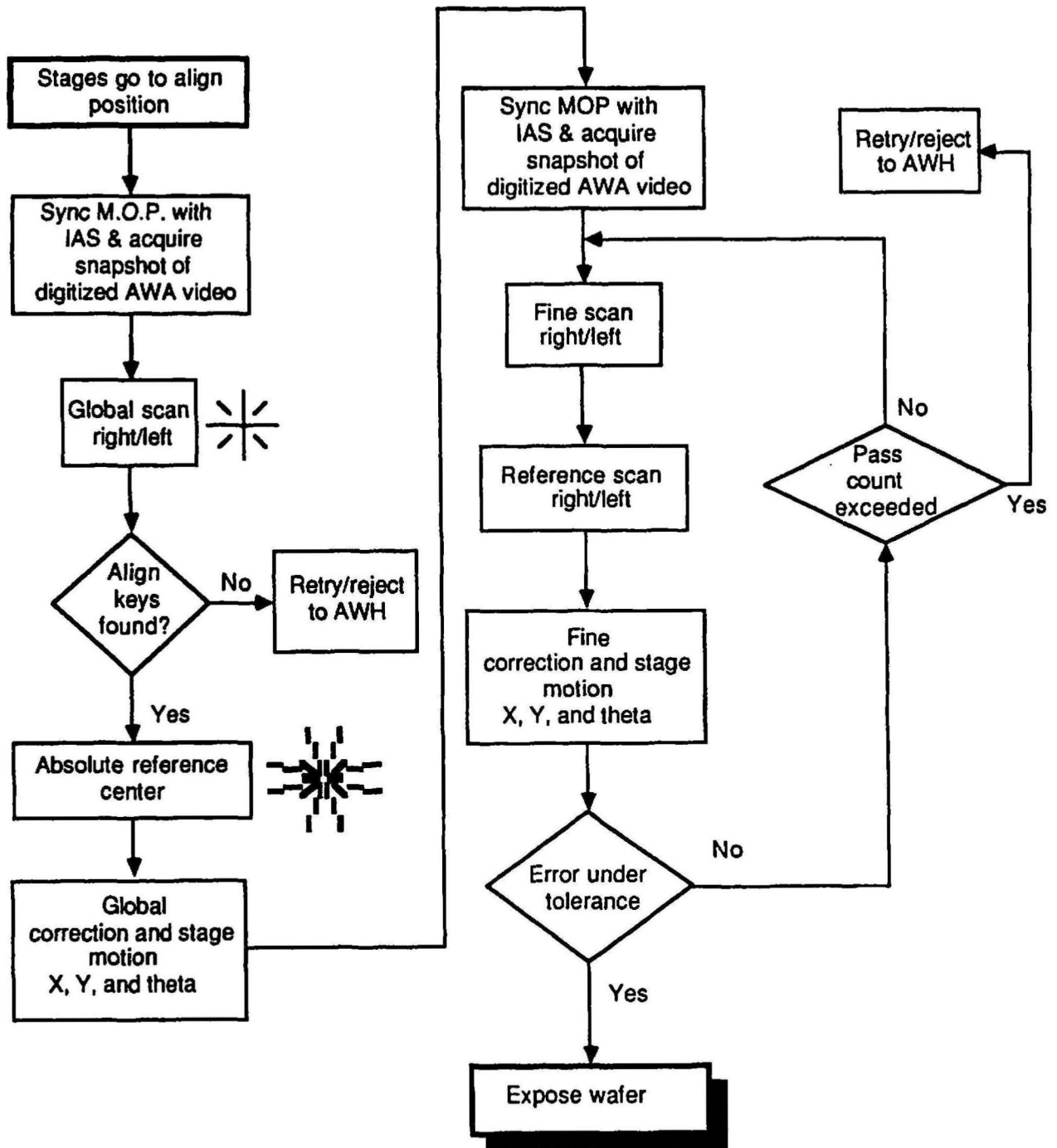
Figure 3-5
AWA/D Operational Flowchart

Section 4 - Local Alignment Systems

Introduction

The GCA 8500 and ALS Wafer Stepper Systems utilize the Dark Field Alignment System (DFAS) technology to perform local alignment of the wafer. The GCA AUTOSTEP 200 Wafer Stepper Systems uses Micro DFAS technology to perform local alignment.

The performance of a local alignment system depends on several factors, some of which can be characterized best by experimental method. Often, the greatest difficulty an alignment system must face is the multitude of film combinations used to create the structure being aligned. Other factors that can play a major role in performance are as follows:

- Practicality of Approach
- Direct Reticle Reference
- Minimal Process Setup and Characterization
- Stability and Reliability
- Low Wafer Dose During Alignment
- Minimal Signal Processing
- Ability to Align with Low Wafer Visibility
- Alignment Throughput

DFAS

Theory of Operation

To obtain maximum stability and reliability, the system has a minimum of moving parts. This is made possible by sacrificing a piece of the exposure field for alignment, and using the wafer stepper's existing laser metered stages for a controlled post alignment motion. The optical system as shown in Figure 4-1 uses a fixed point at the edge of the projection lens field. As both X and Y alignment error information can be derived from the same wafer alignment mark, only one microscope is required.
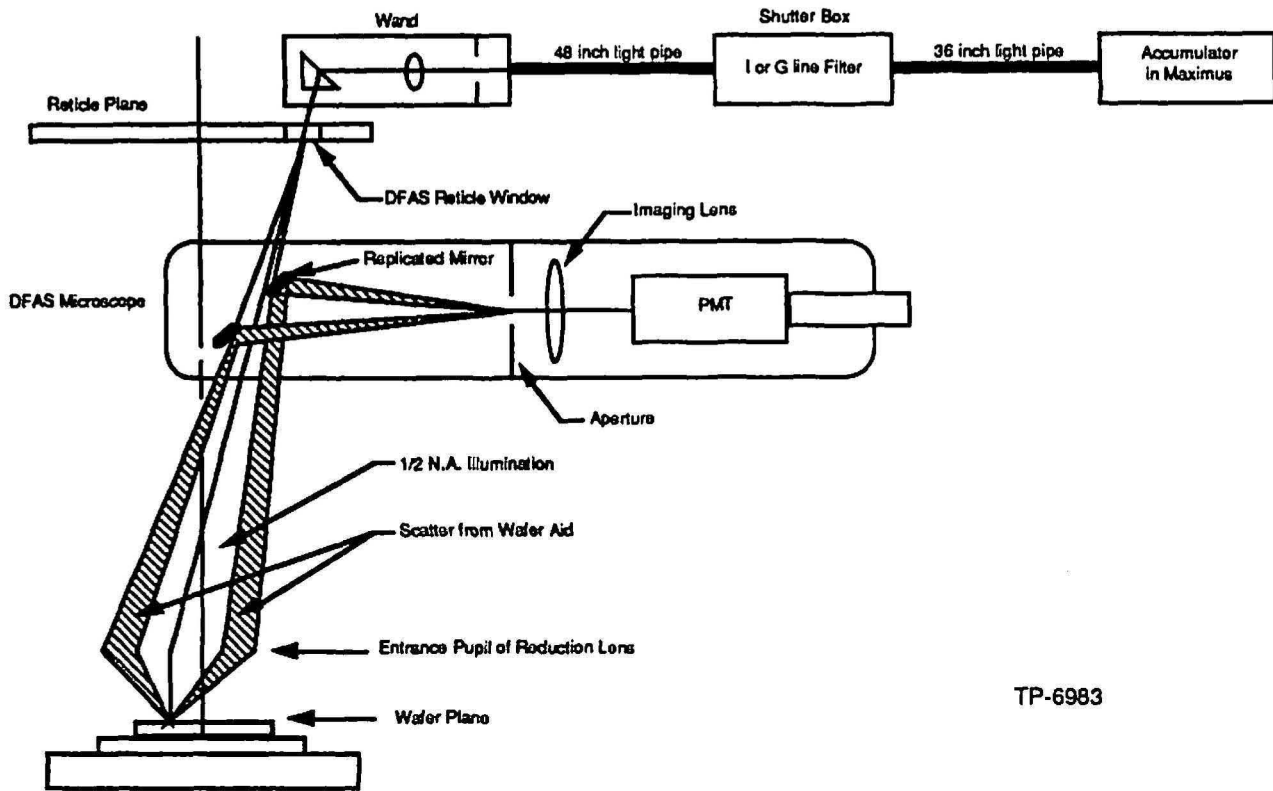
Figure 4-1
DFAS Optical Diagram

Dark Field Microscope

The Dark Field Alignment System microscope is the heart of the DFAS system. This is where the alignment information is collected. The main assemblies are a replicated mirror, imaging lens, aperture, and a photomultiplier tube (PMT).

To produce a dark field wafer image, a fixed mirror with a hole producing a cone of half the numerical aperture (NA) of the projection lens is located in the optical column. This acts as the effective aperture stop for the reticle alignment window and reflects dark field wafer information towards a photomultiplier tube (PMT). At the formation of the wafer/reticle image, a field stop is located to reduce stray and ambient light. A lens is used to collect the reflected light and to image the mirror on the face of the PMT. This lens also serves as a simple microscope objective when the PMT is replaced with a microscope eyepiece for viewing the alignment signal directly.

Local Illuminator

The DFAS illumination system consists of a wand, shutter box assembly, MAXIMUS 2000 pickup assembly, and a fused silica fiber bundle.

To eliminate unwanted field exposure during alignment, a fixed local reticle illumination system is used. Precise illumination centering can be accomplished by adjusting the local source to point into the center of the projection lens entrance pupil. Light is obtained by using unused low NA flux obtained from the projection lens light source. The light is collected through a solid fused silica fiber bundle and is filtered and shuttered independently of the projection optics to allow control of the alignment wavelength bandwidth and dose.

Alignment Marks

The alignment mark layout has the same total length of line in X and in Y, to produce a compact area for the alignment marks, and to obtain a capture range of greater than 5μm. The slits are imaged through the projection lens at one half NA due to the dark field mirror. The maximum width of the slits that can be imaged is 2 lambda /NA. For this application, slit widths of 2μm were used (NA = 0.35, lambda = 0.436μm).

The reticle window is located at a fixed mask location which is dependent on the maximum field diameter of the lens. The penumbra caused by the DFAS optics masks a part of the field. A stage motion is required to bring the wafer alignment mark under the reticle window for alignment. This does, however, offer the flexibility of placing the wafer mark at any field location and if the wafer mark is destroyed, a number of marks can be placed anywhere in the usable field.

Alignment Signal

The image of the window at the wafer is the line spread of the slit imaged through the projection lens at one half NA. Alignment position error can be generated by assuming the light flux striking the PMT is maximum when the image of the reticle slits corresponds to the edges of the wafer alignment marks. The amount of flux changes proportionately to the misalignment of the reticle/wafer marks over a range close to the optimum signal or about ±1.0μm.

The alignment signal is generated by scanning (dithering) the wafer mark, first in X and then in Y, under the image of the reticle alignment window. In order to have no influence from the axis not being scanned, the mark is positioned 2.5μm from the alignment position. To generate the scan, a calibrated stepwise sine wave offset is injected into the wafer stepper's stage control system by means of digital-to-analog converters. The scan start position is determined by the laser interferometer. The length of scan is 5μm, producing a capture range of ±2.5μm. The PMT photocurrent measured as a function of wafer mark to projected reticle window position is collected at discrete scan positions using a 12-bit analog-to-digital converter. Both positive and negative directions of the scan are collected independently to enable cancellation of phase errors in the system.

Micro DFAS

Theory of Operation

Micro DFAS is a hardware/software package that aligns user-selectable sites to acquire mapping correction data. Micro DFAS is an off-axis non-actinic alignment system mounted into the nose cone at the bottom of the Tropel reduction lens. Micro DFAS aligns user-selectable mapping dies to optimize the overlay of production wafers, thereby creating higher throughput and greater yield.

Micro DFAS replaces the nose cone of Tropel reduction lenses as shown in Figure 4-2. The wand assembly, mounted on the nose cone, has a small reticle mounted on the output end. The reticle pattern is identical to that found on the 4800-124 test reticle (used with standard DFAS). The Micro DFAS wand assembly uses white light from the AFS-100 illuminator. The illuminator is equipped with a split-fiber optic cable: one for the Autofocus system and one for the Micro DFAS system.
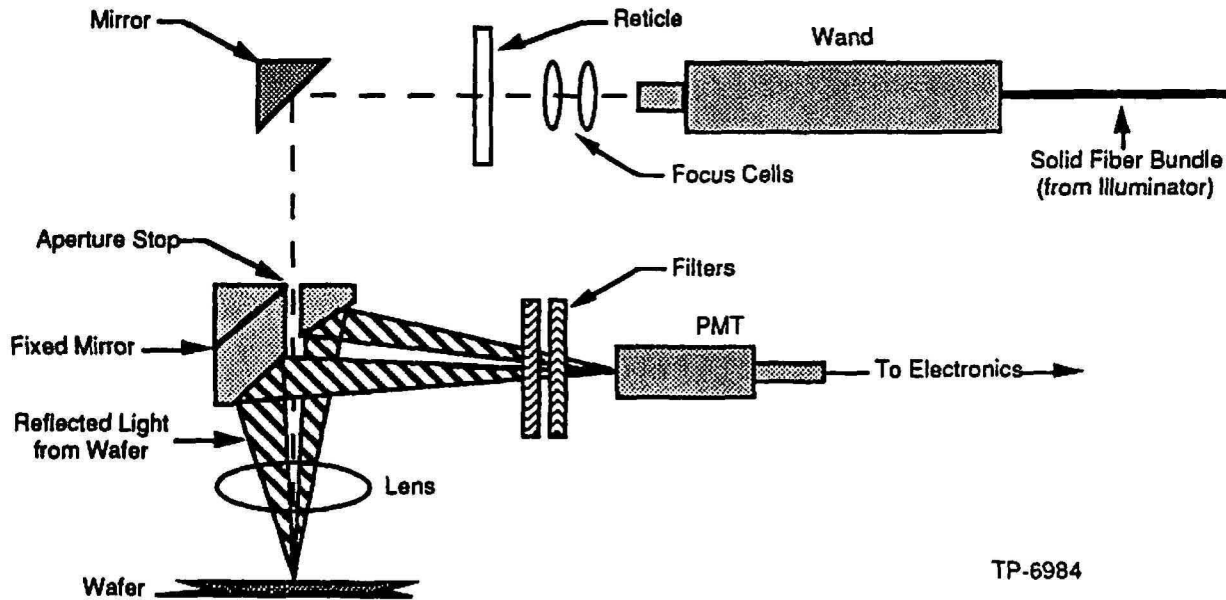
Figure 4-2
Micro DFAS Optical Diagram

The light from the wand assembly travels through the focus cells and the reticle. The reticle allows light to travel through an alignment mark which will be used as a reference for local alignment. The light from the reticle is reflected off the mirror and enters the fixed mirror assembly which is used to produce a dark field wafer image. The hole in the fixed mirror assembly produces a cone that is about half of the numerical aperture of the Micro DFAS objective lens. This mirror acts as the effective aperture stop for the reticle alignment window and reflects dark field wafer data toward a photomultiplier tube (PMT). At the formation of the

wafer/reticle image, a field stop is located to reduce stray and ambient light. A lens collects the reflected light and images the mirror on the face of the PMT.

INSITU Theory of Operation

INSITU is a reticle referenced alignment system comprised of a small detector assembly which contains an INSITU artifact, Micro DFAS alignment mark, and a AWA/D alignment mark) attached to the Theta-III stage as shown in Figure 4-3. The reticle on the platen must also contain a corresponding window for the INSITU detector. The system MOP contains software to control the INSITU local alignment system.

The INSITU detector assembly is made up of an 8mm diameter quartz wafer which is chrome-plated on one side and contains a quad style INSITU artifact, Micro DFAS mark, and a AWA/D alignment mark which are etched through the chrome. Since these alignment marks are etched through the chrome, they are actually windows in the wafer through which light travels. This wafer, commonly referred to as an "artifact", is fixed above a silicon photodiode sensor which detects varying amounts of illumination which travels through the windows in the artifact as it dithers across the light path from the MAXIMUS.

During the INSITU local alignment process, the detector assembly is positioned under the reduction lens to detect the MAXIMUS illumination passing through the window in the reticle. The detector assembly dithers (scans) in the X-axis and Y-axis direction approximately 2.5 microns in an effort to determine the centered or aligned position between the alignment windows in the reticle and the artifact. INSITU determines system focus, intrafield and local alignment system baseline corrections using this alignment scheme.
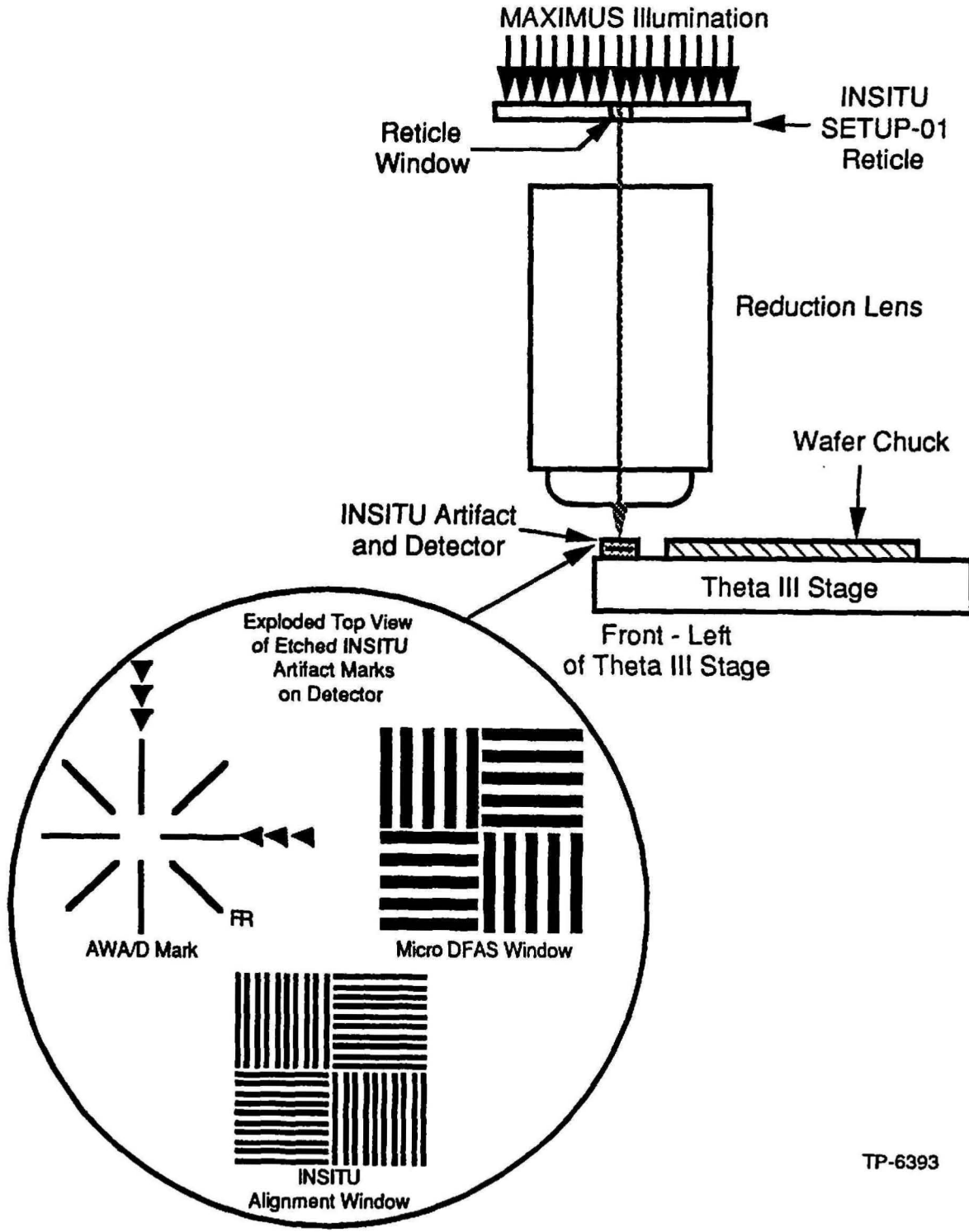
Figure 4-3
INSITU Detector and Alignment Diagram

Section 5 - Alignment Target CAD Layout

Introduction

This section of the reticle handbook covers the information needed to create a product reticle set. The information includes; specification and placement requirements for RMS alignment windows, barcode, global alignment targets, local alignment targets and INSITU alignment targets. Worksheets are supplied in this section for wafer stepper system configuration, product reticle alignment requirements, and wafer stepper system job specifications.

The information in this section should be used in conjunction with a CAD system to lay out the alignment target cells which are then placed on the product reticle. The CAD system provides output on a data tape to create a reticle set.

System Configuration Worksheet

Use the system configuration worksheet to determine the configuration of the wafer stepper system and nominal set-up specifications of various sub-systems. The manufacturing of reticles for the wafer stepper system depend upon the following specifications. The following paragraphs explain the information on the worksheet which is shown in Figure 5-1.

Wafer Size

The diameter of the wafer used on the wafer stepper system. The entire wafer stepper system configuration is based on this wafer size.

Reticle Alignment Target Separation

The reticle alignment window separation can be found on item 4 of the system configuration worksheet maintained in the local GCA field office. The separation can also be measured on the system by a qualified technician. Refer to RMS Reticle Alignment Windows in this section for more information.

Reticle Alignment Window - Offset or Centered

The reticle alignment window separation can be configured offset from center, or centered as shown in Figure 5-2.

Barcode

This is to alert you that the placement of the barcode location is dependent on reticle target separation and if centered or offset.

Microscope Objective Spacing

This is the separation of the objectives of the global alignment microscope. The microscope objective separation can be determined by measuring the ceneter-to-center distance of the microscope objectives with a plastic ruler.

Local Alignment System

This section of the worksheet determines which type of local alignment system is present on the wafer stepper system.

If DFAS

The DFAS window placement can be determined by checking the SMARTSET configuration in "DFAS Utilities Menu".

If Micro DFAS

The INSITU alignment target placement (in millimeters at the wafer) should made standard for all reticles used on the wafer stepper system. These marks are used by INSITU to determine DFAS baseline and reticle rotation. Refer to INSITU Reticle Alignment Targets in this section of the Reticle Handbook for more information.

GCA Wafer Stepper System Number: _____

1	Wafer Size	75mm	100mm	125mm	150mm	200mm

2	Reticle Alignment Target Seperation	105mm	115mm

3	Reticle Alignment Target	Offset	Centered

4	Barcode	Yes	No

5	Microscope Objective Spacing	3 Inch (76.2mm)	4 Inch (101.6mm)

6	Local Alignment System	DFAS	Micro DFAS

7	If DFAS	40mm	44mm	48mm	Other

8	If Micro DFAS	INSITU Target Placement	
		1X = 2X = 3X = 4X=	1Y = 2Y = 3Y = 4Y =

Figure 5-1
System Configuration Worksheet

Constant Reticle Perimeter Data

The constant reticle perimeter data will be consistent for all reticle sets generated for a specific configuration as defined by the system configuration worksheet. It is possible to create a periphery that functions with multiple configurations of GCA wafer stepper systems. The periphery data includes; RMS alignment windows location, barcode location, DFAS reticle windows location, and INSITU alignment target location as shown in Figure 5-2.
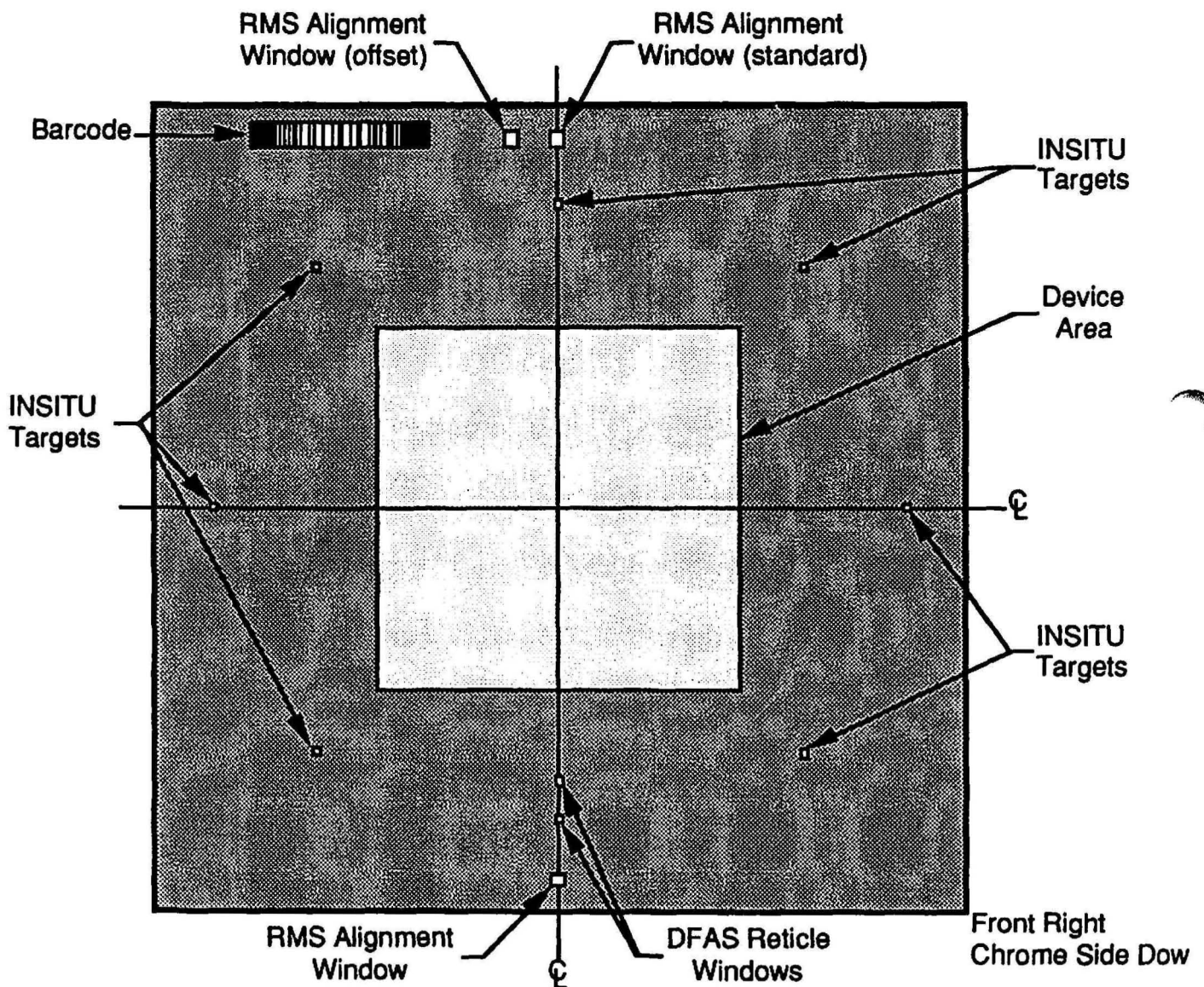
Figure 5-2
Constant Reticle Perimeter Geometries

TP-7018

RMS Reticle Alignment Windows

The reticle alignment windows are used to align the reticle to the platen chuck of the wafer stepper system. The window phase is typically negative, which consists of a square hole in the chrome as shown in Figure 5-3.

The reticle aligner assemblies in the platen casting observe the edge of the reticle alignment window in the chrome. When there is a balance of illumination in the fiducial between window and chrome, the reticle is considered to be aligned as shown in Figure 5-3.

When:

A ≈ C

D ≈ F

B ≈ E

the reticle is aligned

Front of Wafer Stepper System
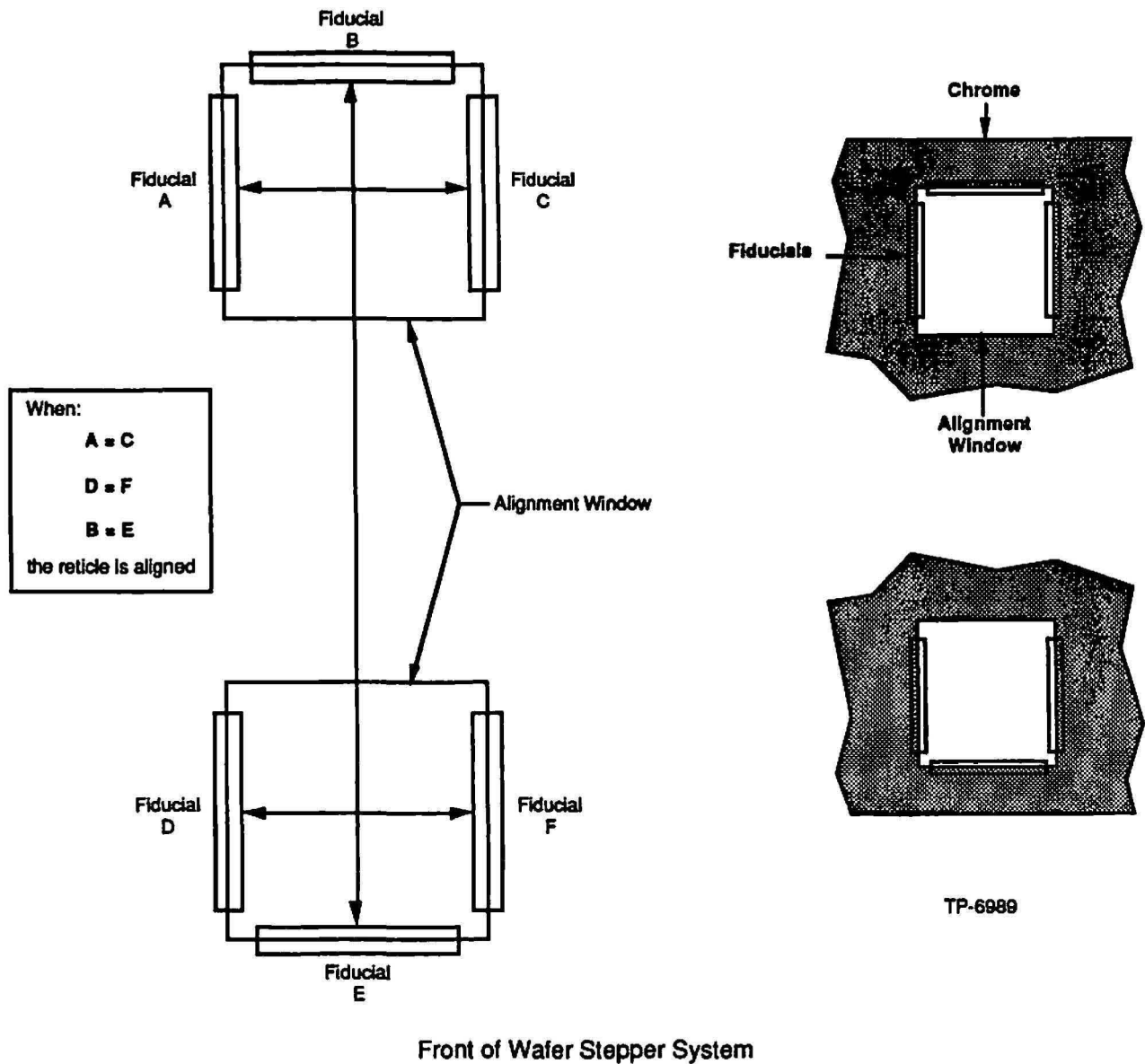
Figure 5-3
Alignment of a Negative Phase Reticle

Standard Alignment Window Specifications

The location and dimensions for RMS alignment marks, position of photomask artwork and bar code are provided in this section and should comply with Figure 5-4.
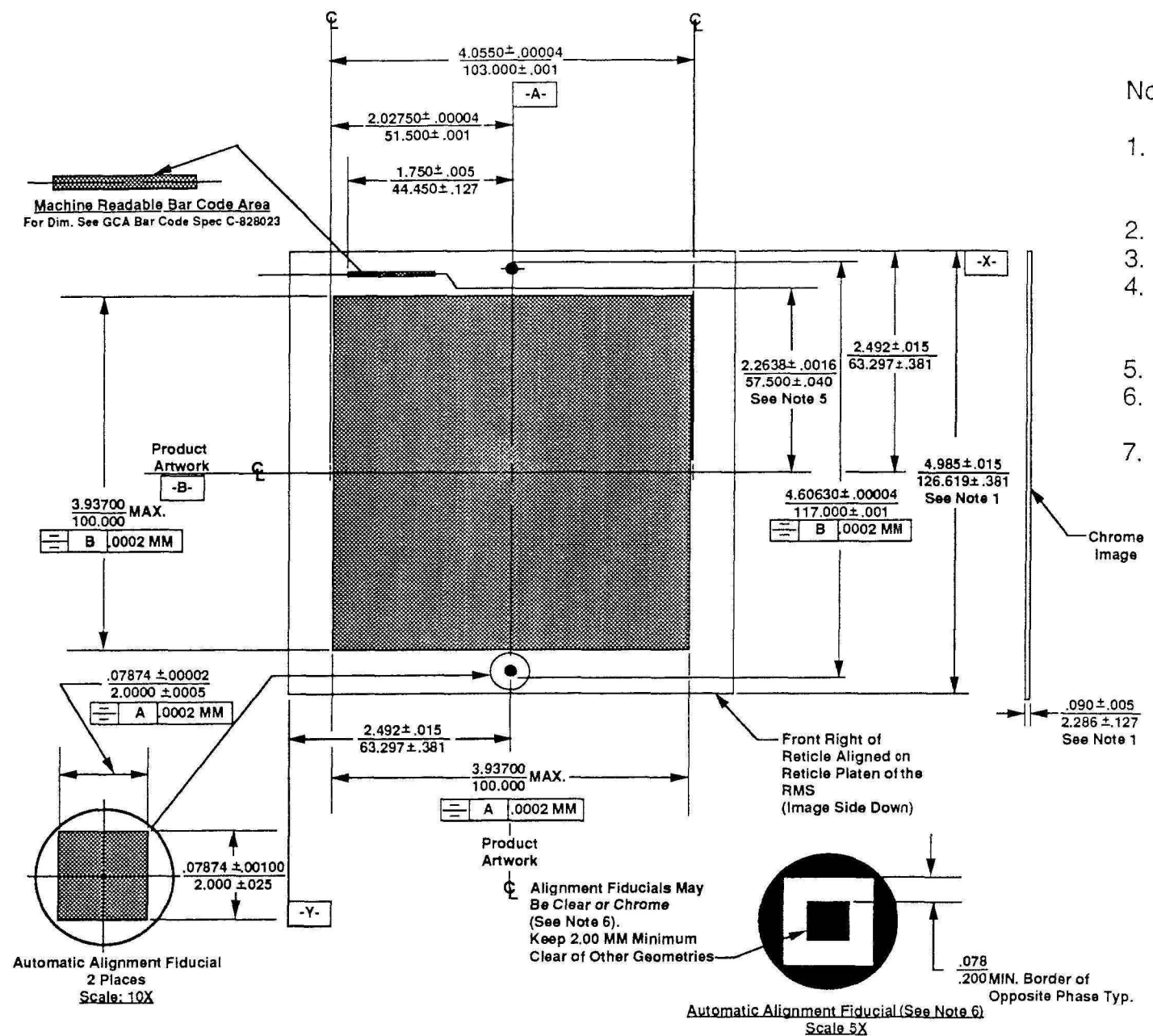
Notes:

1. The Material shall conform to the dimensions and dimensional tolerances as specified in Semi Standard P1.1 STD 1 Standard for Hard Surface Photo Mask Substrates.
2. Unless otherwise specified: dimensions are in inches/millimeters.
3. Top view shown with chrome side down.
4. The Manual Alignment Fiducials are optional. If a RMS Reticle is required to be aligned on a Manual Alignment DSW. The Fiducials may be placed as shown.
5. Barcode requires 59MM print field from center.
6. Automatic Alignment Fiducials and Barcode must be the same color phase.
7. Polished edges recommended.

TP-6968

Figure 5-4
Standard Reticle Artwork Location and Dimensions

Offset Alignment Window Specifications

The offset alignment window option is offered to eliminate interference problems in the manufacture of reticles which preclude the placement of 5600 RMS automatic alignment fiducials in their standard, center, location on the reticle. One of the fiducials is offset from center by 11mm, removing possible pattern generation interferences.

The reticle material shown in Figure 5-4 shall comply with the dimensions and tolerances as specified by SEMI-STANDARD P1.1 of STD1, the Standard for Hard Surface Photo Mask Substrates.

The location and dimensions for the RMS offset alignment fiducial, position of product artwork and bar code shall comply with Figure 5-5.
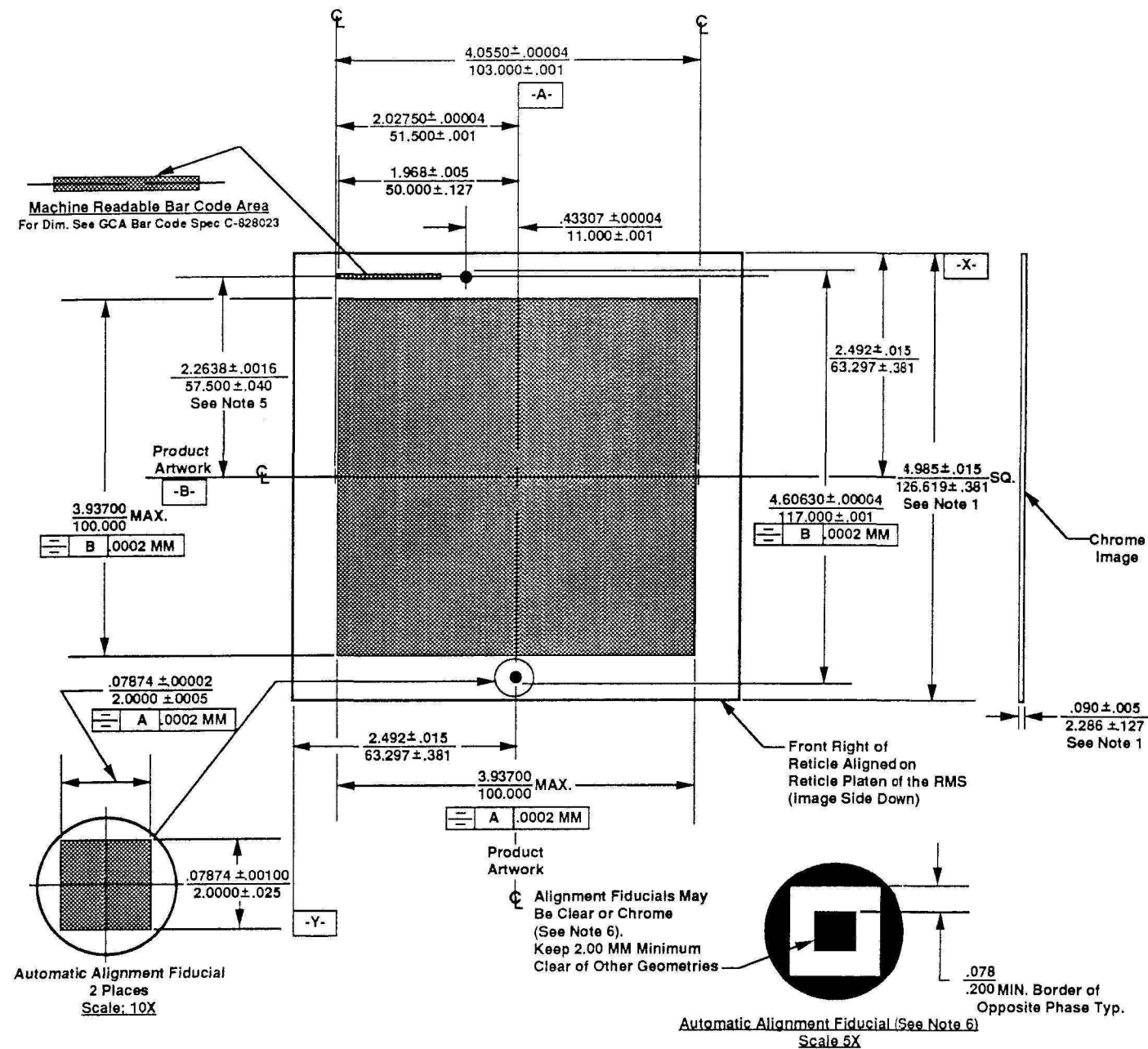
Notes:

1. The Material shall conform to the dimensions and dimensional tolerances as specified in Semi Standard P1.1 STD 1 Standard for Hard Surface Photo Mask Substrates.
2. Unless otherwise specified: dimensions are in inches/millimeters.
3. Top view shown with chrome side down.
4. The Manual Alignment Fiducials are optional. If a RMS Reticle is required to be aligned on a Manual Alignment DSW. The Fiducials may be placed as shown.
5. Barcode requires 59MM print field from center.
6. Automatic Alignment Fiducials and Barcode must be the same color phase.
7. Polished edges recommended.

TP-6967

Figure 5-5
Offset Reticle Artwork Location and Dimensions

Barcode Specifications

The 5600 RMS is capable of reading the unique bar code of each reticle for identification after the reticle has been retrieved from the cassette. The RMS retrieves the reticle from its respective cassette, reads the bar code and performs an identification check of the reticle against the data in the job specification, and if verified, places the reticle on the A fork of the rotary turntable for transfer to the wafer stepper system platen chuck for alignment. A sample bar code is shown in Figure 5-6.

23.3 Sample
(15.8 Min., 1 Character
29.3 Max., 10 Characters)

4 | .9 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | .9 | 4

3mm

Quiet 1 | Sync 1 See Det | Start | * | T | E | S | T | I | CHK CHR | Stop | Sync 2 | Quiet 2

Reticle Name
(1-10 Characters)

0.15
0.15
0.15

0.15
0.15
0.15
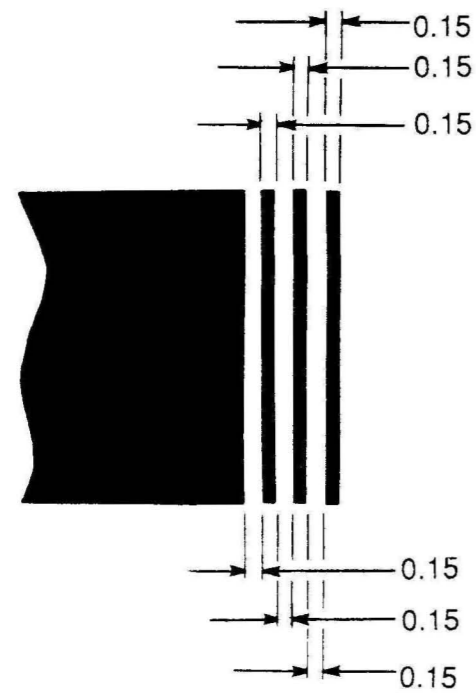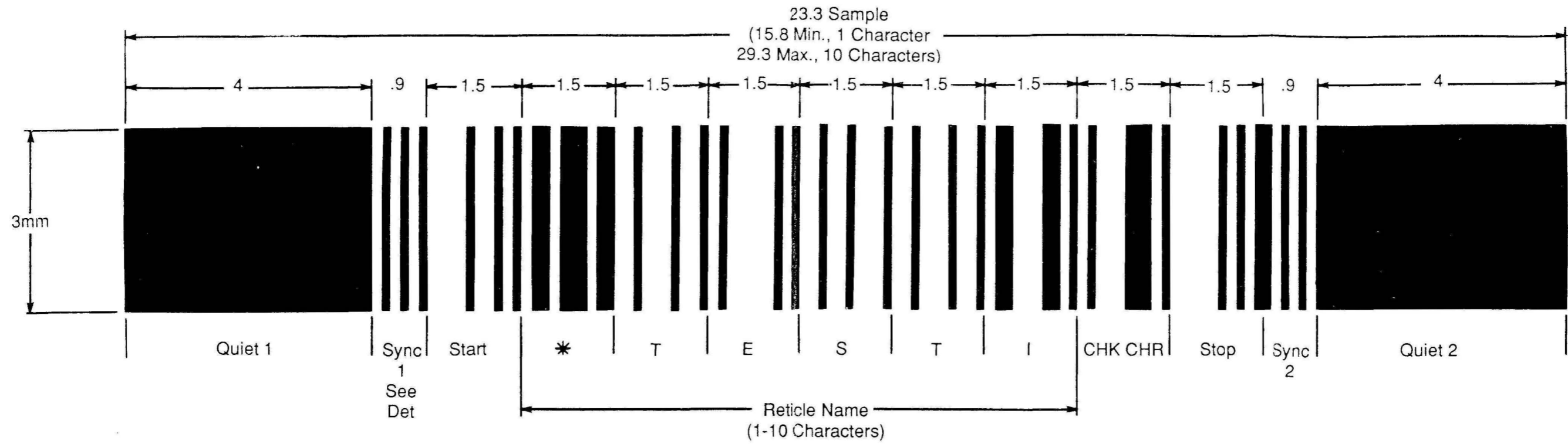
NOTES:
1. Code shown is in Reverse Phase
   (Dark Region Corresponds to Logic False)
2. Reticle Name Contains 1-10 Characters
   Max. Length: 29.3 mm
   Min. Length: 15.8mm
   All Dim. are in mm

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Figure 5-6
Bar Code Sample

Bar Code Character Set

The complete 66 character bar code set for reticle ID generation is shown in Figure 5-7. The 64 ASCII character set shown in Figure 5-7 was selected for convenience and for ease of reading. Lower case and multi-alpha-numeric characters were eliminated from the character set. The character set is comprised of the following ASCII (American Standard Code for Information Interchange) characters:

1. Alphanumeric character symbol set, uppercase A - Z.
2. Numeric character symbol set, 0 - 9.
3. Special character symbol set.
4. Start and Stop characters.
5. Timing and synchronization characters, 1 and 2.
6. Quiet (dead) zone characters, 1 and 2.

Figure 5-7
Bar Code Character Set

CHAR.	ORD.	CHAR.	ORD.	CHAR.	ORD.	CHAR.	ORD.	CHAR.	ORD.	CHAR.	ORD.	CHAR.	ORD.
SPACE	1	•	11	4	21	>	31	H	41	R	51	\	61
!	2	+	12	5	22	?	32	I	42	S	52	]	62
"	3	,	13	6	23	@	33	J	43	T	53	^	63
#	4	− (DASH OR NEG SIGN)	14	7	24	A	34	K	44	U	54	_ (UNDERLINE)	64
$	5	.	15	8	25	B	35	L	45	V	55	START	65
%	6	/	16	9	26	C	36	M	46	W	56	STOP	66
&	7	0	17	:	27	D	37	N	47	X	57		
'	8	1	18	;	28	E	38	O	48	Y	58		
(	9	2	19	<	29	F	39	P	49	Z	59		
)	10	3	20	=	30	G	40	Q	50	[	60		

QUIET 1   SYNC 1
QUIET 2   SYNC 2

NOTES:
1. Code shown is in Reverse Phase (Clear on Chrome)
2. Unit Bars and Spaces are 0.15mm Wide
3. Quiet Zones are 4.00mm Wide
4. **Quiet Zone Phase Must Match Phase of Unite Bars and Spaces**

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Bar Code Identification Design

The bar code ID design consists of the following characters as shown in Figure 5-7.

1. Quiet (dead) zone for beginning the bar code ID.
2. Timing synchronization character is inserted after quiet zone.
3. Start character is inserted after the synchronization character.
4. The first data character of the ID code, 3 marks, 3 spaces with a total of exactly 10 units-per-width per character.

NOTE: Each line and space width in the bar code is equal to 0.15mm. Each barcode character is 1.5mm wide, therfore, each character requires a combination of 10 lines or spaces.

5. Check sum character value is derived from the equation using the ordinal number for each bar code character.
6. The Stop character is inserted after the check sum character.
7. The Timing synchronization character is inserted after the Stop character and before the Quiet zone character.

Check Sum Self Test

The assurance of a correct bar code reading is provided by a self-test feature which verifies the correct reading of the ID by means of a check sum derived value which follows the bar code ID. This check sum has been devised to effectively eliminate any chance of the bar code reader misreading the reticle name. If an error occurs in the bar code, the check sum indicates this, and the RMS alerts the operator of a bar code problem.

Check Sum Characters

The check sum character value contains 3 columns within each character group. The columns are labeled as follows:

- Character
- Code
- Ordinal Value

Select the characters required, and the character ordinal value for the bar code ID. For example, if a test bar code ID was created called: TEST1, the characters and ordinal values would be as follows:

Character	Ordinal Value
*	11
T	53
E	38
S	52
T	53
1	18

ORDINAL SUM TOTAL = Σ = 225

The check sum ordinal value can be calculated as follows:

(Modulo ((Σ-1), 64) + 1)
(Modulo (225 - 1), 64) + 1)
(Modulo (224, 64) + 1)
Check sum ordinal value = 32 + 1 = 33

Check sum ordinal value = **33**

or

An integer number (Modulo 64) is the remainder left over (in 64ths) after Σ - 1 (224) has been divided by 64. For example:

$$224 \div 64 = 3 \frac{32}{64}$$

The remainder is 32 (64ths). Add 1 to the remainder: 32 + 1 = 33 (64ths)

Check sum ordinal value = 32 + 1 = **33**

The ordinal value 33 represents the check sum that is used to verify that the bar code *TEST1 has been read properly by the bar code reader.

DFAS Reticle Window Placement Specifications

The location of the DFAS reticle alignment window, which is the mask feature illuminated by the DFAS and scanned across the wafer alignment target is shown in Figure 5-8.
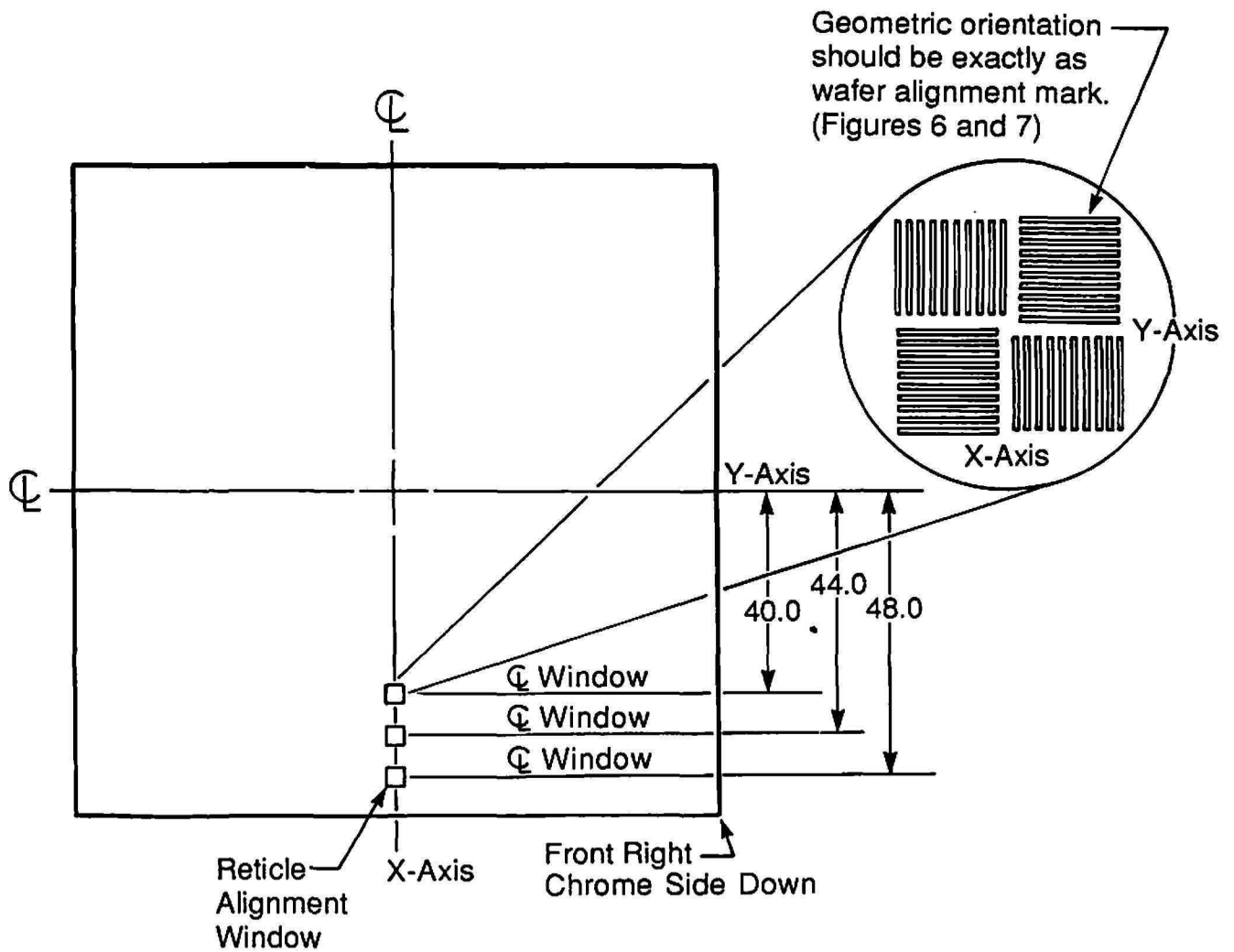
Figure 5-8
DFAS Reticle Window Location

The customer selects the window which corresponds to the field size being used; for example, the window located 40.00mm from the Y-axis centerline is typically used for a 16mm field. The window located 44.00mm from the Y-axis centerline is typically used for a 18 mm field die. The window located 48.00mm from the Y-axis centerline is typically used for a 20-22mm field die. The goal is to select the DFAS window which consumes the least amount of space out of the die but is still capable of being imaged through the lens.

The alignment window is located at a fixed point on the reticle. This location is on the optical center-line of the X-axis for most lenses at a radial distance in the Y-axis from the reticle center determined by the field diameter of the lens. All dimensions in Figure 5-8 are in millimeters at the reticle.

For 20mm (or greater - 5X lenses) field size, the most commonly used standard window location is 48mm (reticle dimension). Optional locations are provided to accommodate considerations in matching alignment target and pellicle location requirements, as well as IC design constraints and reticle platen openings.

Figure 5-9 details several locations of the window for a variety of reduction lenses and the dimensions of the effective penumbra from the DFAS optics.

Platen Opening

Illuminator
(Field Size)

Penumbra

10 cm

1 cm

Front Right
Chrome Side Dow

Reticle Alignment
Window
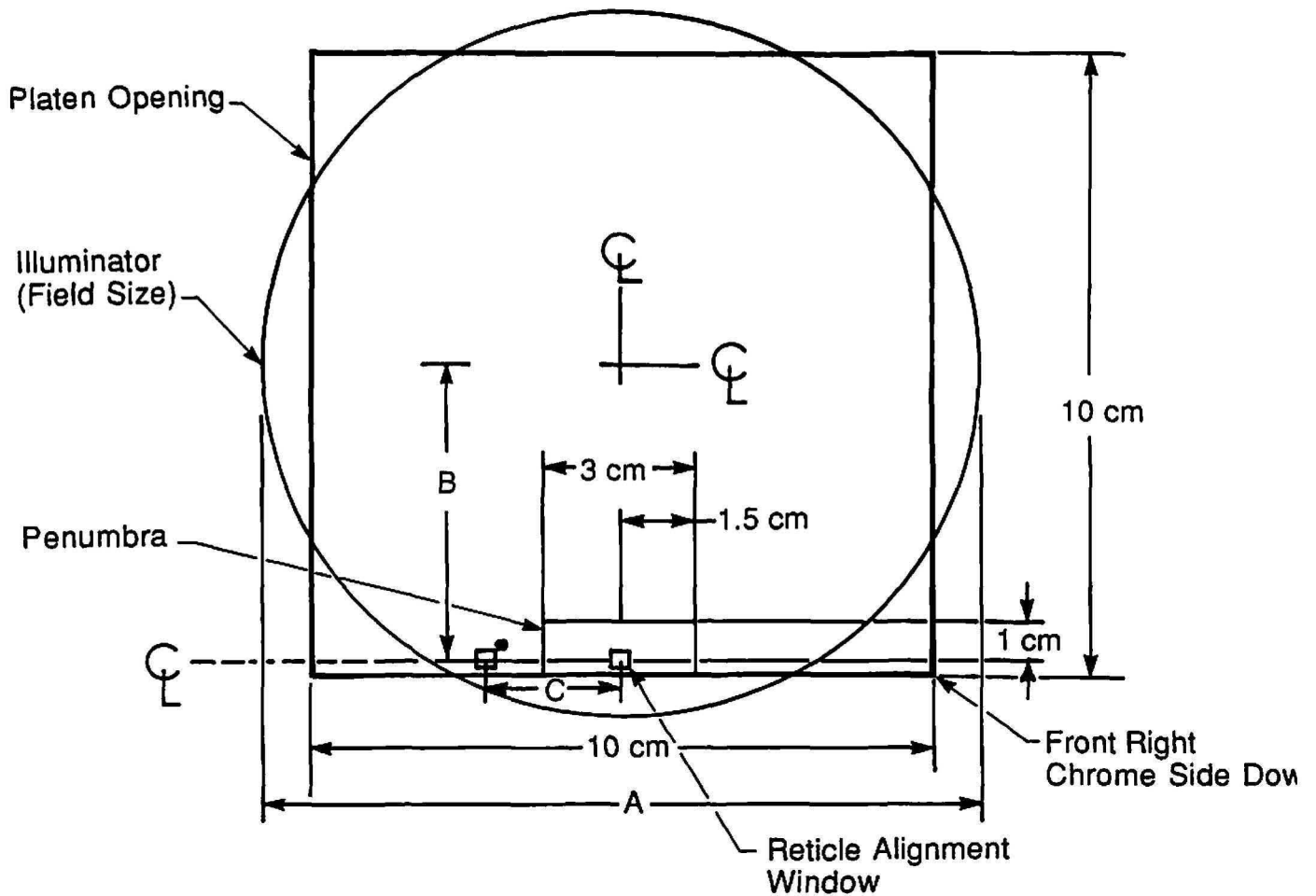
See Figs. 2, 3, & 4.   TP-7067

TABLE

All Dimensions in cm at reticle for UC-II column only.

Lens	A	B	C
2235 (5X)	22	4.8	0
2035 (5X)	20	4.8	0
10-78-46 (5X)	20	4.8	0
1635 (5X)	16	4.0	0
10-78-48 (10X)*	13	5.92	0.8
2529 (5X)*	25	5.92	0.8
10-78-37 (5X)	20	4.8	0
10-78-45 (10X)*	14.5	5.92	0.8
10-78-47 (5X)*	29	5.92	0.8
2232 (5X)	22	4.8	0

*Noted lenses require
require alignment window
offset in X-Axis as listed
in table.

Figure 5-9
DFAS Useable Field Size

The penumbra is a small shadowed area located in the edge of the exposure field as shown in Figure 5-9 closest to the back of the stepper (as printed of the wafer). This area extends approximately 2mm in the Y-axis into the field and ±1.5mm (total 3mm) in the X-axis around the center line as shown in Figure 5-9.

The penumbra does not decrease the usable field size of the largest printable square for a given lens provided the standard GCA window location for each lens is used. The source of this optical occlusion is the optical components (illumination and detection system) for DFAS. If the same reticle is to be used on DFAS systems set up for different field sizes within a given fab, all necessary alignment window locations must be incorporated into the design. The window should be centered within a chrome area no less than 400 micron square (wafer dimension) thus providing a chrome border necessary for proper illumination of the wafer alignment target as shown in Figure 5-10.

All Dimensions at Wafer in Microns
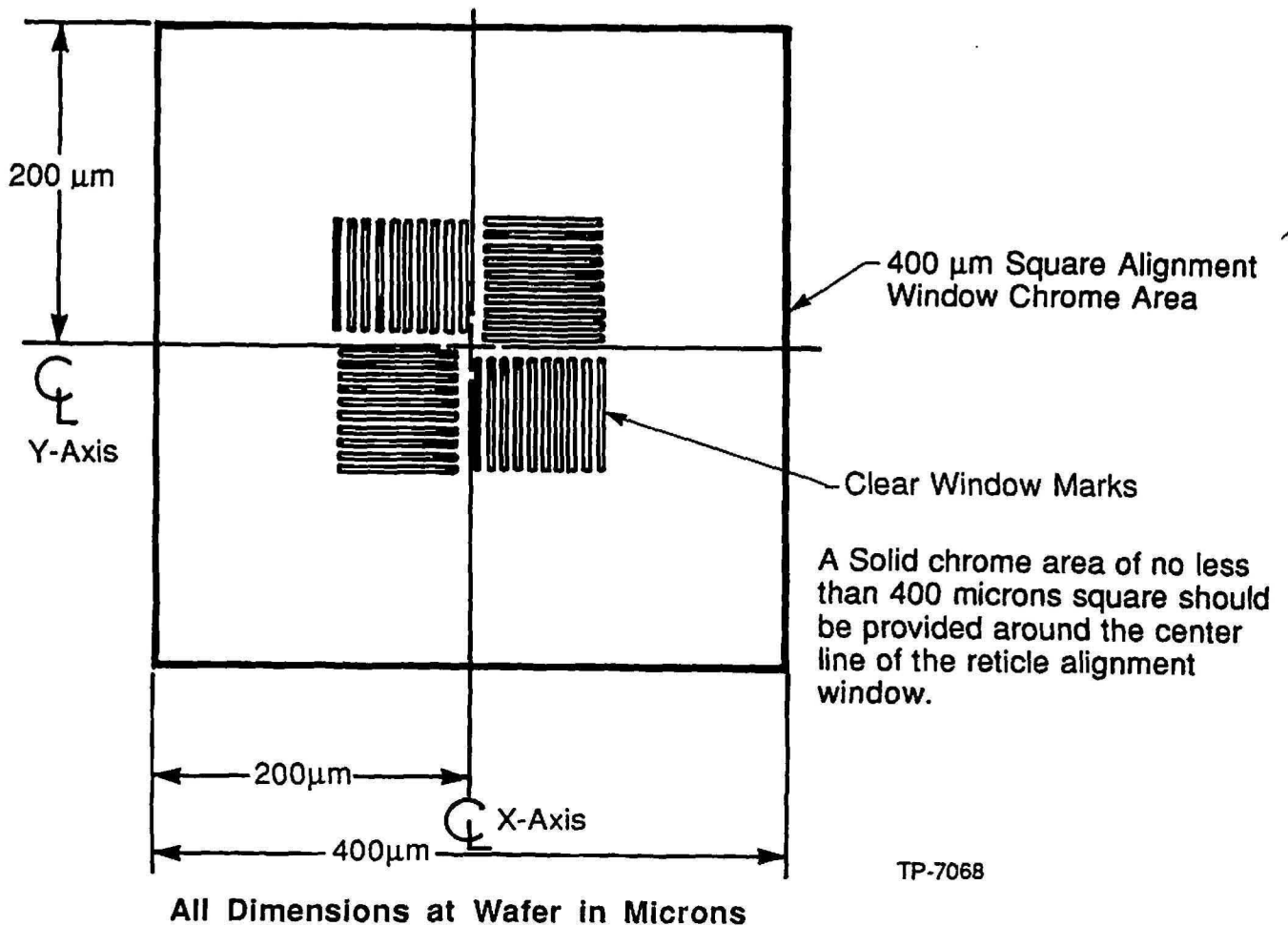
Figure 5-10
DFAS Reticle Alignment Window Border

DFAS Reticle Window Specifications

The DFAS reticle alignment window must be of clear color phase, for example, the features dimensioned in Figure 5-11 must appear as slits in a chrome background on the reticle. If these slits are chrome lines the DFAS system will not function. The reticle alignment window must exhibit the exact same orientation as the wafer alignment target.

The DFAS reticle alignment window geometries and dimensions (at the wafer plane in microns) are shown in Figure 5-11.
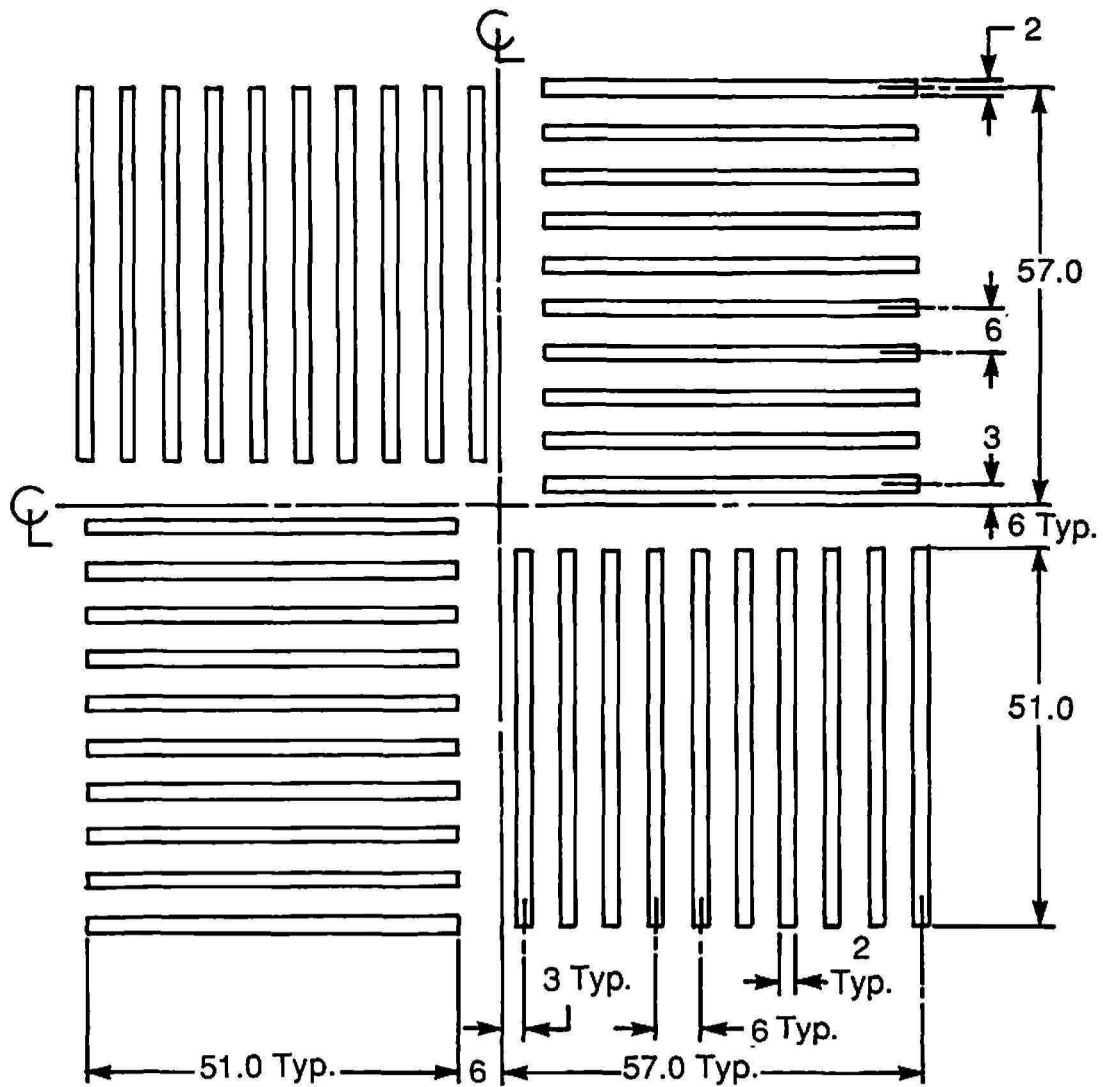
TP-7069

Figure 5-11
DFAS Reticle Alignment Window

INSITU Reticle Alignment Target Placement Specification

To ensure optimum overlay, it is important that the alignment of the product reticle in relation to the previous alignment of the calibration reticle be determined accurately. In order to achieve this, upon completion of the reticle loading and alignment by the Reticle Management System (RMS), the alignment strategy uses INSITU to accurately determine the product reticle position (translation and rotation) by aligning to the INSITU reticle windows located at fixed positions on the product reticle as shown in Figure 5-12.

The INSITU reticle alignment target placement is flexible. The following is a list of rules for each type of placement.

a. According to GCA test data, the use of the 48 mm on axis from center in X and Y INSITU targets should provide the best alignment results as shown in Figure 5-12.

b. Reticle marks can be placed anywhere on axis using whole millimeter centers. Each target must be placed an equal distance from the center of the field in the X and Y axis. see figure

c. INSITU reticle calibration marks can be placed on a forty five degrees. The X and Y placement must be on whole millimeter centers. The distance from the center must be equal on all 4 targets as shown in Figure 5-12.

d. For special requirements, contact the Manager of Applications at GCA Andover, Massachusetts.

Chrome background

TP-6991
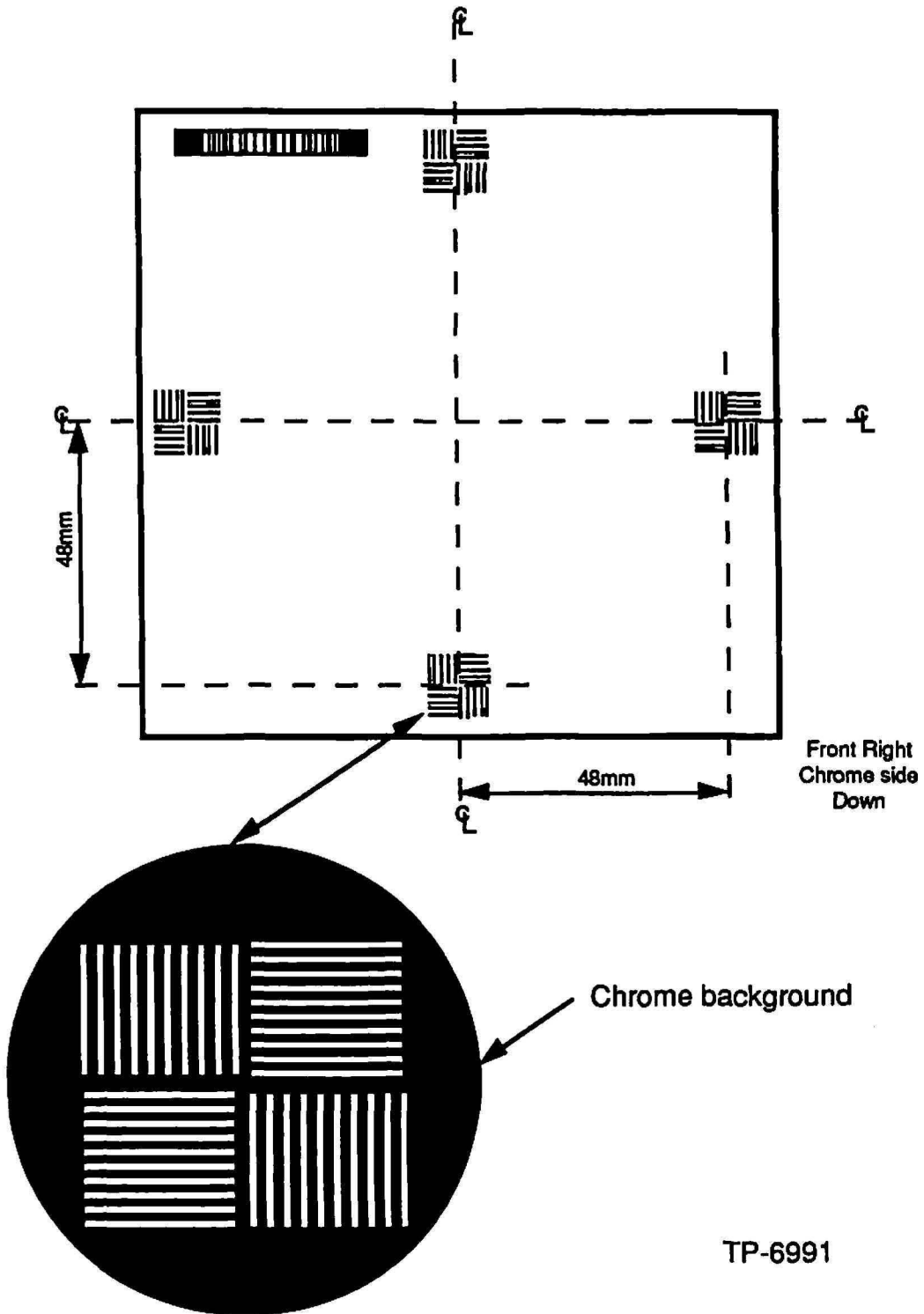
Figure 5-12
INSITU Reticle Window Locations

Alignment Target Placement Strategy

The design rules for the process determines the alignment sequence. The design rules should provide the data for the alignment target worksheet. The alignment strategy should be determined by the type of alignment technique used for all levels.

There are two alignment techniques which are available on the wafer stepper system, they are; Global, which is performed automatically by the AWA/D, and local, which is performed by DFAS, or Micro DFAS depending upon system configuration.

Global Alignment

Global alignment has been used since the introduction of the first wafer stepper system (4800 DSW Models). The global alignment target has been the same for all wafer stepper systems. By aligning two global alignment marks on either side of the wafer for X, Y and theta, total overlay may be acheived for some of the less critical alignments as shown in Figure 5-13.
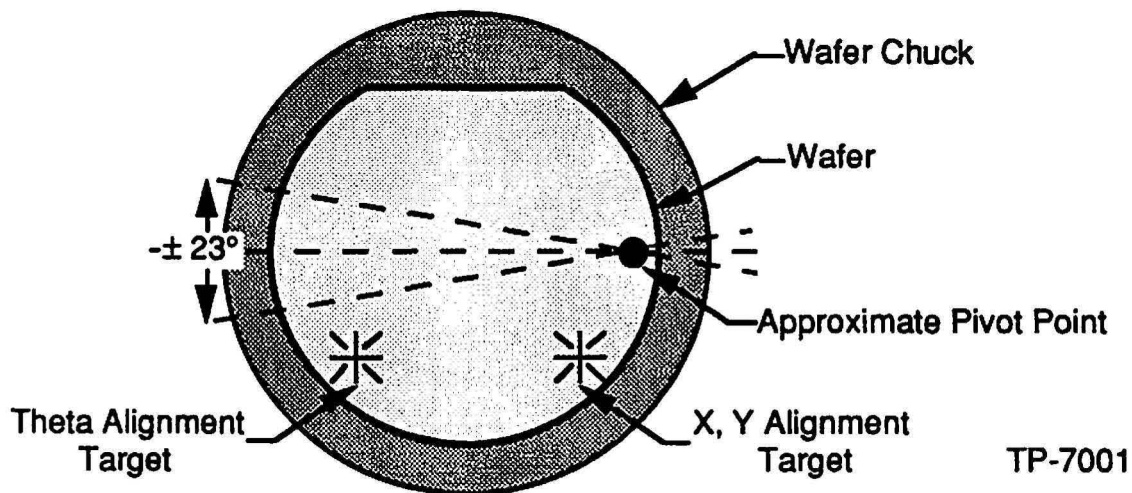
Figure 5-13
X, Y-axis and Theta Wafer Alignment Target Locations

When global alignment is being used exclusively, global alignment targets must appear on all reference layers. Wafer stepper systems without INSITU and RRS must have global alignment targets on all reference layers even if the system is equipped with Micro DFAS, or DFAS.

Local Alignment

Local alignment can be defined as process of aligning previously exposed die before the exposure of that die. There are 2 systems that provide local alignment data based upon the configuration of the wafer stepper system, they are; DFAS and Micro DFAS.

Dark Field Alignment System (DFAS)

The Dark Field Alignment System (DFAS) is the local alignment system on the wafer stepper system system which provides alignment information that increases the registration capability which maintains crucial overlay specifications for today's smaller geometries.

The DFAS aligns a die on the wafer referenced to the reticle on the platen chuck. The DFAS uses an itinic wavelength detection scheme with electronics that indicate the error between the placement of the wafer on the stages and a window on the reticle. Therefore, the circuit device on the wafer is directly aligned to the image that is about to be exposed on the wafer surface.

DFAS is typically installed on 8500, and earlier ALS models of wafer stepper systems.

Micro Dark Field Alignment System (Micro DFAS)

Micro DFAS is a non-itinic alignment system which is factory aligned, and non-adjustable. The Micro Dark Field Alignment System (Micro DFAS) is the local alignment system on the wafer stepper system system which provides alignment information that increases the registration capability which maintains crucial overlay specifications for today's smaller geometries.

Micro DFAS aligns a die on the wafer indirectly referenced to the reticle on the platen chuck. Micro DFAS uses an non-itinic broadband wavelength detection scheme with electronics that indicate the error between the placement of the wafer on the stages and multiple windows on the reticle. Therefore, the circuit device on the wafer is aligned using MAPPING techniques to ensure proper overlay.

INSITU supplies Micro DFAS with the capability of multiple reticle reference points to ensure better than single point reference alignment.

Micro DFAS is typically installed on AUTOSTEP, and later ALS models of wafer stepper systems.

Metrology Software and Wafer Stepper System Calibration

There are several systems which analyze the local alignment system data to provide information which is used to analyze die on the wafer, and to calibrate the wafer stepper system.

SMARTSET

SMARTSET is a menu driven software package that characterizes the wafer stepper system to optimize system performance.

MAPPING

The MAPPING function allows the local alignment system (Micro DFAS or DFAS) to align actual production wafers to determine corrections for six key parameters:

- X and Y stage axis scaling
- X and Y baseline (exposure pass shift)
- Stage orthogonality
- Microscope rotation

MAPPING combines system setup, measurement, and adjustment into a single-step process, which is performed using production wafers which significantly shortens wafer stepper system system setup and alignment time. The mapping process allows calibration for each wafer exposed on the wafer stepper system system and eliminates the need for send-ahead wafers.

INSITU

INSITU is a reticle referenced alignment system comprised of a small detector assembly which contains an INSITU artifact, Micro DFAS alignment mark, and a AWA/D alignment mark) attached to the Theta-III stage. The reticle on the platen must also contain a corresponding window for the INSITU detector. The system MOP contains software to control the INSITU local alignment system.

MATCH Utility

The MATCH utility improves overlay accuracy by using the RRS (Reticle Rotation System) and the INSITU probe to automatically calibrate reticle rotation, and Micro DFAS baseline without the use of send-ahead wafers. The frequency with which the MATCH utility is used is a variable.

Wafer Target Design

The wafer alignment target may be of clear or solid color phase with some considerations given to process. Dimensions of the wafer alignment targets are shown in Figures 5-14 and 5-15. These features are in the dimensions at the wafer after processing. Therefore, on process levels where significant change in linewidth could occur, targets with (+) or (-) biases are recommended so that after processing the wafer dimensions appear as those shown in Figures 5-14 and 5-15.
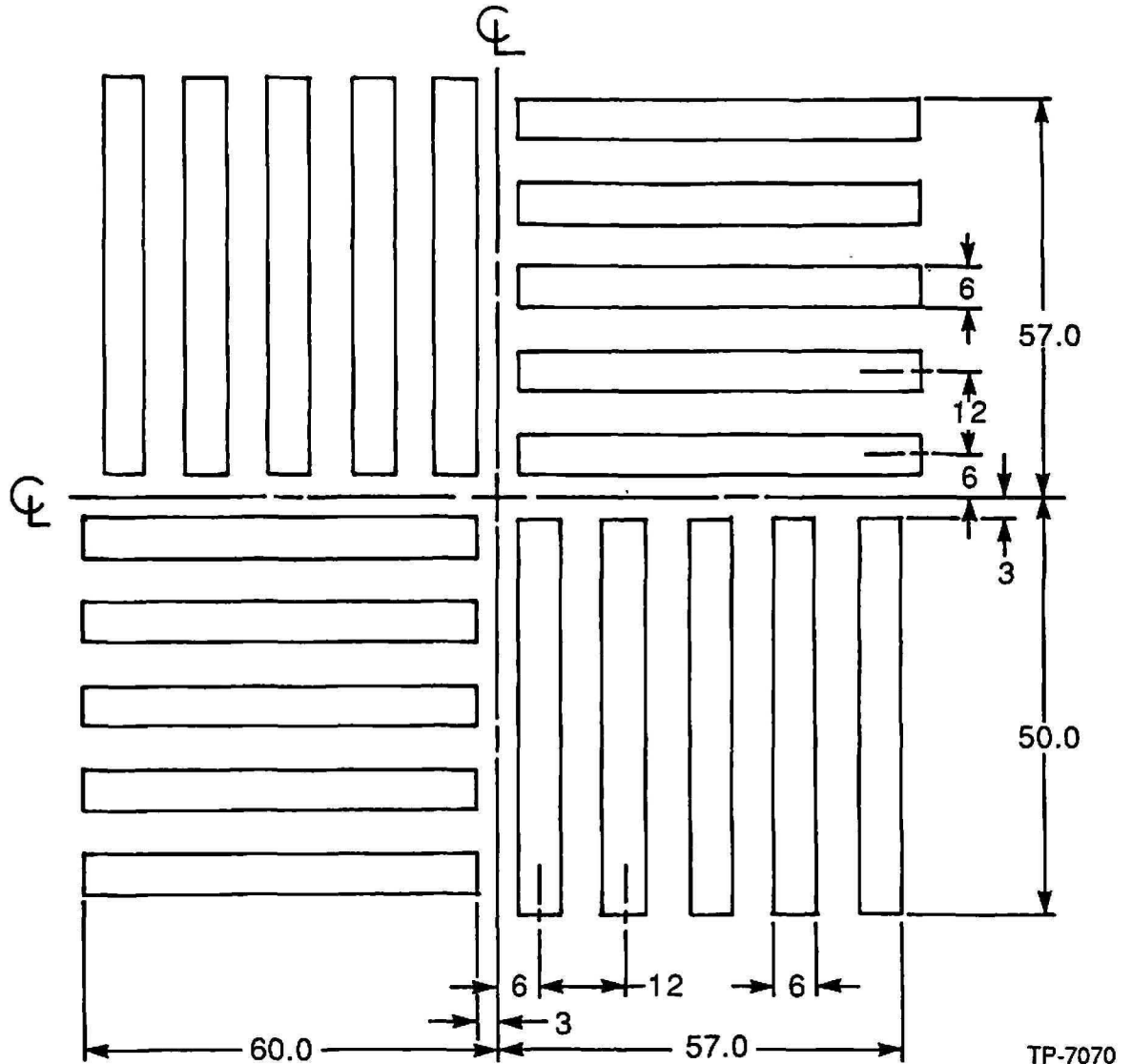
All dimensions at wafer plane in microns.
Drawing not to scale.

Figure 5-14
DFAS Wafer Alignment Target

All dimensions at wafer plane in microns.
Drawing not to scale.

TP-7071
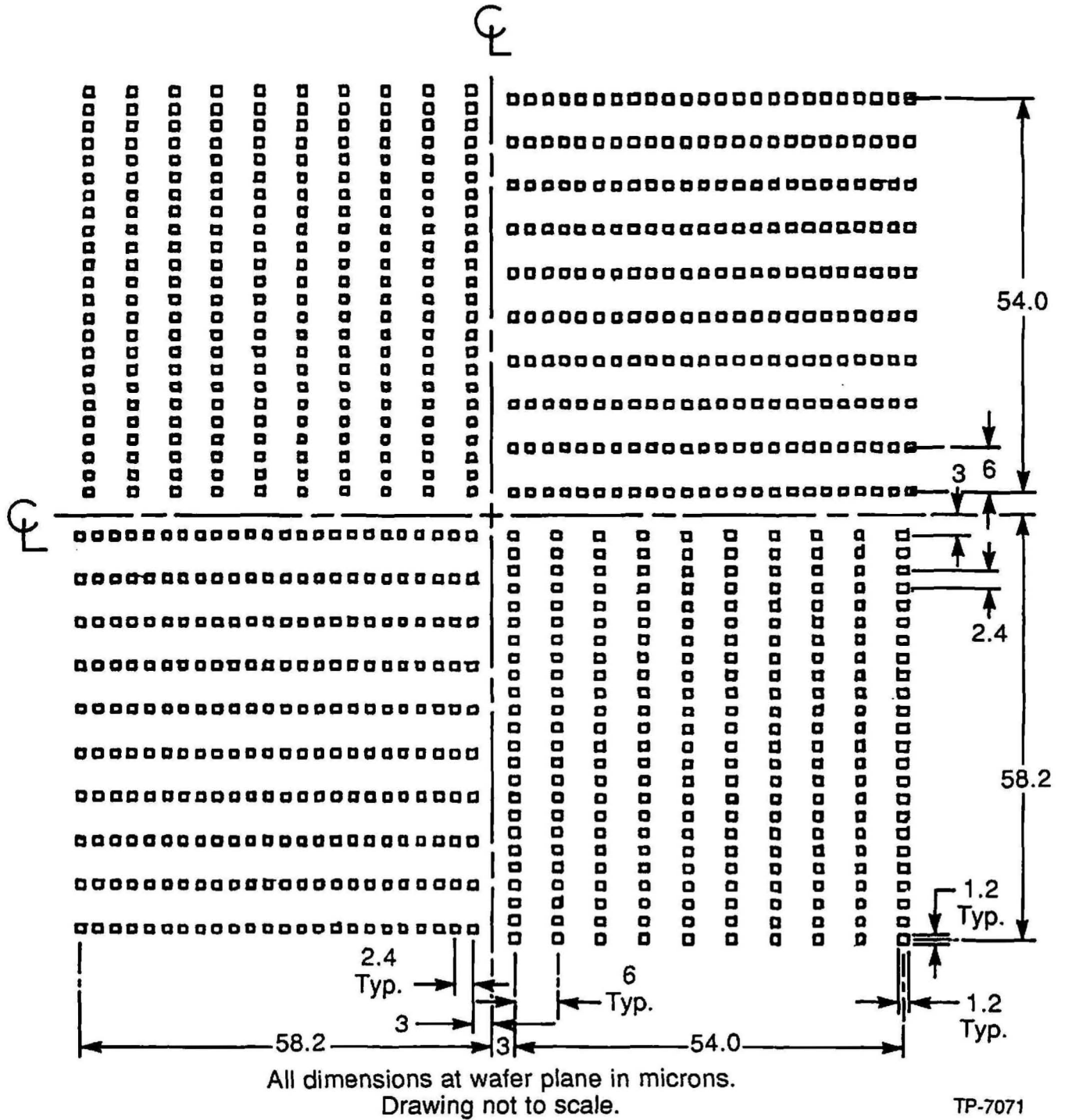
Figure 5-15
1.2 micron Segmented DFAS Wafer Alignment Target

Alignment Target Worksheet

The following is an explanantion of the alignment target worksheet categories.

Calma Level

The calma level is the file or location in the data base that all information pertaining to a given mask level resides.

Masking Level

The masking level is the functional name of the mask level (contact, poly, gate, metal, etc.)

Mask Number

The mask number is the numerical designation of the mask level.

Device Field

The device field is the masking level defined at the wafer which can include the following:

Clear field (CF) - the features (poly, gates, metal leads, etc.) which are covered with photoresist.

Dark Field (DF) - the area around the features (contacts, vias, etc.) which are covered with photoresist.

Scribe

The scribe column denotes whether the scribe street is clear or dark as described below:

Clear (CLR) - no photoresist in the scribe street after processing.

Dark (DK) - photoresist remains in the scribe street after processing.

Reference Layer

The reference layer is the masking level which the design rules designate as the masking level that is aligned to.

Global Alignment Target Used

The global alignment target used column pertains only to reference layers which are used as a reference to align other layers to. The specific global alignment target to be used is indicated on the data base tape provided by GCA. The size and field is defined by the process engineer.

Local Alignment Target Used

The local alignment target used column pertains only to reference layers which are used as a reference to align other layers to. The specific local alignment target to be used is indicated on the data base tape provided by GCA. The size and field is defined by the process engineer.

Target Protect

Target protection is used to protect an alignment target if it appears on a clear scribe street where it is likely to be damaged by processing.

Vernier

A vernier is located on the reference layer. The layers which align to the reference layer contain a scale which uses the vernier on the reference layer for measuring overlay error. Occasionally, other geometries are used to perform the same function.

Scale

The scale is located on subsequent layers which interlocks with the vernier on the reference layer. The combination of a vernier, and a scale provide overlay data which is used to correct the overlay (registration) accuracy.

Alignment Target Worksheet

Process: Example   Date: 2/2/90

1	2	3	4	5	6	7	8	9	10	11
CALMA LEVEL	MASKING LEVEL	MASK NUMBER	DEVICE FIELD	SCRIBE	REF. LAYER	GLOBAL ALIGNMENT TARGET USED	DFAS ALIGNMENT TARGET USED	TARGET PROTECT	VERNIER	SCALE
01	N-WELL	1.0	CF	CL	SI	DG	DG		CLR	
02	FIELDOX	2.0	CF	CL	1.0	DG	DG		CLR	CLR
03	FI IMP	3.0	DF	DK	1.0					DK
04	BURI CON	4.0	DF	CL	2.0					CL
05	P GATE	5.0	CF	CL	2.0	DG	DG		CLR	CLR
06	P+ IMP	3.1	CF	DK	4.0					CLR
07	N+ IMP	3.2	DF	DK	4.0					CLR
08	CONTACT	6.0	DF	CL	2.0	DF	DF		CLR	CLR
09	METAL	7.0	CF	CL	5.0	DG	DG		DK	DK
10	VIA	6.1	DF	CL	7.0	DF	DF		CLR	CLR
11	METAL	7.1	CF	CL	6.1					DK	DK
12	PAD	8.0	DK	CL	7.1					CLR

Figure 5-16
Alignment Target Worksheet

Alignment Schemes

A combination of the global alignment target, and one, two, three, or four local alignment targets can be used to optimize the alignment of critical and non-critical layers and minimize the space used in the scribe line area.

One Local Alignment Target per Field

A single local alignment target can be placed anywhere in the field. The placement of the vernier should be located next to the local alignment target as shown in Figure 5-17. When using a multiple die reticle and the scribe line falls in the center of the field place the alignment cell as close to the center of the field as possible to provide optimum local alignment.

Barcode

Front Right
Corner Chrome
Down

TP-7072
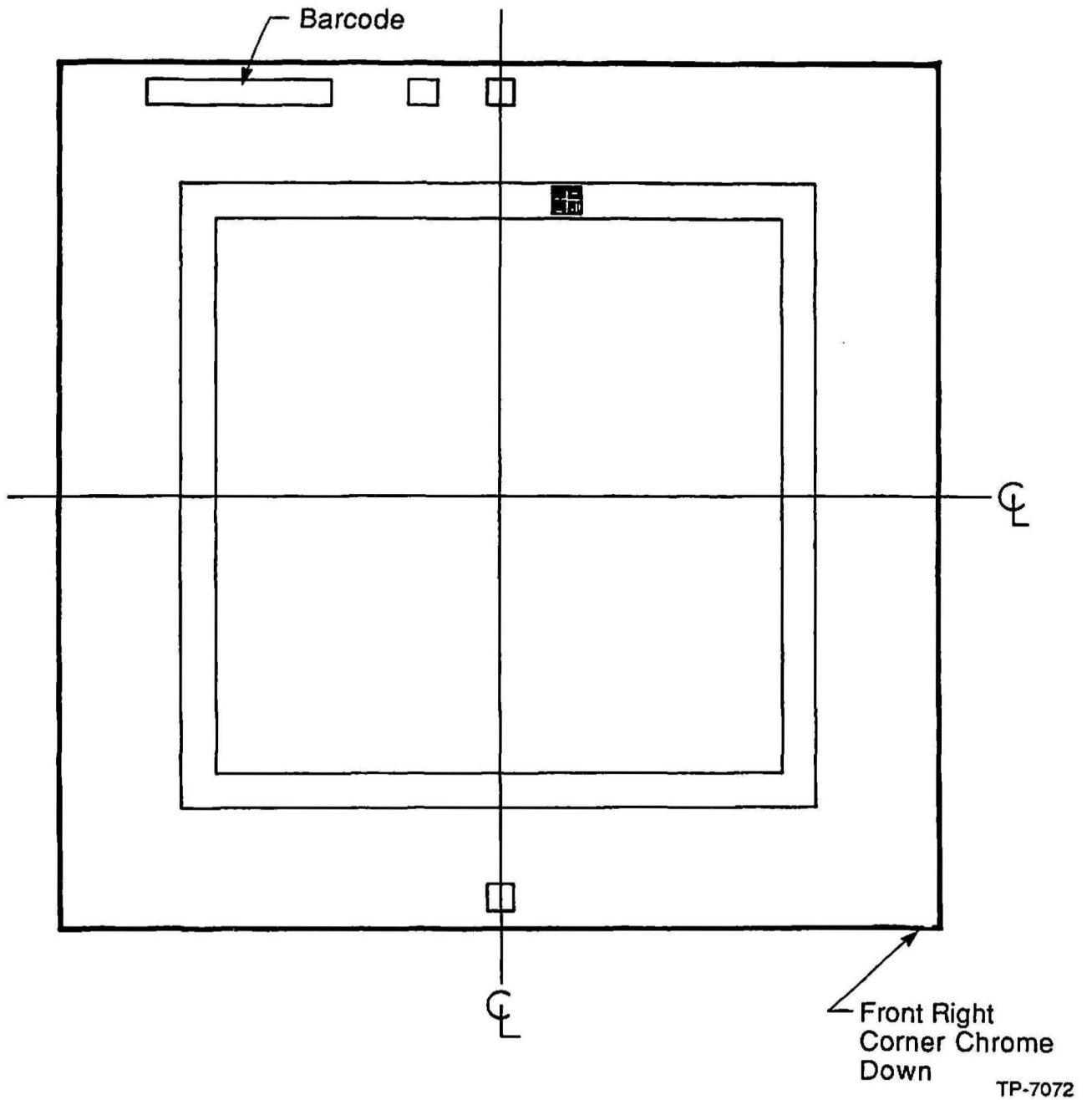
Figure 5-17
One Local Alignment Target per Field

The advantages of one local alignment target per field is that a minimum amount of area is used for the placement of local alignment marks. The disadvantages are if the vernier is overlayed perfectly, there is no method of measuring reduction or rotation errors.

Two Local Alignment Targets per Field

The pair of local alignment targets should be placed across from each other in the field as close to the X-axis centerline as possible.

NOTE: The distance in the X and Y-axis from the center of the reticle to the center of the alignment target on the same masking level should equal the same absolute value.

The vernier must be placed above or below each alignment target as shown in Figure 5-18.
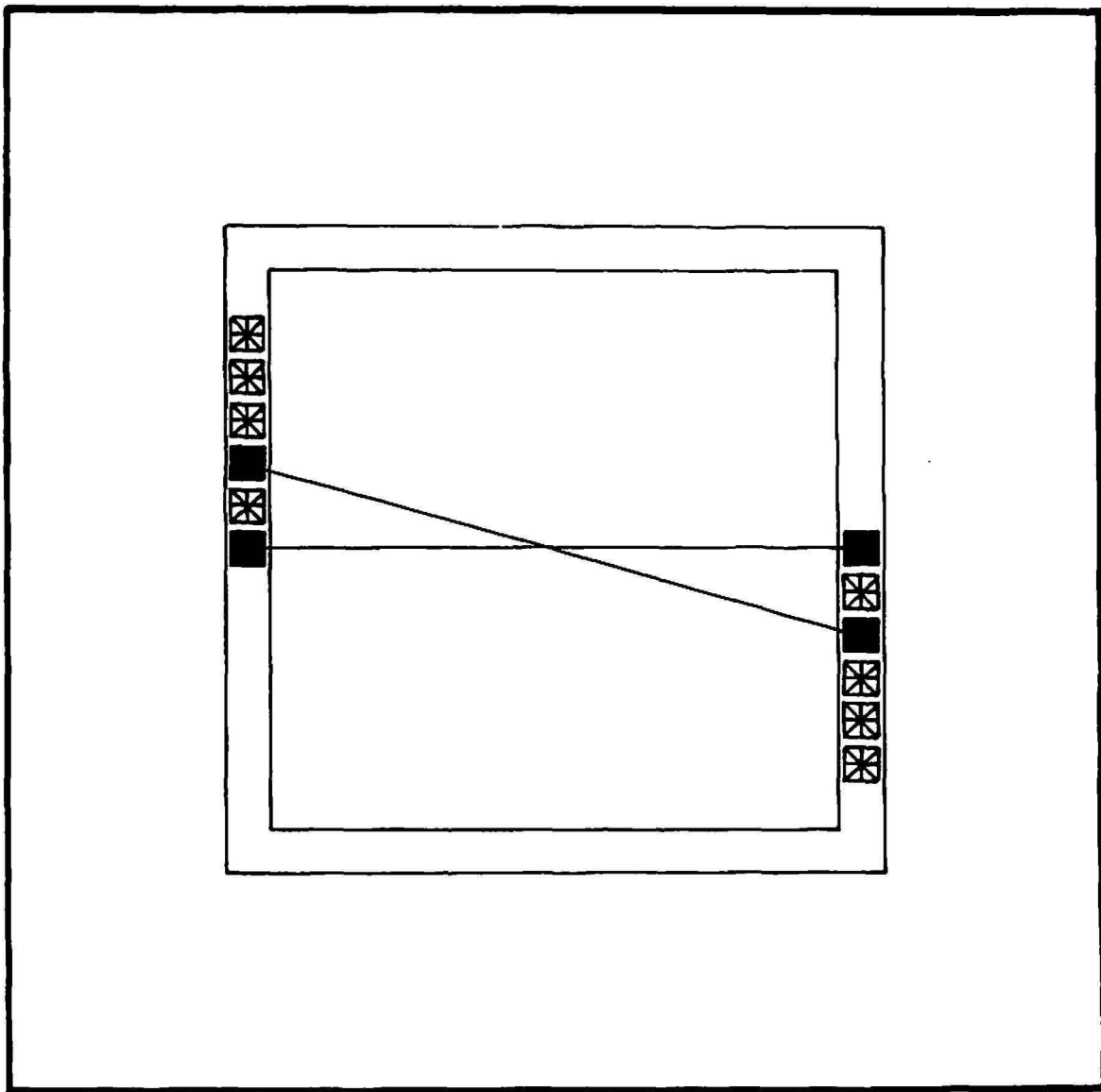
TP-7109

■ = Target

▨ = Vernier

Figure 5-18
Two Local Alignment Targets per Field

The advantages are the minimization of the vector error. If the vernier reading are equal, but opposite in polarity, the die is perfectly centered. The maximum overlay errors are at the edge of the field where the measurement took place. The disadvantages are that this method uses more of the scribe line. More time is typically used if verniers are read manually.

Four Local Alignment Targets per Field

The placement of four local alignment targets per field should be located in the 4 corners, diagonally across from each other, of the reticle as shown in Figure 5-19.

The advantages of four local alignment marks per field is to minimize the maximum vector error. If the vernier readings have equal and opposite readings, the die is perfectly centered. The maximum overlay errors are at the edge of the field where the measurement was taken. Rotation and reduction can be calculated for each wafer if required.

The disadvantages of this method are that the four corners of the scribe line are occupied by the targets. There are more verniers to read which becomes time consuming. The number of MAPPING sites are increased which may decrease wafer stepper system throughput.
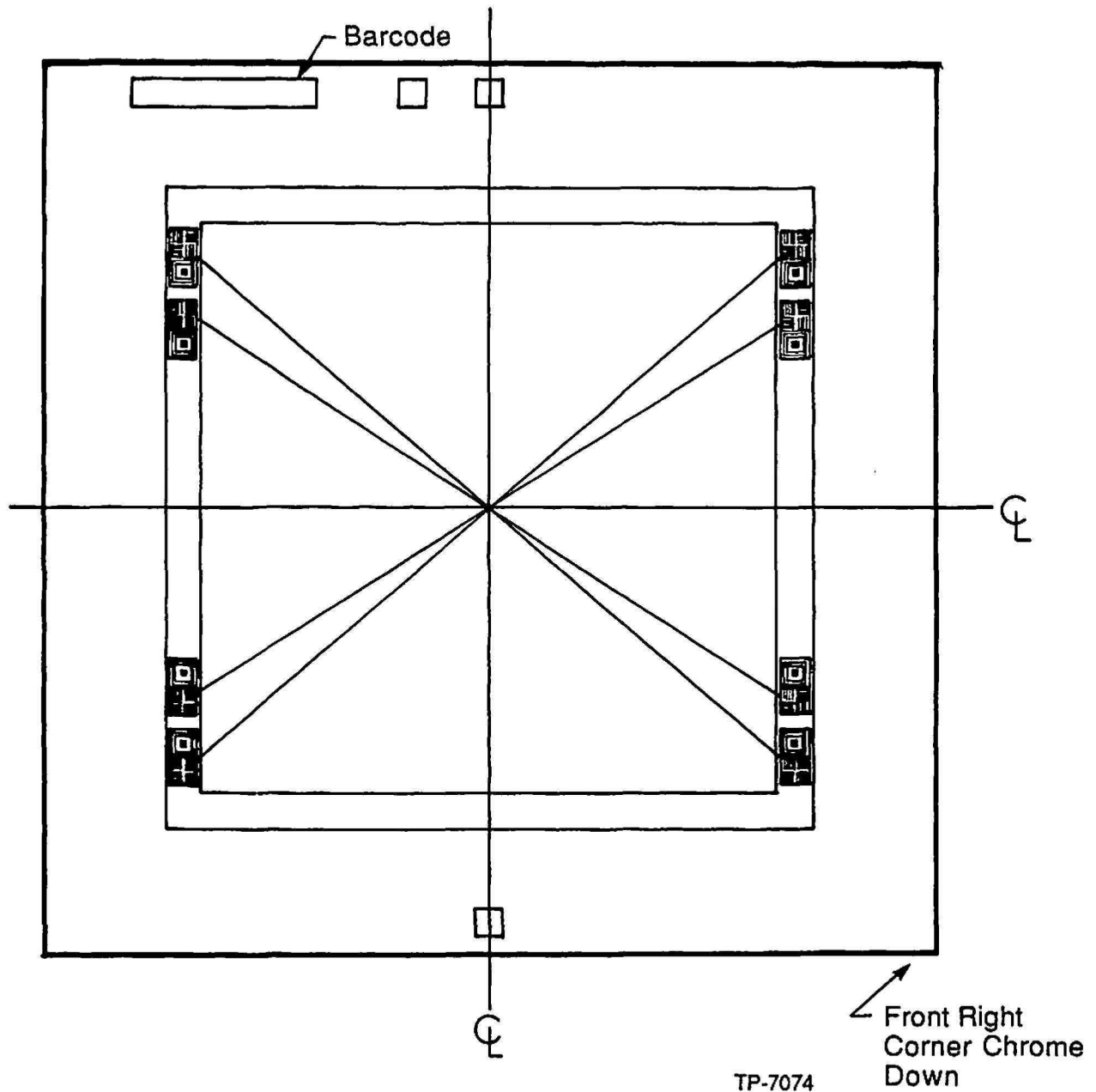
Figure 5-19
Four Local Alignment Targets per Field

Global Alignment Target

The global alignment target is used to align the entire wafer during the global alignment process. The marks that are located at 45° and 135° are used for automatic global alignment which is performed by the AWA/D. The marks located at 90° and 180° are typically used during manual (operator) alignment. The global alignment target shown in Figure 5-20 is typical for manual or automatic wafer global alignment.
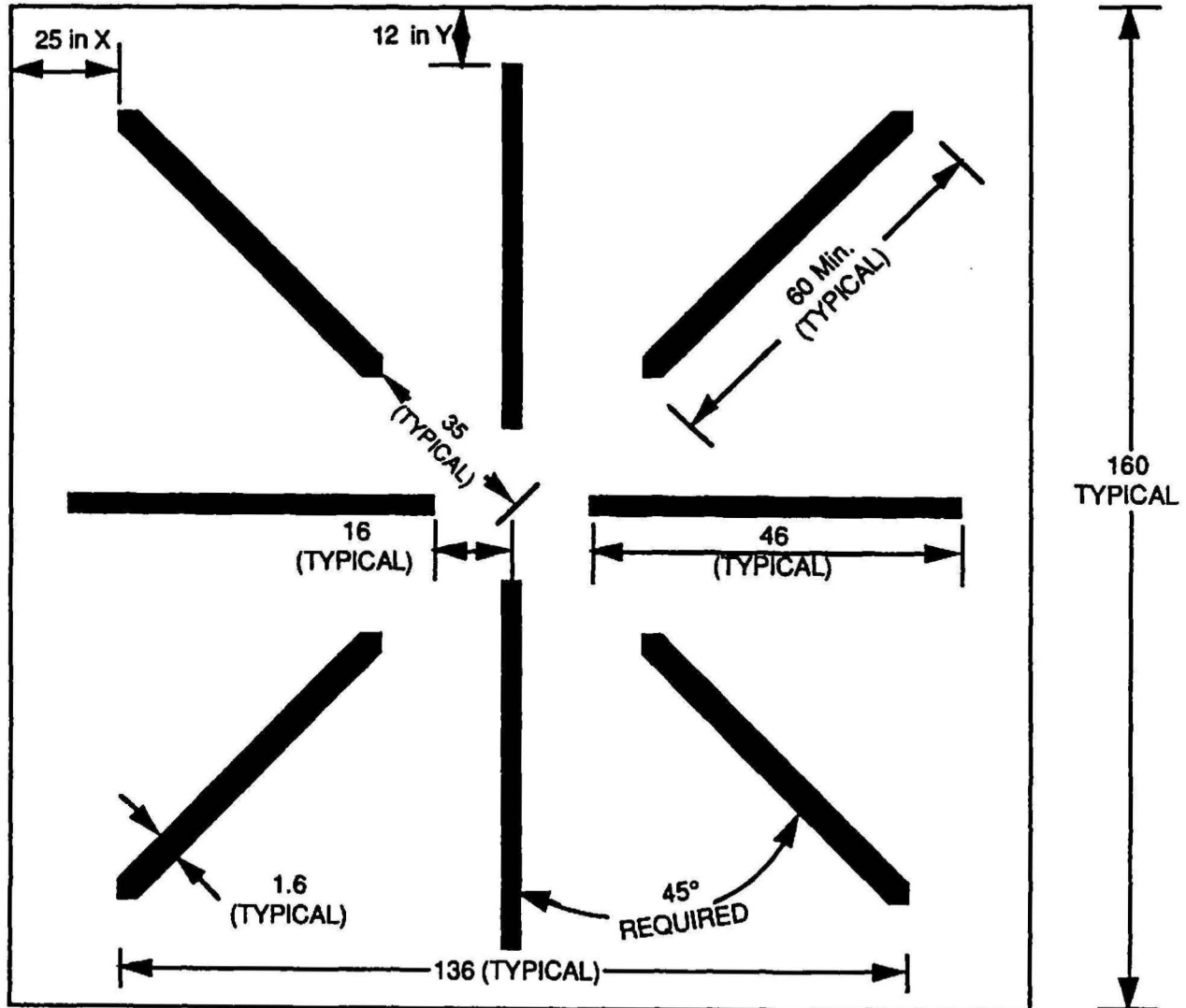
NOTE: All measurements are in microns.

NOTE: Minimum separation distances of 25 microns in the X-axis, and 12 microns in the Y-axis between the ends of the target lines and any other geometries.

Figure 5-20
Typical Wafer Alignment Target for AWA/D

The design of the wafer alignment target is critical to optimize the use of the target as shown in Figure 5-20. The following guidelines should be followed when placing wafer alignment marks on a reticle:

- Line width of target should be 1.0 to 2.4 microns (1.6 is nominal).

- Maintain a minimum separation of 25 microns in the X-axis, and 12 microns in the Y-axis between the ends of the target lines, and any other geometry.

- The AWA/D aligns better to solid targets rather than hollow targets.

- Positive and negative phase targets may be used however, depending on the process level, the target that provides the best optical contrast is preferred.

Alignment Target Spacing

The spacing of alignment target in the wafer alignment microscope is fixed at 76.2 or 101.6mm (spacings for 100mm, 125, 150, and 200mm wafers are also available). If only one alignment target were stepped as part of the first process step it would not generate the necessary 2 alignment keys 76.2 or 101.6mm apart. For example, if the X-axis step distance was 11mm as shown in Figure 5-21, the alignment targets would fall at 0, +11, +22, ... +66, +77mm, none would be exactly at 76.2mm.
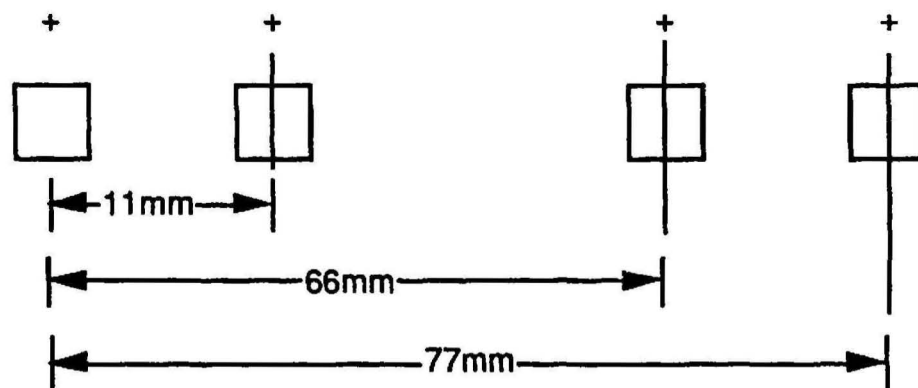
TP-6970

Figure 5-21
Alignment Target Spacing Example

At first glance it appears that the only way to have an alignment target fall at 76.2mm is to step only stepping distances which divide evenly (no remainder) into 76.2mm, which is unacceptable. The solution is to step artwork that contains 2 alignment targets. For example, if in the above case we add a second alignment target at 0.8mm to the left of the one shown in Figure 5-22, an alignment target is located at 76.2 as shown in Figure 5-22.
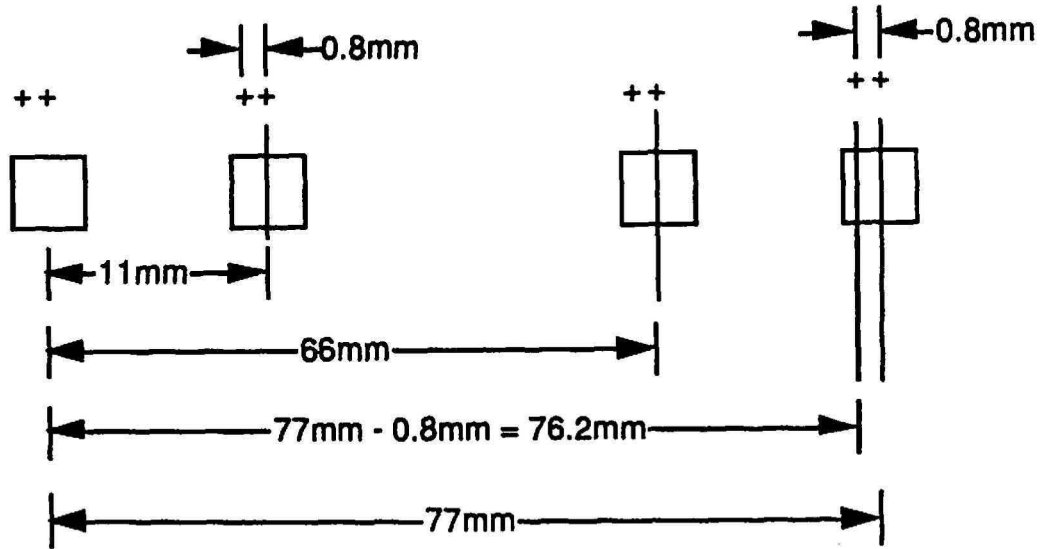
TP-6969

Figure 5-22
Second Alignment Target Example

This procedure can be generalized. The spacing of the 2 alignment targets for 76.2mm or 101.6mm objective spacing is calculated as follows:

Formula 1

$$\frac{76.2\text{mm, (or 101.6mm)}}{\text{step distance(S)mm}} = \text{integer (N)} + \text{remainder (R)}$$

Formula 2

remainder (R) x step distance = the second key's spacing to the right (-X), of the primary alignment target.

Formula 3

step distance(S) - remainder(R) x step distance(s) = the second alignment target to the left (-X), of the primary alignment target.

Either formula 2 or 3 works Formula 3 was used in the above example because it keeps the alignment target within the die size boundary. To use this strategy the device layout engineer needs only to know the planned stepping distance in order to be able to add the necessary artwork to the layout. For simplicity of the layout, GCA recommends that these keys be placed in the scribe area.

The alignment target design shown in Figure 5-22 cannot be used for die sizes where the calculation yields a remainder (R) less than 0.000400in. (10μm). When R is less than 10μm, the 2 alignment targets are to close together to allow good alignment. Since the number of cases yielding an R less than 10μm is very small, it is extremely unlikely that this will ever be a problem. However, if this problem is encountered, GCA can assist with alternative alignment target designs.

Non-Standard Alignment Targets

The use of non-standard targets can be employed when standard alignment targets cannot be used due to location restraints. The position of the targets is measured from the center of the reticle to the center of the left alignment target. It is important to keep the right and left targets on the same Y-axis offset to maintain proper operation of the wafer stepper system wafer scale feature.

The use of non-standard alignment targets cause significant decrease in throughput. Consult the GCA Applications Manager at the GCA Andover facility for assistance.

Digitizing

The digitizing of the components on the reticle can now begin. Information that is present on the System Configuration Worksheet (located in this section), and the Alignment Target Worksheet (located in Section - 7) should be used to create the alignment cells and the constant reticle perimeter geometries.

Process Definitions

During the CAD process, the device data on all masking levels must be defined as a digitized geometry or field. For the purposes of this manual, if text is digitized it would be treated as a digitized geometry by the CAD system as shown in Figure 5-23. To obtain a clear reticle, the maskmaker will expose the field. To obtain a dark field reticle, the maskmaker will expose the digitized geometry.

Digitized Geometry

GEOMETRY

FIELD
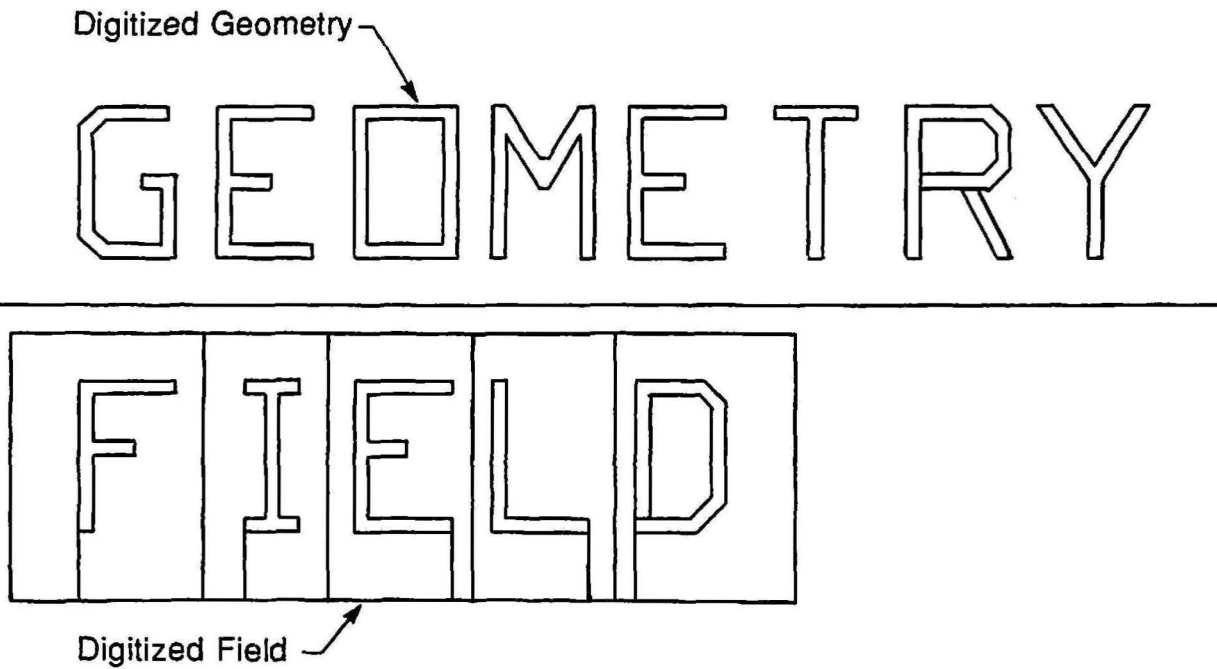
Digitized Field

TP-7075

Figure 5-23
Digitized Field and Text Example

All points or lines must end on a grid point to avoid any error due to a grid snap. Grid snap can be defined as a line or geometry that "snaps" or is fixed to the closest CAD generated grid point, which can be different from the desired point. Grid snap errors may cause problems with the location of geometries on a reticle.

Reticle Processing

For the purposes of this manual, reticles are generated using positive resist technology regardless if they are generated optically, with a laser or with an E-beam system.

Wafer Processing

For the purposes of this manual, wafers are being processed using positive resist technology.

Creating Verniers

Verniers are used for measuring the relative difference in position beteween 2 masking levels. A vernier set contains 2 components, the vernier and the scale. The vernier is laid out so the center-to-center distance between each structure is (plus or minus) the minimum resolution of the measurement needed. The minimum resolution of measurement is associated with the grid size used when creating the vernier. The scale is the interlocking component of the vernier set and is equal to the center-to-center that was used when the vernier was created.

For example; if the vernier is placed on 7.9 micron centers, the scal would be placed on 8.0 micron centers. The resolution of these verniers would be 0.1 micron.

The vernier set shown in Figure 5-24 was constructed using a 0.05 micron grid. The structures beneath the 05 label are placed on 7.95 micron centers which have a resolution of 0.05 micron. The structures above the 0, 2, 4, 6, and 8 are on 7.9 micron centers which have a resolution of 0.1 micron. This type of vernier allows for a resolution of 0.05 micron for the first 0.5 micron of measurement. The vernier is to be placed on the reference levels of a device and is usable with a zero bias, or a ±1 micron bias. The scale of the vernier set shown in Figure 5-24 is on 8.0 micron centers for both the vernier and the scale. The feature is 4 micons wide. The scale will appear centered over some point of the vernier structure after processing.
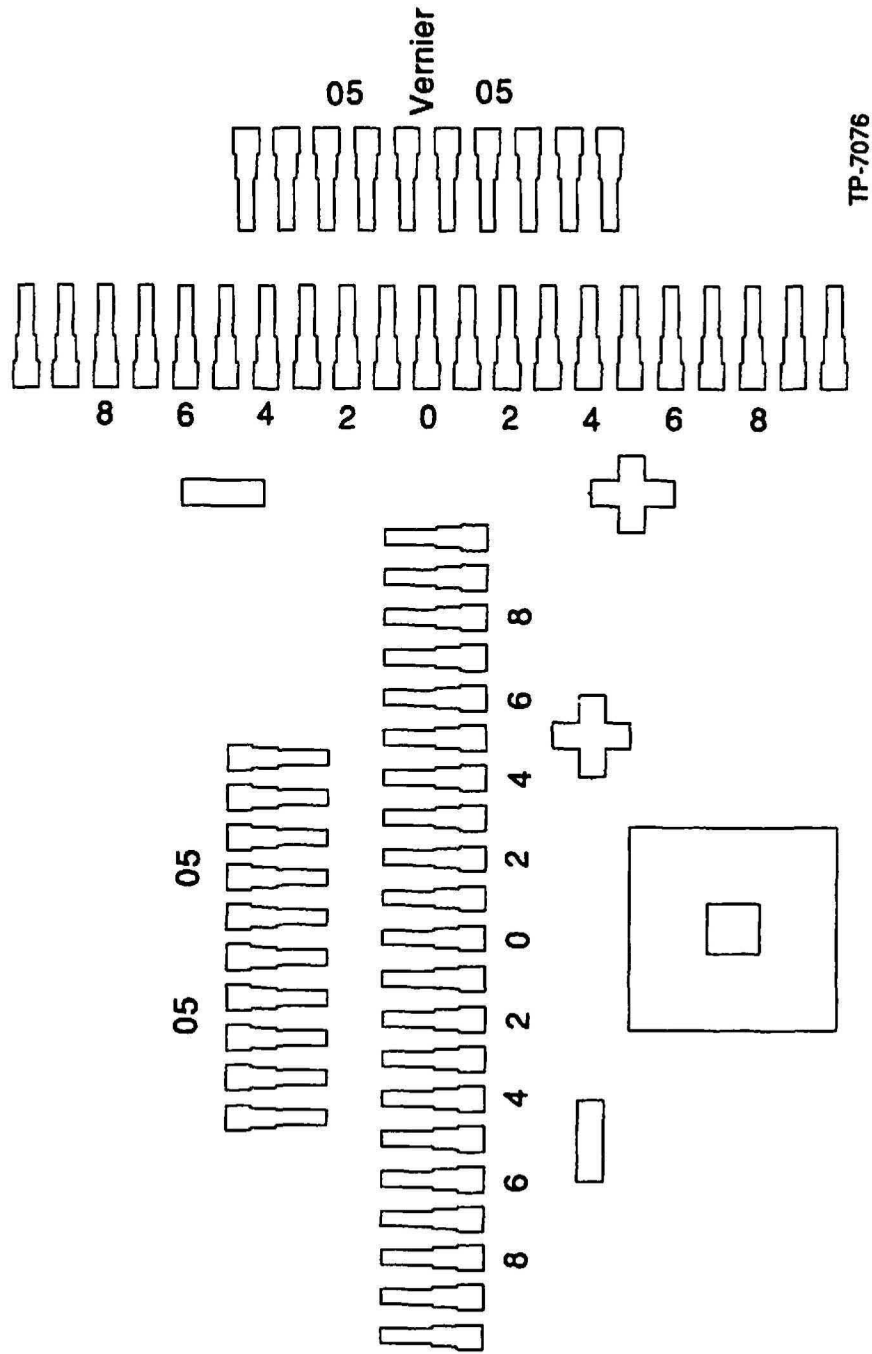
Figure 5-24
Vernier Example
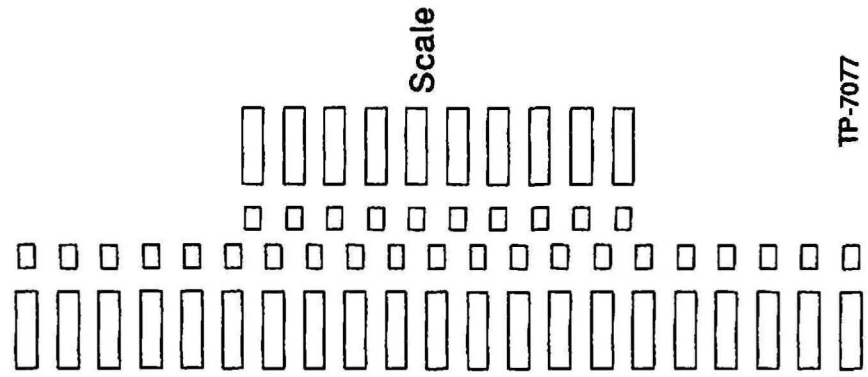
TP-7076
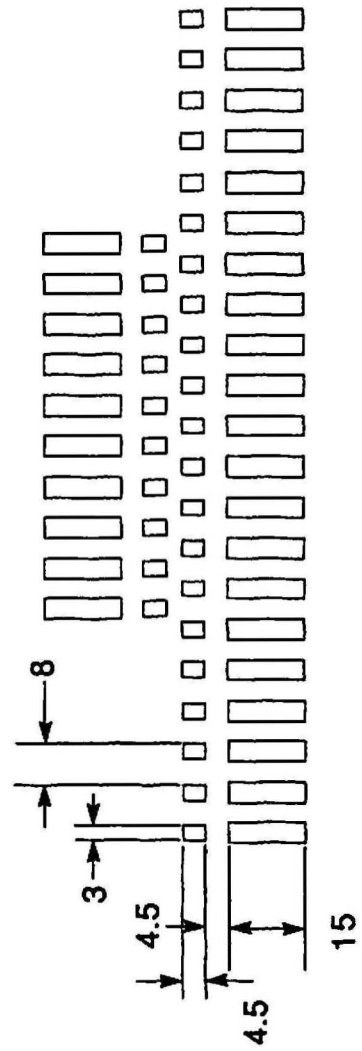
Figure 5-25
Scale Example

TP-7077

Scale

8

3

4.5

15

4.5

A vernier set can be created from any geometric shape as shown in Figure 5-26.
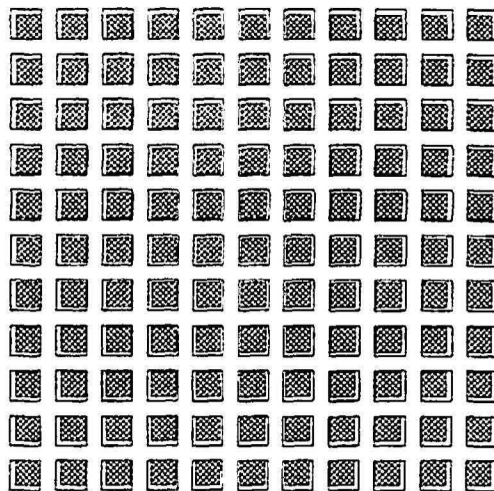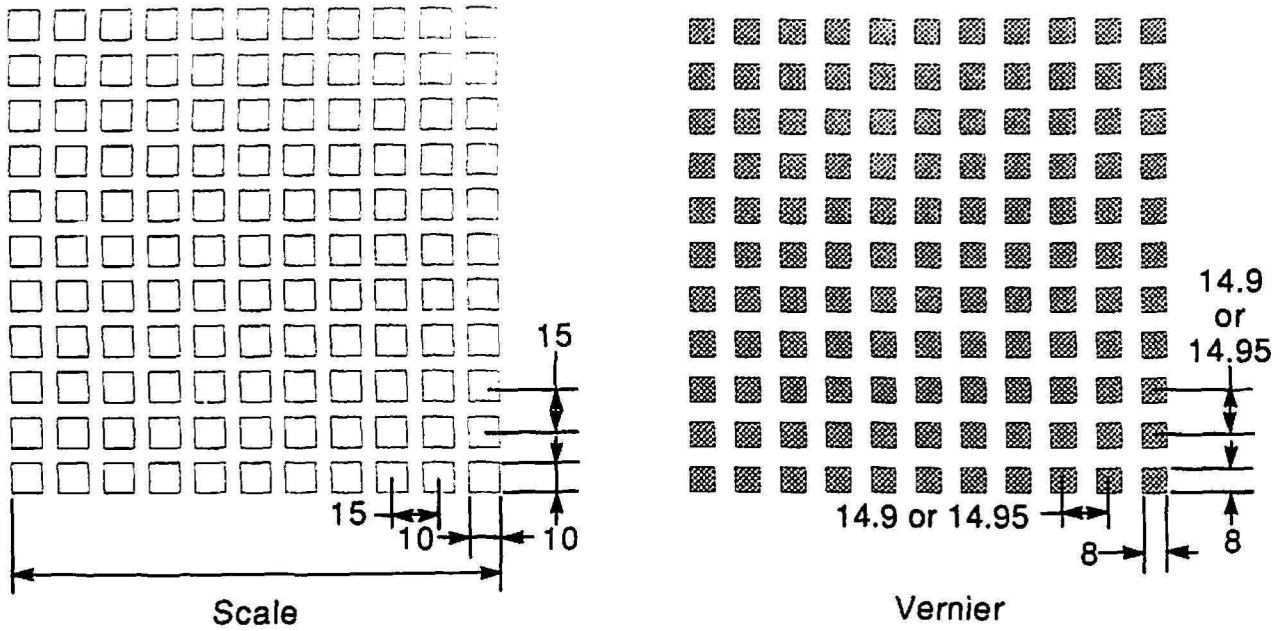
Scale

Vernier

Scale: All Dimensions in Microns at One X.

Interlocked

TP-7078

Figure 5-26
Vernier Set Geometry Examples

Box in a Box Vernier Structures

These structures do not need to be placed on different centers as the previous verniers required. These structures are typically used on automated bright-field illuminated measurement systems. They are simple devices and can be made smaller than the visually read verniers and the strycture size ans shape is dependent upon the measurement system being used. Consideration should be given to the structures so the optimum signal is achieved to gain the highest precision and reliability.

Creating Components within a Cell

A cell can be defined as a group of alignment marks, or other geometries which are grouped together as shown in Figure 5-27.
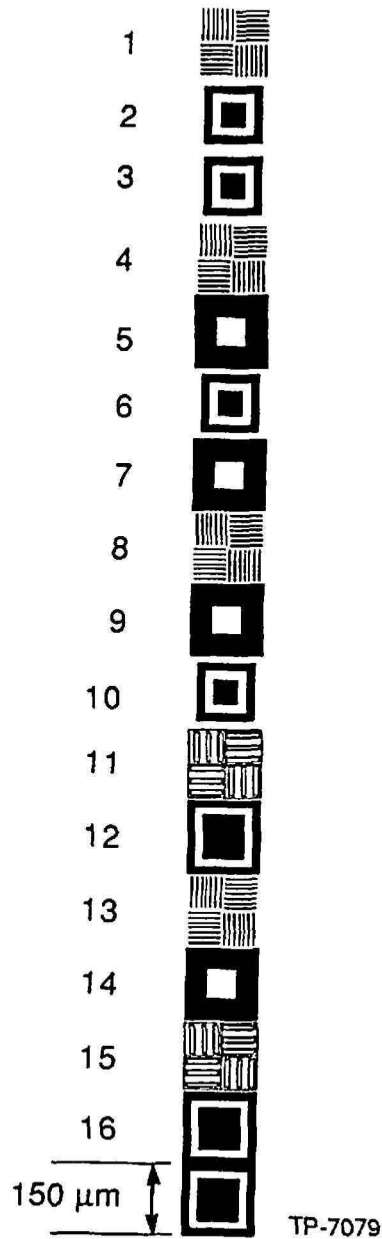
Figure 5-27
Cell Example

Each component within a cell should be digitized individually. All digitizing should be performed at 1X. The exact center of the component is to be 0,0. constant reticle perimeter components can be digitized at 5X.

RMS Alignment Window

The RMS alignment window is not within the field of the reduction lens therefore, it will be digitized at reticle plane dimensions.

Barcode

The barcode is not within the field of the reduction lens therefore, it will be digitized at reticle plane dimensions.

Local Alignment Reticle Window

The Local alignment window is within the field of the reduction lens but it does not print on the wafer. Therefore, the window should be digitized as shown in Figure 5-11. When digitizing the reticle window, draw the upper left quadrant of the target and use the copy and rotation commands to generate the remaining 3 quadrants as shown in Figure 5-28.

Local Alignment Wafer Targets

The local alignment wafer targets are sensitive to process induced dimension changes.

When digitizing the target, draw the upper left quadrant of the target and use the copy and rotation commands to generate the remaining 3 quadrants as shown in Figure 5-28.

60

6

3

12

3

0.0

90 Degrees

180 Degrees

270 Degrees

TP-7080
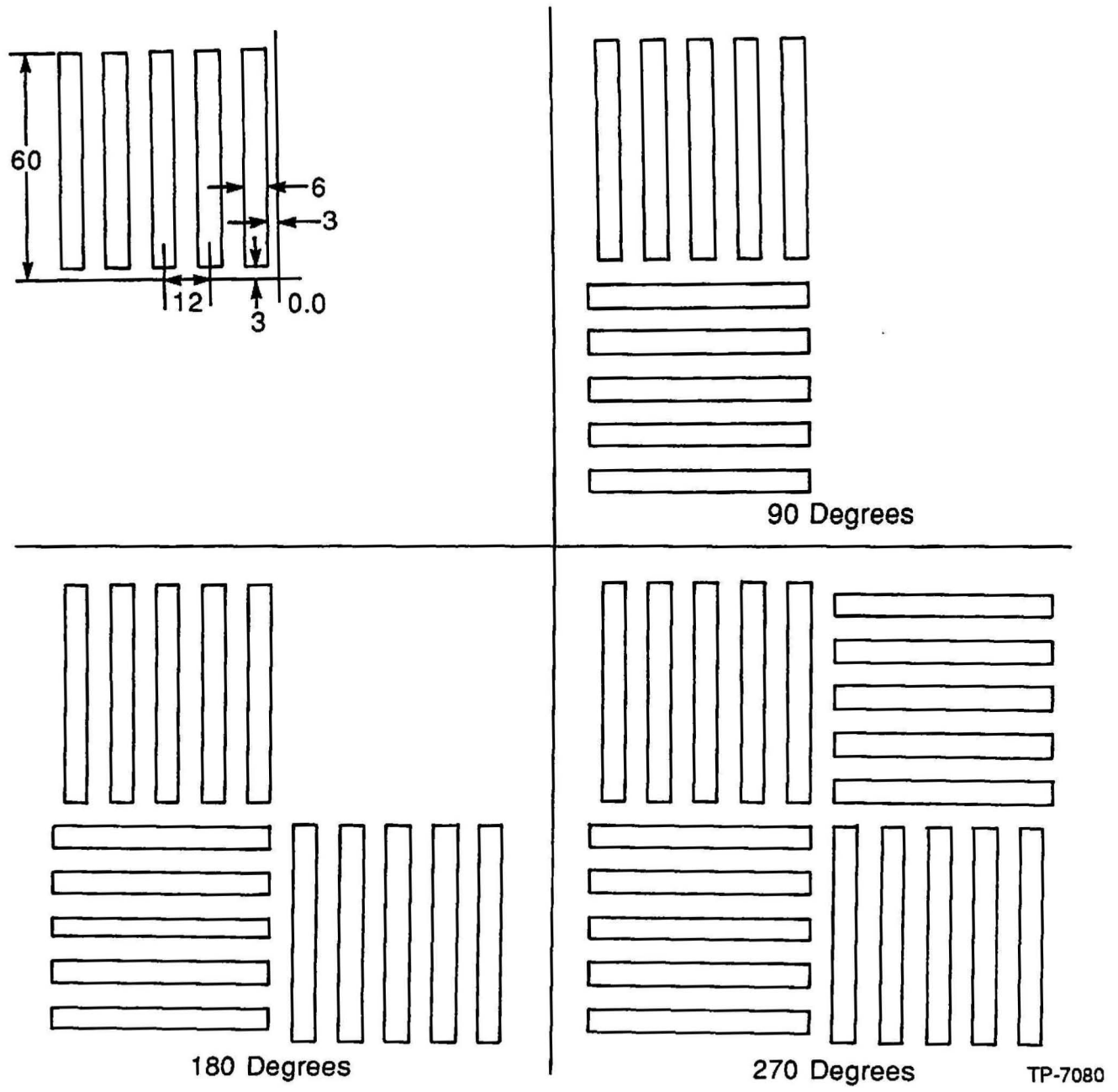
Figure 5-28
Local Wafer Alignment Target Creation

The quadrant should be rotated about its 0,0 point. This method ensures that the quadrant dimensions are the same and should eliminate quadrants with different size geometrie and ensures that the quadrants are drawn on-grid.

Global Alignment Targets

Care must be excersised when creating the 45° and 135° geometries of the global alignment wafer target. The width of the these geometries must be the same as the vertcal or horizontal geometries otherwise global alignment errors may result at the wafer. Refer to Table 5-1 and Figures 5-29 - 5-30 for the creation of the global alignment target digitized geometry. Refer to Table 5-2 and Figure 5-31 for the creation of the global alignment target digitized field.

Table 5-1
Global Alignment Target (Digitized Geometry) Coordinates

Mark Width	POS A1X	POS A1Y	POS A2X	POS A2Y	POS A3X	POS A3Y	POS A4X	POS A4Y	POS A5X	POS A5Y	POS A6X	POS A6Y	POS A7X	POS A7Y	POS A8X	POS A8Y
0.6	24.9	24.5	24.5	24.9	66.5	66.9	66.9	66.5	16	0.3	62	0.3	62	-0.3	16	-0.3
0.8	25	24.4	24.4	25	66.4	67	67	66.4	16	0.4	62	0.4	62	-0.4	16	-0.4
1	25.1	24.3	24.3	25.1	66.3	67.1	67.1	66.3	16	0.5	62	0.5	62	-0.5	16	-0.5
1.2	25.1	24.3	24.3	25.1	66.3	67.1	67.1	66.3	16	0.6	62	0.6	62	-0.6	16	-0.6
1.4	25.2	24.2	24.2	25.2	66.2	67.2	67.2	66.2	16	0.7	62	0.7	62	-0.7	16	-0.7
1.6	25.3	24.1	24.1	25.3	66.1	67.3	67.3	66.1	16	0.8	62	0.8	62	-0.8	16	-0.8
1.8	25.3	24.1	24.1	25.3	66.1	67.3	67.3	66.1	16	0.9	62	0.9	62	-0.9	16	-0.9
2	25.4	24	24	25.4	66	67.4	67.4	66	16	1	62	1	62	-1	16	-1
2.2	25.5	23.9	23.9	25.5	65.9	67.5	67.5	65.9	16	1.1	62	1.1	62	-1.1	16	-1.1
2.4	25.5	23.9	23.9	25.5	65.9	67.5	67.5	65.9	16	1.2	62	1.2	62	-1.2	16	-1.2
2.6	25.6	23.8	23.8	25.6	65.8	67.6	67.6	65.8	16	1.3	62	1.3	62	-1.3	16	-1.3
2.8	25.7	23.7	23.7	25.7	65.7	67.7	67.7	65.7	16	1.4	62	1.4	62	-1.4	16	-1.4
3	25.8	23.6	23.6	25.8	65.6	67.8	67.8	65.6	16	1.5	62	1.5	62	-1.5	16	-1.5
3.2	25.8	23.6	23.6	25.8	65.6	67.8	67.8	65.6	16	1.6	62	1.6	62	-1.6	16	-1.6
3.4	25.9	23.5	23.5	25.9	65.5	67.9	67.9	65.5	16	1.7	62	1.7	62	-1.7	16	-1.7
3.6	26	23.4	23.4	26	65.4	68	68	65.4	16	1.8	62	1.8	62	-1.8	16	-1.8
3.8	26	23.4	23.4	26	65.4	68	68	65.4	16	1.9	62	1.9	62	-1.9	16	-1.9
4	26.1	23.3	23.3	26.1	65.3	68.1	68.1	65.3	16	2	62	2	62	-2	16	-2
4.2	26.2	23.2	23.2	26.2	65.2	18.2	18.2	65.2	16	2.1	62	2.1	62	-2.1	16	-2.1
4.4	26.3	23.1	23.1	26.3	65.1	68.3	68.3	65.1	16	2.2	62	2.2	62	-2.2	16	-2.2
4.6	26.3	23.1	23.1	26.3	65.1	68.3	68.3	65.1	16	2.3	62	2.3	62	-2.3	16	-2.3
4.8	26.4	23	23	26.4	65	68.4	68.4	65	16	2.4	62	2.4	62	-2.4	16	-2.4
5	26.5	22.9	22.9	26.5	64.9	68.5	68.5	64.9	16	2.5	62	2.5	62	-2.5	16	-2.5
5.2	26.5	22.9	22.9	26.5	64.9	68.5	68.5	64.9	16	2.6	62	2.6	62	-2.6	16	-2.6
5.4	26.6	22.8	22.8	26.6	64.8	68.6	68.6	64.8	16	2.7	62	2.7	62	-2.7	16	-2.7
5.6	26.7	22.7	22.7	26.7	64.7	68.7	68.7	64.7	16	2.8	62	2.8	62	-2.8	16	-2.8
5.8	26.8	22.6	22.6	26.8	64.6	68.8	68.8	64.6	16	2.9	62	2.9	62	-2.9	16	-2.9
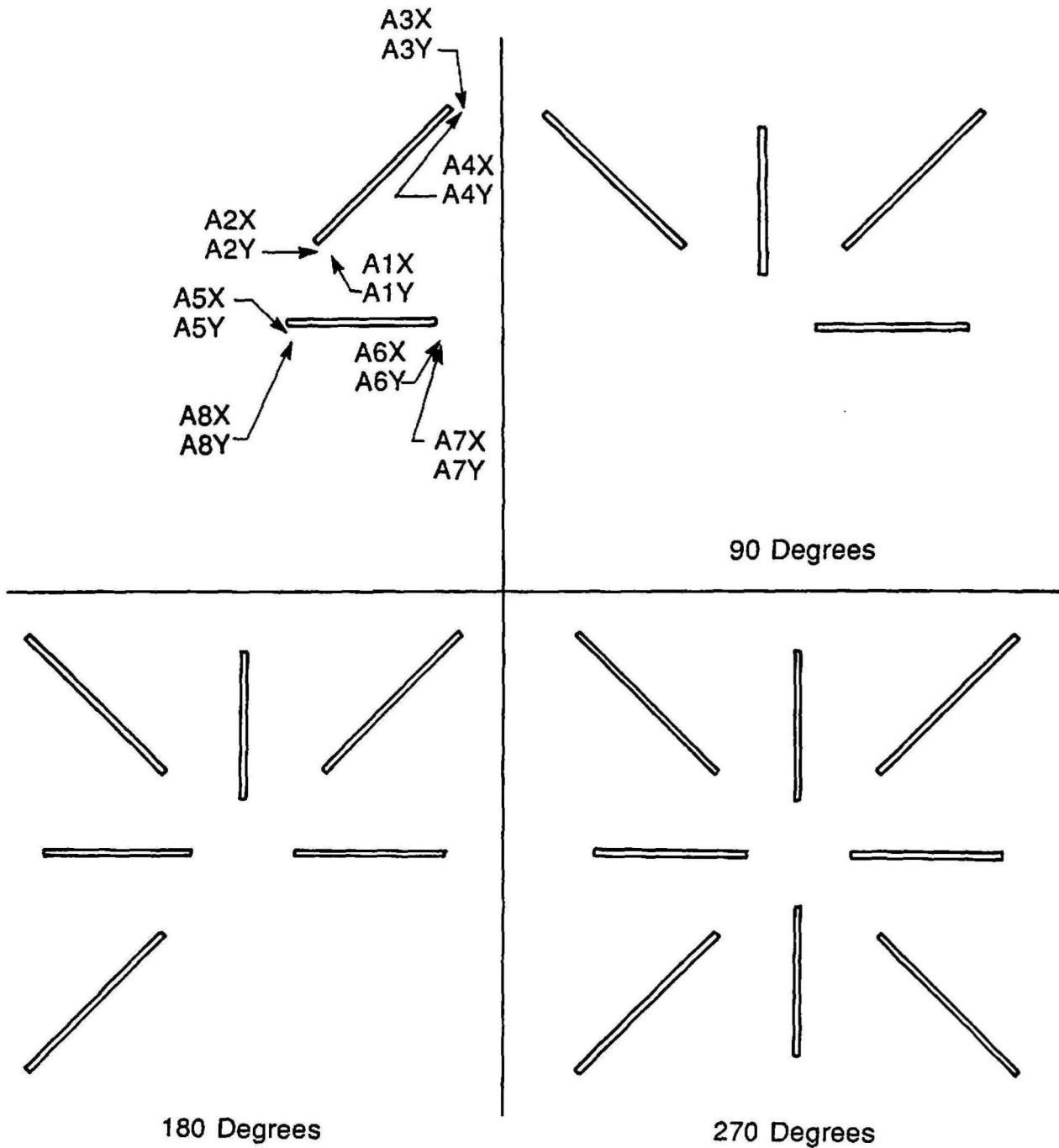
Figure 5-29
Upper Right Quadrant of Global Alignment Target
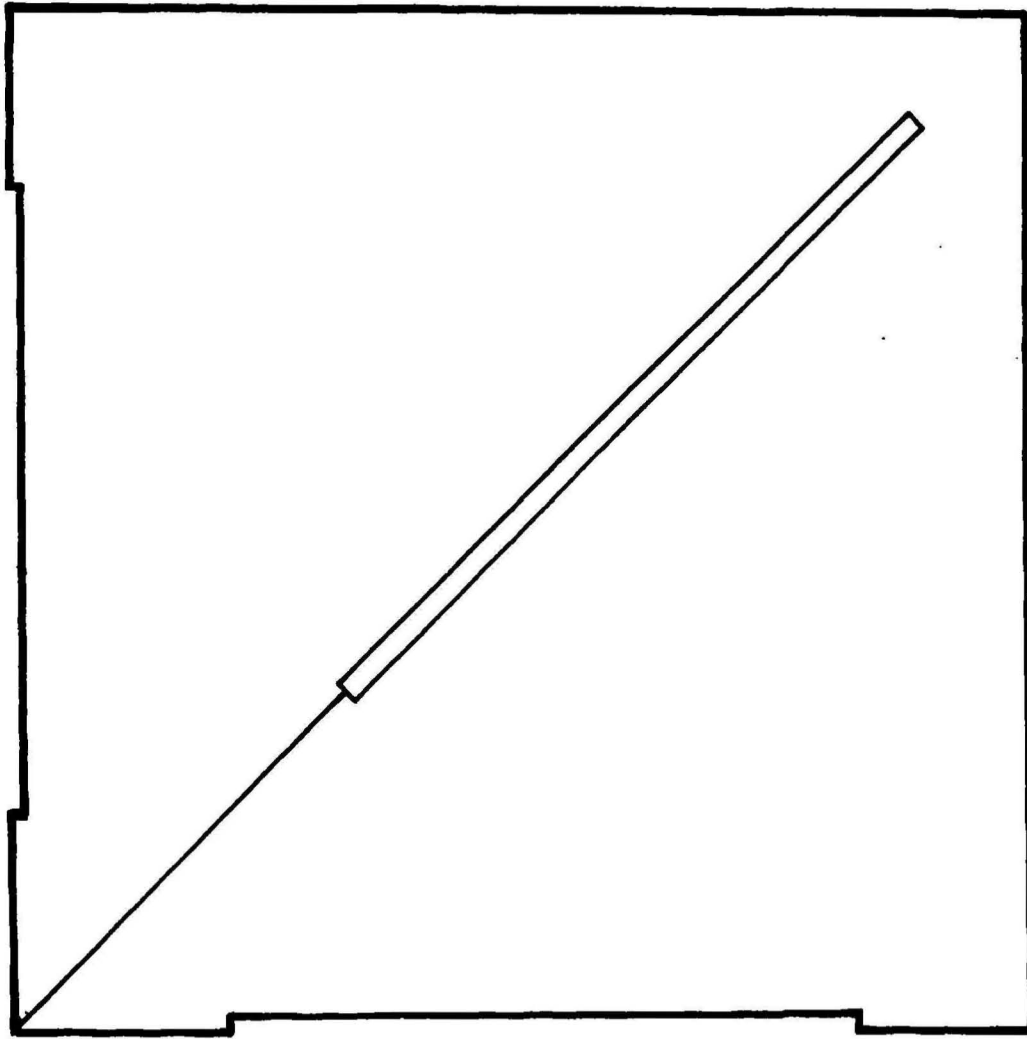
TP-7081

TP-7082

Figure 5-30
Global Wafer Alignment Target Creation

Mark Width	POS DFX1	POS DFY1	POS DFX2	POS DFY2	POS DFX3	POS DFY3	POS DFX4	POS DFY4	POS DFX5	POS DFY5	POS DFX6	POS DFY6	POS DFX7	POS DFY7	POS DFX8	POS DFY8	POS DFX9	POS DFY9	POS DFX10	POS DFY10	POS DFX11	POS DFY11	POS DFX12	POS DFY12	POS DFX13	POS DFY13	POS DFX14	POS DFY14	POS DFX15	POS DFY15	POS DFX16	POS DFY16	POS DFX17	POS DFY17	POS DFX18	POS DFY18	POS DFX19	POS DFY19	POS DFX20	POS DFY20
0.6	0	0	24.7	24.7	24.9	24.5	66.9	66.5	66.5	66.9	24.5	24.9	24.7	24.7	0	0	0	16	0.3	16	0.3	62	0	62	0	75	75	75	75	75	0	62	0	62	0.3	16	0.3	16	0	0
0.8	0	0	24.7	24.7	25	24.4	67	66.4	66.4	67	24.4	25	24.7	24.7	0	0	0	16	0.4	16	0.4	62	0	62	0	75	75	75	75	75	0	62	0	62	0.4	16	0.4	16	0	0
1	0	0	24.7	24.7	25.1	24.3	67.1	66.3	66.3	67.1	24.3	25.1	24.7	24.7	0	0	0	16	0.5	16	0.5	62	0	62	0	75	75	75	75	75	0	62	0	62	0.5	16	0.5	16	0	0
1.2	0	0	24.7	24.7	25.1	24.3	67.1	66.3	66.3	67.1	24.3	25.1	24.7	24.7	0	0	0	16	0.6	16	0.6	62	0	62	0	75	75	75	75	75	0	62	0	62	0.6	16	0.6	16	0	0
1.4	0	0	24.7	24.7	25.2	24.2	67.2	66.2	66.2	67.2	24.2	25.2	24.7	24.7	0	0	0	16	0.7	16	0.7	62	0	62	0	75	75	75	75	75	0	62	0	62	0.7	16	0.7	16	0	0
1.6	0	0	24.7	24.7	25.3	24.1	67.3	66.1	66.1	67.3	24.1	25.3	24.7	24.7	0	0	0	16	0.8	16	0.8	62	0	62	0	75	75	75	75	75	0	62	0	62	0.8	16	0.8	16	0	0
1.8	0	0	24.7	24.7	25.3	24.1	67.3	66.1	66.1	67.3	24.1	25.3	24.7	24.7	0	0	0	16	0.9	16	0.9	62	0	62	0	75	75	75	75	75	0	62	0	62	0.9	16	0.9	16	0	0
2	0	0	24.7	24.7	25.4	24	67.4	66	66	67.4	24	25.4	24.7	24.7	0	0	0	16	1	16	1	62	0	62	0	75	75	75	75	75	0	62	0	62	1	16	1	16	0	0
2.2	0	0	24.7	24.7	25.5	23.9	67.5	65.9	65.9	67.5	23.9	25.5	24.7	24.7	0	0	0	16	1.1	16	1.1	62	0	62	0	75	75	75	75	75	0	62	0	62	1.1	16	1.1	16	0	0
2.4	0	0	24.7	24.7	25.5	23.9	67.5	65.9	65.9	67.5	23.9	25.5	24.7	24.7	0	0	0	16	1.2	16	1.2	62	0	62	0	75	75	75	75	75	0	62	0	62	1.2	16	1.2	16	0	0
2.6	0	0	24.7	24.7	25.6	23.8	67.6	65.8	65.8	67.6	23.8	25.6	24.7	24.7	0	0	0	16	1.3	16	1.3	62	0	62	0	75	75	75	75	75	0	62	0	62	1.3	16	1.3	16	0	0
2.8	0	0	24.7	24.7	25.7	23.7	67.7	65.7	65.7	67.7	23.7	25.7	24.7	24.7	0	0	0	16	1.4	16	1.4	62	0	62	0	75	75	75	75	75	0	62	0	62	1.4	16	1.4	16	0	0
3	0	0	24.7	24.7	25.8	23.6	67.8	65.6	65.6	67.8	23.6	25.8	24.7	24.7	0	0	0	16	1.5	16	1.5	62	0	62	0	75	75	75	75	75	0	62	0	62	1.5	16	1.5	16	0	0
3.2	0	0	24.7	24.7	25.8	23.6	67.8	65.6	65.6	67.8	23.6	25.8	24.7	24.7	0	0	0	16	1.6	16	1.6	62	0	62	0	75	75	75	75	75	0	62	0	62	1.6	16	1.6	16	0	0
3.4	0	0	24.7	24.7	25.9	23.5	67.9	65.5	65.5	67.9	23.5	25.9	24.7	24.7	0	0	0	16	1.7	16	1.7	62	0	62	0	75	75	75	75	75	0	62	0	62	1.7	16	1.7	16	0	0
3.6	0	0	24.7	24.7	26	23.4	68	65.4	65.4	68	23.4	26	24.7	24.7	0	0	0	16	1.8	16	1.8	62	0	62	0	75	75	75	75	75	0	62	0	62	1.8	16	1.8	16	0	0
3.8	0	0	24.7	24.7	26	23.4	68	65.4	65.4	68	23.4	26	24.7	24.7	0	0	0	16	1.9	16	1.9	62	0	62	0	75	75	75	75	75	0	62	0	62	1.9	16	1.9	16	0	0
4	0	0	24.7	24.7	26.1	23.3	68.1	65.3	65.3	68.1	23.3	26.1	24.7	24.7	0	0	0	16	2	16	2	62	0	62	0	75	75	75	75	75	0	62	0	62	2	16	2	16	0	0
4.2	0	0	24.7	24.7	26.2	23.2	68.2	65.2	65.2	68.2	23.2	26.2	24.7	24.7	0	0	0	16	2.1	16	2.1	62	0	62	0	75	75	75	75	75	0	62	0	62	2.1	16	2.1	16	0	0
4.4	0	0	24.7	24.7	26.3	23.1	68.3	65.1	65.1	68.3	23.1	26.3	24.7	24.7	0	0	0	16	2.2	16	2.2	62	0	62	0	75	75	75	75	75	0	62	0	62	2.2	16	2.2	16	0	0
4.6	0	0	24.7	24.7	26.3	23.1	68.3	65.1	65.1	68.3	23.1	26.3	24.7	24.7	0	0	0	16	2.3	16	2.3	62	0	62	0	75	75	75	75	75	0	62	0	62	2.3	16	2.3	16	0	0
4.8	0	0	24.7	24.7	26.4	23	68.4	65	65	68.4	23	26.4	24.7	24.7	0	0	0	16	2.4	16	2.4	62	0	62	0	75	75	75	75	75	0	62	0	62	2.4	16	2.4	16	0	0
5	0	0	24.7	24.7	26.5	22.9	68.5	64.9	64.9	68.5	22.9	26.5	24.7	24.7	0	0	0	16	2.5	16	2.5	62	0	62	0	75	75	75	75	75	0	62	0	62	2.5	16	2.5	16	0	0
5.2	0	0	24.7	24.7	26.5	22.9	68.5	64.9	64.9	68.5	22.9	26.5	24.7	24.7	0	0	0	16	2.6	16	2.6	62	0	62	0	75	75	75	75	75	0	62	0	62	2.6	16	2.6	16	0	0
5.4	0	0	24.7	24.7	26.6	22.8	68.6	64.8	64.8	68.6	22.8	26.6	24.7	24.7	0	0	0	16	2.7	16	2.7	62	0	62	0	75	75	75	75	75	0	62	0	62	2.7	16	2.7	16	0	0
5.6	0	0	24.7	24.7	26.7	22.7	68.7	64.7	64.7	68.7	22.7	26.7	24.7	24.7	0	0	0	16	2.8	16	2.8	62	0	62	0	75	75	75	75	75	0	62	0	62	2.8	16	2.8	16	0	0
5.8	0	0	24.7	24.7	26.8	22.6	68.8	64.6	64.6	68.8	22.6	26.8	24.7	24.7	0	0	0	16	2.9	16	2.9	62	0	62	0	75	75	75	75	75	0	62	0	62	2.9	16	2.9	16	0	0

Table 5-2
Global Alignment Target (Digitized Field) Coordinates
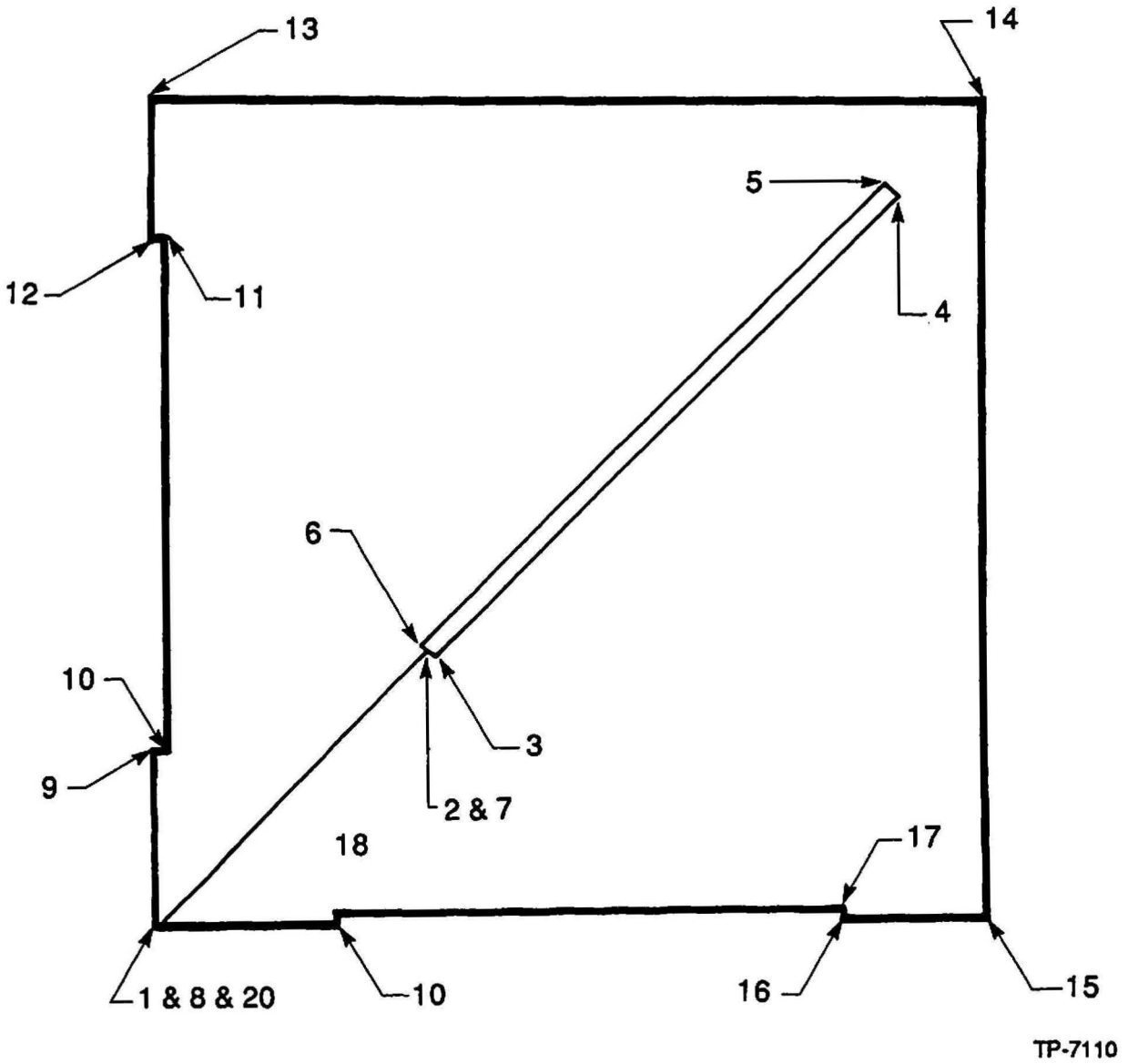
Figure 5-31
Global Alignment Target (Digitized Field)

Global and Local Alignment Cells

A cell includes all alignment targets and verniers as defined by the process engineer after characterization for the appropriate reference levels.

Global Alignment Cell

The placement of the gloabal alignment targets varies with changes in the X stepping centers. For this reason, a permanent cell cannot be created. The correct alignment targets can be selected and placed on the correct calma levels. When the X-axis steppinbg centers are specified the cell can be created for that device.

After the seperation has been calculated as discussed in ALIGNMENT TARGET SPACING the left and right global alignment targets are placed for each reference level if required.

NOTE: It is good practice to identify the right and left alignment target with text for verification or setup.

NOTE: If global alignment is only used to access the local alignment capture range, alignment targets may not need to be placed on every reference level thus saving valuable scible line space.

The alignment target worksheet as shown in Figure 5-16 was used to create the global alignment target cell as shown in Figure 5-32.
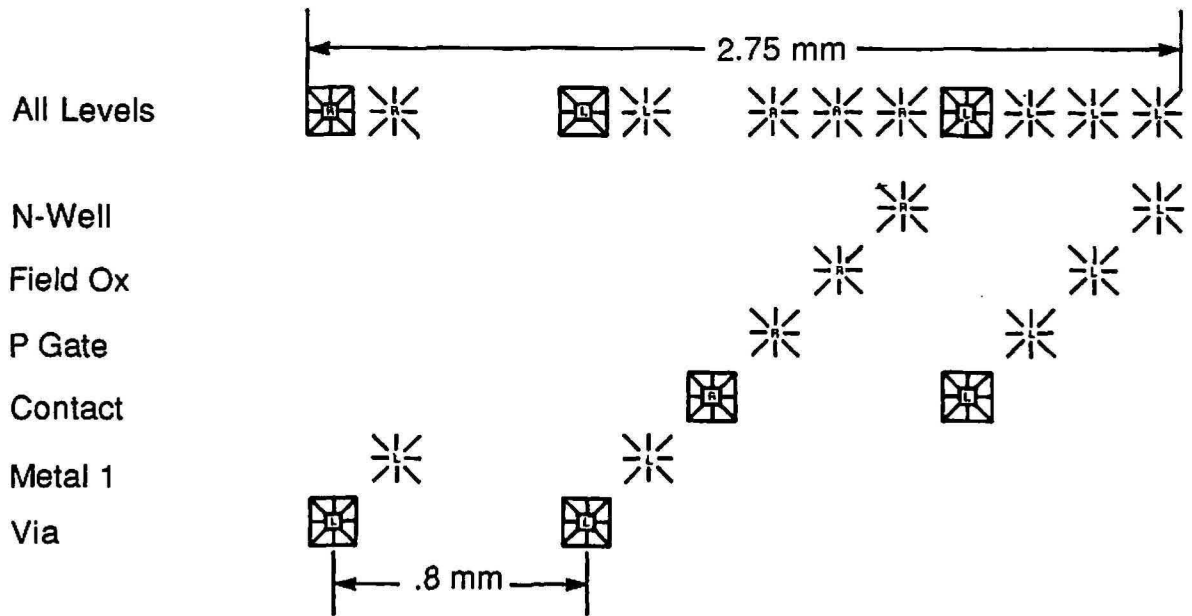
Figure 5-32
Global Alignment Target Cell Example

Local Alignment Cell

NOTE: The orientation and parody of the local alignment target is critical to the proper operation of the Micro DFAS alignment system. Alignment targets may be rotated 90° or 180° from their original position without causing problems to Micro DFAS.

The local alignment cell is created from the information on a completed alignment target worksheet. Each local alignment cell is designed to be placed on 150 micron center-to-center distances.

Use the following equation to determine the length of the local alignment cell:

LENGTH OF LOCAL ALIGNMENT CELL = number of masking levels - 1 X vernier cell size + (number of reference levels X cell size)

Verniers within a Local Alignment Cell

Determining whether verniers are a digitized geometry or field usually depends on the scribe line polarity. The polarity of the scribe line must be maintained throughout the alignment cell. If we consider positive resist for reticle and wafer processing, there are 4 conditions which must be me at the wfare plane:

device clear field, clear scribe line : a digitized geometry structure would be used.

device clear field dark or opaque scribe line: a digitized field structure would be used.

device dark field, clear scribe: a digitized geometry structure would be used.

device dark field, dark scribe: a digitized field structure would be used.

Creating a Cell from the Alignment Target Worksheet

The following information is an example to be used to describe the use of the alignment target worksheet as it applies to the creation of a local alignment cell.

Masking Level N-WELL at Calma Level 01

Assign the designated vernier half and local alignment target to this calma level. The N-WELL level is the first masking level transferred on to the wafer and is the reference level for the field oxide and field implant levels. A local alignment target is placed in position 1 as shown in Figure 5-33.

The first vernier half for the alignment of the field oxide and field implant levels are to be placed in positions 2 and 3 as shown in Figure 5-33.
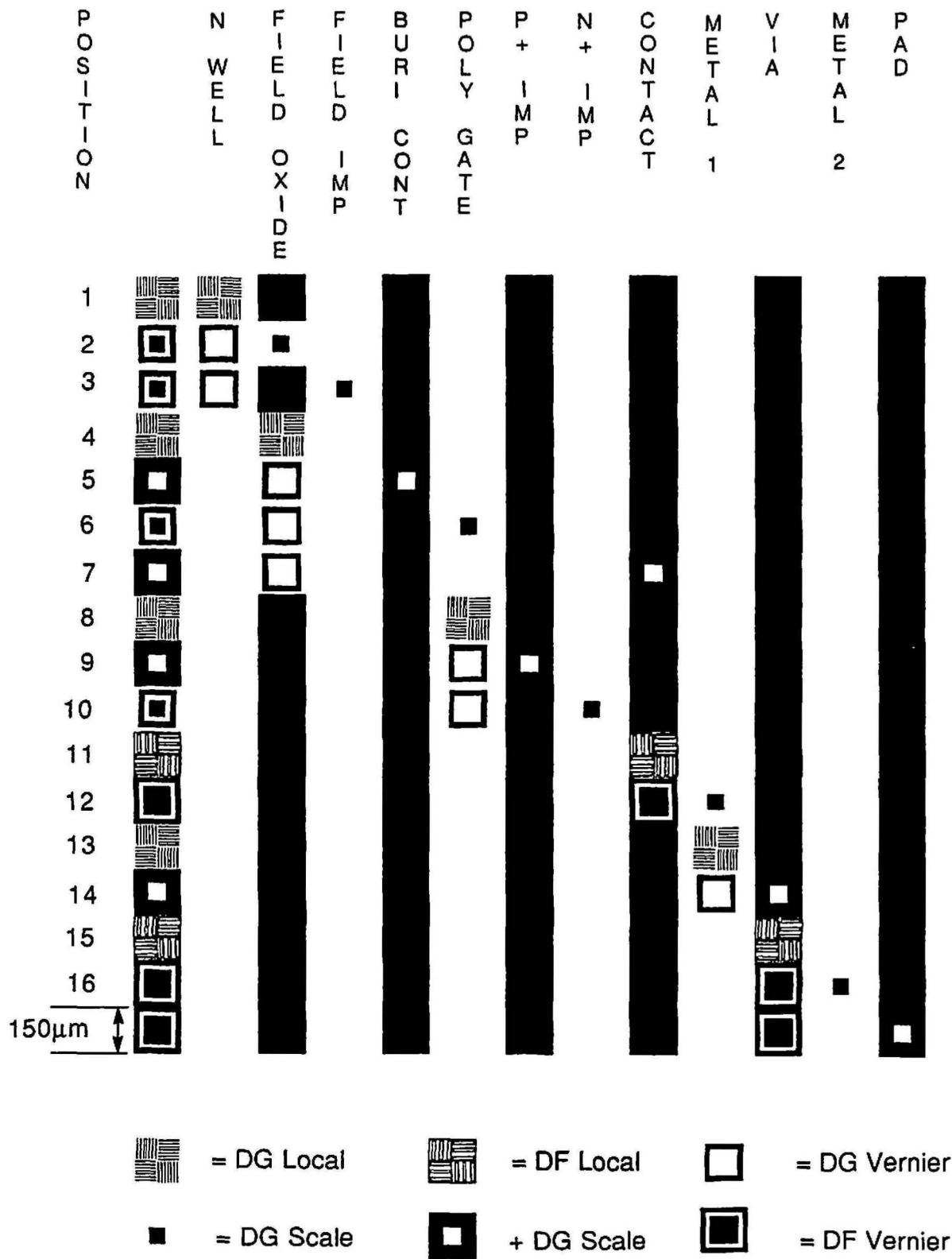
Figure 5-33
Vernier Examples

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Masking Level FIELDOX at Calma Level 02

Assign the local alignment targets and verniers to the **specified** level. The field oxide level is referenced to the N-WELL level. A vernier scale is placed in the same relative position as the first vernier below the N-WELL local alignment or position 2.

The FIELDOX mask is the refernce layer for the 3 other masking levels. A local alignment target is to be placed in position 4 and digitized geometry verniers in positions 5, 6 and 7.

Scribe Lines

After the cells have been selected and placed the scribe lines may be brought up to the edge of the cell. This should only be neccesary for clear field layers with dark scribe lines and dark field layers with clear scribe lines.

Section 6 - Alignment Target Characterization

Introduction

The process of alignment target characterization provides an alignment target that demonstrates the greatest process latitude which provides optimum overlay due to large process variations. In this section we will discuss how to use the GCA 4800-124 alignment target evaluation reticle. This reticle is used for characterization of both global and local targets.

GCA 4800-124 5X Alignment Mark Evaluation Reticle

The GCA 4800-124 5X Alignment Mark Evaluation reticle can be used to evaluate line width dimensions of global and local alignment targets in various process levels.

Global Alignment Targets

The 4800-124 reticle has global alignment targets that are clear field and dark field which vary in line-width size from 1.2 to 2.6 microns. The reticle provides the X and Y-axis coordinates of the target location which can be seen under a microscope.

Standard Local Alignment Targets

The standard local alignment target of the 4800-124 reticle consists of four quadrants, each having five 6μm lines on 12μm center-to-center spacing. These targets are in clear field and dark field. The reticle provides the X and Y-axis coordinates of the target location which can be seen under a microscope.

Segmented Local Alignment Targets

Segmented alignment targets on the 4800-124 reticle are used to provide better overlay accuracy in various process levels. The segmented targets are 0.8 to 2.0μm squares on 2.4 micron centers. These are clear field and dark field. The reticle provides the X and Y-axis coordinates of the target location which can be seen under a microscope. The reticle provides the X and Y-axis coordinates of the target location which can be seen under a microscope.

Local Alignment Reticle Window

DFAS reticle windows are placed at 8, 8.8 and 9.6mm (1X dimensions) in Y-axis and in the X-axis.

Verniers Available for Use

There are six sets of verniers that can be independently interlocked by changing the aperture position to avoid double exposure of the targets. To interlock the verniers a pass shift of X= -0.5 mm and Y= 0.5 mm.

Stepping Requirements for Global Alignment

NOTE: When creating an array for 76.2mm objective spacing make sure the array contains at least 7 columns to ensure placement of global alignment targets under each objective of the wafer alignment microscope.

NOTE: When creating an array for 101.6mm objective spacing make sure the array contains at least 9 columns to ensure placement of global alignment targets under each objective of the wafer alignment microscope.

The stepping centers are 12.7 millimeters in both the X and Y-axis. The stepping center needs to be maintained since it is evenly divisible into 76.2 and 101.6 millimeter objective spacing.

Restrictions of the 4800-124 Reticle

The layout of the 4800-124 reticle will not allow the interlocking of verniers and the exposure of a new set of alignment targets at the same time.

The 4800-124 reticle does not provide a clear area to expose over the global and local alignment targets. The clear area would be used to remove photo resist over the targets to allow the etching process to occur which removes the thin film from the alignment target.

The 4800-124 reticle allows characterization of only 1 set of reference level marks at one time.

Job Specifications for the 4800-124 Reticle

NOTE: The following job specification example can be specified for 100, 125, 150 and 200mm wafers. The numbers that appear in HOW MANY COLUMNS and HOW MANY ROWS are for the respective wafer sizes as shown in WAFER SIZE.

Refer to Tables 6-1 for the appropriate FZT offset.

: SPEC CLEAR OR SOLID

COMMENT: Pass 1 exposes the array. Passes 2 - 8 are used for alignment.

WAFER SIZE: 100, 125, 150 or 200mm
STEP SIZE IN X: 12.7

*C-OUNT, S-PAN, OR A-LL: C
HOW MANY COLUMNS: 7, 9, 11, 15
STEP SIZE IN Y: 12.7
*C-OUNT, S-PAN, OR A-LL: C
HOW MANY ROWS: 7, 9, 11, 15
TRANSLATE ORIGIN
X: 0
Y: 3.51

Alignment Parameters:

STANDARD KEYS? Y
RIGHT ALIGNMENT DIE CENTER
  R:
  C:

NOTE: If you already have characterized a global target for this level, then place the optimum key offset for the optimum target. If not, use the key offsets shown for the 1.6μm target and manually align the wafer.

RIGHT KEY OFFSET
  IN X: **3.7**
  IN Y: **0.0**

PASS: 1
PASS COMMENT: **Exposes the first level of the array.**
EXPOSURE TIME:

USE LOCAL ALIGNMENT: N
USE MICRO DFAS: N

RETICLE BAR CODE: **4800-124**

MASKING APERTURE SETTING:
  XL: 2
  XR: 2
  YF: 2
  YR: 2

RETICLE ALIGNMENT OFFSET:
  XL: 0
  XR: 0
  Y: 0

RETICLE ALIGNMENT MARK PHASE (P, *N, X): N

NOTE: Select a minimum of 12 fields per wafer on an area of the wafer that provides the greatest consistency of film thickness

A-RRAY, P-LUG, L-ABEL: **P**
DROPOUTS:
   R:
   C:
Each pass is testing a different local alignment target. Repeat the pass information for passes 2-10 and insert the FZT offsets found in Table 6-1 in each pass for the CLEAR or SOLID job file.

Table 6-1
FZT Offsets

PASS 2		PASS 3		PASS 4		PASS 5		PASS 6	
+2µm Local Target		+1µm Local Target		Nominal		-1µm Local Target		-2µm Local Target	
Solid	Clear	Solid	Clear	Solid	Clear	Solid	Clear	Solid	Clear
X=1.0 Y=-5.3	X=3.5 Y=-5.3	X=1.0 Y=-5.45	X=3.5 Y=-5.45	X=1.0 Y=-5.6	X=3.5 Y=-5.6	X=1.0 Y=-5.75	X=3.5 Y=-5.75	X=1.0 Y=-5.9	X=3.5 Y=-5.9

PASS 7		PASS 8		PASS 9		PASS 10	
0.8µm Local Target		1.2µm Local Target		1.6µm Local Target		2.0µm Local Target	
Solid	Clear	Solid	Clear	Solid	Clear	Solid	Clear
X=1.0 Y=-6.05	X=3.5 Y=-6.05	X=1.0 Y=-6.2	X=3.5 Y=-6.2	X=1.0 Y=-6.35	X=3.5 Y=-6.35	X=3.7 Y=-1.2	X=3.3 Y=-1.2

NOTE: Solid - opaque on a clear background. Clear - clear on a opaque background.

PASS: (Passes 2 through 10)
PASS COMMENT: +2.0µm
EXPOSURE TIME:

USE LOCAL ALIGNMENT: **Y**
USE MICRO DFAS: **Y (depending upon system configuration)**

PASS SHIFT:
   X: **-0.5 (if interlocking of verniers is desired)**
   Y: **0.5**

RETICLE BAR CODE: **4800-124**

MASKING APERTURE SETTING:
   XL: **0**
   XR: **0**
   YF: **0**
   YR: **0**

```
RETICLE ALIGNMENT OFFSET:
    XL:    0
    XR:    0
    Y:     0
RETICLE ALIGNMENT MARK PHASE (P, *N, X):  N

A-RRAY, P-LUG, L-ABEL: A
DROP OUTS:
    R:
    C:
```

Global Target Characterization and Selection

The following procedure may be used to select the optimum global alignment targets for use with a process level. The AWA/D works best when the global target is a solid line on a light background. The typical line width of a global mask is between 1.2 to 1.6μm as a finished etched dimension which will give a good contrast. The line should remain dark through a focus change of ±3 microns on the IAS focus potentiometer or setting on the AUTOSTEP 200.

1. Edit the job specification file used for the process level and enter a process file name in the appropriate pass.
2. Using the AWASPEC command, create a process file for the process level being analyzed and name the process file the same as entered in the job specification file in step 1.
3. At the system prompt (:), enter the command **ALIGN jobname\pass**, where jobname\pass is the corresponding job and pass for the process level being analyzed.
2. Load and manually align a wafer of the process level being set up.
3. Type **B**, then press RETURN. The system then displays the IASDBG main menu.
4. Enter **TEST**. The system then displays the IASDBG Test menu.
5. Enter **INSPECT**. The system then displays the inspect screen.
6. From the inspect screen, perform one of the following:

    *   To analyze all positive target masks from 1 to 22 (for wafers with a light background and a dark alignment cross), enter **AM 12**.
    *   To analyze all negative target masks from 1 to 12 (for wafers with a dark background and a light alignment cross), enter **AM -12**.

Entering this command displays the 12 global masks convolved with an output scan across the target arm. A line across the upper left target arm shows where the signal is being scanned. Only 1 line is scanned in this command. An intensity profile of this line is shown above the cross. On the left-side of the display are shown 12 plots of the same signal, but processed with each of masks 1 though 12. Refer to Figure 6-1 for a display of the AM 12 command.
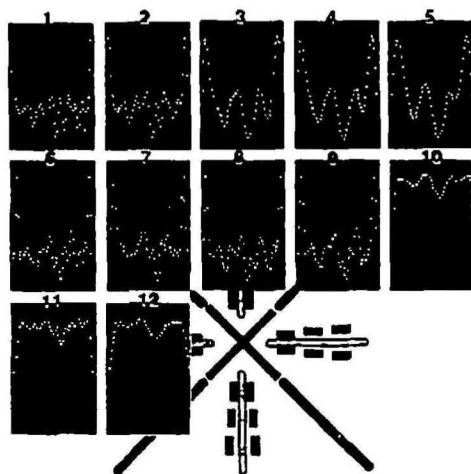
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Figure 6-1
Display of AM 12 Command

7. Select the best mask which shows the center of the alignment mark as a sharp, well-defined, downward spike as shown in mask number 4 in Figure 6-1. The masks are numbered from left to right starting with mask 1 in the upper-left corner. Record the mask number showing the best results on the Global Target Worksheet found at the end of this procedure.

8. Return to the IASDBG main menu by simultaneously pressing the Ctrl and Z keys twice.

Determining the Global Threshold

NOTE: Make sure that the OPER/TEST switch on the IAS chassis is in the OPER position for 8500 and ALS systems. To stop the test, switch the OPER/TEST switch to TEST, then at the prompt PROCEED OR QUIT, type Q.

Determine the global threshold as follows:

1. From the IASDBG main menu, enter CALIBRATE. The system then displays the IASDBG Calibrate menu.

2. Enter GLOBAL. This initiates the global threshold routine.

3. At the prompt ENTER TRIAL GLOBAL-MASK NUMBER, enter the global mask number (chosen in the previous procedure Selecting the Optimum Global Alignment Target, step 7), then press RETURN.

The system then runs a repeatability test at several threshold values, starting at 20 and ending at 300, in increments of 20 (this procedure takes about 3 minutes). During the repeatability test, the system displays various test data on the monitor. When the test is complete, the system displays a table that shows the results of the repeatability test as shown in Table 6-2.

Table 6-2
Example of Global Mask Threshold Test Summary

```
Trial/Current global-mask number and threshold: 5/4 60

Thresh   20   TIR (lx,ly,rx&ry) = 1.93, 1.60;   0.00,  0.00:  1.60  #
Thresh   40   TIR (lx,ly,rx&ry) = 0.00, 0.00;   0.00,  0.00:  0.00  #
Thresh   60   TIR (lx,ly,rx&ry) = 0.00, 0.00;   0.00,  0.00:  0.00  #
Thresh   80   TIR (lx,ly,rx&ry) = 0.00, 0.00;   0.00,  0.00:  0.00  #
Thresh  100   TIR (lx,ly,rx&ry) = 0.00, 0.00;   0.00,  0.00:  0.00  #
Thresh  120   TIR (lx,ly,rx&ry) = 0.00, 0.00;   0.00,  0.00:  0.00  #
Thresh  140   TIR (lx,ly,rx&ry) = 0.00, 0.00;   0.00,  0.00:  0.00  #
Thresh  160   TIR (lx,ly,rx&ry) = 0.64, 0.80;   0.00,  0.00:  0.80  #
Thresh  180   TIR (lx,ly,rx&ry) = 1.93, 1.60;   0.00,  0.00:  1.60  #
Thresh  200   TIR (lx,ly,rx&ry) = 1.93, 1.60;   0.65,  0.80:  3.05  #
Thresh  220   TIR (lx,ly,rx&ry) = 0.00, 0.00;   0.65,  0.80:  1.45  #
Thresh  240   TIR (lx,ly,rx&ry) = 0.00, 0.00;   0.00,  0.80:  0.80  #
Thresh  260   TIR (lx,ly,rx&ry) = 0.64, 0.80;   0.00,  0.00:  0.80  #
Thresh  280   TIR (lx,ly,rx&ry) = 0.64, 0.00;   0.00,  0.00:  0.00  #
Thresh  300   TIR (lx,ly,rx&ry) = 0.64, 0.00;   0.00,  0.00:  0.00  #
```

The top line of the summary screen identifies the global mask that the test was run with (in this example, the mask number was 5), and the global mask and threshold that are currently in memory (4 and 60). The threshold values are then printed out with their corresponding X and Y scatter numbers (TIR), and the sum of the lx, rx, and ry scatter. The smaller the sum of the lx, rx, and ry scatter, the more repeatable the global scan is for that threshold value.

4.   Select the best global threshold and record the number on the Global Target Worksheet found at the end of this procedure.

To select the best global threshold, find the columns on the table for which all 4 numbers (left X and Y, right X and Y) are zero: these present the threshold with the most repeatability. When there are several, select the the threshold value as the average of the largest range (in the example, 40 through 140 show good repeatability, so select their average, which is 90).

5. Return to the IASDBG Calibrate menu by simultaneously pressing the **Ctrl** and **Z** keys.
6. Return to the IASDBG main menu by entering **EXIT**.

Selecting a Reference Mask

This is an automatic routine that convolves masks 1 through 12 with the output video signal of several scans taken across the reference fiducials. For each mask, 10 convolutions are performed with the system calculating the center of the reference fiducial with the absolute reference position and determines the deviation for each trial. At the end of the routine, the masks are ranked from those having the smallest scatter TIR (most repeatable) to those having the largest scatter TIR (least repeatable). Select a reference mask as follows:

1. From the IASDBG main menu, enter the command **CALIBRATE**.
2. From the IASDBG Calibrate menu, enter the command **REFERENCE**.

The system then runs a repeatability test of the 12 reference masks (this procedure takes about 2 minutes). During the repeatability test, the system displays various test data on the monitor. When the test is complete, the system displays a table that shows the results for each reference mask as shown in Table 6-3.

Table 6-3
Example of Reference Mask Test Summary

```
Current reference mask number: 3
Recapitulation:

Mask    4    TIR  (lx,ly,rx&ry)  =  0.06,  0.04;    0.02,   0.04:   0.10  #

Mask    3    TIR  (lx,ly,rx&ry)  =  0.14,  0.02;    0.10,   0.06:   0.18  #

Mask    5    TIR  (lx,ly,rx&ry)  =  0.15,  0.04;    0.11,   0.07:   0.22  #

Mask    2    TIR  (lx,ly,rx&ry)  =  0.10,  0.06;    0.10,   0.06:   0.22  #

Mask    1    TIR  (lx,ly,rx&ry)  =  0.08,  0.09;    0.11,   0.05:   0.26  #

Mask    8    TIR  (lx,ly,rx&ry)  =  0.15,  0.07;    0.13,   0.11:   0.31  #

Mask    9    TIR  (lx,ly,rx&ry)  =  0.08,  0.06;    0.17,   0.09:   0.32  #

Mask    6    TIR  (lx,ly,rx&ry)  =  0.15,  0.10;    0.11,   0.13:   0.34  #

Mask   1 0   TIR  (lx,ly,rx&ry)  =  0.06,  0.05;    0.16,   0.14:   0.35  #

Mask   1 2   TIR  (lx,ly,rx&ry)  =  0.23,  0.16;    0.13,   0.14:   0.44  #

Mask    7    TIR  (lx,ly,rx&ry)  =  0.18,  0.12;    0.30,   0.17:   0.59  #
```

The system summary includes for each mask, the TIR numbers for left X, left Y, right X, right Y, and the sum of those TIR numbers. The summary also displays the masks in the order from best to worst. Any mask that has a TIR sum of over 100.00 is not shown on the summary display. A TIR sum of over 100.00 indicates a scan error occurred during this test, and the mask is not suitable for use (for example, mask 11 reported 100's for the scatter TIR).

3. Select and record the mask number showing the best results on the Global Target Worksheet found at the end of this procedure. To verify the best reference mask, make sure that all 4 numbers (left X and Y, right X and Y) are the lowest and most uniform, and the last number has the lowest TIR (in the example, mask 4 is the best mask).

4. Return to the IASDBG Calibrate menu by simultaneously pressing the Ctrl and Z keys.

5. Return to the IASDBG main menu by entering EXIT.

Selecting a Fine Algorithm Table Entry

The IAS contains many different algorithms which have proved useful for AWA analysis. Selecting the appropriate target algorithm table entry is aided by the use of the IASDBG function called FINE. The FINE routine automatically analyzes a wafer target with 11 of the most commonly used algorithms and displays the results for inspection.

Select a fine algorithm table entry as follows:

1. Enter the job using the align command as **ALIGN jobname\pass**.
2. Load and manually align a wafer of the process level being set up.
3. Bring the test wafer out to the AWA align position and type **B**.
4. From the IASDBG main menu, enter **CALIBRATE**.
5. From the IASDBG Calibrate menu, enter **FINE**. This command runs a repeatability test on 11 preselected fine-scan algorithms (41, 42, 0, 1, 2, 4, 5, 7, 13, 15, and 18). This procedure takes about 3 minutes. When the test is complete, the system displays a table that shows the results of the test as shown in Figure 6-4 which is a partial summary table.

Table 6-4
Example of Fine Algorithm Table Entry Test Summary

```
     SET  42:#

42:  (lx&y)  (rx&y)  dev:sca =  (0.12,  0.04)  (0.14,  0.05)  1.86  : 0.23 #

     SET  4:#

 4:  (lx&y)  (rx&y)  dev:sca =  (0.09,  0.11)  (0.11,  0.07)  2.03  : 0.29 #

     SET  41:#

41:  (lx&y)  (rx&y)  dev:sca =  (0.17,  0.07)  (0.14,  0.09)  2.06  : 0.30 #

     SET  2:#

 2:  (lx&y)  (rx&y)  dev:sca =  (0.16,  0.06)  (0.15,  0.11)  1.81  : 0.32 #
```

The summary includes for each table set that was run, the average results of the 25 frames analyzed with the table set. This includes the average TIR numbers for left X, left Y, right X, and right Y, the sum of the average deviations of ly, rx, and ry, and the sum of the scatter of ly, rx, and ry in units of microns.

The summary also displays the table sets in the order typically from best to worst based on the sum of the ly, rx, and ry scatter values.

6. Record all algorithms whose scatter value is less than 0.3μm as shown in Table 6-5 and on the Global Target Worksheet found at the end of this procedure. These are the algorithms that show the most repeatability.

Table 6-5
Fine Algorithm Table Entry Test Result Matrix

		# 1	# 2	# 3
F	+3μm	alg #	alg #	alg #
O				
C	B F	alg #	alg #	alg #
U				
S	-3μm	alg #	alg #	alg #

7. Return to the system command by simultaneously pressing the **Ctrl** and **Z** keys twice. The system displays the message **ALIGNING...COMPLETE**.
8. Change the AWA focus by approximately 3μm either up or down.
9. Repeat steps 3 through 7.
10. Change the AWA focus by approximately 3μm in the opposite direction from the original position.
11. Repeat steps 3 through 7.
12. Repeat steps 1 through 11 for 2 more wafers that are chosen randomly from the process lot.

From the accumulated information, tabulate the different algorithms that appear promising and the frequency with which they occurred. Typical data may appear as follows as shown in Figure 6-2. Record the mask number showing the best results on the Global Target Worksheet at the end of this procedure.

Poly-FOX

1.6µm CL AWA Key

"FINE" results:

	Wafer #1			Wafer #2			Wafer #3		
	-3	0	+3	-3	0	+3	-3	0	+3
The six	41	4	15	13	42	42	1	13	41
best	15	41	0	42	7	4	7	0	15
algorithm	7	0	41	5	4	18	13	15	2
table	18	15	17	7	1	7	18	1	0
entries	1	13	4	0	0	0	2	7	7
	0	42	5	4	13	5	42	18	1

Algorithm	41	15	7	18	1	0	13	42	5	4	2
Frequency	4	4	7	4	5	8	5	5	2	4	2

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Figure 6-2
Example of FINE Test Results

The algorithm that occurs most frequently through the range of different test conditions is probably the best one. Experience dictates that several of the table sets should be put through one or more performance tests before the final choice is made. This is also true if several table sets appeared with equal frequency.

Testing AWA/D Performance

There are several test methods used for testing the performance of the IAS setup. The following methods are discussed in this section:
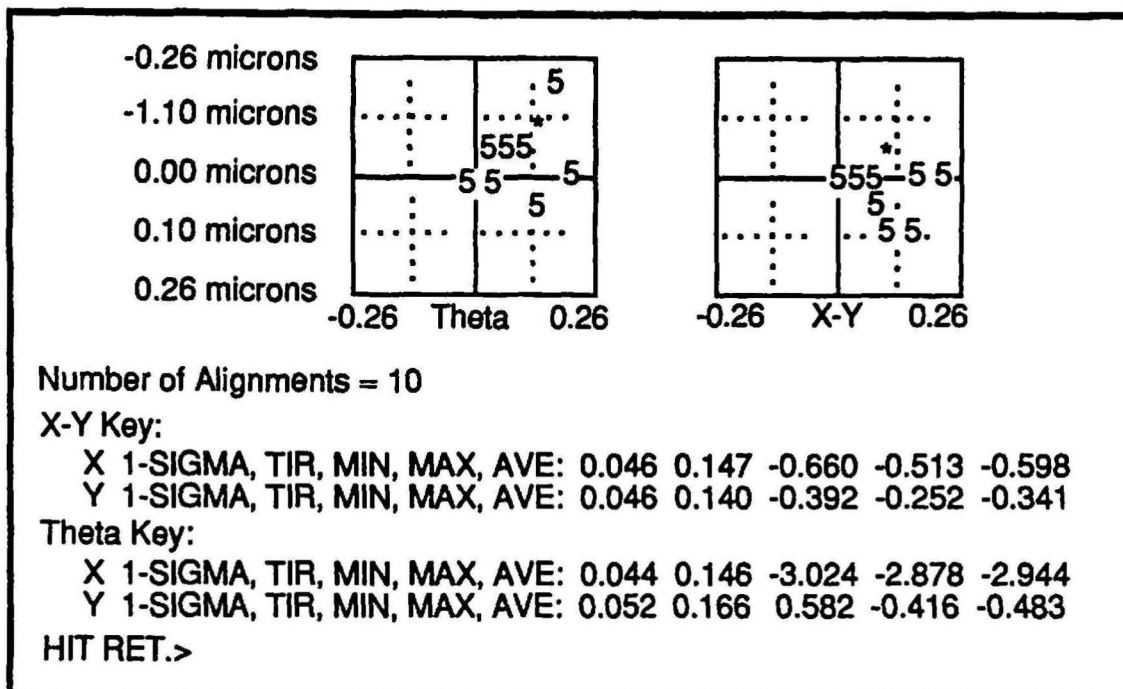
- AWA and ALGO Scatter Plot Tests
- Around-the-World Test
- Micro DFAS Metrology Test

AWA and ALGO Scatter Plot Tests

The AWA and ALGO test procedures verify the algorithm table entries chosen by the FINE, LEARN, or XYONLY commands. The commands perform a user-defined number of alignments (the stages never move) on the alignment marks, and then calculate how repeatable the algorithm determines the center of the alignment marks. Test the algorithm table entries using the following procedure:

1. Enter the command **ALIGN jobname\pass**, where jobname\pass is the corresponding jobname and pass for which the process parameters are being defined.
2. Load, then manually align the wafer being tested.
3. Type **B**. The system then displays the IASDBG main menu.
4. Enter **TEST**. The system then displays the IASDBG Test menu.
5. From the IASDBG Test menu, perform one of the following:

    - To test the algorithm currently specified in the process file, perform the following:

        a. Enter the command **AWA**.
        b. At the prompt **ENTER CYCLE COUNT**, enter a number greater than 10, followed by a comma (for example, enter **25,** for 25 repetitions).
        c. To exit the task, press RETURN.

    - To test any algorithm, perform the following:

        a. Enter the command **ALGO n**, where n is the table entry set number to be analyzed.
        b. At the prompt **ENTER ALIGNMENT COUNT**, enter a number greater than 10 that represents the number of repetitions to be performed, followed by a comma (for example, enter **25,** for 25 repetitions).
        c. To exit the task press RETURN.

    After the last alignment is performed, the system then displays a scatter plot diagram and a numerical summary of the alignment statistics similar to the following as shown in Figure 6-3.

```
-0.26 microns
-1.10 microns
 0.00 microns
 0.10 microns
 0.26 microns
        -0.26   Theta   0.26        -0.26    X-Y    0.26
```

Number of Alignments = 10

X-Y Key:
   X 1-SIGMA, TIR, MIN, MAX, AVE: 0.046 0.147 -0.660 -0.513 -0.598
   Y 1-SIGMA, TIR, MIN, MAX, AVE: 0.046 0.140 -0.392 -0.252 -0.341
Theta Key:
   X 1-SIGMA, TIR, MIN, MAX, AVE: 0.044 0.146 -3.024 -2.878 -2.944
   Y 1-SIGMA, TIR, MIN, MAX, AVE: 0.052 0.166 0.582 -0.416 -0.483
HIT RET.>

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Figure 6-3
Example of Scatter Plot Diagram and Numerical Summary

The Scatter Plot Diagram gives the user a graphic representation of the repeatability of the fine algorithm alignments. The first alignment measures the offset from the calculated center of the reference fiducial and is plotted in the center of the above graph at position 0,0. Subsequent alignments also measure the offset from the reference fiducial center but plot the difference of this offset from the first alignment offset.

The diagram also displays the distribution of the alignment scatter by depicting the relative number of hits at any location with either an asterisk, or a number. The asterisk represents the maximum number of hits on the screen, and the numbers represent a percentage of the maximum. In the example, on the theta (left) side, a total number of 10 hits has been recorded. These are made up of the asterisk = 2 hits, and the eight 5's = 50% of 2, or 1 hit each for a total of 10 hits.

The Numerical Summary breaks up the information into the X and Y components for the X/Y alignment side and the theta alignment side. The numerical data displayed are (from left-to-right): the 1-sigma of the scatter, the TIR of the scatter, and the minimum, maximum, and average numbers for the offsets from the absolute reference positions. Typical test results are as follows as shown in Figure 6-4.

AWA SCATTER PLOT: Algorithms #0, 7, 13 at Best Focus; 25 trials

Wafer #1		X/Y Key		Theta Key	
		1 SD	TIR	1 SD	TIR
0)	x:	0.041μm	0.161μm	0.032μm	0.114μm
	y:	0.030	0.125	0.022	0.093
7)	x:	0.047	0.181	0.045	0.176
	y:	0.032	0.133	0.039	0.124
13)	x:	0.036	0.160	0.034	0.136
	y:	0.025	0.095	0.029	0.129

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Figure 6-4
Example of AWA Scatter Plot Test Results

This test can be repeated on several different wafers form the lot, although it is probably not necessary unless significant wafer-to-wafer variation was noted during the FINE test. Choices can be made based simply on the best average 1-sigma value *and* the best average TIR. In this case, mask 0 and 13 both have average sigma values of 0.03μm but the average TIR for mask 0 is slightly better: 0.12μm versus 0.13μm. This is a very slight distinction and both algorithms may work equally well. An additional method of sorting, is to look for the table set which shows the least variations in sigma and TIR.

6. Record the best algorithm on the Global Target Worksheet found at the end of this procedure.
7. Perform one of the following:

   - To return to the IASDBG main menu, simultaneously press the Ctrl and Z keys.
   - To abort the ALIGN program, enter the command EXIT, simultaneously press the Ctrl and C keys, then type A.

Around-the-World Test

The around-the-world test is similar to the AWA scatter test, except that the wafer is being moved to various points on the AWA screen before alignment is performed. This adds the variable of stage motion to the alignment equation which provides a more realistic test. The test requires that the wafer be moved to 8 different positions around the fiducial with alignment being performed after each move. When alignment is complete, the stage X/Y positions are noted. A TIR done on the 8 values is an indicator of alignment precision. Typically, in the best case (i.e. developed resist images) the TIR value is ≤ 0.15μm. The actual TIR depends on the table entry set and

target characteristics. One drawback to this test is that it does not measure theta alignment performance and repeatability.

1. Enter the command **AWAEDIT filename**, where **filename** is the process parameter file created to hold these parameters being defined.
2. Edit the file to include the masks, the global threshold, and the fine scan algorithm table entry chosen.
3. Execute the job corresponding to the process being tested by entering **EXEC jobname\pass**.
4. To automatically align the wafer, type **B** (typing B again will stop the alignment). If a global failure occurs, either the global mask or the global threshold needs changing in the process parameter file.
5. Note the X and Y alignment position (for example, X: 1227, Y: 594).
6. Move the alignment crosses away from the center of the fiducial (Figure 9-11).
7. To align the wafer again, type **B**.
8. Record the X and Y values as indicated in Figure 6-5. Note the scatter of these results. These values are displayed in microns/100 (for example, 4475 means 44.75 microns).
9. Repeat steps 6 through 8 eight times. Typical results of an around-the-world test are shown in Figure 6-6.
10. To abort the job, simultaneously press the **Ctrl** and **C** keys.
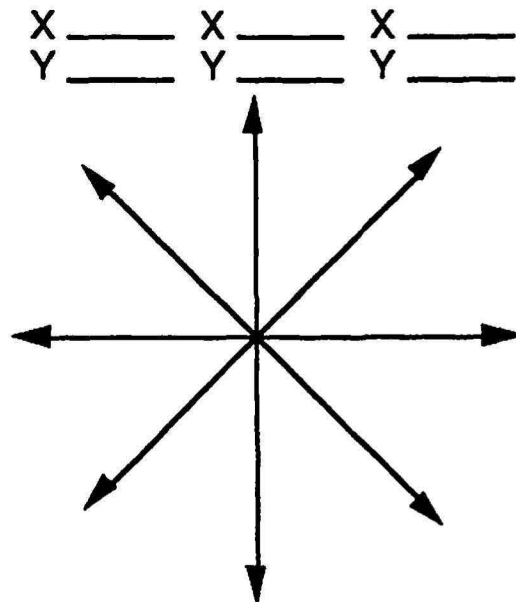
TP-5961

Figure 6-5
Alignment Cross Directions of Movement

```
┌─────────────────────────────────────────┐
│                                           │
│       "AROUND-THE-WORLD"; #0              │
│                                           │
│                 X          Y              │
│            1   1227       594             │
│            2   1227       596             │
│            3   1227       587             │
│            4   1219       585             │
│            5   1224       596             │
│            6   1227       598             │
│            7   1227       592             │
│            8   1224       586             │
│                                           │
│           TIR  0.08       0.13  μm        │
│                                           │
└─────────────────────────────────────────┘
                                      TP-6871
```

Figure 6-6
Example of Around-the-World Test Results

When the around-the-world test is complete, enter the new values in the process parameter file by performing the procedure in Editing the Process Parameter File in this section of the manual.

Micro DFAS Metrology Test

The Micro DFAS alignment system can be used as the metrology tool to test set selection and AWA performance. Assuming acceptable local alignment performance on the process level of interest, a job can be run that maps every die on the wafer with no exposure. After the wafer is mapped, grid parameters of X/Y baseline and AWA microscope rotation as well as wafer/stage scale and stage orthogonality are output on the Micro DFAS monitor.

With the chosen AWA process parameter file in place, the metrology job is executed. The wafer being analyzed is brought up under the AWA alignment microscope and aligned. When the EXP button is pressed, the wafer is mapped by Micro DFAS. Each AWA/D alignment and mapping generates a measurement of X/Y baseline and wafer rotation. The variation seen from alignment to alignment is exactly analogous to the AWA repeatability performance on the process level.

Editing the Process Parameter File

Once all the parameters have been determined for the process parameter file, edit the process parameter file by performing the following:

1. From the system prompt (:), enter the command **AWAEDIT** filename where filename is the process level just analyzed.
2. Edit the file by entering the new parameter values as determined in the preceding paragraphs.
3. Choose the best algorithm as the one with the lowest change in X and Y alignment numbers in the table of step 6. If the accuracy is similar between two or more masks, the best mask would be the one that best aligns the cross in the fiducial. If the cross does not align perfectly, alignment offsets can be added later using the AWAOFFSET program (described later in this section of the manual under the heading Determining and Saving the Global Alignment Offset).
4. At the system prompt (:), enter the command **AWAEDIT** filename.
5. At the prompt **ALGORITHM CONTROL**, enter the table entry number of the algorithm chosen.

Determining and Saving the Global Alignment Offset

The AWAOFFSET routine measures the difference between the AWA/D alignment and an operator's manual alignment. The command AWASAVE is then used to upload this difference to the appropriate process parameter file. Determine and save the global alignment offset by performing the following:

1. From the system prompt (:), enter the command **AWAOFFSET** jobname\pass, where jobname\pass is the jobname and pass corresponding to the process level being defined.
2. Load, then manually align a wafer.
3. Type **B**. This initiates the AWAOFFSET routine.
4. Align the wafer in X, Y, and theta, then type **B**.

The system measures the difference between the AWA/D alignment and the operator's alignment, and then moves the targets out of alignment.

5. Align the right (X/Y) side, then type **B**.
6. Repeat step 5 three times.
7. Manually align the left (theta) side key in both X and Y, then type **B**.
8. Repeat step 7 three times.
9. At the message **AWAOFFSET ANALYSIS COMPLETE**, abort the job by simultaneously pressing the **Ctrl** and **C** keys, then typing **A**.
10. From the system prompt (:), enter the command **AWASAVE** filename where filename is the name of the corresponding process parameter file.

AWA/D Filename: _____ Evaluation Level: _____

Alignment Target Type: _____ Size: _____

Global Mask: _____ Global Threshold: _____

Reference Mask: _____

Fine Mask Focus Test

Test	Wafer #___			Wafer #___			Wafer #___			Wafer #___			Wafer #___		
FOCUS	-3	0	+3	-3	0	+3	-3	0	+3	-3	0	+3	-3	0	+3
1															
2															
3															
4															
5															
6															

Algorithm	41	15	7	18	1	0	13	42	5	4	2
Frequency											

Wafer Results Summary

Wafer Number 1			Wafer Number 2			Wafer Number 3		
AVG0	AVG TIR	AVG SIG	AVG0	AVG TIR	AVG SIG	AVG0	AVG TIR	AVG SIG

Fine Algorithm Results

Focus	#1	#2	#3
+3µm	alg#	alg#	alg#
Best Focus	alg#	alg#	alg#
-3µm	alg#	alg#	alg#

Wafer Number 1			Wafer Number 2			Wafer Number 3		
AVG0	AVG TIR	AVG SIG	AVG0	AVG TIR	AVG SIG	AVG0	AVG TIR	AVG SIG

Figure 6-7
Global Target Data Worksheet

Local Alignment Target Characterization (Version 6.6 Metrology Software)

This procedure should be used if the system is equipped with version 6.6 Metrology software.

1. Select menu option 5 - UTILITIES from the metrology system menu.
2. Select menu option 2 - EDIT ALIGNMENT DEFAULTS from the metrology utility menu.
3. Select menu option 8 - AUTO PRINT from the edit alignment defaults menu. This step allows the metrology computer to automatically print the DFAS wafer summary screen after each wafer is MAPPED during this procedure.
4. Select menu option 2 - AUTOPRINT ON from the autoprint menu.
5. Select menu option 9 - PREVIOUS MENU to return to the metrology utility menu.
6. Select menu option 12 - PREVIOUS MENU to return to the metrology system menu.
7. Select menu option 1 - PREPARE FOR ALIGNMENT to begin job execution.
8. Make sure the printer is turned on and SELECT indicator is illuminated. This means the printer is ready to accept data from the metrology computer.
9. Load 3 wafers to be characterized on the AWH send cassette.
10. Execute passes 2-10 of the job named CLEAR as shown in the following example:

   : EX   CLEAR\2,3,4,5,6,7,8,9,10

   Passes 2-10 of the job CLEAR will be executed and the alignment data will be printed on the printer. Remove the information from the printer and retain for further analysis.

11. Load 3 wafers to be characterized on the AWH send cassette.
12. Execute passes 2-10 of the job named SOLID as shown in the following example:

   : EX   SOLID\2,3,4,5,6,7,8,9,10

   Passes 2-10 of the job SOLID will be executed and the alignment data will be printed on the printer. Remove the information from the printer. Retain the data for further analysis.
13. Turn AUTOPRINT off.

Local Alignment Target Characterization (Version 6.5 Metrology Software)

This procedure should be used if the system is equipped with version 6.5 Metrology software.

1. Select menu option 5 - DFAS UTILITIES from the metrology system menu.
2. Select menu option 2 - EDIT DFAS DEFAULTS from the metrology utility menu.

NOTE: The AUTOPRINT mode toggles between ON and OFF when option 8 is selected.

3. Select menu option 8 - AUTO PRINT from the edit alignment defaults menu to turn AUTOPRINT ON. This step allows the metrology computer to automatically print the DFAS wafer summary screen after each wafer is MAPPED during this procedure.
4. Select menu option 9 - PREVIOUS MENU to return to the DFAS utility menu.
5. Select menu option 12 - PREVIOUS MENU to return to the system program menu.
6. Select menu option 1 - DFAS ALIGNMENT to begin job execution.
7. Make sure the printer is turned on and SELECT indicator is illuminated. This means the printer is ready to accept data from the metrology computer.
8. Load 3 wafers to be characterized on the AWH send cassette.
9. Execute passes 2-10 of the job named CLEAR as shown in the following example:

    : EX   CLEAR\2,3,4,5,6,7,8,9,10

    Passes 2-10 of the job CLEAR will be executed and the alignment data will be printed on the printer. Remove the information from the printer and retain the data for further analysis.

10. Load 3 wafers to be characterized on the AWH send cassette.
11. Execute passes 2-10 of the job named SOLID as shown in the following example:

    : EX   SOLID\2,3,4,5,6,7,8,9,10

    Passes 2-10 of the job SOLID will be executed and the alignment data will be printed on the printer. Remove the information from the printer. Retain the data for further analysis.
12. Turn AUTOPRINT off.

Local Target Summary Worksheet Instructions

1. Make enough copies of the Alignment Target Worksheet found in Appendix for each masking level.

2. Take the X and Y-axis residual and signal-to-noise level data from the printout of each masking level and plot the data on the worksheet. Use the legend on the worksheet to record the data points on the worksheet.

    NOTE: When one reference level has several levels that align to it select the target that provides the best results for all alignments. If no single target can be found, then two alignment targets may be needed to achieve optimum alignment.

3. Select the target that has the lowest residuals (<200) and the highest signal-to-noise ratio. Record the optimum target data on the Local Target Summary Worksheet.

Reference Level: _____ Masking Level: _____

Clear Targets

MARK SIZE

Dark Targets

MARK SIZE
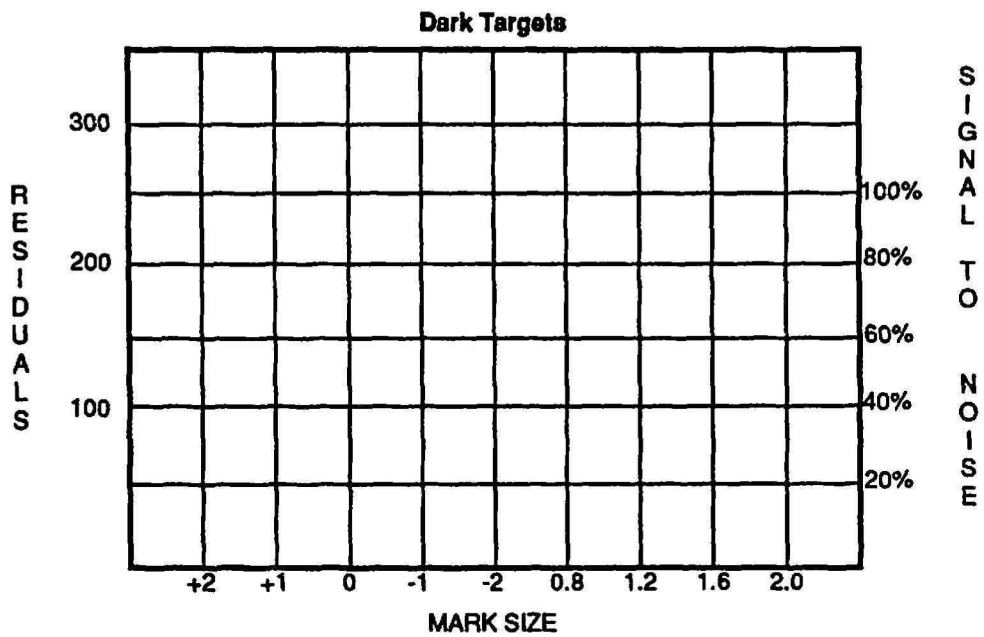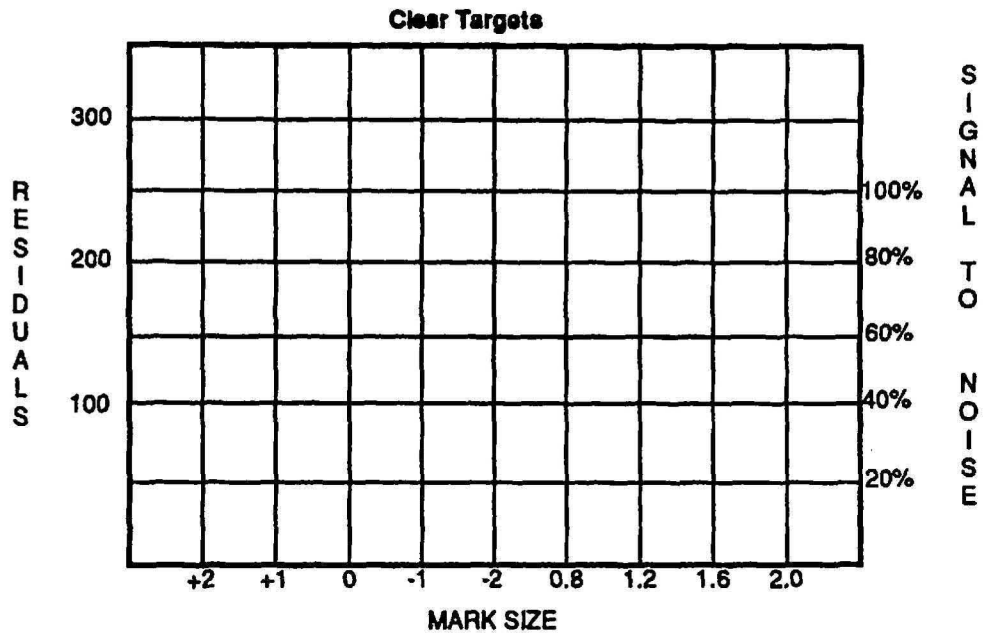
Legend	
+ = X Signal to Noise	△ = X Residuals
0 = Y Signal to Noise	☐ = Y Residuals

Figure 6-8
Local Target Summary Worksheet

Global and Local Alignment Target Characterization Test

Excellent overlay can be achieved when a local alignment signal is derived from a developed image over thermal oxide. If an alignment target could provide this type of signal on processed wafers then local alignment would never be a problem. Through alignment target characterization, the optimum alignment signal can be achieved.

The alignment target work sheet, found in Section 5, is required to be filled out in order to simulate the process steps that affect the alignment target. A copy of the design rules and process flow documentation for all process steps that specify thin film type, target thickness and tolerance is required. It is normal for the scribe line to be where the alignment targets are placed. The scribe line is always subject to some of the following abuses:

- Since the scribe line will usually be exposed silicon most of the time the practice of etching the assorted films from the scribe line may cause damage to the silicon in the scribe but not to the device. This could effect existing targets as well as where new targets will be placed. It is better to sometimes protect the target with resist or where future targets are to be placed whenever practical.

- Since the scribe line is at the lowest point (silicon) on the topography, the photo resist is thicker and makes it difficult to clear minimum feature size alignment targets. As a result, target size variation may occur.

These problems can be overcome with planning and characterization of the alignment targets.

Process characterization provides the optimum alignment target for specific thin film combinations for a set of design rules. After proper target characterization, variations in the thin film thicknesses are easily tolerated, but changes in thin film layer sequence may affect alignment target quality.

Characterization Example

The example "Alignment Target Work Sheet" that is filled out in section 5 is what we will use in the following section and is required to set up a full process characterization.

FieldOx and Field Implant Alignment to N-Well

Processing of N-WELL

NOTE: Ten wafers should be prepared through pad oxidation, nitride, expose and etched process steps. Five wafers are to be used for n-well processing and the remaining five wafers should be used for field oxide process simulation.

A thin pad oxidation of 750 angstroms is grown on the wafer. A deposition of approximately 1000 angstroms of nitride is applied then coated with resist.

1. Specify two job files with 10 passes each as shown in the Job Specifications for the 4800-124 Reticle. Job number 1, CLEAR characterizes an alignment target with clear lines on a dark background. Job number 2, SOLID characterizes an alignment target with dark lines on a clear background.

NOTE: Make sure the jobs specified for the 4800-124 reticle function properly before proceeding with step 2.

2. Execute the first level pass of the job named CLEAR or SOLID with an appropriate exposure time and focus setting on five wafers.
3. Develop and etch the five wafers exposed in step 2.

After developing, the nitride is etched and an implanted before the resist is stripped. Approximately 3000 angstroms of thermal oxide is grown in the area where the nitride was removed. When the thermal silicon dioxide is grown, it will consume about 45% of the total oxide thickness will be below the level of the silicon. The nitride and oxide are chemically stripped and a step is formed. This step is not vertical since the oxide will grow laterally to some extent but will be surpressed by the nitride forming a "birds beak". A new pad oxide is then grown and a new layer of nitride is deposited and coated with resist.

The alignment target on level 01 is now protected from any further processing. The following evaluation will qualify global and local alignment targets for alignment of the field oxide and the field implant levels.

4. Perform the Global Alignment Target Characterization procedure.
5. Perform the Local Alignment Target Characterization procedure.

Buried Contact to Field Oxide

Field Oxide Processing

NOTE: The five wafers that were prepared for the field oxidation reference level can now proceed with field oxidation.

The following sequence of events occur:

1. A thin pad oxidation of approximately 750 angstroms is grown. Then a deposition of approximately 1000 angstroms of nitride is deposited.
2. Pass 1 of the job named CLEAR OR SOLID is executed.
3. After the wafer is developed, the nitride is etched and the resist is stripped.
4. Field oxide (approximately 6000 angstroms) is then thermally grown. The nitride is then stripped and the LTO oxide of approximately 1000 angstroms is deposited and then coated with resist.
5. The Global Alignment Target Characterization procedure is then performed.
6. The Local Alignment Target Characterization procedure is then performed.
7. Perform an etch simulation to remove the LTO oxide from the alignment target area.

Poly Gate to Field Oxide

Poly Gate Processing

NOTE: Add 5 wafers to the gate oxide and poly deposition steps for the P+ and N+ poly gate masking levels alignment simulation.

The following sequence of events occur:

1. The wafers used for buried contact to field oxide and the 5 new wafers are put through gate oxidation and poly silicon deposition.
2. Coat all wafers with photo-resist.
3. Remove the wafers that were added to the lot at the beginning of this procedure and hold them for P+ and N+ Alignment Simulation to be performed later.
4. Perform global alignment tests on the 5 field oxide wafers which were coated with gate oxide and poly-silicon.
5. Perform local alignment tests on the 5 field oxide wafers which were coated with gate oxide and poly-silicon.
6. Perform an etch simulation to remove the poly silicon from the alignment target area.

P+ and N+ Implants to Poly Gate

Poly Gate Processing

NOTE: The target evaluation need only be done once since masking levels aligning to this level do not effect the targets on the reference level.

1. The 5 wafers with gate oxide and poly silicon deposition are exposed using the CLEAR or SOLID job, pass 1, with the correct exposure time and focus setting.
2. The resist is stripped and re-coated.
3. The Global Alignment Target Characterization procedure is then performed.
4. The Local Alignment Target Characterization procedure is then performed.

Contact to Field Oxide Alignment

Contact Processing

NOTE: Add ten wafers to go through contact LTO oxide deposition. Five wafers for metal 1 alignment simulation, and five wafers for via to metal 1 alignment simulation.

1. The field oxide reference wafers, and the ten new start wafers added in this procedure are sent through LTO oxide deposition (5000 angstroms) and are coated with photo-resist.
2. The Global Alignment Target Characterization procedure is then performed.
3. The Local Alignment Target Characterization procedure is then performed.

Metal 1 to Contact

Metal 1 Processing

1. Five of the wafers that have the LTO oxide for contact are coated with resist.
2. The five wafers that have the LTO oxide are exposed using the CLEAR or SOLID job, pass 1, with the correct exposure time and focus setting. The wafers will require developing, etching and photo-resist stripping.

NOTE: The five wafers for the Metal 1 to via simulation are to go through metal deposition. These five wafers have already gone through LTO deposition for contact level.

3. The five wafers then go through reflow, then metal deposition and are coated with photo-resist.
4. The Global Alignment Target Characterization procedure is then performed.
5. The Local Alignment Target Characterization procedure is then performed.

Via to Metal 1

Via Processing

1. The five wafers that have been through LTO oxide and Metal 1 deposition are coated with photo-resist.
2. The five wafers that have been through LTO oxide and Metal 1 deposition are exposed using the CLEAR or SOLID job, pass 1, with the correct exposure time and focus setting. The wafers will require developing, etching and photo-resist stripping.

   NOTE: Add five wafers to the LTO deposition for Metal 2 to Via alignment.

3. LTO deposition of approximately 7000 angstroms then takes place. The wafers are once again coated with resist.
4. The Global Alignment Target Characterization procedure is then performed.
5. The Local Alignment Target Characterization procedure is then performed.

Metal 2 to VIA

Metal 2 Processing

1. Five of the wafers that have 7000 angstroms of LTO oxide for via are coated with photo-resist.
2. The five wafers that have been through LTO oxide are exposed using the CLEAR or SOLID job, pass 1, with the correct exposure time and focus setting. The wafers will require developing, etching and photo-resist stripping.
3. The wafers go through metal deposition and are coated with photo-resist.
4. The Global Alignment Target Characterization procedure is then performed.
5. The Local Alignment Target Characterization procedure is then performed.
6. Etch the Metal 2 from the wafers to simulate the Metal 2 etch process.

PAD to VIA

Pad Processing

1. Using the wafers from the Metal 2 to Via, deposit LTO pad oxidation and coat the wafers with photo-resist.
2. The Global Alignment Target Characterization procedure is then performed.
3. The Local Alignment Target Characterization procedure is then performed.

Section 7 - Designer/Maskmaker Interface

Introduction

One of the most frequent causes of error in the manufacture of reticle is poor communication between the designer and the reticle shop. Since every new reticle set built by a reticle shop is essentially a unique job, it is vital that the reticlemaker be provided with accurate and consistent information. If the reticle shop does not have a photomask order form specifically for reticles, then use the the Sample Reticle Order Forms in this section. Alternatively, you can use these forms as a starting point and create your own order form to suit your individual circumstances.

This section is not intended to address all the potential problem areas which might cause reticles to be built incorrectly. It is intended to ensure that reticle orders are well organized. Additionally, several issues which can improve the probability of getting good reticles will be discussed in the hope that this will result in fewer rejected reticles.

Sample Reticle Order Forms

The next several pages contain a suggested reticle order forms. An explanation of all items on this form is given immediately following the form.

Date:_____

Company Name:_____

Address:_____

_____

_____

Engineer: _____

Phone: _____

Device Name: _____

P.O. Number: _____

Specification: _____

Plots/Films

Versatec Plots: ☐ YES ☐ NO

    Scale: _____X

    Material: ☐ Mylar ☐ Vellum ☐ Paper

    Approval Required? ☐ YES ☐ NO

Figure 7-1
General Information Worksheet

The following text explains the information which is required on the General Information Worksheet.

Date: Date this order form is completed.

Company Name: Full name of the company ordering the reticles.

Address: Address to which the reticles will be delivered.

Engineer: Name of engineer to be contacted in case questions arise.

Phone: Engineer's phone number and extension.

Device Name: Circuit designation to appear as reticle ID on the reticle.

P.O. Number: Purchase order number.

Specification: Reference specification for building reticles.

Versatec Plots: If Versatec plots are required, mark the scale and plotting medium. Check with the reticle shop for allowable scale range.

Approval Required: Is approval of the Versatec plots required before tooling is built?

Units: ☐ English ☐ Metric

Digitized Grid Unit: _____

Orientation: Right Reading   Wrong Reading

Data Scale: ☐ 1 X ☐ 5X ☐ 10X ☐ Other: _____

Data Scale Factor: ☐ None   Amount: _____

Minimum Dimension at 1X: Geometry: _____   Space: _____

On Layers: _____

Data Window:

Output Window: Inside of Scribe   Device Center

A: X _____   C: X _____   E: X _____
   Y _____   Y _____   Y _____
B: X _____   D X _____
   Y _____   Y _____

Die Orientation

Die Orientation				
Source Data	Output Data			
F	F	⌐	⅃	┑
	( )0°	( ) 90°	( )180°	( ) 270°
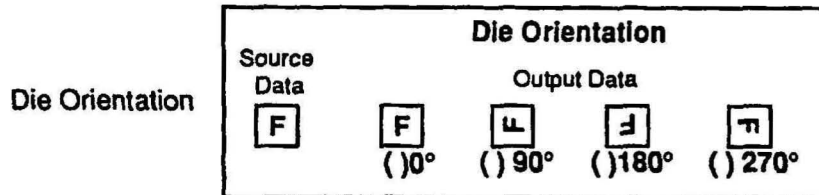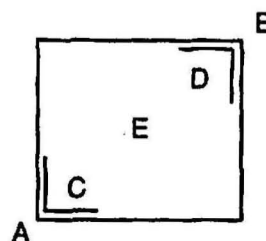
Data Base: ☐ GDS1 ☐ GDS2 ☐ Other: _____

Library Name: _____

Structure Name: _____

Minimum Digitizing Increment _____ μm/mil

MEBES: ☐ Extended Address Mode ☐ Reticle Mode ☐ Mode I/II

Address Size: _____ μm   Stripe Height: _____ μm

Tape Density: ☐ 800BPI ☐ 1600BPI ☐ 6250 BPI ☐ Other: _____

Figure 7-2
Tape Data Information Worksheet

The following text explains the information which is required on the Tape Data Information Worksheet.

Units: Is tape data in English or metric units?

Digitized Grid Unit: What is the minimum grid spacing used on the CAD system to produce this circuit? Is this the same for all layers? Are units in microns or mils?

Orientation: Is tape data right reading or wrong reading?

Data Scale: Is tape data written at 1X, 5X, or 10X?

Data Scale Factor: Is tape data at 100% of the final reticle size, or does it need to be scaled (shrunk) before building reticles?

Minimum Dimension: Indicate the smallest line and space on the data tapes, and the layers containing these minimum dimensions. Units in microns.

Data Window:

Output Window: The lower left and upper right coordinates where all reticle data is contained.

Inside of Scribe: Lower left and upper right coordinates inside of the scribe line.

Device Center: Exact coordinates of the device center.

Die Orientation: If output data (MEBES) is to be rotated, or if the orientation is different from the data base.

Data Base: If a data base tape is provided, indicate whether this is a Calma GDS2 tape, or from another CAD system. If Calma tape, state the library and structure names.

MEBES: For MEBES data, indicate the mode used to create the data, and the address size and stripe height. Mode I is limited to a 0.5 micron spot size and 32,767 address units in both X and Y directions. Mode II is limited to a 0.25 micron spot size and 32,767 address units in both X and Y directions. Reticle mode is limited in address units in X and Y only by the reticle size. Extended address mode is capable of spot sizes from 0.1 to 1.1 microns, and 65,536 address units in X and Y.

Tape Density: Mark whether the tape was written at 800 or 1600 bits per inch (BPI).

Device Information Form

Device Name: _____

Library Name: _____

Input Data Format

Mann 3600	MEBES Data
Mann 3000	Reticle Mode
E-Mask 2000	Mode I/II
ALF	Extended Address
Other: _____	Tape Units: English Metric

	Layer Title	File #	Pattern File or GDS Layer(s)	Add. Size	Dig. Data		CD Dig.		Critical Dimension				Data Ch. Down		Scribe		Stack To	Flash/Trap. Count
					CL	DK	Y	N	Tape CD	Mask CD	CD Tol. (+/-)	CD Unif.	RR	WR	CL	DK		
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		

Figure 7-3
Device Information Worksheet

The following text explains the information which is required on the Device Information Worksheet.

Device Name: Circuit designation to appear as reticle ID on the reticle.

Library Name: library that holds all pattern files.

Input Data Format: The format that is provided to mask maker.

Layer ID: Layer identifier title to appear on final reticle, for example FIELD OXIDE 2.0.

File No: The number of the tape file on which the data for this layer is stored.

Pattern File or GDS Layer(s): pattern files required to create this masking level.

Dig. Data: Indicate whether a digitized geometry needs to appear clear (glass) or dark (chrome) on the final reticle.

CD Dig: Is the specified critical dimension for this layer a digitized geometry or not? This determines whether a chrome line or clear space will need to be measured for CD readings.

Critical Dimensions: Indicate the CD value on the data tape, what it needs to be on the reticle and the acceptable tolerance between the desired and actual CDs. All units in microns.

Data Chrome Down: Indicate whether the image on the glass side of the reticle is right reading (RR) or wrong reading (WR). For reticles, this should always be right reading.

Scribe: Indicate whether the scribe lines on the reticle will be clear or dark. This determines whether an opaque border should surround the 5X or 10X reduction reticles for optical step and repeat.

Stack To: Indicate layer(s) which the reticle will be stacked against for registration checking.

Flash /Trap. Count: Number of trapezoids in the E-beam data base.

Reticle Type:

☐ 5X   ☐ 4X

☐ Other

Substrate:

Type: ☐ QZ   ☐ LE

Thickness: ☐ 0.090"   ☐ 0.120"   ☐ 0.250"

Flatness: ☐ 2µm   ☐ 1µm   ☐ Other _____

Chrome Type:

☐ AR   ☐ LR

Reticle Finish:

Size: ☐ 5X5

Pellicle: NONE   ☐   Bottom (glass side)
Stand-off - P/N: _____

☐   Bottom (chrome side)
Stand-off - P/N: _____

Checkplate:

☐ None   ☐ Yes _____ Layer

Figure 7-4
Reticle Manufacture Worksheet

The following text explains the information which is required on the Reticle Manufacture Worksheet.

Reticle Type: Type of reduction system 4X, 5X or other.

Substrate: Indicate the substrate type, thickness, and flatness for the final reticles. QZ is quartz, LE is low expansion. Quartz is required for all I-line and Deep UV applications. Reticle thickness is 0.090, 0.120, OR 0.250 inches depending upon overlay requirements.

NOTE: Ensure quartz material is I-Line and DUV compatible.

Chrome Type: Select the chrome type required on the reticles. AR is anti-reflective, LR is low-reflective.

Reticle Finish: If a pellicle is required on a 5X5 reticle (glass side) bottom (chrome side). Reticle standoff defines pellicle height.

Checkplate: Indicate whether a checkplate is necessary, and if so, for which layer. A checkplate is a trial pass of one of the reticles in a set, useful for checking correct die placements, orientation, reticle fiducial placements, etc. Checkplates are strongly recommended for first-time reticle sets. If a part number for the pellicle is known, insert it.

RMS Alignment Window

provided on tape   YES ☐ NO ☐

115mm ☐   Centered ☐   Offset ☐

Bar code

Provided on tape   YES ☐ NO ☐

Maksing Level   Barcode Characters

_____ ☐☐☐☐☐☐☐☐☐
_____ ☐☐☐☐☐☐☐☐☐
_____ ☐☐☐☐☐☐☐☐☐
_____ ☐☐☐☐☐☐☐☐☐
_____ ☐☐☐☐☐☐☐☐☐
_____ ☐☐☐☐☐☐☐☐☐
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Local Alignment Reticle Window

DFAS	MicroDFAS	
Location	Location	
X = 0 or Other_____	X1 = _____ mm	Y1 = _____ mm
Y = 8mm 8.8mm 9.6mm	X2 = _____ mm	Y2 = _____ mm
NOTE: These measurements are at 1X.	X3 = _____ mm	Y3 = _____ mm
	X4 = _____ mm	Y4 = _____ mm

NOTE: These measurements are at 1X.

Figure 7-5
RMS Barcode Worksheet

The following text explains the information which is required on the RMS Barcode Worksheet.

RMS Alignment Window: RMS reticle alignment window provided on the device or if reticle maker is to supply. Specify 150mm separation and if the window is centered or offset.

Barcodes: Each reticle can have a unique identifier of up to 10 characters. It can display, device, masking level and revision.

Local Alignment Reticle Window: If DFAS is required, specify location of the local alignment reticle window. If Micro DFAS is required, specify location of the window positions from the center of the reticle.

NOTE: All 4 Micro DFAS window positions should be symmetrical with respect to the center of the reticle.

CD Measurements: ☐ Nikon 2I   ☐ Other_____

Calibration ☐ NBS   ☐ Other_____

CD Data to Ship ☐ Yes   ☐ No

CD Correlation Done ☐ Yes   ☐ No

Date Completed _____

Registration: Reference Layer_____

Die Fit (Primary)_____ (Drop-Ins) _____

Field Fit_____

Total Registration _____

Equipment   ☐ Nikon 2I   ☐ Other_____

Registration Data to Ship ☐ Yes   ☐ No

Nikon 2I Marks ☐ Yes   ☐ No

Defects: Inspection Equipment: ☐ KLA   ☐ NJS   ☐ Other

Max Defect Size: Clear_____   Dark_____

Defect Data to Ship ☐ Yes   ☐ No

Klaris Required? ☐ Yes   ☐ No

Klaris Data to Ship ☐ Yes   ☐ No

Figure 7-6
Reticle Quality Worksheet

The following text explains the information which is required on the Reticle Quality Worksheet.

CD Measurements: Select the type of equipment you want CD measurements to be made on, the standard you want this equipment calibrated to, and whether you want a copy of all CD measurements. Also, if CD correlation has been performed between your equipment and the reticle shop's equipment. CD drawings must be included with the order.

Registration: Select the layer used as a standard for registration measurements. All other layers in the set will be compared to this standard layer to obtain relative registration vectors. Specify the die fit for primary circuit die and drop-in die and the required total registration.

Equipment: Indicate the type of equipment to be used for registration measurements and whether this data needs to be shipped with the reticles.

Nikon 2I Marks: If a Nikon X-Y 2I is used for registration measurements, indicate whether 2I marks are included in the die layout, and if so, give their locations relative to the data center.

Inspection Equipment: Select the type of equipment you want used for defect detection, the maximum size of allowable clear and dark defects, and whether the defect inspection results should be shipped with the reticles.

Klaris Required?: Indicate whether you want the reticles compared to the original data base on a KLA Klaris machine, and if you want a copy of the results.

Job Specification Worksheets

The following Job Specification Worksheets can be used to input the data required for GCA wafer stepper systems. These worksheets can be used at the same time the reticle worksheets are sent to the reticle shop. Refer to the following manuals for questions regarding job specifications; AUTOSTEP 200 System Operation Manual, P/N 069424G1, LASERSTEP 200 System Operation Manual, P/N 069881 and DSW System Operation, P/N 039617G1.

JOB COMMENT:

WAFER DIAMETER:

<<ARRAY PARAMETERS>>

STEP SIZE:
X:

STEP SIZE:
Y:

<<ALIGNMENT PARAMETERS>>

STANDARD KEYS? (Y/*N):

RIGHT KEY OFFSET
X:
Y:

LEFT KEY OFFEST
X:
Y:

EPI SHIFT
X:
Y:

NAME (<CR> TO EXIT PASS SETUP):

PASS COMMENT:

USE LOCAL ALIGNMENT? (Y/*N):Y

FZT OFFSETS
X:
Y:

AWA PARAMETER FILE NAME (NO EXTENSION):

PASS SHIFT:
X:
Y:

RETICLE BAR CODE:

MASKING APERTURE SETTING:
XL:
XR:
YF:
YR:

RETICLE ALIGNMENT OFFSET (MICRONS):
XL:
XR:
Y:

RETICLE ALIGNMENT MARK PHASE (P, *N, X):

Figure 7-7
Job Specification Worksheet

Designer/Maskmaker Communication

Field layout plots for each unique field of the reticle should be generated before ordering reticles, and supplied to the reticle shop. Two sets of parts should be generated, at a minimum - one for the designer's files and the other for the reticle shop. Additional plots may be required for the fab area, incoming QC, and so on. Photocopying may cause some numbers to become illegible and can result in reticlemaking errors. If your plotter can handle 11x17 inch sheets, these are preferred over 8.5x11 inch size, again to improve legibility. Check all plots for accuracy before release.

Field layout plots give the coordinate positions of the center X- and Y-reference dimensions of all die within a field with reference to the image reference point. These coordinates will be used by the reticle shop to calculate the placement location of every die on the reticle with reference to the coordinate origin of the machine being used to build the reticle. For this reason, field layout plots are an invaluable tool for the reticle shop. These plots also give an easy visual representation of what all the fields will look like on the reticle.

Critical dimensions require careful consideration by the circuit designer. Frequently, a standard geometry such as a few line/space pairs, or CD bars, will be included in the periphery of the circuit for CD measurements. These standard geometries are often drawn at a suitable round number while the geometries making up critical circuits may be much smaller. This means that the standard geometry could be well within specification but because of size-dependent effects, the critical geometries may be outside specification.

Additional problems are caused by the fact that critical circuit geometries are generally closely packed, as in the case of a memory array, whereas standard geometries, resulting in a differential sizing bias. The effect increases for smaller minimum dimensions. Therefore, CDs which relate to actual critical circuit functions rather than non-functioning standard geometries are best. If standard geometries must be used, make their line and space widths exactly the same as the minimum circuit dimension (excluding verniers and other non-functional geometries). Also, try to simulate the optical proximity effects which will occur on closely packed critical geometries by placing other geometries around the standard geometry.

For layers with large minimum dimensions, standard geometries are a nominal value. In the case of passivation, for example, a standard geometry can be placed in the circuit periphery or scribe street without regard to proximity effects. The advantage of this is a CD that is easily located by the reticle shop, and more importantly, by fab area operators who must find and measure this CD repeatedly.

Whether critical dimensions or standard geometries are specified, drawings or plots should be provided by the designer to the reticle shop to clearly show the locations to be measured. A Versatec plot at about 25X, to fit on an 8.5x11 inch sheet, can be used to show the global position of the CD location within the die. An additional plot at 100-200X may zoom in on the precise CD location, showing the actual line or space to be measured. Plots of this type should be included for all individual die on all layers of the reticle set.

A copy of the computer printouts form the job used to create the data tapes shipped to the reticle shop can also be included with the data to be used by the reticlemaker. These printouts identify the size and location of all data files on the tapes, which can then be read by the reticlemaker provided all tapes are properly labelled.

Section 8 - Glossary

Absolute Position Measurement

X or Y-axis positional measurement of certain geometries on a mask with reference to an origin point.

Address Size

Refer to "MEBES"

Alignment Mark Cell

The CAD cell into which stepper alignment marks are drawn.

Aperture

A hole in the motor-operated shutter plate of the photomultiplier stage assembly. One aperture selects only the left eye, one the right eye, and a third for both eyes simultaneously.

Array Reference Point

A wafer array reference point is the location marked by an asterisk on wafer layout plots, to which OAT coordinates are referenced. For field array reference point, see "image reference point".

Array Registration

X or Y-axis positional accuracy of field or wafer array.

Automatic Inspection System

A machine which performs automatic detection and classification of mask defects.

Baseline

The distance from the center of the main optical axis (reduction lens) to the center of the right objective of the wafer alignment microscope.

Biasing (Sizing)

The process of symmetrically expanding or contracting mask geometry dimensions to compensate for mask making or fabrication area processing effects.

Blind Stepping

Stepping a pattern layer without aligning to any marks on the wafer, as in a first layer pattern.

Blocking

Combining multiple die together to make more scribe street space available for alignment marks, or for other reasons.

Blowbacks

Color or black and clear films made from 5X or 10X reticles for verification of the photomask patterns.

Borosilicate

A low expansion glass substrate material.

Checkplate

A low quality test plate built by a mask shop before an entire photomask set is made, to verify die placement and orientation, and fiducial placement.

Checkplots

Plots produced after CAD layout is completed to verify correct placement of all geometries.

Chrome Blank

Raw material used for mask fabrication, consisting of a glass substrate with a thin layer of chrome film. Usually supplied pre-coated with resist.

Chrome Reflectivity

Reflectivity of chrome film used in photomask manufacturing which varies from low reflectivity (approximately 10%) to bright chrome (approximately 50%).

Chrome Spots

Excess chrome remaining in glass areas after the photomask is manufactured.

Composite Plot

Plot of multiple layers of a device.

Computer Aided Design (CAD) Systems

A graphics computer system used for layout of circuit geometries.

Contact Print

A medium quality photomask produced by contact printing from a master photomask.

Critical Dimension (CD)

A geometry or space width on a photomask whose dimension is used as a measurement tool to ensure proper circuit functionality.

CD Correlation

An adjustment of CD measurement results to match that of other measurement equipment.

CD Maps

X and Y-axis maps that display CD measurement results taken by the mask shop.

CD Tolerance

An allowable deviation from the nominal CD measurement.

Dark Field Alignment System

An alignment system used by the GCA wafer stepper system for local alignment of die on a wafer. This system enhances the registration capabilities of the GCA wafer stepper system.

Data Base

A collection of raw data to be processed by a computer, for example, the layout patterns of an integrated circuit (IC).

David Mann

Founder of David W. Mann Company, which was purchased by GCA Corporation. Mann/GCA Models 3000, and 3600 pattern generators are commonly used by many mask shops. Mann/GCA 3696 Pattern Generators and 4800 DSW systems are frequently used to produce 1X photomask patterns by many mask shops.

Defect

An unwanted clear or chrome anomaly on the photomask (hard defect), or airborne contamination (soft defect) on the photomask surface.

Defect Density

A number which represents the number of defects per unit area on a mask or photomask. A low defect density number is desired which indicates a small amount of error.

Design Rules

A set of rules which describe spacing, minimum dimensions, etc., of circuit geometries.

Die Fit

A comparison of measured X and Y-axis die positions to perfect placement grid on the photomask, or to another plate used as a reference.

Digitizing

The process of converting circuit geometry drawings to numerical X and Y-axis coordinates for the CAD system data base.

Drop-In

A pattern such as a process control monitor or OAT which replaces a circuit die in a 1X photomask.

E-Beam

An electron beam exposure system used for the creation of reticles.

E-Beam Spot Size

The diameter of a focused electron beam used to write reticles. The spot size is important for e-beam write time.

E-Beam Write Time

The time required for an e-beam machine to write a photomask.

Electromask 2000

The data format for the Electromask 2000 optical pattern generator.

Emulsion

A film used for masking layers of certain types of masks. Emulsion has a lower scratch resistance than chrome.

Exposure Field

The field size over which lens specifications are guaranteed.

Field Fit

The comparison of measured X and Y-axis field positions of a 1X photomask to the perfect placement grid.

Fielding

Specifies whether the area surrounding a digitized circuit geometry is to be considered clear (glass) or dark (chrome) by the data fracturing program.

Field Layout Plot

A plot of die positions within the 1X photomask field produced by Reticle Manager which is useful for mask shop 1X photomask job planning.

Field Utilization

The percentage of useable lens area occupied by die patterns.

Films

Black and clear, or color films are produced by the mask maker from intermediate reticles, usually at 100-200X magnification for verification of photomask circuit patterns.

THIS IS NOT A DEFINITION!

Flash Count

The total number of exposure geometries into which a single circuit layer has been broken down for optical pattern generator (PG) photomask making.

Flat Finder

The device on the Automatic Wafer Handler of the GCA wafer stepper systems which aligns the major flat of the wafer parallel to the X-axis of the system.

Fracturing

The process of composing digitized circuit geometries into rectangles for a PG system, or trapezoids for an e-beam system, which can be exposed by the photomask making system.

Frosty Wafer

A wafer with aluminum and oxide layers used to scatter light back to the photomultiplier tube (PMT) of the GCA wafer stepper system during photomask alignment.

Full Field Scribe Frame

Scribe street areas of several adjacent IC chips which are grouped together on the CAD layout as one large picture frame.

Glass Cutting Fixture

A fixture which cuts 1X reticles from 5 X 5 inches to 3 X 3 inches.

Glass Wafer

A glass wafer coated with chrome and photo-resist used for the qualification of 1X photomask patterns.

Global Alignment

To align the wafer in the X, Y, and rotational axis after it has been placed on the GCA wafer stepper system wafer chuck by the automatic wafer handler. Global alignment is the first step in aligning the wafer to the GCA wafer stepper system and must take place before local alignment can begin. Global alignment is performed automatically by the AWA/D system.

Graphics Computer

A computer system which forms the basis of a CAD system.

Hard Surface Mask

A mask which uses chrome as a masking film.

Intermix

The combination of 2 or more pieces of lithography equipment used to print wafers.

Klaris

KLA Instruments Corporation automatic photomask inspection system which allows comparison of photomask images against the original CAD database.

Low Expansion Glass

A mask substrate material with a low thermal coefficient of expansion.

Mann

The data format for the David Mann/GCA PG system.

MEBES

Manufacturing Electron Beam Exposure System.

MEBES Address Size

The size of the address for the MEBES e-beam system

MEBES Stripe Height

The height of the stripe (in microns) written in a single sweep of the MEBES system.

Micron

One millionth of a meter (3.93×10^{-5} inches)

Mil

One thousandth of an inch (0.001in.)

Offset

A shift of field, wafer array, or die position from the nominal position.

Opaque Area

The photomask area which is covered by chrome, therefore not transparent to light.

Optical Proximity Effect

A change in the line width of a printed feature due to close proximity of other pattern features.

Overlay

Two distinct photomask patterns, usually on different layers, which are superimposed on an overlay comparitor to check the accuracy of the overlay. Also called registration.

Passivation

A thick overcoat layer put on an IC for protection of scratches.

Pattern Generator (PG)

An optical instrument used to create geometric patterns on a photomask during the photomask manufacturing process.

Pattern Generator Fiducials

Alignment marks which are placed at the edges of s photomask during pattern generation. These marks are used for alignment of the photomask to the step and repeat camera.

Pellicle

A thin transparent membrane placed over a photomask to prevent particles from landing on the reticle image plane.

Pellicle Alignment Fiducials

Alignment marks on a photomask which are used to align the pellicle during installation.

Pellicle Frame

A metal frame to which the pellicle is attached. The frame provides a 50mm distance between the pellicle and the chrome surface of the photomask.

Pellicle Mounting Fixture

A tool used to mount the pellicle to the photomask.

Pen Plotter

A drawing device which typically draws in the X and Y-axis using several different color ball point pens. A plotter is used to draw large drawings such as IC levels, photomask plots, schematics, etc.

Photomask

A mask or reticle used for photolithographic manufacture of integrated circuits.

Photomultiplier Tube (PMT)

A light-sensitive detector used to determine alignment signal strength in the DFAS, and Micro DFAS local alignment systems of the GCA wafer stepper system.

Photoplate

An unprocessed glass plate with chrome and photoresist layers on one side which will be used to manufacture a photomask.

Physical Center Point of Wafer

The center point of the wafer disregarding the wafer flats.

Pinhole

An unwanted space in the chrome masking film.

Plate Cleaner

An automatic machine used to clean particles and residues from the surfaces of a photomask.

Plate Title

An identifying title placed on the photomask during manufacture.

Prealignment (Prealign)

The alignment of the wafer by the automatic wafer handler (AWH) which aligns the major flat of the wafer so it is parallel with the X-axis of the GCA wafer stepper system. The wafer is then transferred from the AWH to the wafer chuck while maintaining the prealignment position.

Primary Die

A term used to describe the main circuit die on a reticle.

Prober

An instrument used for testing the electrical characteristics of an IC device on a finished wafer.

Process Control Monitor (PCM)

A test die containing electrical test structures used to monitor the performance of various phases of an IC manufacturing process.

Quartz

A very high quality glass with a low thermal coefficient of expansion used for manufacturing photomask substrates.

Random Defects

Defects that occur at random throughout a photomask pattern.

Reduction Reticles

A photomask with circuit images which will be reduced through a 5X or 10X lens of a GCA wafer stepper system.

Reference Dimensions

A circuit dimension, not including scribe street.

Registration

The accuracy of an IC layer which aligns to (overlays) another layer.

Repeating Defect

A defect appearing in the same position of every die on the photomask, most commonly caused by a defect on the reduction reticle used to step and repeat the mask.

Reticle

A photomask containing one or more die used in step and repeat systems.

Reticle Alignment

The process of aligning the photomask to the GCA wafer stepper system. This function is performed automatically by the Reticle Management System (RMS).

Reticle Alignment Window

The alignment window is a square window in the photomask chrome which is used by the RMS to align the photomask to the GCA wafer stepper system. There is a window located on the front and rear of the photomask.

Reticle Management System (RMS)

The RMS is a micro processor-controlled subsystem that automates the storing, loading, aligning and unloading of up to 10 reticles on the GCA wafer stepper system. The RMS increases system throughput and ensures consistent alignment and cleanliness of the reticle and the GCA wafer stepper system.

Reticle Rotation

Rotational misalignment of the reticle with respect to the X and Y-axis of the GCA wafer stepper system.

Right Reading

A term used to describe the orientation of geometric patterns on a reticle as being similar to that of normal text, for example, not mirrored, when the reticle is viewed chrome side up. Same as wafer orientation.

Runout

The expansion or contraction of a mask or reticle pattern layer relative to other layers.

Saw

A dicing machine used to cut wafers along scribe streets between IC chips.

Scale Factor

A multiplication factor by which all circuit geometries are scaled, or reduced. Also called shrink factor.

Scaling

The process of reducing a circuit's overall size by multiplying by a factor less than one.

Scribe Line

The inactive space between IC circuit chips which often contain alignment marks and test geometries. Wafers are cut along scribe line to separate individual IC chips before packaging. Also called scribe streets, or scribes.

Scribe Street Overlap

The amount by which the total die size exceeds the stepping distance, (usually 5 microns). This overlap prevents unintentional gaps between IC chips during mask and wafer stepping.

Superimposed Scribe Lines

Whole scribe lines that are superimposed on opposite sides of the IC chip during of the mask and wafer.

Whole Scribe Lines

Scribe lines which are digitized symmetrically on the top, bottom left, and right side of a IC chip. These lines are superimposed during stepping, and do not create double scribe line widths.

Shrink

The same as scaling.

Site-by-Site Alignment (Local Alignment)

Alignment that takes place after global alignment of the wafer and before exposure of a die. Local alignment enhances GCA wafer stepper system registration.

Soda Lime

A low quality glass substrate material.

Standard Geometry

A fixed geometry type placed in the circuit periphery or scribe street for ease of CD measurement.

Step and Repeat

The process of exposing a die, moving to the next position to be exposed, expose the die again, and this process is repeated.

Step Center

The center of each stepping position.

Stepping Distance

The distance (center-to-center) between each die on the wafer.

Stripe Height

Refer to MEBES.

Substrate

A base material fro mask or reticle production.

Taping Border

An opaque border, usually about 0.001 in. wide, surrounding clear fielded scribe lines so that the dark tape can be placed on the reduction reticle to block unwanted light outside the scribe area during optical step and repeat exposure.

Target

A topographical mark etched into a film on the wafer surface to which subsequent layers are aligned.

Test Die

To perform the same purpose as the process control monitor (PCM). Also called a test pattern.

Test Reticle

One of several reticles supplied by GCA to perform mark evaluation and diagnostic tests.

Theta Stage

A mechanical stage which supports the wafer chuck and the wafer. This stage has the capability of correcting for rotational wafer errors and wafer levelling.

Throughput

Them number of wafers per hour which can be processed on a GCA wafer stepper system.

Tooling

Any plate built by a photomask shop.

Versatec Plot

A black and white shaded plot produced by a Versatec plotter.

Wafer Array

The layout of the wafer array which indicates the number of die, and the number of rows and columns that contain exposure locations.

Wafer Coverage

The percentage of the total wafer area occupied by the wafer array.

Wrong Reading

A chrome side reticle image with pattern orientation which is a mirror image of the wafer pattern.

X-axis Key to Reference Dimension

The spacing between the field image reference point and the key for the layer being aligned (in millimeters).

X-axis Reference Dimension (X-ref.)

The circuit dimension, excluding scribes, which is parallel to the X-axis.

X-Street

The scribe line which runs parallel to the X-axis, also called the horizontal street.

Y-axis Reference Dimension (Y-ref.)

The circuit dimension, excluding scribes, which is parallel to the Y-axis.

Y-Street

The scribe street which runs parallel to the Y-axis, also called the vertical street.

Appendix A - Worksheets

Appendix A contains all the worksheets used throughout the Reticle Handbook which can be used for the reticle design and manufacturing process.

GCA Wafer Stepper System Number: _____

1	Wafer Size	75mm	100mm	125mm	150mm	200mm

2	Reticle Alignment Target Seperation	105mm	115mm

3	Reticle Alignment Target	Offset	Centered

4	Barcode	Yes	No

5	Microscope Objective Spacing	3 Inch (76.2mm)	4 Inch (101.6mm)

6	Local Alignment System	DFAS	Micro DFAS

7	If DFAS	40mm	44mm	48mm	Other

8	If Micro DFAS	INSITU Target Placement	
		1X = 2X = 3X = 4X=	1Y = 2Y = 3Y = 4Y =

System Configuration Worksheet

Process: _____ | Date: _____

1	2	3	4	5	6	7	8	9	10	11
CALMA LEVEL	MASKING LEVEL	MASK NUMBER	DEVICE FIELD	SCRIBE	REF. LAYER	GLOBAL ALIGNMENT TARGET USED	DFAS ALIGNMENT TARGET USED	TARGET PROTECT	VERNIER	SCALE

Alignment Target Worksheet

AWA/D Filename: _____ Evaluation Level: _____

Alignment Target Type: _____ Size: _____

Global Mask: _____ Global Threshold: _____

Reference Mask: _____

Fine Mask Focus Test

Test	Wafer #____			Wafer #____			Wafer #____			Wafer #____			Wafer #____		
FOCUS	-3	0	+3	-3	0	+3	-3	0	+3	-3	0	+3	-3	0	+3
1															
2															
3															
4															
5															
6															

Algorithm	41	15	7	18	1	0	13	42	5	4	2
Frequency											

Wafer Results Summary

Wafer Number 1			Wafer Number 2			Wafer Number 3		
AVG0	AVG TIR	AVG SIG	AVG0	AVG TIR	AVG SIG	AVG0	AVG TIR	AVG SIG

Fine Algorithm Results

Focus	#1	#2	#3
+3µm	alg#	alg#	alg#
Best Focus	alg#	alg#	alg#
-3µm	alg#	alg#	alg#

Wafer Number 1			Wafer Number 2			Wafer Number 3		
AVG0	AVG TIR	AVG SIG	AVG0	AVG TIR	AVG SIG	AVG0	AVG TIR	AVG SIG

Global Target Data Worksheet

Reference Level: _____   Masking Level: _____

Clear Targets

MARK SIZE

Dark Targets

MARK SIZE
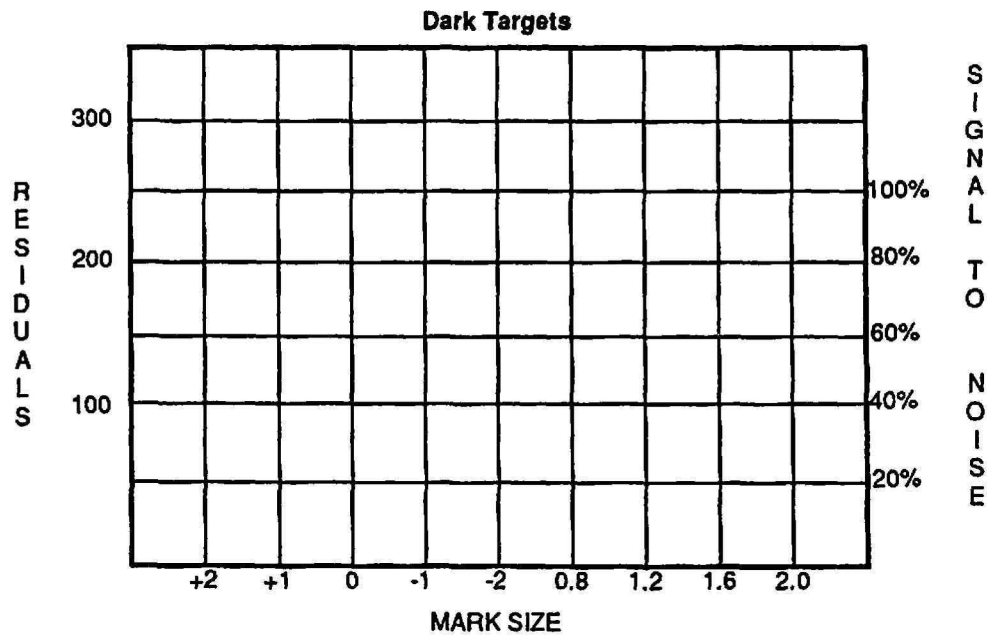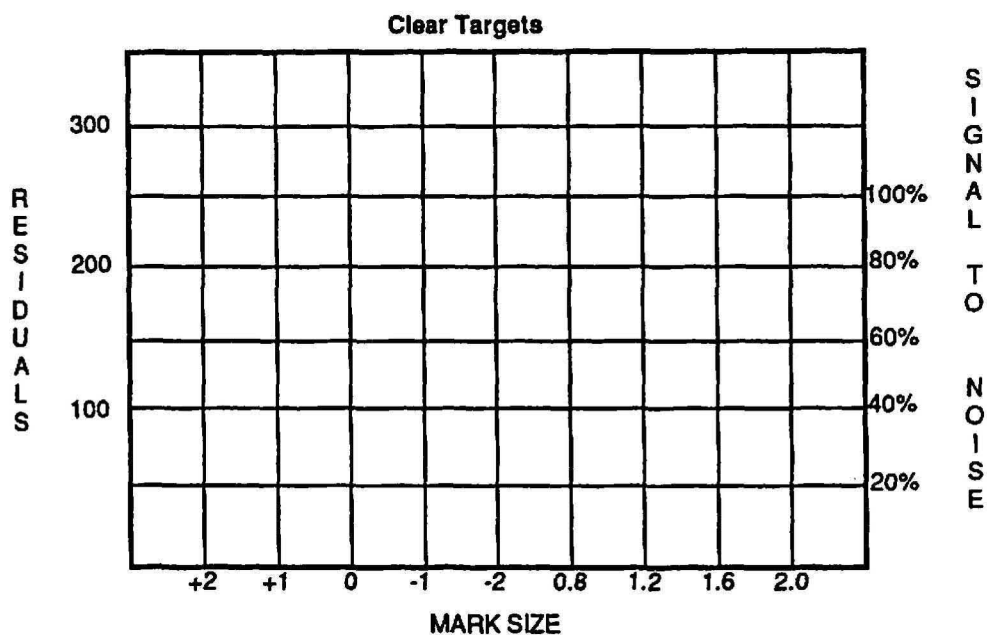
Legend	
+ = X Signal to Noise	△ = X Residuals
0 = Y Signal to Noise	☐ = Y Residuals

Local Target Summary Worksheet

Date:_____

Company Name:_____

Address:_____

_____

_____

Engineer: _____

Phone: _____

Device Name: _____

P.O. Number: _____

Specification: _____

Plots/Films

Versatec Plots: ☐ YES   ☐ NO

　　　Scale:_____X

　　　Material: ☐ Mylar   ☐ Vellum   ☐ Paper

　　　Approval Required? ☐ YES   ☐ NO

General Information Worksheet

Units: ☐ English ☐ Metric

Digitized Grid Unit: _____

Orientation: Right Reading   Wrong Reading

Data Scale: ☐ 1 X ☐ 5X ☐ 10X ☐ Other: _____

Data Scale Factor: ☐ None   Amount: _____

Minimum Dimension at 1X: Geometry: _____ Space: _____

On Layers: _____

Data Window:

Output Window: Inside of Scribe   Device Center

A: X _____   C: X _____   E: X _____
   Y _____   Y _____   Y _____
B: X _____   D X _____
   Y _____   Y _____

Die Orientation				
Source Data	Output Data			
F	**F**	**ᘂ**	**ᖴ**	**ᖴ**
	( ) 0°	( ) 90°	( ) 180°	( ) 270°

Die Orientation
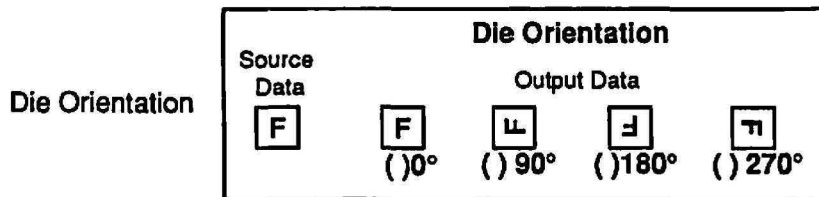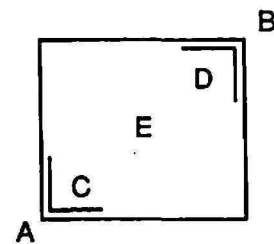
Data Base: ☐ GDS1 ☐ GDS2 ☐ Other: _____

Library Name: _____

Structure Name: _____

Minimum Digitizing Increment _____ µm/mil

MEBES: ☐ Extended Address Mode ☐ Reticle Mode ☐ Mode I/II

Address Size: _____ µm   Stripe Height: _____ µm

Tape Density: ☐ 800BPI ☐ 1600BPI ☐ 6250 BPI ☐ Other: _____

Tape Data Information Worksheet

Device Information Worksheet

Device Information Form

Device Name: _____

Library Name: _____

Input Data Format

Mann 3600	MEBES Data
Mann 3000	Reticle Mode
E-Mask 2000	Mode I/II
ALF	Extended Address
Other: _____	Tape Units: English Metric

| | Layer Title | File # | Pattern File or GDS Layer(s) | Add. Size | Dig. Data | | CD Dig. | | Critical Dimension | | | | Data Ch. Down | | Scribe | | Stack To | Flash/Trap. Count |
					CL	DK	Y	N	Tape CD	Mask CD	CD Tol. (+/-)	CD Unif.	RR	WR	CL	DK		
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		

Reticle Type:

☐ 5X   ☐ 4X

☐ Other

Substrate:

Type: ☐ QZ   ☐ LE

Thickness: ☐ 0.090"   ☐ 0.120"   ☐ 0.250"

Flatness: ☐ 2μm   ☐ 1μm   ☐ Other _____

Chrome Type:

☐ AR   ☐ LR

Reticle Finish:

Size: ☐ 5X5

Pellicle: NONE   ☐   Bottom (glass side)
                          Stand-off - P/N: _____

                ☐   Bottom (chrome side)
                          Stand-off - P/N: _____

Checkplate:

☐ None   ☐ Yes _____ Layer

Reticle Manufacture Worksheet

RMS Alignment Window

provided on tape   YES   ☐ NO   ☐

115mm ☐   Centered ☐   Offset ☐

Bar code

Provided on tape   YES   ☐ NO   ☐

Masking Level   Barcode Characters

_____   ☐☐☐☐☐☐☐☐☐☐
_____   ☐☐☐☐☐☐☐☐☐☐
_____   ☐☐☐☐☐☐☐☐☐☐
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_____   ☐☐☐☐☐☐☐☐☐☐

Local Alignment Reticle Window

DFAS	MicroDFAS
Location	Location
X = 0 or Other _____	X1 = _____ mm Y1 = _____ mm
Y = 8mm 8.8mm 9.6mm	X2 = _____ mm Y2 = _____ mm
NOTE: These measurements are at 1X.	X3 = _____ mm Y3 = _____ mm
	X4 = _____ mm Y4 = _____ mm
	NOTE: These measurements are at 1X.

RMS Barcode Worksheet

CD Measurements: ☐ Nikon 2I   ☐ Other_____

Calibration ☐ NBS   ☐ Other_____

CD Data to Ship ☐ Yes   ☐ No

CD Correlation Done ☐ Yes   ☐ No

Date Completed _____

Registration: Reference Layer_____

Die Fit (Primary)_____ (Drop-Ins) _____

Field Fit_____

Total Registration _____

Equipment ☐ Nikon 2I   ☐ Other_____

Registration Data to Ship ☐ Yes   ☐ No

Nikon 2I Marks ☐ Yes   ☐ No

Defects: Inspection Equipment: ☐ KLA   ☐ NJS   ☐ Other

Max Defect Size: Clear_____   Dark_____

Defect Data to Ship ☐ Yes   ☐ No

Klaris Required? ☐ Yes   ☐ No

Klaris Data to Ship ☐ Yes   ☐ No

Reticle Quality Worksheet

JOB COMMENT:

WAFER DIAMETER:

<<ARRAY PARAMETERS>>

STEP SIZE:
X:

STEP SIZE:
Y:

<<ALIGNMENT PARAMETERS>>

STANDARD KEYS? (Y/*N):

RIGHT KEY OFFSET
X:
Y:

LEFT KEY OFFEST
X:
Y:

EPI SHIFT
X:
Y:

NAME (<CR> TO EXIT PASS SETUP):

PASS COMMENT:

USE LOCAL ALIGNMENT? (Y/*N):Y

FZT OFFSETS
X:
Y:

AWA PARAMETER FILE NAME (NO EXTENSION):

PASS SHIFT:
X:
Y:

RETICLE BAR CODE:

MASKING APERTURE SETTING:
XL:
XR:
YF:
YR:

RETICLE ALIGNMENT OFFSET (MICRONS):
XL:
XR:
Y:

RETICLE ALIGNMENT MARK PHASE (P, *N, X):

Job Specification Worksheet