Introduction to Reduction Steppers

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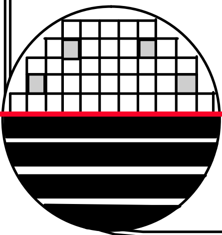

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GCA STEPPER

g-Line Stepper

$\lambda = 436$ nm

NA = 0.28

$\sigma = 0.6$

Resolution

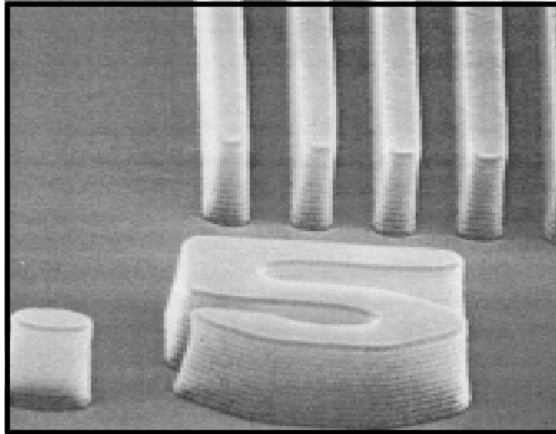
$0.6\ \lambda / NA = \sim 1 \mu m$

20 x 20 mm Field Size

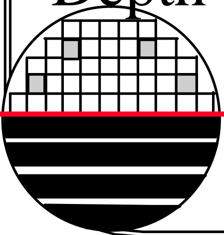
Depth of Focus

$= k_2\ \lambda/(NA)^2 = 3\ \mu m$

CANON FPA-2000 i1 STEPPER



i-Line Stepper $\lambda = 365$ nm
NA = 0.52, $\sigma = 0.6$
Resolution = 0.7 λ / NA = ~0.5 µm
20 x 20 mm Field Size
Depth of focus = $k_2 \lambda/(NA)^2$
= 0.8 µm

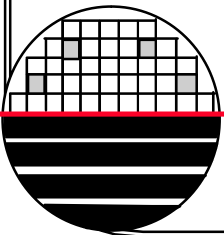


ASML 5500/90 STEPPER

KrF Excimer Laser Stepper
$\lambda = 248$ nm
NA = 0.52, $\sigma = 0.6$
Resolution = 0.7 λ / NA = ~0.3 µm
20 x 20 mm Field Size
Depth of Focus = $k_2\ \lambda/(NA)^2$
~ 0.64 µm

OUTLINE

GCA Stepper
X-Y Stage Laser Interferometer
GCA Reticle
MEBES Mask Making
User Interface
Basic Stepper Jobs
Advanced Stepper Jobs
Irradiance Measurement
Best Focus & Exposure
Baseline Correction
Automatic Wafer Alignment System
Canon APA 2000 i1 Stepper
Canon Reticle
Canon Stepper Jobs
Mini Operation Manual
ASML 5500/90 Stepper



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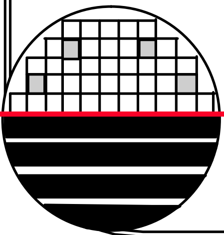
GCA STEPPER

g-Line Stepper
λ = 436 nm
NA = 0.28
σ = 0.6
Resolution
0.6 λ / NA = ~1µm
20 x 20 mm Field Size
Depth of Focus
= $k_2\ \lambda/(NA)^2$ = 3 µm



ELECTRONICS RACK

Computer & Disk Drive

Automatic Digital Wafer Alignment

TV Monitor

Camera Control

Key Board

Manual Shutter &
Integrate / Time Select

Reticle Management System

Automatic Wafer Handler

ARC Lamp Power Supply

STEPPER BODY

RMS - 10

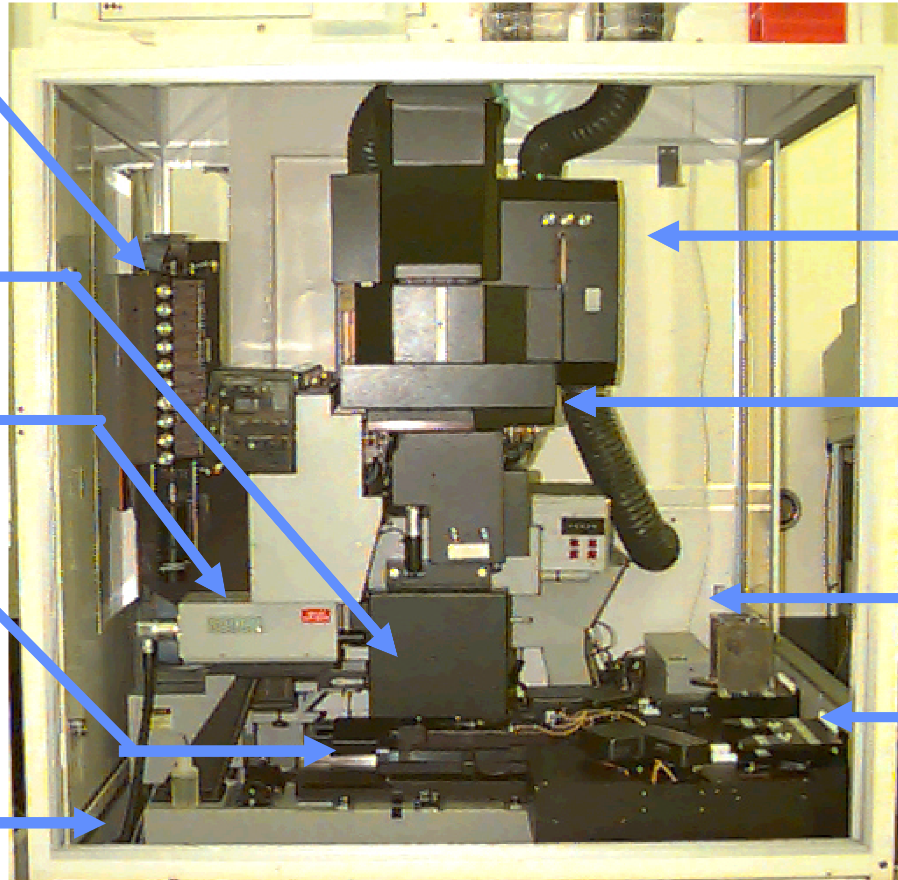
Environmental Chamber (+/- 0.1 C)

Alignment Microscope (76.2 mm)

TV Camera

X-Y Stages, Wafer Chuck

Vibration Isolation Table



Lamp Maximus 1000

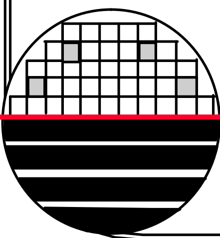
Reticle Apertures

Lens

AWH

Rochester Institute of Technology
Microelectronic Engineering

OPTICAL COLUMN



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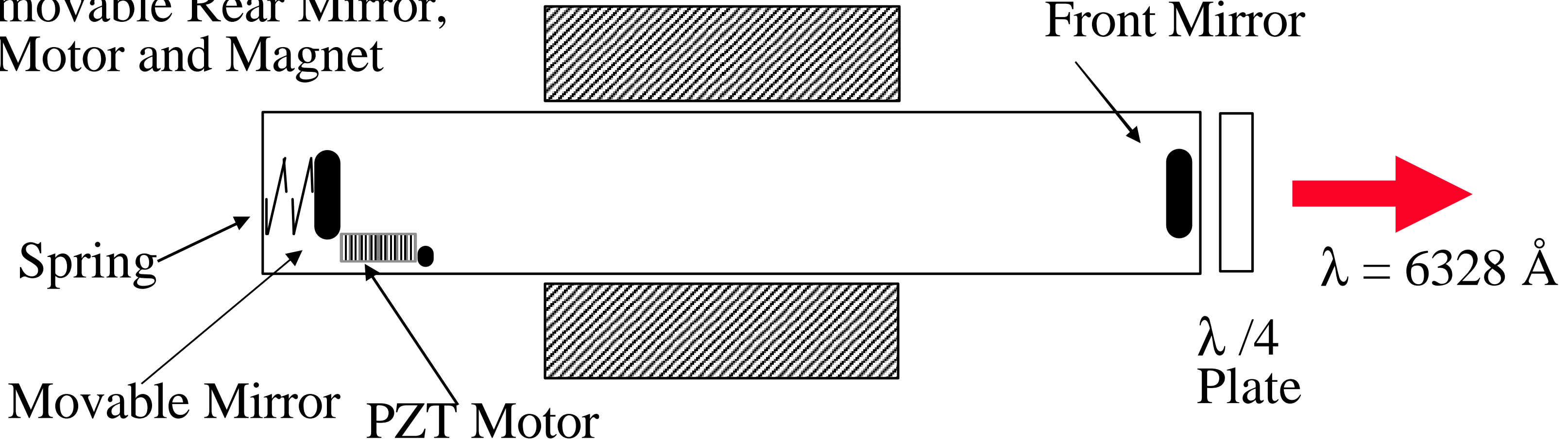
LASER FOR STAGE POSITION MEASUREMENT



The magnet causes Zeeman splitting of the LASER frequency resulting in two circularly polarized frequency components. One left-hand circularly polarized (LHCP) the other RHCP and about 1 M Hz above and below the center frequency, fo. By applying a voltage between 270 and 1800 Volts to the piezoelectric transducer (PZT), the rear mirror can be moved, giving a small amount of resonate cavity length tuning. Tuning makes the strength of LHCP and RHCP components equal. A quarter wave plate makes the output beam have two equal strength, linearly polarized, mutually perpendicular beams.

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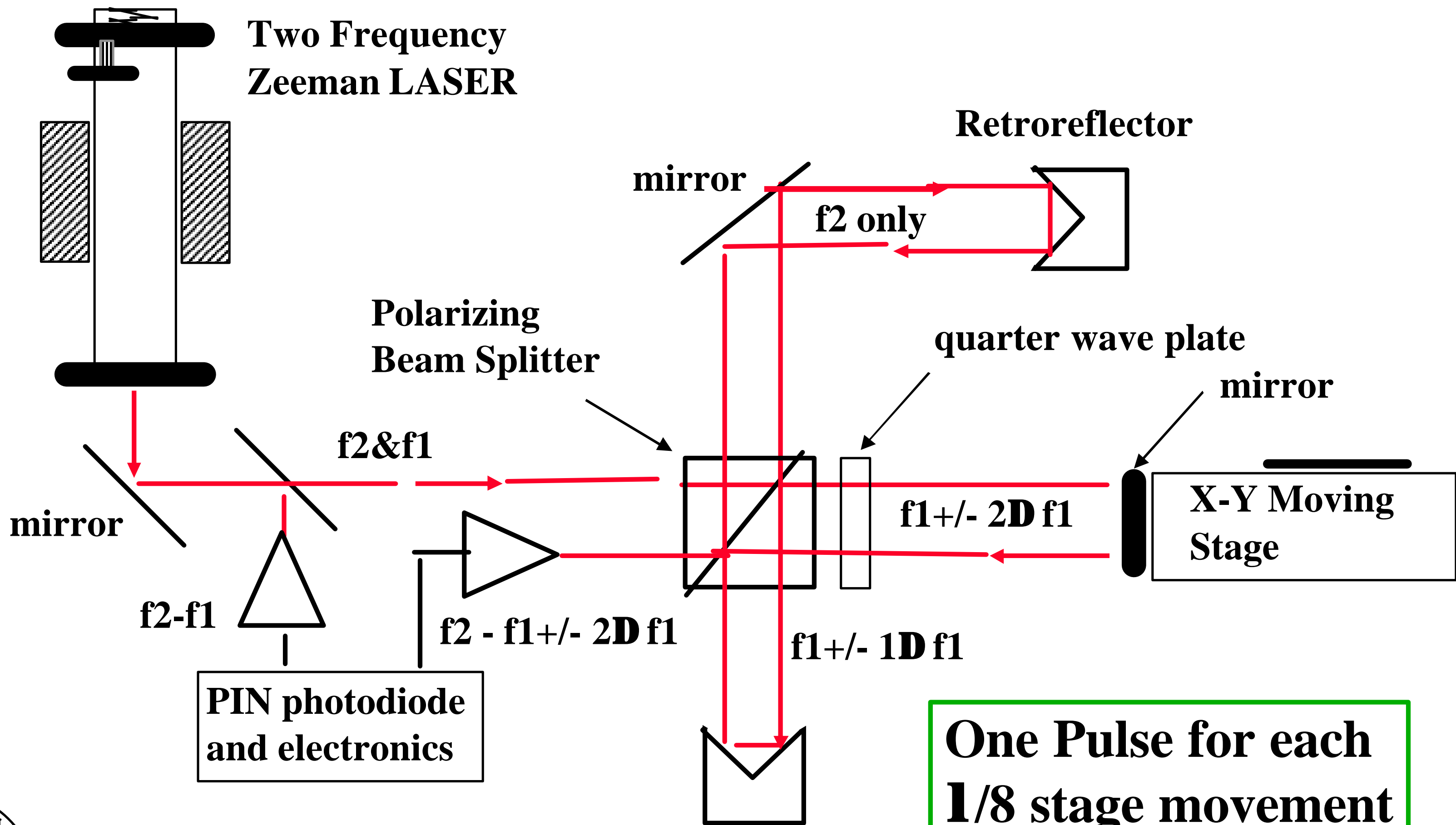
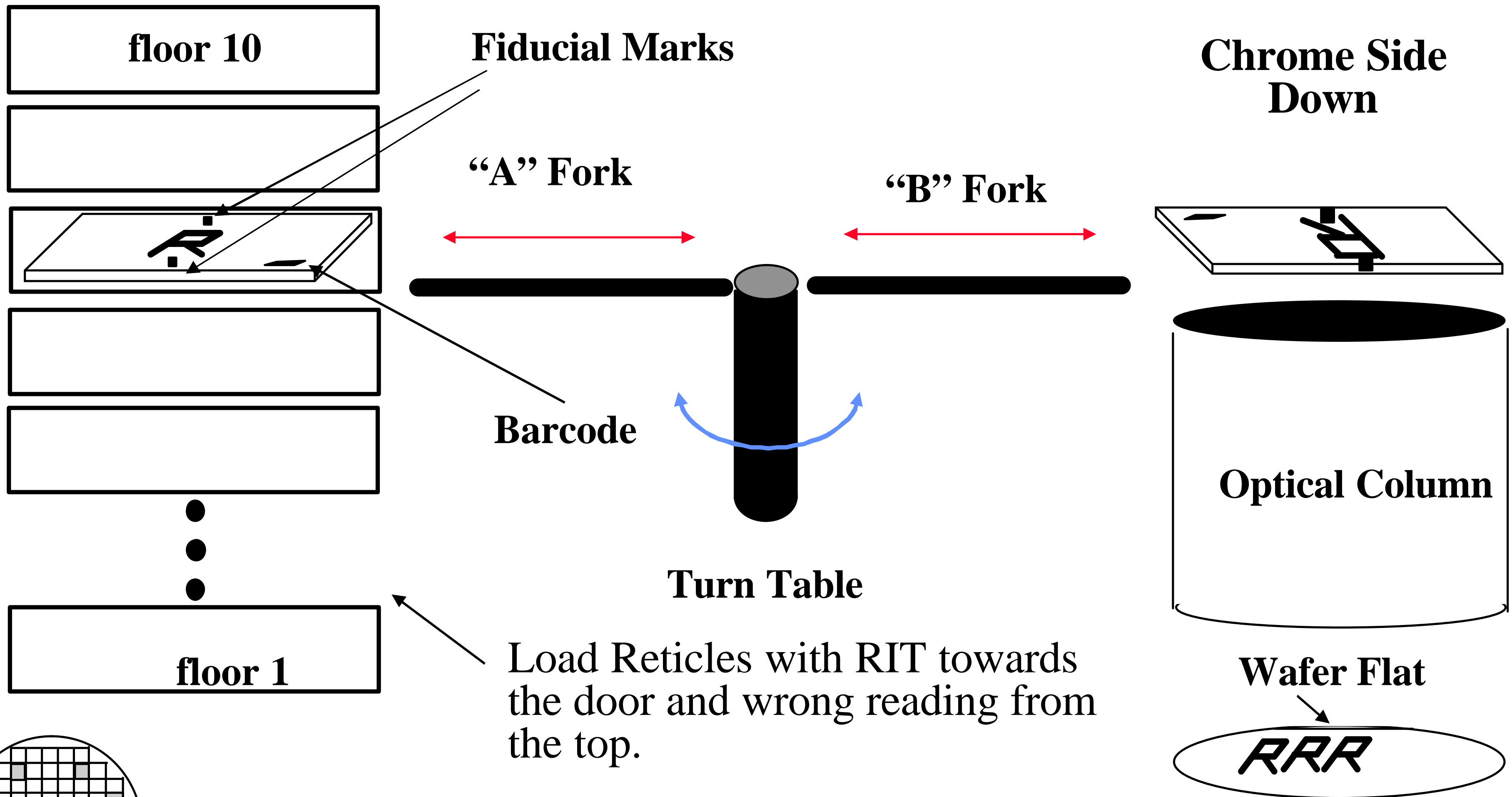
PLANE MIRROR INTERFEROMETR



One Pulse for each
1/8 stage movement
1/8 = 0.08 µm

RETICLE MANAGEMENT SYSTEM



Load Reticles with RIT towards the door and wrong reading from the top.

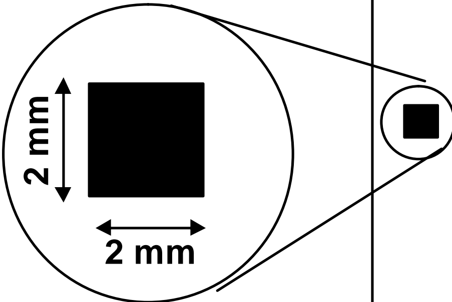
GCA STEPPER RETICLE

12 cm

TITLE1

TITLE2

Clear Fiducials are Negative



Opaque Fiducials are Positive

Maximum 100 mm by 100 mm

BARCODE

RIT

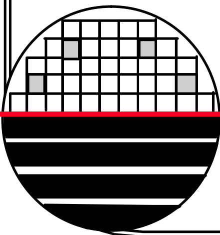
Chip Wrong Reading from Chrome Side

0.0

0.0

12 cm

RIT reads correct from chrome side all other titles read correct from non chrome side



MEBES

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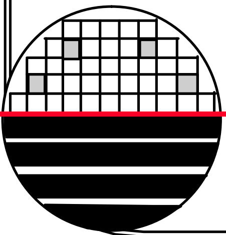
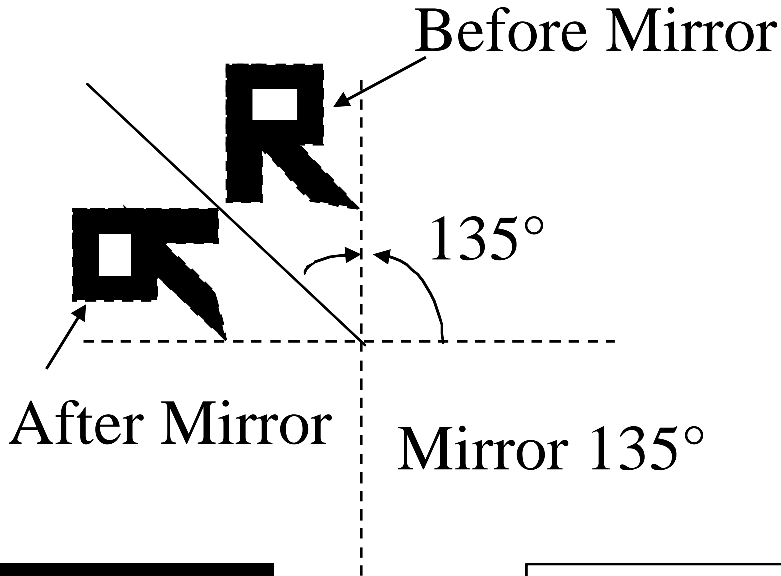
DATA PREP

1. Convert the design files to the proper format for the mask making tool
2. Mirror the design so the lettering will come out correct reading on the wafer
3. Size everything by 5X for stepper reticles
4. Do Boolean combinations of design layers to generate correct lithographic layers. (add resolution targets and overlay verniers)
5. Bias or bloat patters as necessary
6. Add titles, barcodes and labels
7. Add Fiducial marks



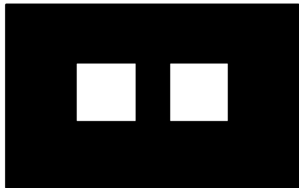
DATA PREP



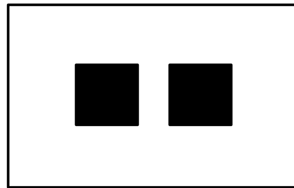
Mentor- ICGraph files (filename.iccel), all layers, polygons with up to 200 vertices

GDS2- CALMA files (old IC design tool) (filename.gds), all layers, polygons

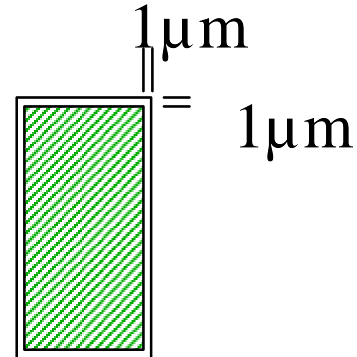
MEBES- files for electron beam maskmaking tool, each file one layer, trapezoids only



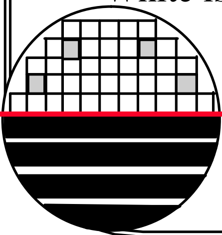
Dark Field: Black is chrome, White is Quartz.



Light Field: Black is chrome, White is Quartz.



BIAS +1µm



EXAMPLE OF A MEBES JOB DECK

SLICE EDIT, 14
OPTICON AA=0.5, BA=0.5, PA, SA=40, VA=10

14 means 5” by 5” glass
AA means address all levels = 0.5 µm
BA means beam size all levels = 0.5 µm
PA means all levels positive resist
SA means all levels spot current 40 nA
VA means all levels acceleration = 10KV

MTITLE 1, PMOS DIFFUSION LAYER
MTITLE 2, PMOS OXIDE LAYER
MTITLE 3, PMOS CONTACT CUTS
MTITLE 4, PMOS METAL LAYER
DTITLE A, RIT SHORT COURSE MASK
ITITLE A, BARCODE
ORIENT A, ITITLE, TITLEROT=90, LOC=116000, 60000

CHIP1, (1,SHORT-LVL-01, RC=15),
$(2,SHORT-LVL-02, RC=15),
$(3,SHORT-LVL-03, RC=15),
$(4,SHORT-LVL-04, RC=15),
ROWS 51918/51915,2,21170

first level of SHORTCOURSE CHIP maskset

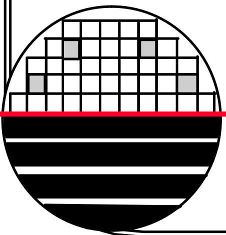
center placed at y=5.1918 cm and repeated twice at x=5.1915 cm and 2.1170 cm

CHIP2, (1,TEST-LVL-01, RC=15),
$(2,TEST-LVL-02, RC=15),
$(3,TEST-LVL-03, RC=15),
$(4,TEST-LVL-04, RC=15),
ROWS 51918/51915,2,21170

first level of PMOS TESTCHIP

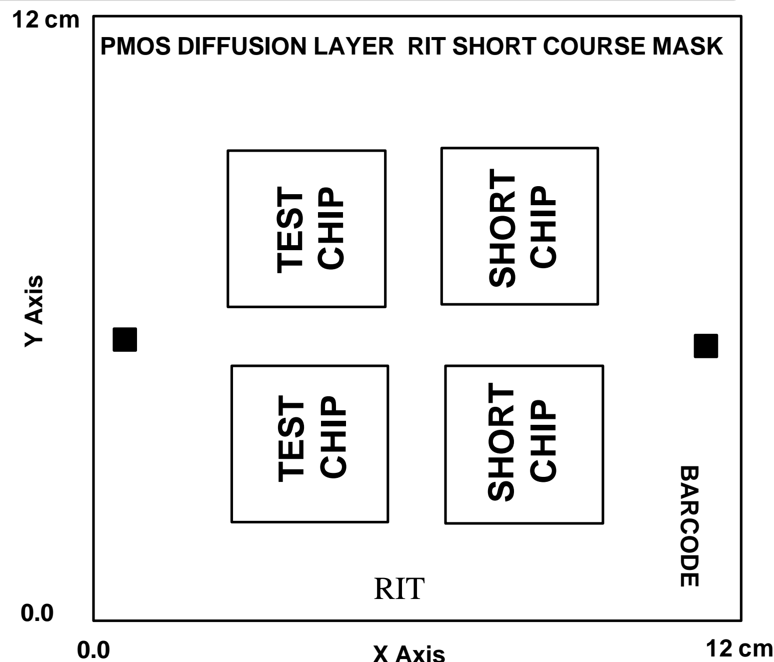
center placed at y=7.3082 cm and repeated twice at x=5.1915 cm and 2.1170 cm

END

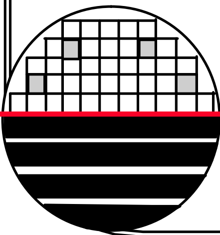


EXAMPLE OF A MEBES PLOT JOB

2/25/93 9:12:23 MEBES 967
REV, 4.6
SPECIFICATION FILE: JOB:SHORT.JB
DTITLE: RIT SHORT COURSE MASK
ITITLE: BARCODE
MTITLE: PMOS DIFFUSION LAYER
CASSETTE TYPE ID:14
LEVEL PLOTTED: 1
JOB SCALE: 1
JOB SCALE: 1.000000
ADDRESSING: 0.500000 MICRONS
PLOT SCALE: 1.00 TO 1 CM



ID PATTERN	X DIMENSION	Y DIMENSION	PLACEMENT	ORIENTATION	TONE
1. SHORTLVL.01	20000.00	20000.00	UNMIRROR	UNMIRROR	NORMAL
2. TESTLVL.01	20000.00	20000.00	UNMIRROR	UNMIRROR	NORMAL
3. GCA6700F1.05	2000.00	2000.00	UNMIRROR	UNMIRROR	NORMAL



HUMAN INTERFACE TO STEPPER

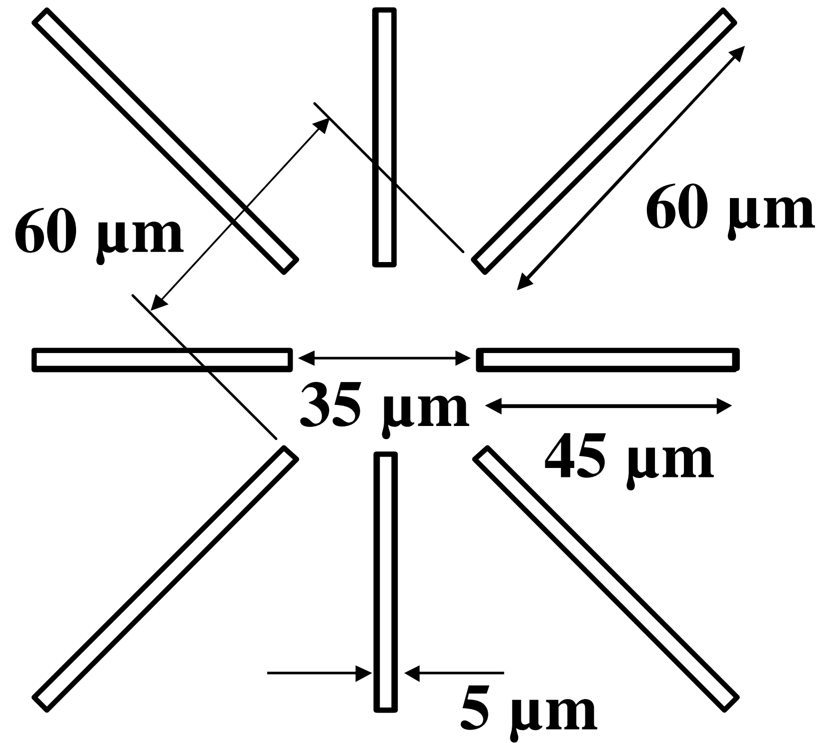
LOG IN

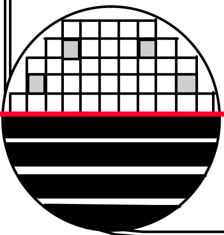
- LOG IN [10,10] password OPER
- LOG IN [13,35] password CLASS

BASIC COMMANDS

- IASLOAD - Loads Integrated Alignment System Software
- RESET - Resets Reticle Management Hardware
- LISTF[XX,YY] - Lists Job Filenames in [XX,YY]account
- SPEC jobname- Creates a Job File
- EDIT filename - Change a Job File
- EXPO jobname - Exposure Matrix with Different Exposue and Focus in Each Die Site
- EXEC jobname - Executes a Job, Only One Exposue Sequence (Pass)
- EXEC jobname\passname1,passname2 - Executes a Job, More Than One Exposue Sequence (Pass)
- COPY [XX,YY]jobname [WW,ZZ]newjobname – copies a Job to a new jobname

GCA ALIGNMENT KEYS





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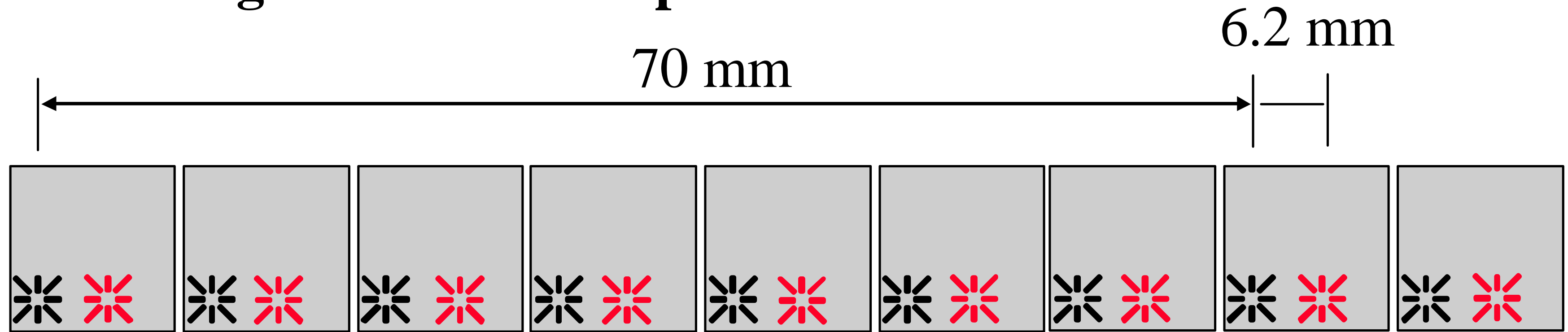
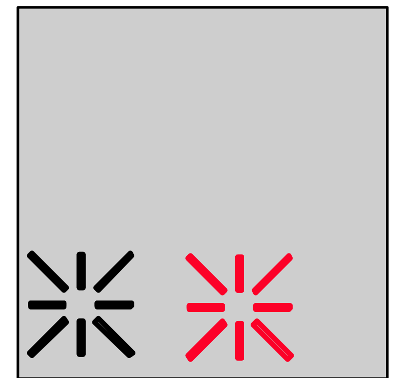
SECONDARY ALIGNMENT MARKS

Alignment marks must be 76.2 mm apart to match the spacing on the alignment microscope.



Example: Assume that the die plus street distance is 10 mm Then 76.2 mm/10mm is not an integer so secondary alignment mark is needed 6.2 mm to right of primary alignment mark.



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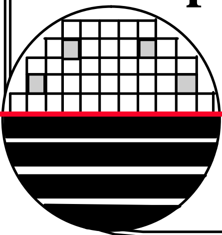
BASIC STEPPER JOBS

Wafer Diameter	**100 mm**			
Step Size in X	**76.2mm/5mm=15.24 and 76.2mm/15=5.08 mm**			
How Many Columns	**100/5.08 = 19 minus 1 because of flat = 18**			
Step Size in Y	**5.08mm**			
How Many Rows	**18**			
Right Alignment Die	**R:**	**11**	**C:**	**16**
Right Key Offset	**X:**	**1.88468 mm**	**Y:**	**-1.94205 mm**
Left Alignment Die	**R:**	**11**	**C:**	**2**
Left Key Offset	**X:**	**1.88468 mm**	**Y:**	**-1.94205 mm**
Pass 1				
Exposure	**0.6 seconds**			
Focus	**250**			
Shift	**X:**	**0**	**Y:**	**0**
Aperture Setting	**XL=37.5 mm, XR=37.5, YF=37.5, YR=37.5**			
Aperture Offset	**XL=0, XR=0, YF=0, YR=0**			



EXAMPLE OF SIMPLE (ONE PASS) STEPPER JOB

EXAMPLE: (Device Chip Only, One Level Per Reticle, One Die Per Reticle)
This example is for jobs where there is only a device chip on the wafer. The device chip reticle patterns are placed on the photomask one level per piece of quartz and the center of the chip is placed at the center of the reticle. The maximum size of the device chip is 10000 um by 10000 um. Such a job is run by the command EXEC JOBNAME\PASS_1_NAME for all lithography steps.

The first level must have alignment marks in two die locations 76.2mm apart. An easy way to achieve this is to divide 76.2 mm by the die size and truncate that number creating an integer. Then divide 76.2 by this integer (or any integer smaller than this) to get the die-to-die spacing. for example, a 4000 X 4000 micron die gives 76.2mm/4mm = 19.05; thus the die-to-die space is 76.2mm/19 = 4.0105263mm This spacing leaves 10 microns between die for sawing which is tight. Using n=18 gives 76.2mm/18 = 4.23333 mm die-to-die spacing, leaving 233 microns between die for sawing. Which is easy. The number of die per row is equal to the wafer diameter divided by the step size. Example: 100 mm/4.2333mm = 23 die.

The GCA steppers are programmed in an interactive conversational mode using the EDIT or SPEC command. The items that may change from job to job are highlighted in the example below.

EXAMPLE OF SIMPLE (ONE PASS) STEPPER JOB

:SPEC **JOBNAME**
METRIC JOB CREATED: time,date
UPDATE CREATION DATE?(*Y/N)
JOB COMMENT:
4" WAFER, DEVICE CHIP ONLY, 5X5MM CHIP
TOLERENCE(1,2,*3,4,5,6):
SCALE CORRECTIONS
X, PPM (-128<P<+128):
Y, PPM (-128<P<+128):
ORTHOGONALITY, PPM (-128<P<+128):
LEVELER BATCH SIZE [1-25]: 1
WAFER DIAMETER 108
<<ARRAY PARAMETERS>>
STEP SIZE IN X: **5.08000**
*C-OUNT, S-PAN OR A-LL:
HOW MANY COLUMNS? **18**
STEP SIZE IN Y: **5.08000**
*C-OUNT, S-PAN OR A-LL:
HOW MANY ROWS? **18**
TRANSLATE ORIGIN
IN X:
IN Y:
DISPLAY? (Y/*N):
LAYOUT?(Y/*N):
ADJUST?(Y/*N)

<<ALIGNMENT PARAMETERS>>
STANDARD KEYS? (Y/*N):
RIGHT ALIGNMENT DIE CENTER
R:11
C:16
RIGHT KEY OFFSET
IN X: **1.88468**
IN Y: **-1.94205**
LEFT ALIGNMENT DIE CENTER
R:11
C: 2
LEFT KEY OFFSET
IN X: **1.88468**
IN Y: **-1.94205**
EPI SHIFT
IN X:
IN Y:

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EXAMPLE OF SIMPLE (ONE PASS) STEPPER JOB

<<PASS>>
NAME: **1**
PASS COMMENT:
USE PASS 1 FOR ALL LITHOGRAPHY STEPS
EXPOSURRE (SEC.): **0.350**
FOCUS SETTING: **250**
DXD BATCH CHARACTERIZATION SIZE (-1=NO DXD): -1
AWA PARAMETER FIKLE NAME (NO EXTENSION) (NONE)
SHIFT
IN X:
IN Y:
RETICLE BAR CODE: NONE

XL MASKING APERTURE SETTING: **37mm**
XR MASKING APERTURE SETTING: **37mm**
YF MASKING APERTURE SETTING: **37mm**
YR MASKING APERTURE SETTING: **37mm**

XL MASKING APERTURE OFFSET:
XL MASKING APERTURE OFFSET:
YF MASKING APERTURE OFFSET:
YR MASKING APERTURE OFFSET:

XL RETICLE ALIGNMENT OFFSET:
XR RETICLE ALIGNMENT OFFEST:
Y RETICLE ALIGNMENT OFFSET:

RETICLE ALIGNMENT MARK PHASE (P,*N,X): **N**
A-RRAY OR P-LUG: A

<<END PASS SET-UP>>
SAVE PASS?(*Y/*N):
NAME (<CR> TO EXIT PASS SETUP):
WRITE TO DISK? (*Y/N):
PURGE EDITED FILES ? (*Y/N):

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EXAMPLE OF 4 LEVEL PER MASK STEPPER JOB

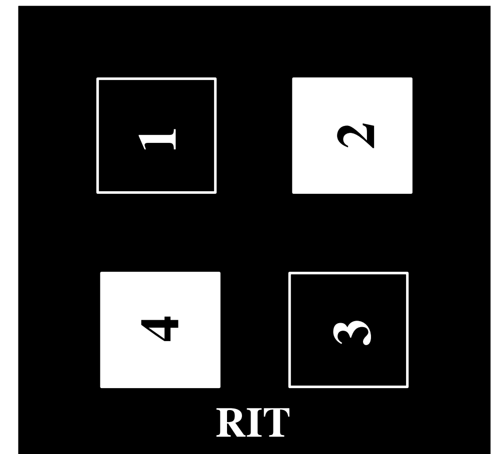
EXAMPLE: (Device Chip Only, Four Levels of One Die Per Reticle)

This example is for jobs where there is only a device chip on the wafer. The device chip reticle patterns are placed on the photomask four levels per mask. Level 1 in quadrant 2, level 2 in quadrant 1, level 3 in quadrant 4, level 4 in quadrant 3 as viewed from the chrome side of the mask with the RIT at the bottom. The masking apertures are offset to block out all but the desired pattern. The images are shifted to the center of the row and column die location. The global alignment mark is on level one and is located with respect to the center of the alignment die at the given row and column. The center of the chip design in the second quadrant is located at X= -20mm and Y= -20mm with respect to the center of the reticle, and will thus be placed off center on the wafer by X= -4mm and Y= -4mm so the first pass should have shifts of X= 4mm and Y= 4mm.

Such a job is run by the command:

EXEC JOBNAME\PASS_1_NAME for the first lithography step
EXEC JOBNAME\PASS_2_NAME for the second lithography step
EXEC JOBNAME\PASS_3_NAME for the third lithography step
EXEC JOBNAME\PASS_4_NAME for the fourth lithography step
use pass 1,2,3,4 again for levels 5,6,7,8, etc.

Chrome Side



EXAMPLE OF 4 LEVEL PER MASK STEPPER JOB

:SPEC JOBNAME
METRIC JOB CREATED: time,date
UPDATE CREATION DATE?(*Y/N)
JOB COMMENT:
4" DEVICE CHIP ONLY, 5X5MM CHIP, 4 LEVELS/MASK TYPE PROJECTS
TOLERENCE(1,2,*3,4,5,6):
SCALE CORRECTIONS
X, PPM (-128<P<+128):
Y, PPM (-128<P<+128):
ORTHOGONALITY, PPM (-128<P<+128):
LEVELER BATCH SIZE [1-25]: 1
WAFER DIAMETER 108
<<ARRAY PARAMETERS>>
STEP SIZE IN X: **5.08000**
*C-OUNT, S-PAN OR A-LL:
HOW MANY COLUMNS? **18**
STEP SIZE IN Y: **5.08000**
*C-OUNT, S-PAN OR A-LL:
HOW MANY ROWS? **18**
TRANSLATE ORIGIN
IN X:
IN Y:
DISPLAY? (Y/*N):
LAYOUT?(Y/*N):
ADJUST?(Y/*N)

<<ALIGNMENT PARAMETERS>>
STANDARD KEYS? (Y/*N):
RIGHT ALIGNMENT DIE CENTER
R:11
C:16
RIGHT KEY OFFSET
IN X: **1.88468**
IN Y: **-1.94205**
LEFT ALIGNMENT DIE CENTER
R:11
C: 2
LEFT KEY OFFSET
IN X: **1.88468**
IN Y: **-1.94205**
EPI SHIFT
IN X:
IN Y:

PASS 1

<<PASS>>
NAME: **1**
PASS COMMENT:
LEVEL 1, 2ND QUADRANT, FROM CHROME SIDE
EXPOSURE (SEC.): **0.350**
FOCUS SETTING: **250**
DXD BATCH CHARACTERIZATION SIZE (-1=NO DXD): -1
AWA PARAMETER FILE NAME (NO EXTENSITON) (NONE)
SHIFT
IN X: **+4.00**
IN Y: **+4.00**
RETICLE BAR CODE: NONE
XL MASKING APERTURE SETTING: **36.50000**
XR MASKING APERTURE SETTING: **36.50000**
YF MASKING APERTURE SETTING: **36.50000**
YR MASKING APERTURE SETTING: **36.50000**

XL MASKING APERTURE OFFSET: **20.00000**
XR MASKING APERTURE OFFSET: **-20.00000**
YF MASKING APERTURE OFFSET: **-20.00000**
YR MASKING APERTURE OFFSET: **20.00000**

XL RETICLE ALIGNMENT OFFSET:
XR RETICLE ALIGNMENT OFFEST:
Y RETICLE ALIGNMENT OFFSET:

RETICLE ALIGNMENT MARK PHASE (P,*N,X): **N**
A-RRAY OR P-LUG: A
<<END PASSSET-UP>>
SAVE PASS? (*Y/N):

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PASS 2

<<PASS>>
NAME: **2**
PASS COMMENT:
LEVEL 2, 1st QUADRANT, FROM CHROME SIDE
EXPOSURE (SEC.): **0.350**
FOCUS SETTING: **250**
DXD BATCH CHARACTERIZATION SIZE (-1=NO DXD): -1
AWA PARAMETER FILE NAME (NO EXTENSITON) (NONE)
SHIFT
IN X: **-4.00**
IN Y: **+4.00**
RETICLE BAR CODE: NONE
XL MASKING APERTURE SETTING: **36.50000**
XR MASKING APERTURE SETTING: **36.50000**
YF MASKING APERTURE SETTING: **36.50000**
YR MASKING APERTURE SETTING: **36.50000**

XL MASKING APERTURE OFFSET: **20.00000**
XR MASKING APERTURE OFFSET: **-20.00000**
YF MASKING APERTURE OFFSET: **20.00000**
YR MASKING APERTURE OFFSET: **-20.00000**

XL RETICLE ALIGNMENT OFFSET:
XR RETICLE ALIGNMENT OFFEST:
Y RETICLE ALIGNMENT OFFSET:

RETICLE ALIGNMENT MARK PHASE (P,*N,X): **N**
A-RRAY OR P-LUG: A
<<END PASSSET-UP>>
SAVE PASS? (*Y/N):

PASS 3

<<PASS>>
NAME: **3**
PASS COMMENT:
LEVEL 3, 4TH QUADRANT, FROM CHROME SIDE
EXPOSURE (SEC.): **0.350**
FOCUS SETTING: **250**
DXD BATCH CHARACTERIZATION SIZE (-1=NO DXD): -1
AWA PARAMETER FILE NAME (NO EXTENSITON) (NONE)
SHIFT
IN X: **-4.00**
IN Y: **-4.00**
RETICLE BAR CODE: NONE
XL MASKING APERTURE SETTING: **36.50000**
XR MASKING APERTURE SETTING: **36.50000**
YF MASKING APERTURE SETTING: **36.50000**
YR MASKING APERTURE SETTING: **36.50000**

XL MASKING APERTURE OFFSET: **20.00000**
XR MASKING APERTURE OFFSET: **-20.00000**
YF MASKING APERTURE OFFSET: **20.00000**
YR MASKING APERTURE OFFSET: **-20.00000**

XL RETICLE ALIGNMENT OFFSET:
XR RETICLE ALIGNMENT OFFEST:
Y RETICLE ALIGNMENT OFFSET:

RETICLE ALIGNMENT MARK PHASE (P,*N,X): **N**
A-RRAY OR P-LUG: A
<<END PASSSET-UP>>
SAVE PASS? (*Y/N):

PASS 4

<<PASS>>
NAME: **4**
PASS COMMENT:
LEVEL 4, 3RD QUADRANT, FROM CHROME SIDE
EXPOSURE (SEC.): **0.350**
FOCUS SETTING: **250**
DXD BATCH CHARACTERIZATION SIZE (-1=NO DXD): -1
AWA PARAMETER FILE NAME (NO EXTENSITON) (NONE)
SHIFT
IN X: **+4.00**
IN Y: **-4.00**
RETICLE BAR CODE: NONE
XL MASKING APERTURE SETTING: **36.50000**
XR MASKING APERTURE SETTING: **36.50000**
YF MASKING APERTURE SETTING: **36.50000**
YR MASKING APERTURE SETTING: **36.50000**

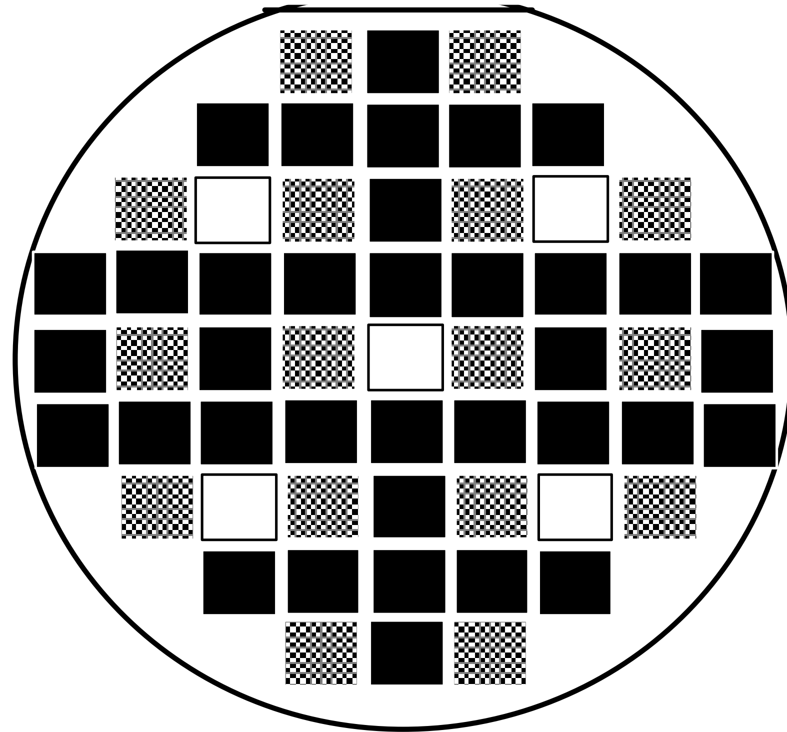
XL MASKING APERTURE OFFSET: **-20.00000**
XR MASKING APERTURE OFFSET: **20.00000**
YF MASKING APERTURE OFFSET: **20.00000**
YR MASKING APERTURE OFFSET: **-20.00000**

XL RETICLE ALIGNMENT OFFSET:
XR RETICLE ALIGNMENT OFFEST:
Y RETICLE ALIGNMENT OFFSET:

RETICLE ALIGNMENT MARK PHASE (P,*N,X): **N**
A-RRAY OR P-LUG: A
<<END PASSSET-UP>>
SAVE PASS? (*Y/N):

ADVANCED STEPPER JOBS

- Blank Test Site
- Device Die Locations
- Test Die Locations



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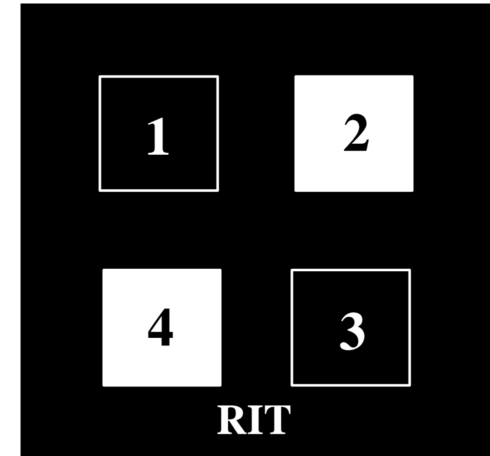
ADVANCED STEPPER JOBS (CONTINUED)

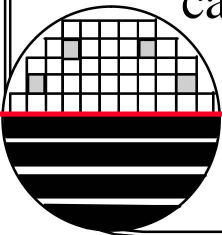
Each Level has Three Passes, Test Chip - Device Chip - Test Site
Each Plate has Four Levels
Alignment is Always to the Test Chip
Step Size is Selected to be Compatible with Semi-Automated Tester
GCA 6700 Steppers, 5X, G-Line, Positive Resist,
Overlay Vernier and CD Linewidth Measurements made each Level



Chrome Side

EXEC [10,20]CMOS0944A.FAC\3T,3D,OPEN

by setting the aperture blades to cover three of the levels a single level can be exposed. Combined with the correct shift of the wafer for each level the images can be made to overlay.

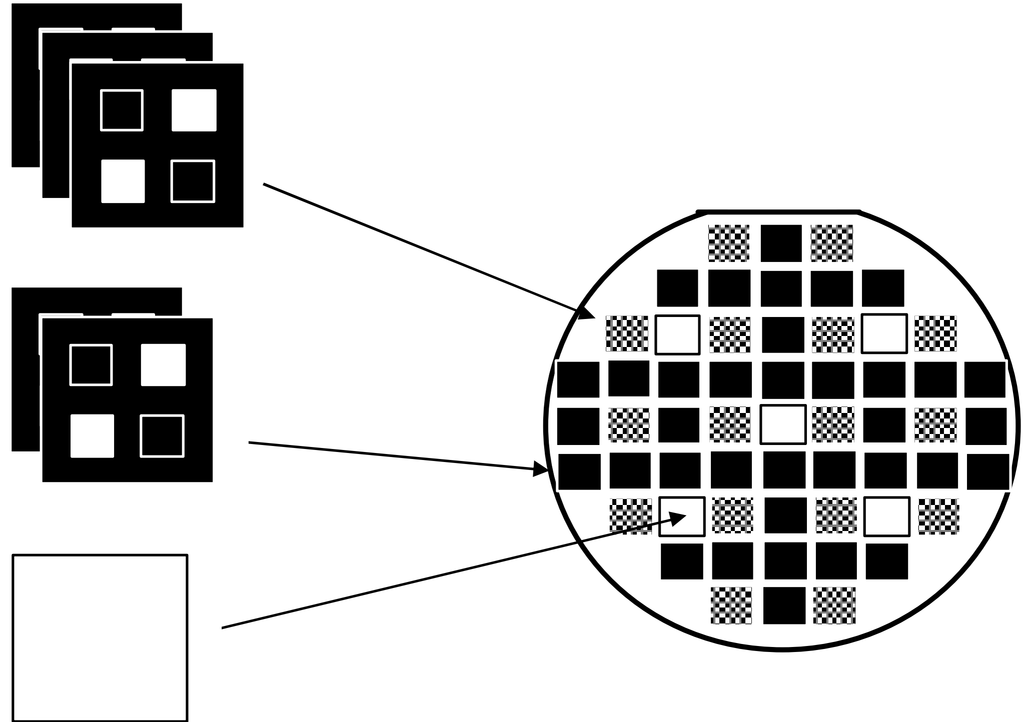


EXAMPLE MASK SET NEEDED FOR FACTORY JOB

Testchip Plate 1,2,3
- Plate 1 has levels 1,2,3,4
- Plate 2 has levels 5,6,7,8
- Plate 3 has levels 9,10,11

Analog Chip 971
- Plate 1 has levels 1,2,3,4
- Plate 2 has levels 5,6,8,9
- Level 4 and 7 are the same

Blank Glass



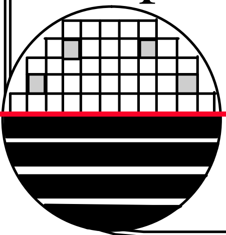
To do a level 7 (n+ D/S) job use Testchip Plate 2 and Analog Chip Plate 1 and Blank Glass and stepper job: EXEC [10,20]CMOS0944B.FAC\7T,7D,OPEN

IRRADIANCE MEASUREMENT

Run any job (example: EXEC MAXIMUS) and load plain glass plate, set radiometer on the glass plate and close the illumination condenser housing, open the shutter using the manual shutter switch, measure the irradiance and multiply by 25 to get irradiance, I, at the wafer.

With the shutter select switch in the timed position the shutter will actually be opened the exact time stated in the execute or expose job. The exposure E will equal I times t. **(E = it)**

In the integrate position the dose will be relative to the dose obtained for a 0.1 second open shutter measured during machine set up in February 1991. At that time with the lamp in use the 0.1 seconds was equal to 25 mj/cm2. Thus a 0.1 time setting in the integrate position will always give 25 mj/cm2 but the time may be longer if the lamp output is lower or shorter if the lamp output is higher. Example: 0.5 seconds will give a dose of 125 mj/cm2 in the integrate mode.

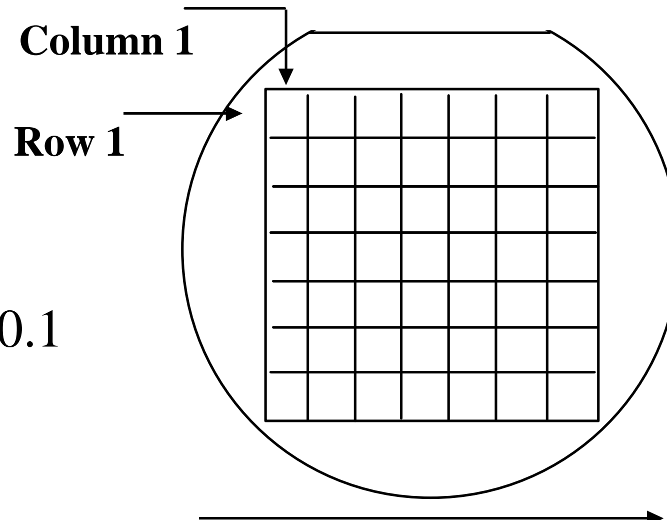


BEST FOCUS & EXPOSURE

To experimentally determine the best focus and exposure for a stepper one can use a special photomask that has focus stars and resolution targets and a special stepper job that sets up an array in which each row is at a different focus setting and each column is at a different exposure setting.

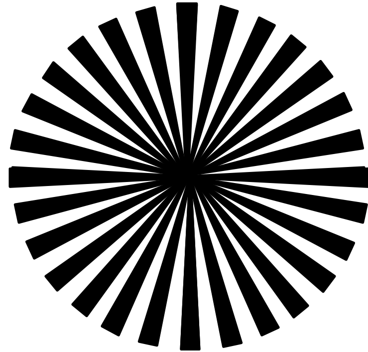
The RIT mask and stepper job (EXPO FOCEX.NEW) makes it possible to view the entire 7 by 7 array without moving the microscope stage. This makes it easy to compare focus stars and resolution patterns.

STEPPER DIALOG
Rows = 7
Columns = 7
Start Exposure = 0.1
Exposure Increments = 0.1
Start Focus = 220
Focus Increments = 10

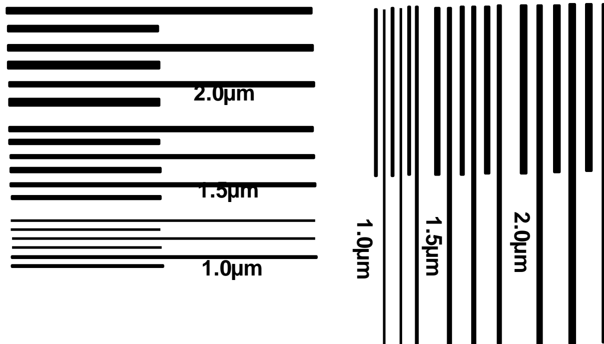


Focus values from 0 to 500 Nominal is 250, each 50 units is about 1 µm focus change

FOCUS STARS & RESOLUTION STRUCTURES



Focus stars are 2 µm at outside perimeter and each tick mark is 0.5 µm. The image with the smallest diameter center in a given column is the row of best focus.



Resolution structures are 1.0, 1.5 and 2.0 µm lines and spaces in both horizontal and vertical orientation. The column with equal lines and spaces is the best exposure.

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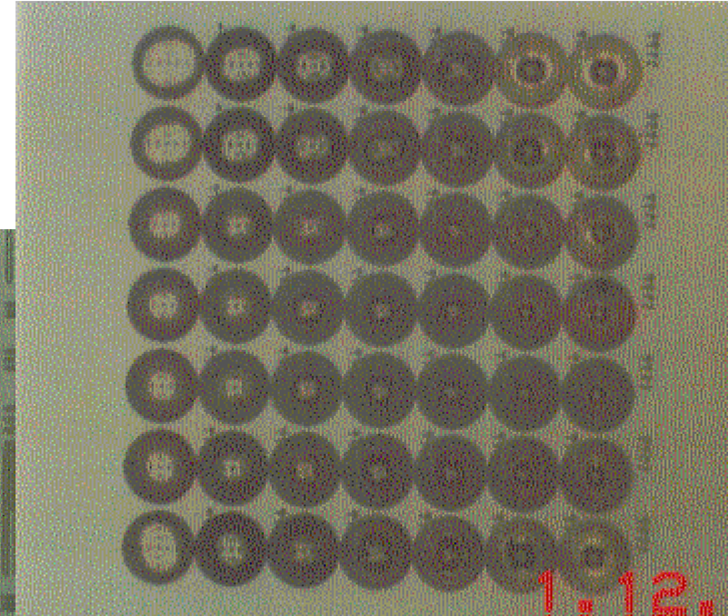
FOCEX.NEW

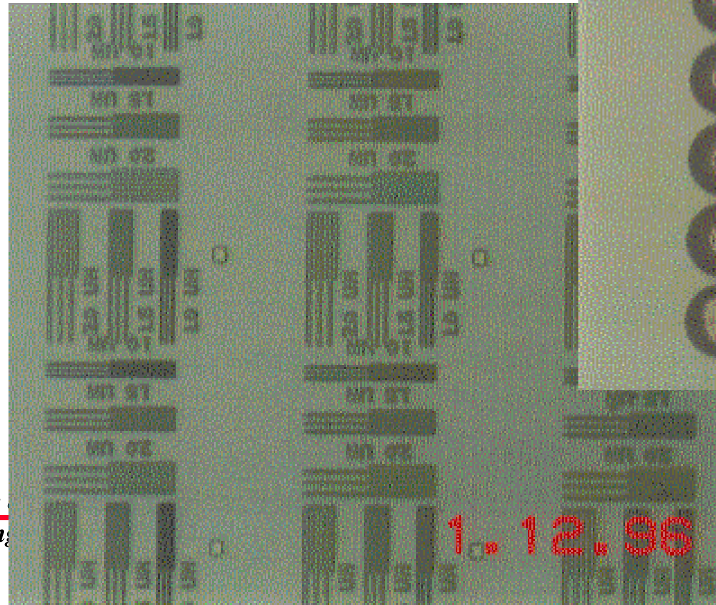
To experimentally determine the best focus and exposure for a stepper one can use a special photomask that has focus starts and resolution targets and a special stepper job that sets up an array in which each row is at a different focus setting and each column is at a different exposure setting.

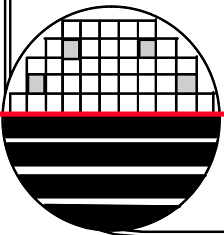
The new mask and stepper job (new in January 1996) makes is possible to view the entire 7 by 7 array without moving the microscope stage. This makes it easy to compare focus stars and resolution patterns.

THE PROCEEDURE:
1. Find and load the new focus exposure mask labeled FOCEX.NEW.
This mask has a focus star and resloution targets with patterns from 2.0 to 0.5 micrometers

2. Use the stepper command **EXPO FOCEX.NEW**
In the stepper dialog use the following settings
number of rows = 7
number of columns = 7
starting exposure = 0.1
exposure increments = 0.1
starting focus = 220
focus increments =10





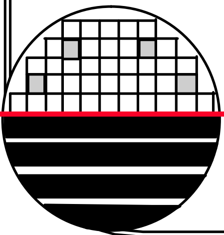


BASELINE CORRECTION

Base Line correction is a precise measurement of the difference between the actual and nominal distance to the center of the optical column from the location of the alignment microscope. Since the wafers are aligned to the alignment reticle then moved under the optical column for exposure, this distance must be know to ~ 0.1μm.

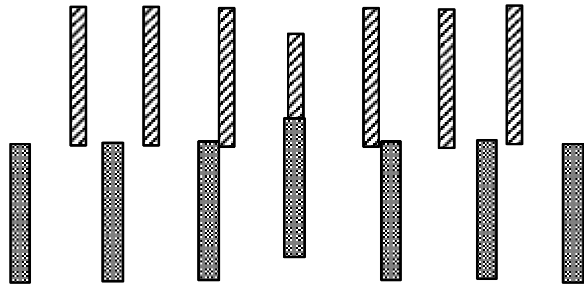
To make this measurement a special mask with optical overlay verniers is used with a special exposure sequence. A wafer is exposed with the first level and after development is placed in the stepper for exposure of the second level. The second level is aligned and is shifted during exposure so that the verniers can interlock. Any error must be due to an error in the base line correction number.

The error in the base line correction is a statistical quantity. Ideally the number is randomly distributed around zero with a small variance. These fluctuations are caused by slight errors in loading the mask, alignment errors, temperature change, etc. To make good working devices at 1 μm alignment must be good to about 0.3 μm.

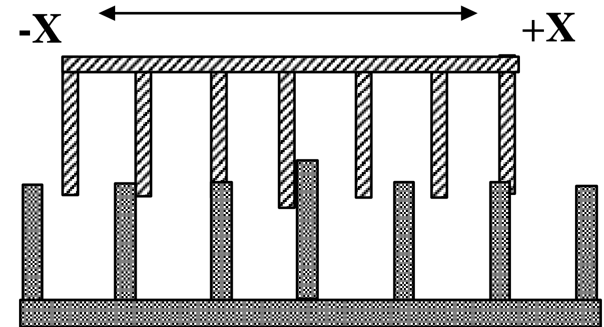


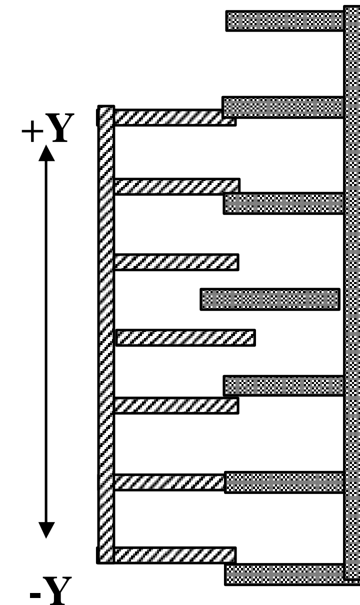
OVERLAY VERNIERS

Second Level Marks on 10 µm Spaces

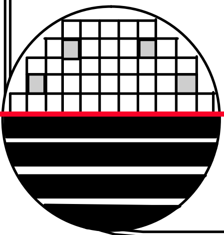


First Level Marks on 11 µm Spaces



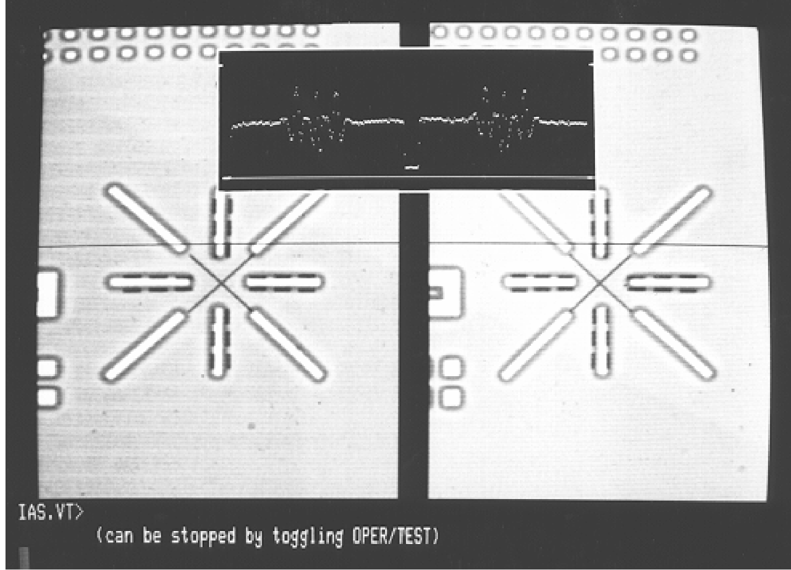


Example shows alignment error of -1 µm in X and -2 µm in Y

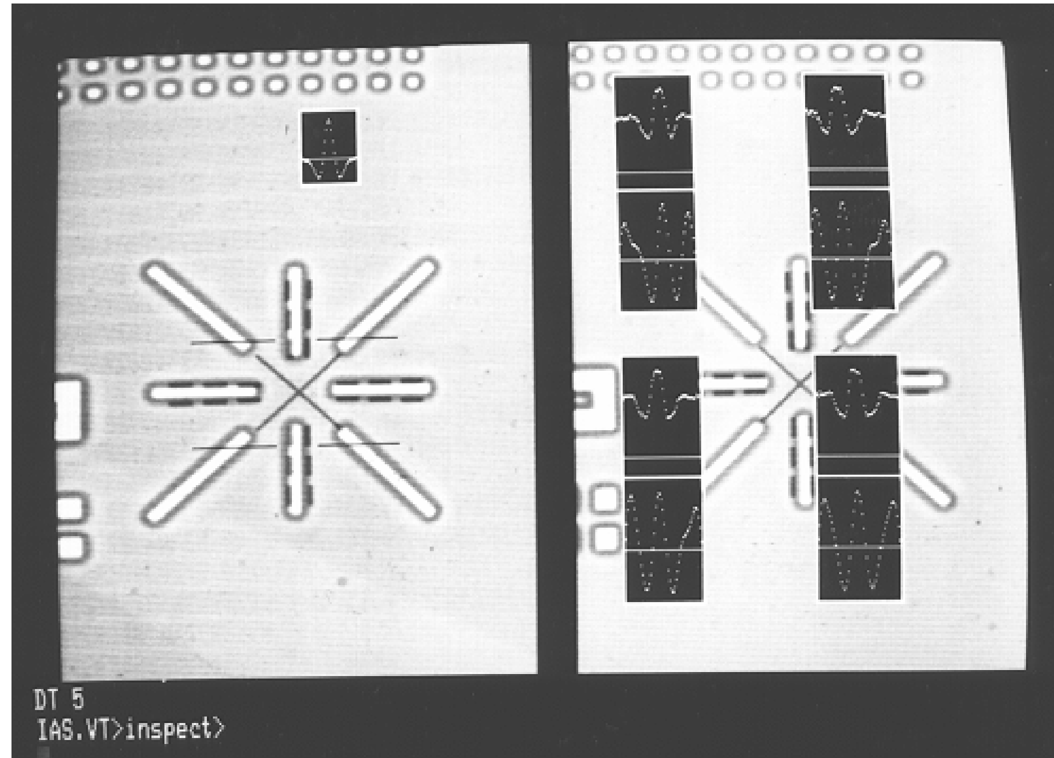


GCA AUTOMATIC WAFER ALIGNMENT SYSTEM

Digital pattern recognition system is used to auto align wafers



Intensity scan to set gain and contrast



Digital filter on the left, four scans, digital intensity on top, convolved output on bottom

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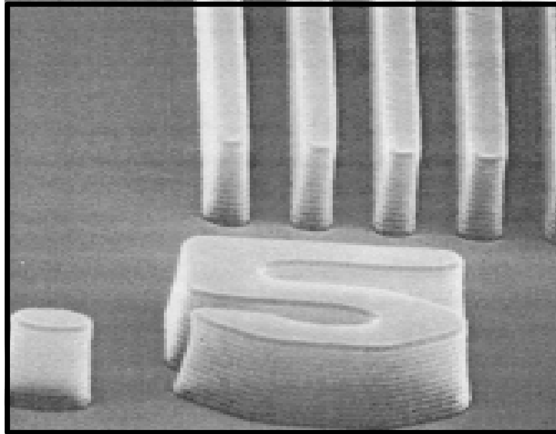
CANON FPA-2000 i1 STEPPER



i-Line Stepper λ = 365 nm

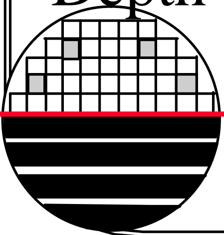
NA = 0.52, σ = 0.6

Resolution = 0.7 λ / NA = ~0.5 µm

20 x 20 mm Field Size

Depth of focus = $k_2 \lambda/(NA)^2$

= 0.8 µm



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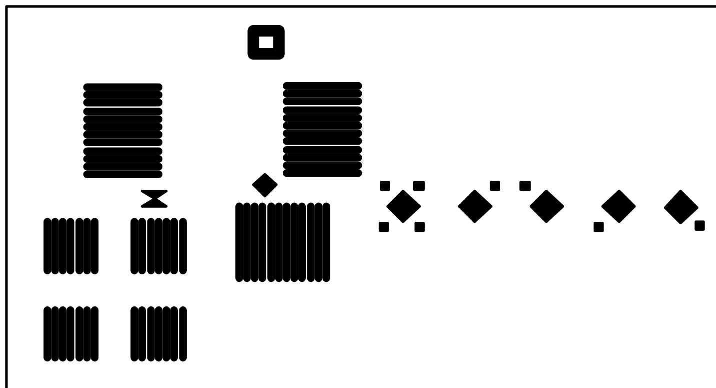
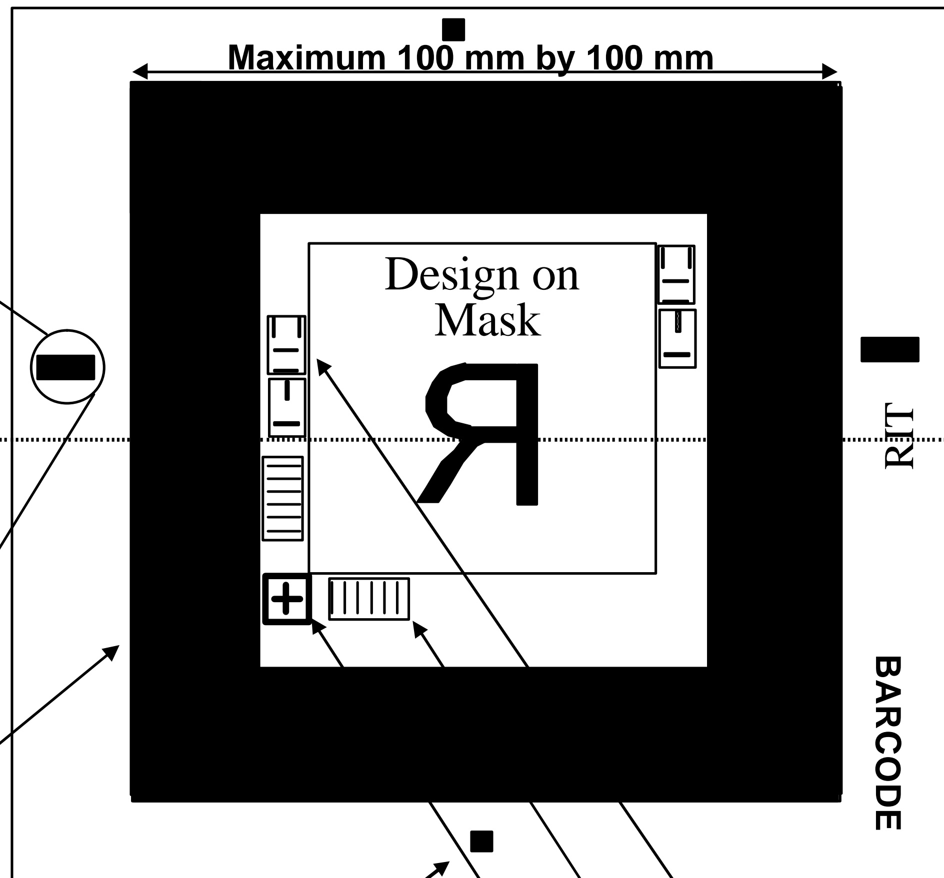
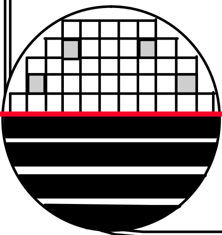
CANON FIDUCIAL MARKS

RIT reads correct from chrome side all other titles read correct from non-chrome side, Chip is wrong reading from chrome side.

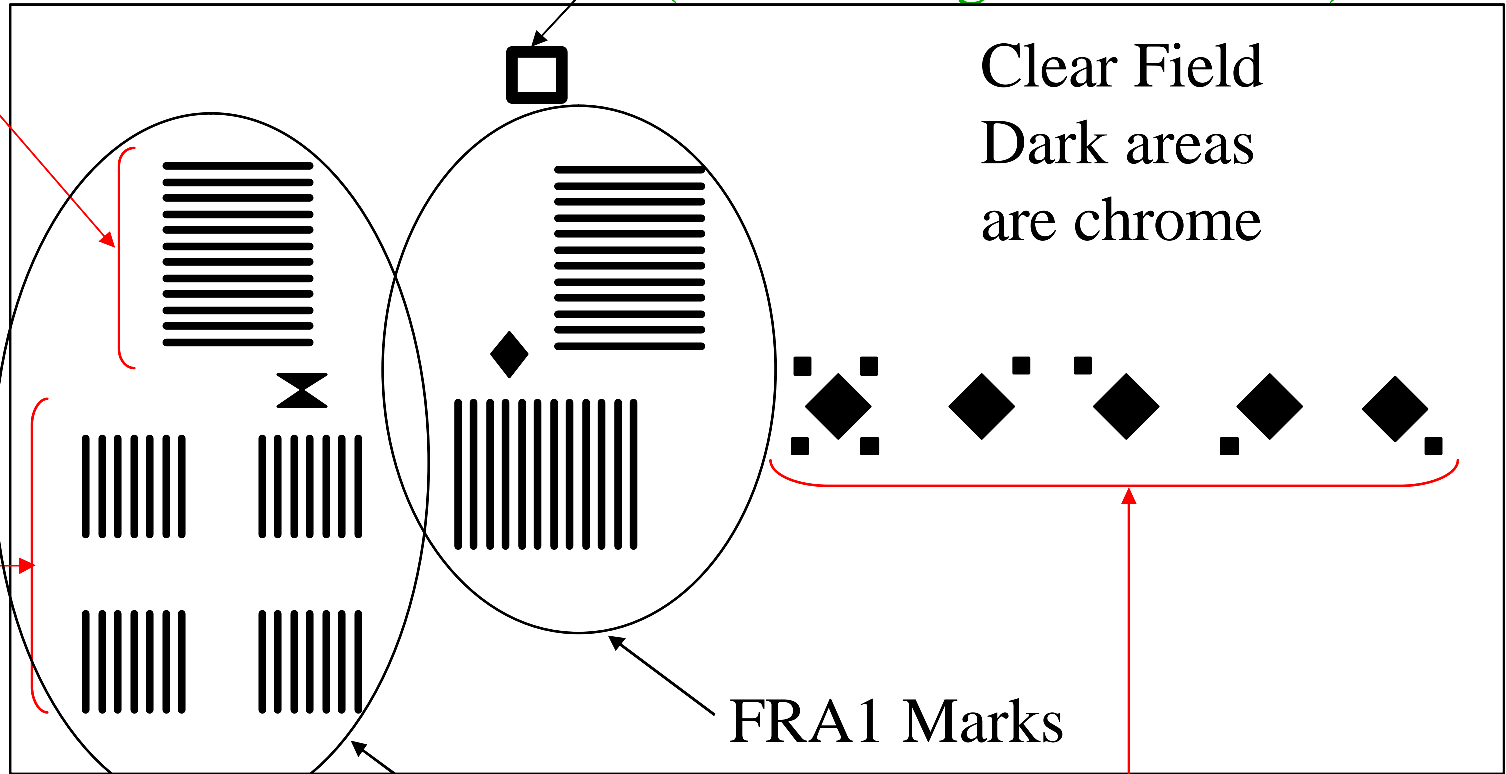


Opaque Fiducials marks in clear field





FINE RETICAL ALIGNMENT (FRA) FIDUCIAL MARKS



TV PRE ALIGNMENT (TVPA) MARKS

- The TVPA Marks are placed by the designer on design
- TVPA Marks may be copied from the RITPUB directory
- Dimensions are given for sizes on the wafer
- TVPA Marks are used to adjust for rotation (theta)
- On 6" wafers TVPA marks should be placed on the wafer > 90mm apart, on the front half of the wafer

TYPE 0

W=6µm

B

A

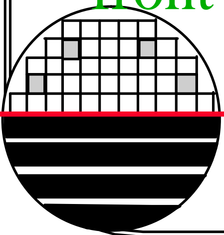
C

B=40µm

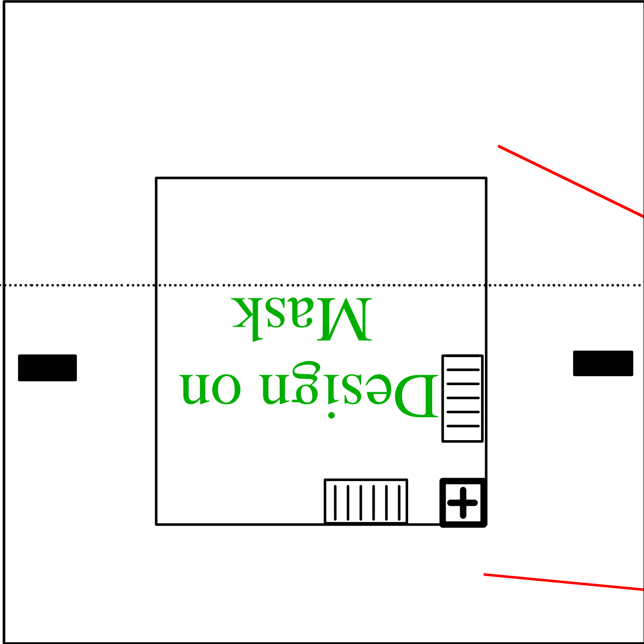
W

A=60µm

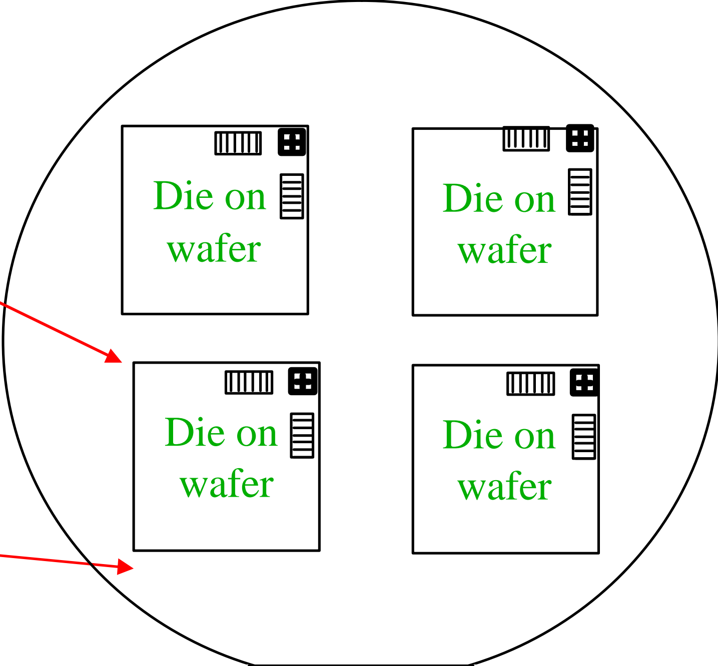
C=100µm



WAFER AUTO ALIGNMENT MARKS for HeNe OR B^2

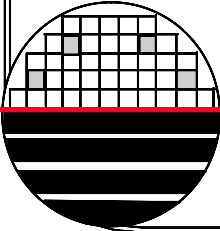


Non Chrome Side



HeNe means marks are illuminated with HeNe Laser
B^2 means broadband (white) light illumination

Need 4 die on the wafer with HeNe or B^2 marks for auto alignment. (actually 2-8 die)



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WAFER AUTO ALIGNMENT MARKS for HeNe OR B^2

x-direction Measurement

150 µm

20µm

50 µm

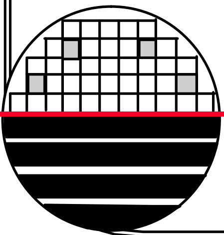
600µm

Type 20P-4F

Dimensions are for Sizes on the Reticle. Need both x and y patterns and locations of center for each. These marks are normally in the streets around the edge of the chip. These marks are called multi-marks.

170 µm

y-direction Measurement

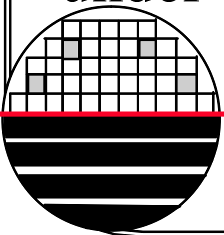


HeNe means marks are illuminated with HeNe Laser
B^2 means broadband (white) light illumination

HeNe or B^2 AA USING B-SCOPE AND C-SCOPE

The B and C scopes are alignment microscopes mounted to the right and back of the lens. These scopes have patterns that match the multi-marks (HeNe or B^2 marks) on the wafer and a light intensity detector to determine the alignment signal.

Knowing the location of the y-direction multi-mark on the die, the stage is moved to place the mark under the B-scope (13.0 mm in x-direction). The stage is adjusted slightly in y to give correct alignment signal. The necessary adjustment is recorded. The stage moves the x-direction multi-mark under the C-scope (13.1 mm in y-direction). The stage is adjusted slightly to give correct alignment. The necessary adjustment is recorded. The stepper then calculates the stage position to center the die under the optical column. The stage moves the die under the optical column. The die is exposed.



WAFER AUTO ALIGNMENT (AA) MARKS FOR i-LINE

Chip
Level 1

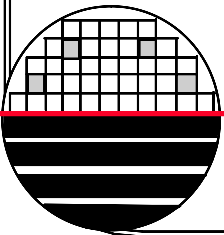
280 µm
apart minimum

Chip
Level 2

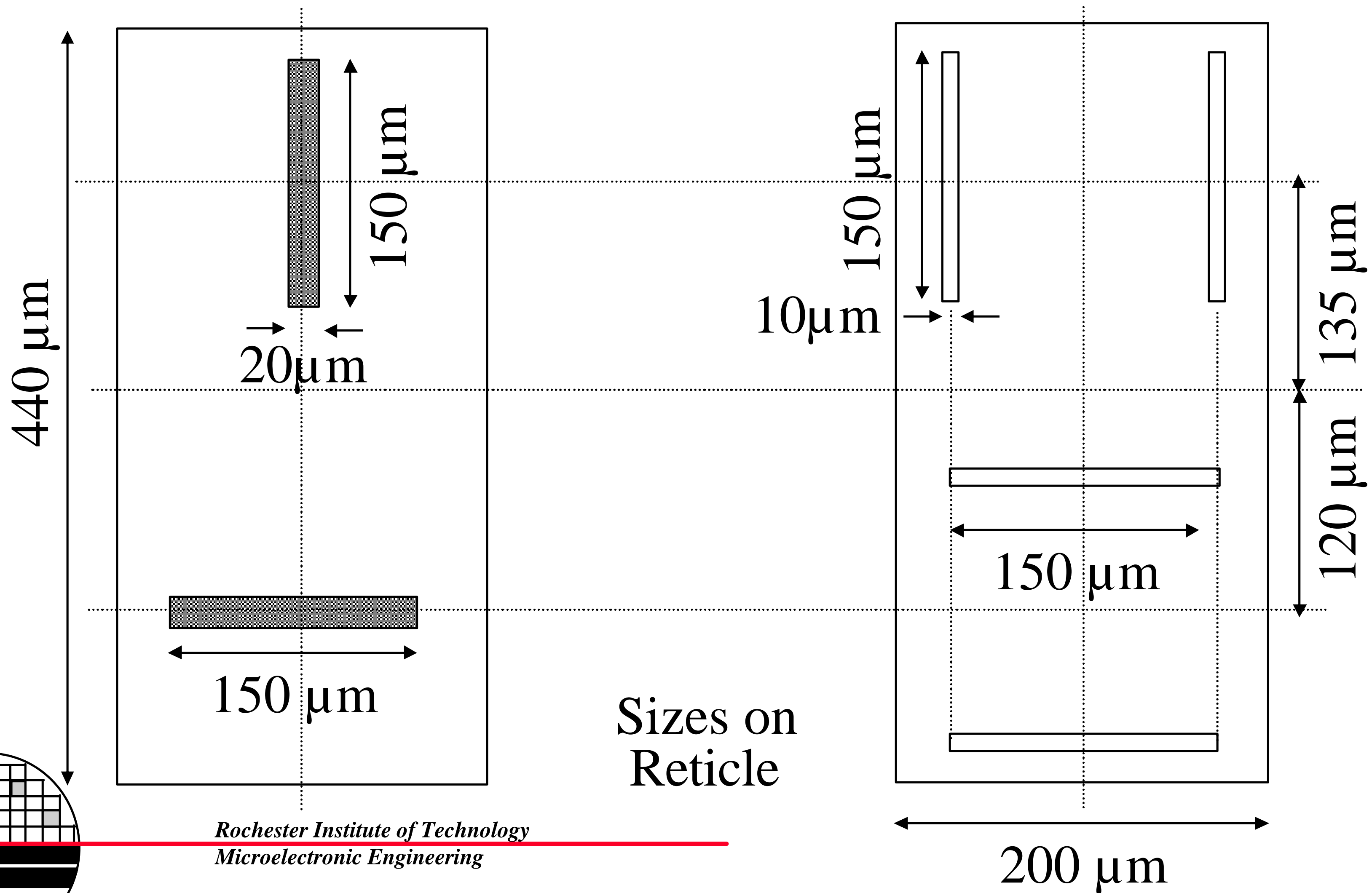
Marks on wafer used to align subsequent levels

Marks on mask used to align to previous level marks on the wafer

Optional marks on mask used to create new wafer marks for subsequent layer alignment

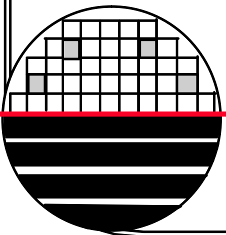


WAFER AUTO ALIGNMENT (AA) MARKS FOR i-LINE



i-LINE TV AA USING A SCOPE

Marks on the wafer from a previous level are illuminated through the lens with a small rectangle of i-line light. The reflected light goes through complementary marks on the reticle and is collected by the A scope. The signal is analyzed as the stage is moved slightly. The best alignment position is found and the adjustment is measured. The correct position to center the die under the optical column is calculated and the stage is moved to that location. The die is exposed.



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STEPPER JOBS AND RELATED FILES/TABLES

(all layers)

Reticle File (Table) - information about all reticles to be used for this product

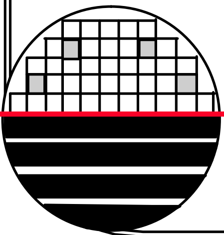
Layout File - information about exposure matrix, rows, columns, step size,

(for each layer)

Job? **File** - Links Layout, Reticle, Shot, Process Files for this layer ?

Shot File Layer ? - exposure dose, focus, blade positions, which locations in matrix are to be exposed or skipped

Process File Layer ? - 1st mask level yes/no, alignment method, compensation, etc.



NAMING HIERARCHY

Since these files are all linked together at the end it is convenient to use a naming hierarchy similar to this example for the files needed for the RIT submicron CMOS testchip product (16 characters max):

Jobname:	Shot file:	Process file:
F012subcmos_well	SF012subcmos1	Psubcmos1
F012subcmos_act	SF012subcmos2	PF012subcmos2
F012subcmos_stop	SF012subcmos3	PF012subcmos3
F012subcmos_vt	SF012subcmos4	PF012subcmos4
F012subcmos_poly	SF012subcmos5	PF012subcmos5
F012subcmos_lddn	SF012subcmos6	PF012subcmos6
F012subcmos_lddp	SF012subcmos7	PF012subcmos7
F012subcmos_n+ds	SF012subcmos8	PF012subcmos8
F012subcmos_p+ds	SF012subcmos9	PF012subcmos9
F012subcmos_cc	SF012subcmos10	PF012subcmos10
F012subcmos_m1	SF012subcmos11	PF012subcmos11

Layout file: LF012subcmos

Reticle Table: RF012subcmos

Reticle ID:

subcmos012nwell	subcmos012poly	subcmos012p+ds
subcmos012active	subcmos012lddn	subcmos012cc
subcmos012stop	subcmos012lddp	subcmos012m1
subcmos012vt	subcmos012n+ds	

An 11 level chip requires up to 46 names for files and reticles

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SUGGESTED NAME CONVENTION FOR RIT JOBS

A991XXXXXXX_YYYY

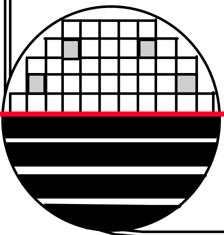
A is the letter **F**,**L**,**S** or **R** where **F** is for **F**actory jobs, **L** is **L**aboratory courses jobs, **S** is **S**hort course jobs, **R** is **R**esearch jobs

the number **012** is the quarter code

XXXXXXX is any code like EMCR632 or SUBCMOS or PMOS

YYYY is the name of the level like WELL, CC, M1, M2, OX, DIFF

Shot files start with letter **S** — **SA012XXXXXXX_YYYY**
Process files start with letter **P** — **PA012XXXXXXX_YYYY**
Reticle files start with letter **R** — **RA012XXXXXXX_YYYY**



NAMING HIERARCHY - METAL GATE PMOS SHORTCOURSE EXAMPLE

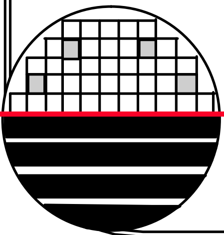
Jobname:	Shot file:	Process file:
L981short_diff	SL981short_diff	PL981short_diff
L981short_ox	SL981short_ox	PL981short_ox
L981short_cc	SL981short_cc	PL981short_cc
L981short_m1	SL981short_m1	PL981short_m1

Layout file: LL981short

Reticle Table: RL981short

Reticle ID: short981diff, short981ox, short981cc, short981m1

A 4 level chip requires up to 18 names for files and reticles



FILE EDITOR

The various files are created using the edit (ed RT, ed L, ed P, or ed S) command and then linked together using the link (LNKS) command.

The editor is a "form" with 1 or more pages and entries are made to fill out the "form" (or defaults are used)

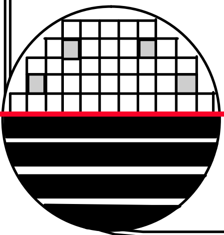
Example entries are indicated by red type in a gray box as shown below

RF012subcmos

Once the four files are created then they are linked using the link command LNKS

Auto

Use the softkeys to save and/or print files



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CANON RETICLE TABLE FILE EDITOR

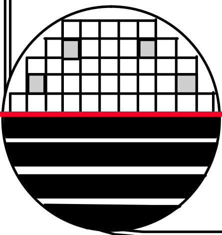
RETICLE TABLE EDITOR (File ID)### (page-1)

File name; RF012subcmos

1. Comment; anything you want

RETICLE TABLE EDITOR (File ID)### (page-2)

1. ID: subcmos012nwell
2. Reticle Alignment Mode (0:No Use,1:FRA1, 2:FRA2) **2** Select **0** slot **12**
3. Setting Offset for FRA; **X=21.6 um Y = -14.25 um Theta = 2415.4 ppm**
4. Bar Code (0:No, 1:Yes) 0 slice select (0-7): **0** type: **0**
5. Type of TTLAF mark (0:MF-mark, 1:TTLAF-mark) 1
6. Throughout Rate: Re= 50% Auto RT (0:off, 1:on) 1
7. ****Reserve****
8. Effective Pattern Area: Bl=-3mm, Br=3mm, Bu=3mm, Bd=-3mm
9. Sampling Pitch X= 0.01 mm Y = 0.01 mm



There is an additional page for each additional reticle

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CANON - LAYOUT FILE EDITOR

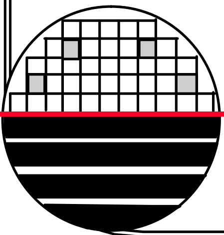
LAYOUT EDITOR (File ID)### (page-1)

File name; LF012subcmos

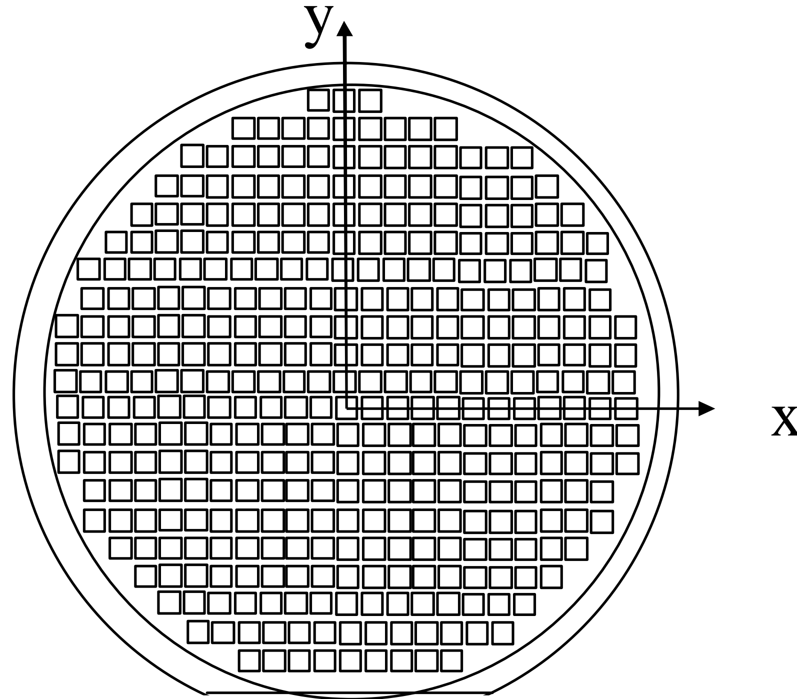
1. Comment; anything you want

LAYOUT EDITOR (File ID)### (page-2)

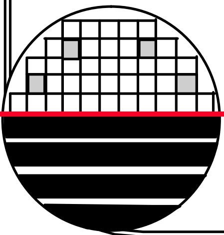
1. Matrix Invalid Area: 5 mm
2. Step Size; Sx = 6 mm Sy = 6 mm
3. Matrix; Clm = 23 Row = 23
4. Origin; X= 0 mm Y= 0 mm
5. Reticle Table Name ; RF012subcmos



CANON – LAYOUT



Assume 5 mm square die, pick 1mm street, pick 5 mm space around wafer edge, that is a Matrix invalid area of 5 mm. Find: step size =6 mm, for 150 mm wafers (6") find matrix of (150-10)/6 or 23 rows and 23 columns.



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CANON STEPPER - SHOT FILE EDITOR

SHOT EDITOR (File ID)### (page-1)

File name; SF012subcmos1

1. Comment; anything you want

SHOT EDITOR (Parameter Set)### (page-2)

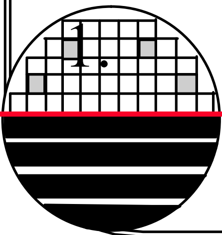
1. Exposure; 160 mj/cm2
2. Focus Offset; 0 µm
3. AA Mark; Auto **Auto**
4. Blade Position; Bl=-3mm, Br=3mm, Bu=3mm, Bd=-3mm
5. Dummy Shot; No
6. Skip shot; No

SHOT EDITOR (Shot Order)### (page-3)

1. Sequential; Auto

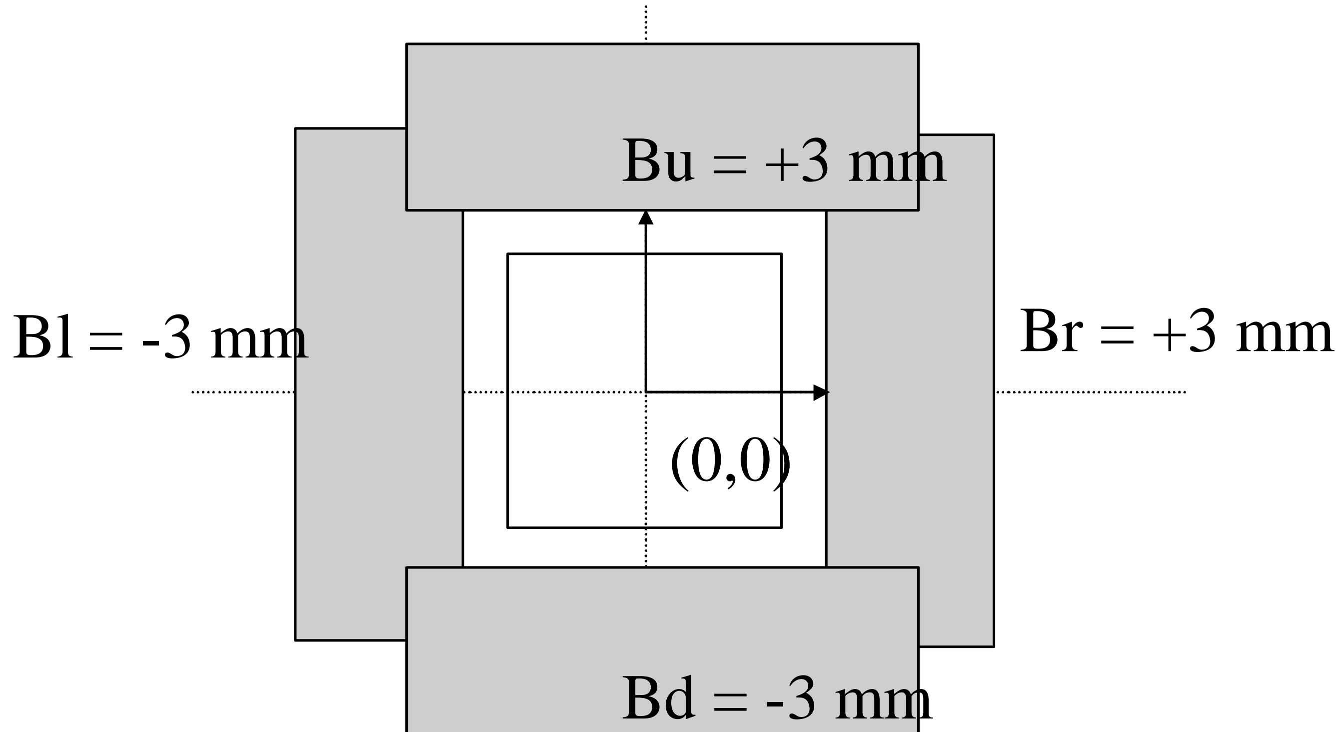
SHOT EDITOR (Parameter Display)### (page-4)

1.



BLADE POSITION CALCULATION

Note: Assume the Reticle is opaque outside the chip area. The blade opening should be a little larger than the chip size so divide by 2. For example a 5mm square chip should have blades open a little more than 2.5 mm in each direction. Pick 3 mm. Blade openings should be less than ½ step size, for 6 mm step size that is 3 mm.



CANON STEPPER - PROCESS FILE EDITOR

PROCESS EDITOR (File ID)### (page-1)

File name; LF012subcmos/PF012subcmos2

1. Comment; anything you want, like: second level active
2. Alignment Sequence: 1st Mask or AGA …. AGA
3. TTL Alignment Mode (none, I-line or HeNe/B^2) HeNe-TV
4. TV PA Measurement Mode; PA

PROCESS EDITOR (Reticle ID)### (page-2)

1. Reticle ID Active

PROCESS EDITOR (Fine Reticle Alignment)### (page-3)

1. Fine Align Tol xy = 0.03 µm Theta = 0.03 µm

The Process file has 36 pages, only highlighted pages can be accessed, if AGA in item 2 page 2 is selected then page 4 is highlighted and gives row and column and x,y location of the prealignment marks. If alignment mode HeNe is selected page 13 gives the x&y coordinates of the fine alignment marks, if I-line was selected then pg 10&11give fine alignment mark locations

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CANON STEPPER - PROCESS FILE EDITOR (cont.)

PROCESS EDITOR (TV Prealignment-1)### (page-4)

1. L) Shot ; clm = 3 row = 12
   PA Mark Position; Xlp = 2.2 mm Ylp= 1.65 mm
2. R) Shot ; clm = 20 row = 12
   PA Mark Position; Xlp= 2.2 mm Ylp= 1.65 mm

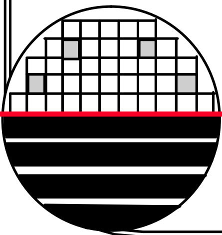
note: this is where the user inputs the **pre alignment** mark locations. X and Y locations are relative to the center of the die

PROCESS EDITOR (HeNe TV Alignment - 1)### (page-12)

1. all offsets are zero on this page initially

PROCESS EDITOR (HeNe TV Alignment - 2)### (page-13)

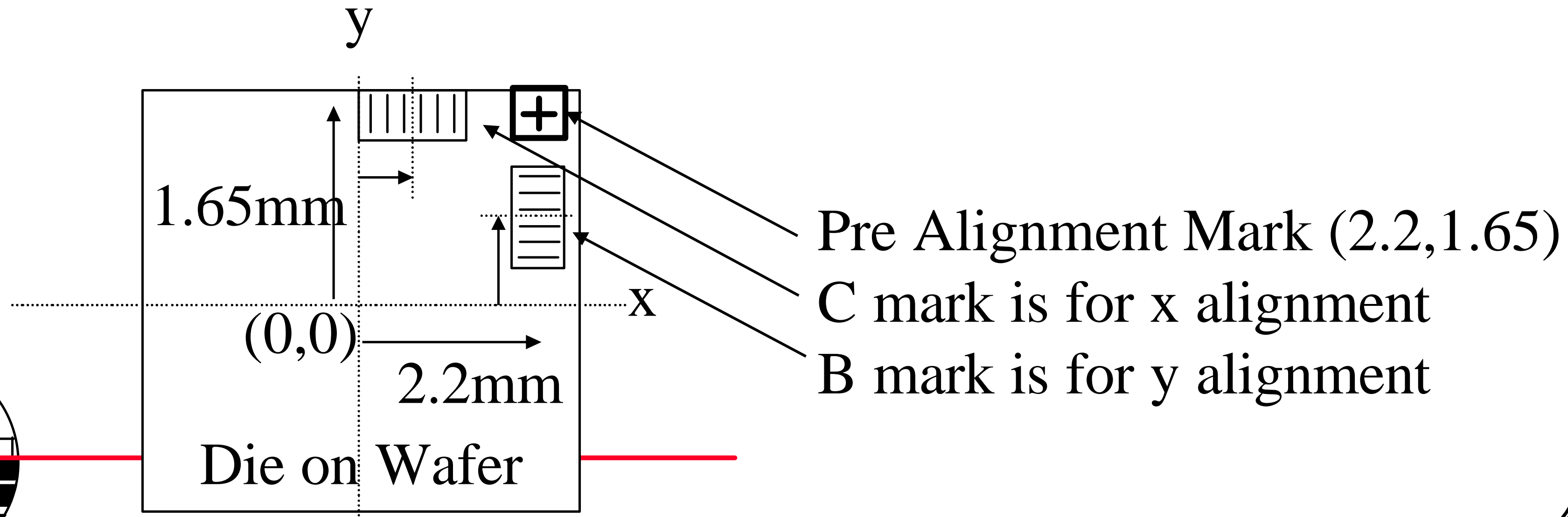
note: this is where the user inputs the **fine alignment** mark locations for HeNe or Broadband (B^2) alignment method. X and Y locations are relative to the center of the die. Page 4 and 13 make it possible to overlay two levels



CANON STEPPER - PROCESS FILE EDITOR (cont.)

PROCESS EDITOR (HeNe TV Alignment - 2)### (page-13)

1. AA Mark Position; B X = 2.2 mm Y = 0.8 mm
   C X = 0.7 mm Y = 1.65 mm
   Brot X = 0.00 Y = 0.00
2. AA Mark Pattern: 20P-4F
   XY Mark: Multi
3. Mark Condition (Window or Island) Island
4. Wafer Surface Condition 0



CANON STEPPER - PROCESS FILE EDITOR (cont.)

PROCESS EDITOR (TV Prealignment)### (page-15)

1. AA Illumination Mode [3]

   Mode 1: He-Ne normal

   Mode 2: He-Ne high contrast

   Mode 3: B-B (broadband)

   Mode 4: B-B with filters

PROCESS EDITOR (AGA Sample Shot) ### (page-17)

1. Number of Sample Shots (2,3,6,8,12,16) [2]
2. AGA for 1st wafer [AGA]

   AGA for 2nd and more wafers [AGA]

PROCESS EDITOR (Tilt Mode)### (page-21-23)

1.Bypass

PROCESS EDITOR (TTL Auto Focus)### (page-24)

1.Bypass

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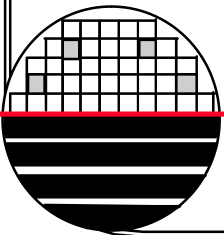
CANON STEPPER - JOB FILE EDITOR

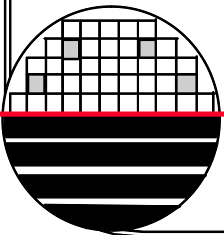
START JOB : PARAMETER CHECK### (page-1)

1. Data Acquisition (0:Off; 1:on) OFF
2. AA Mode (1: 1st, 1=no Use, 2 = No 4
3. Number of processing Wafer ; 1
4. Jobname ; F012subcmos_act
5. Layout File ; LF012subcmos2
6. Process File ; PF012subcmos2
7. Shot File ; SF012subcmos
8. Focus Offset ; 0 µm
9. Exposure ; 160 mj/cm2
10. Reticle Table ; RF012subcmos
    Reticle ID subcmos012active
    Select No.: 0 Reticle Slot #: 12
11. AA Offset ; X=0.0, y=0.0, rot=0.0, mag=0.0



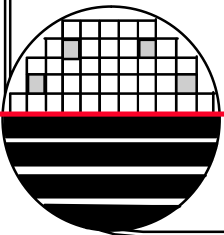
SOME CANON COMMANDS

Category	Command	Description
Operations	rpa	retry tv pre align
	st	load up original job name from hard drive
	st ;c	load job from cpu, original or modified
	h	list of commands
	err	shows last 10 errors
	ld	load wafer
	rrld	unload wafer
	aux fec	turns a normal job into focus/exposure
	qrs	quick reset
	lf	list job files
	cont	restart the current job
job	ed p	edit the process file
	ed s	edit the shot file
	ed rt	edit the reticle file
	ed l	edit the layout file
	lnk s	link the various job files
	pu	purge (delete) selected files



SOME CANON COMMANDS

Category	Command	Description
reticle	rrl	unload reticle from stepper to cassette
	ra	align reticle
	rch	prepare reticle library to accept reticle
	roc	align reticle-idle tool
	rmv	prepare reticle library to remove retile
	rpa	reticle pre alignment (retry tv FRA align)
Alignment	por	pre offset read



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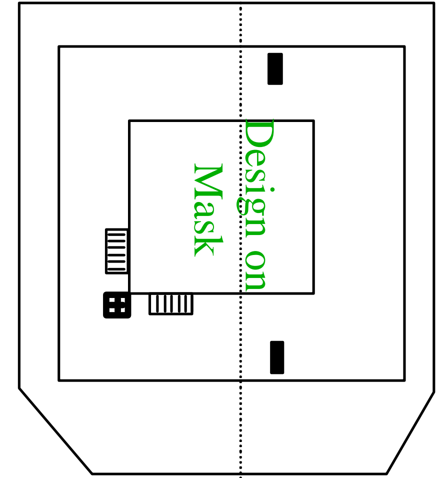
CANON MINI OPERATION MANUAL

1. Load the mask in the reticle tray
   a) Remove reticle tray from stepper
   b) Flip wire latch & remove cover from the tray
   c) Load the mask in the tray chrome side down,
   with the fiducial marks on top and bottom but
   closer to the right side of the tray.
   a) The mask has to be in the correct slot. Factory jobs use slot 12.
2. Run a job
   a) Start the stepper job. Type ST steper_jobname <RET>



Lith. Level	Operation #	Retical ID	Stepper Job Name	Process File	Shot File
1	6	NWELL	SUBCMOS_NWELL	PSUBCMOS1	SSUBCMOS1
2	19	ACTIVE	SUBCMOS_ACTIVE	PSUBCMOS2	SSUBCMOS2
3	22	STOP	SUBCMOS_STOP	PSUBCMOS3	SSUBCMOS3
4	30	VT	SUBCMOS_VT	PSUBCMOS4	SSUBCMOS4
5	38	POLY	SUBCMOS_POLY	PSUBCMOS5	SSUBCMOS5
6	41	LDD-N	SUBCMOS_LDDN	PSUBCMOS6	SSUBCMOS6
7	44	LDD-P	SUBCMOS_LDDP	PSUBCMOS7	SSUBCMOS7
8	51	N+DS	SUBCMOS_NDS	PSUBCMOS8	SSUBCMOS8
9	54	P+DS	SUBCMOS_PDS	PSUBCMOS9	SSUBCMOS9
10	60	CC	SUBCMOS_CC	PSUBCMOS10	SSUBCMOS10
11	65	METAL	SUBCMOS_METAL	PSUBCMOS11	SSUBCMOS11

Factory Stepper Job Names

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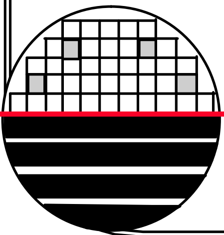
CANON MINI OPERATION MANUAL

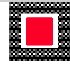
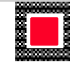
b) Check that the mask is in the slot shown in the stepper job.
c) Verify other job details. If any changes are made press enter. If changes are permanent be sure to press F4 (Transmit) so the changes take effect.
d) Load the wafers and press the flashing light to select that cassette.
e) Press F1 (Go)
f) Wait for the mask to be loaded into the stepper and the wafer loaded onto the stage.

3) Reticle Alignment
a) May see an error “Reticle not aligned”… to manually align the reticle press R/A button on console (or type RPA <RET>). Turn on the Ikegami TV monitor. Align fine FRA2 or FRA1 marks using the joystick (right for x-y, left for Theta) The FRA2 aligned marks should look as shown on the next page.*
b) Press CONT button to the right of the right hand joystick.

*Type ROK (ret) to skip reticle alignment.

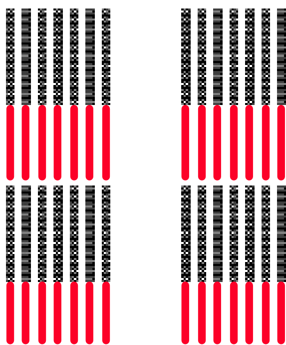


CANON MINI OPERATION MANUAL

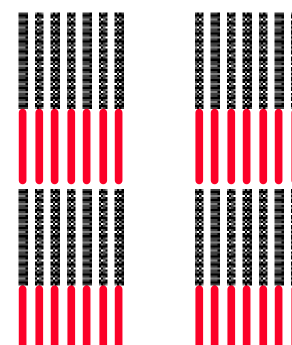



Reticle Coarse Alignment Marks

These Marks on the Stepper
These Marks on the Reticle



Fine Reticle Alignment (FRA2) Marks



Right Side of Reticle

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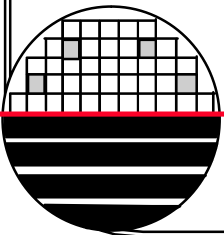
CANON MINI OPERATION MANUAL

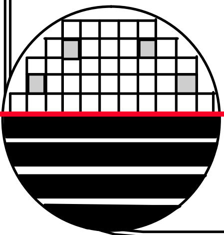
4) If this is an alignment job and there is an auto alignment failure do the following.
   a) Press P/A on the console
   b) Press the L button next to the P/A button on console
   c) Using the right joystick, move the alignment TVPA mark to center of the cross hairs on TV monitor
   d) Type POR to capture the alignment mark location, repeat as necessary
   e) Press the R button next to the P/A button on console
   f) Using the right Joystick, move the alignment TVPA mark to center of the cross hairs on TV monitor
   g) Type POR to capture the alignment mark location, repeat as necessary.
   h) Type RPA, retry pre alignment
   i) Press continue

5) Fine Alignment – should be automatic



CANON MINI OPERATION MANUAL

6. Finish Running a Job
   a) Type RRL<RET> and wait for the mask to be put back in the tray
   b) Then type RRET to return the elevator holding all the masks to the low position.
   c) Press the Cont button on the elevator
   d) Remove your mask and return the tray to the elevator.



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CANON PHOTORESIST PROCESSING

COAT

DEHYDRATE BAKE
200 °C, 120 sec.

→

SPIN COAT
HMDS
4000 rpm, 60 sec.
OIR 620-10 RESIST
4000 rpm, 60 sec.

→

SOFT BAKE
90 °C
60 sec.

→

DEVELOP

OPTIONAL
POST EXPOSURE BAKE
115 °C, 60 sec.

→

DEVELOP
DI Wet
CD-26 Developer
50 sec., Puddle
Rinse, Spin Dry

→

OPTIONAL
HARD BAKE
125 °C, 60 sec.

→

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CANON 4" PIGGY BACK WAFER PROCESS

1st Run Exposure Data

Mask: RIT CMOS WELL&ACTIVE

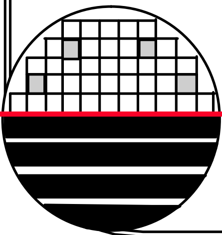
Stepper Job: F983TC_WELL5x5 (all focus sensors were bypassed)

Exposure: 160 mJ/cm^2

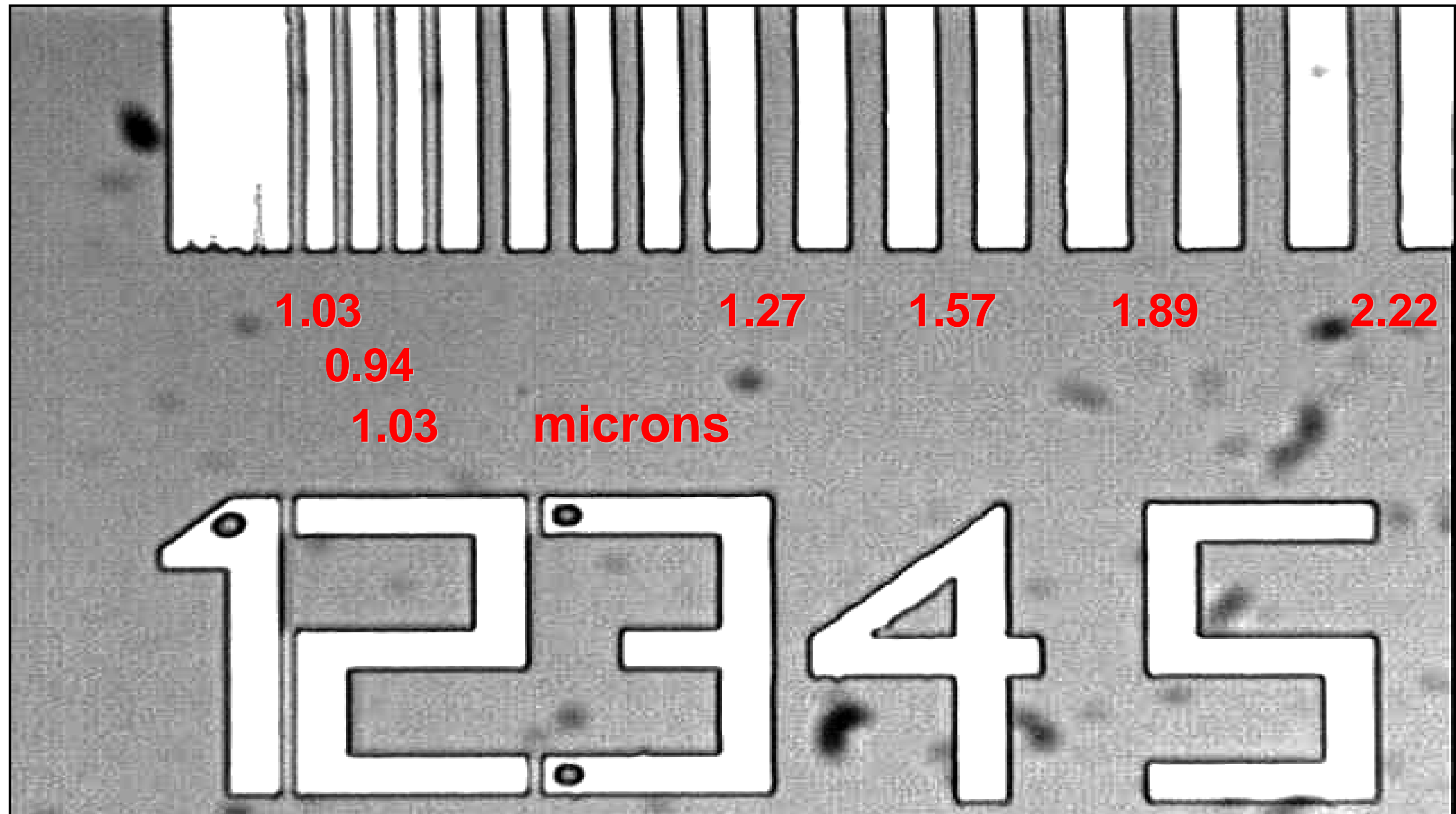
Focus: 0.0 um (possible: +/- 50 um)

Coating & Development: Standard Process (6 inch wafer)

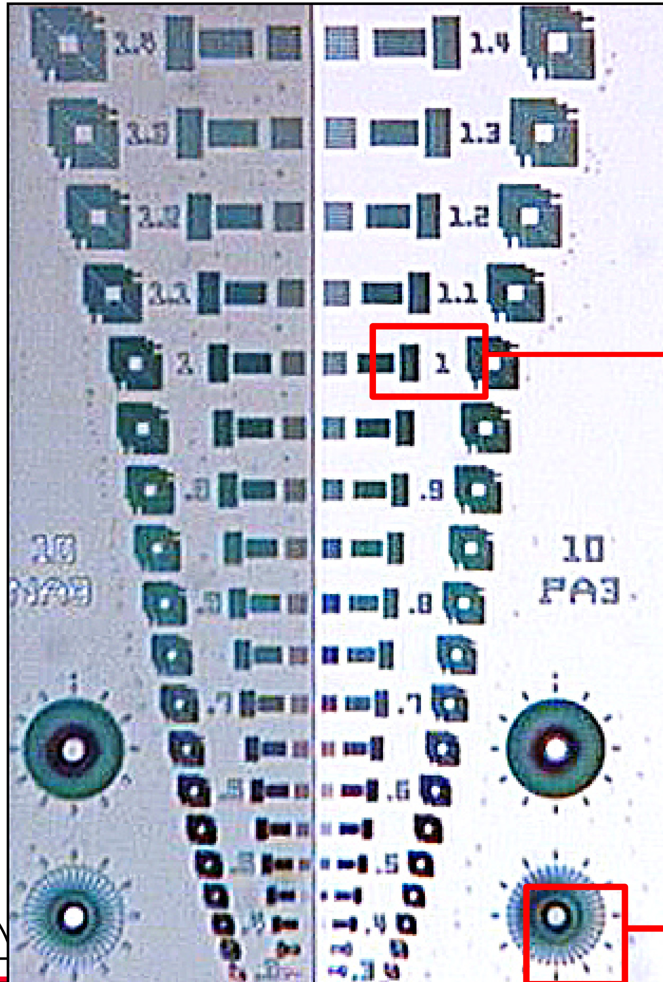
The 4 inch wafer was centered on the 6 inch carrier wafer. One drop DI water was used to create enough attraction between the to wafers. Found best *Exposure*: 179 mJ/cm^2 *and Focus:* -0.6 um

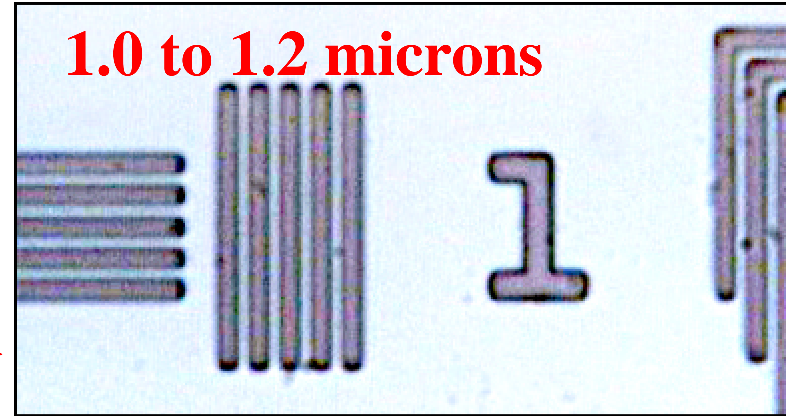


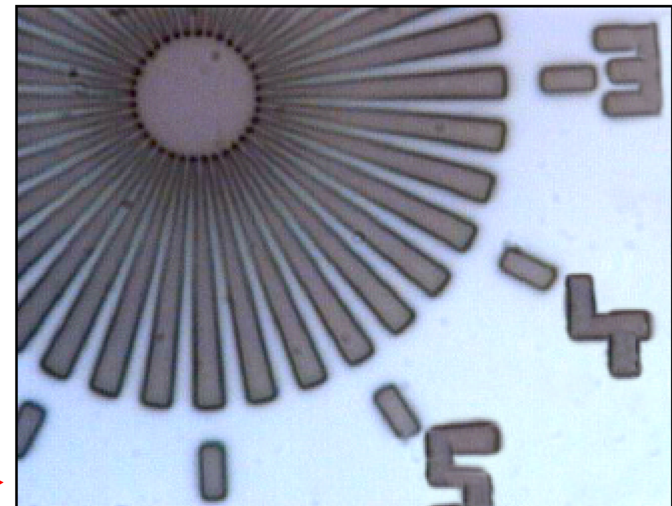
CANON 4" PIGGY BACK WAFER PROCESS



CANON 4" PIGGY BACK WAFER PROCESS







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ASML 5500/90 STEPPER

KrF Excimer Laser Stepper

λ = 248 nm

NA = 0.52, σ = 0.6

Resolution = 0.7 λ / NA = ~0.3 µm

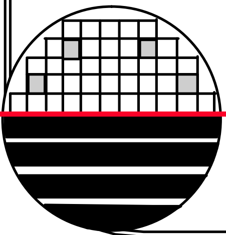
20 x 20 mm Field Size

Depth of Focus = $k_2\ \lambda/(NA)^2$

~ 0.64 µm

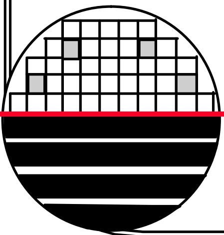
LABORATORY EXERCISES

1. Stepper basics.
2. Irradiance measurements.
3. Focus exposure matrix.
4. Alignment demonstration.
5. Baseline correction demonstration.
6. Automatic wafer alignment demonstration.



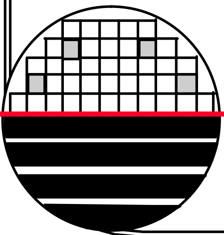
REFERENCES

1. MEBES operation manual.
2. GCA 6700 operation manual.
3. Canon operation manual.
4. “Maskmaking for Canon FPA 2000i”, Suraj Bhaskaran, November 30, 1998, RIT presentation.



HOMEWORK QUESTIONS - STEPPERS

1. What is the difference between fiducial marks and alignment marks?
2. What is the definition of alignment key offset? How is the alignment key offset, left alignment die and right alignment die (row and column) used in a stepper job?
3. How accurate can a stepper overlay images? What determines this accuracy?
4. What are the 20P-4F marks used by the Canon stepper?
5. Explain how the Canon stepper overlays images accurately.
6. Why are four levels placed on a single mask at RIT? What are the advantages and disadvantages of this approach? Can this be done on the Canon stepper?



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