TEST STRUCTURES FOR THE ELECTRICAL CHARACTERIZATION OF OPTICAL LITHOGRAPHY

by

A.R. Neureuther, W.G. Oldham, R.C. Anderson,
D.M. Drako, W.E. Haller, B. Huynh, D.E. Lyons,
G.R. Misium, D.P. Sutija, K.K.H. Toh, and
B. Uathavikul

Memorandum No. UCB/ERL M88/39

27 May 1988

TEST STRUCTURES FOR THE ELECTRICAL CHARACTERIZATION OF OPTICAL LITHOGRAPHY

by

A.R. Neureuther, W.G. Oldham, R.C. Anderson,
D.M. Drako, W.E. Haller, B. Huynh, D.E. Lyons,
G.R. Misium, D.P. Sutija, K.K.H. Toh, and
B. Uathavikul

Memorandum No. UCB/ERL M88/39

27 May 1988

ELECTRONICS RESEARCH LABORATORY

College of Engineering
University of California, Berkeley
94720

TEST STRUCTURES FOR THE ELECTRICAL CHARACTERIZATION OF OPTICAL LITHOGRAPHY

by

A.R. Neureuther, W.G. Oldham, R.C. Anderson, D.M. Drako,
W. E. Haller, B. Huynh, D.E. Lyons, G.R. Misium,
D.P. Sutija, K.K.H. Toh, and B. Uathavikul

Abstract

Special parameter-isolating electrical test patterns have been designed, calibrated and documented for stepper characterization. The patterns include traditional and exploratory targets for monitoring exposure, focus, astigmatism, coma, flare and printability of defects. The contact pads are designed for a 2 by 10 probe card with 80 μm pads on 160 μm centers. For each test pattern the electrical drive and sense parameters are specified and algorithms for interpreting the electrical signals are also given. The test pattern shapes and sizes were selected through simulation of pattern sensitivities to various optical system parameters. The two-dimensional aerial image simulator SPLAT and resist profile simulation with SAMPLE were used for this purpose. The patterns were designed and laid out as a graduate class project at U.C. Berkeley during the fall semester. The patterns were then scaled for use with the AWIS deep-UV optical stepper with 0.5 resolution during the Spring 1988 semester by George Misium.

TEST STRUCTURES FOR THE ELECTRICAL CHARACTERIZATION OF OPTICAL LITHOGRAPHY

George R. Misium

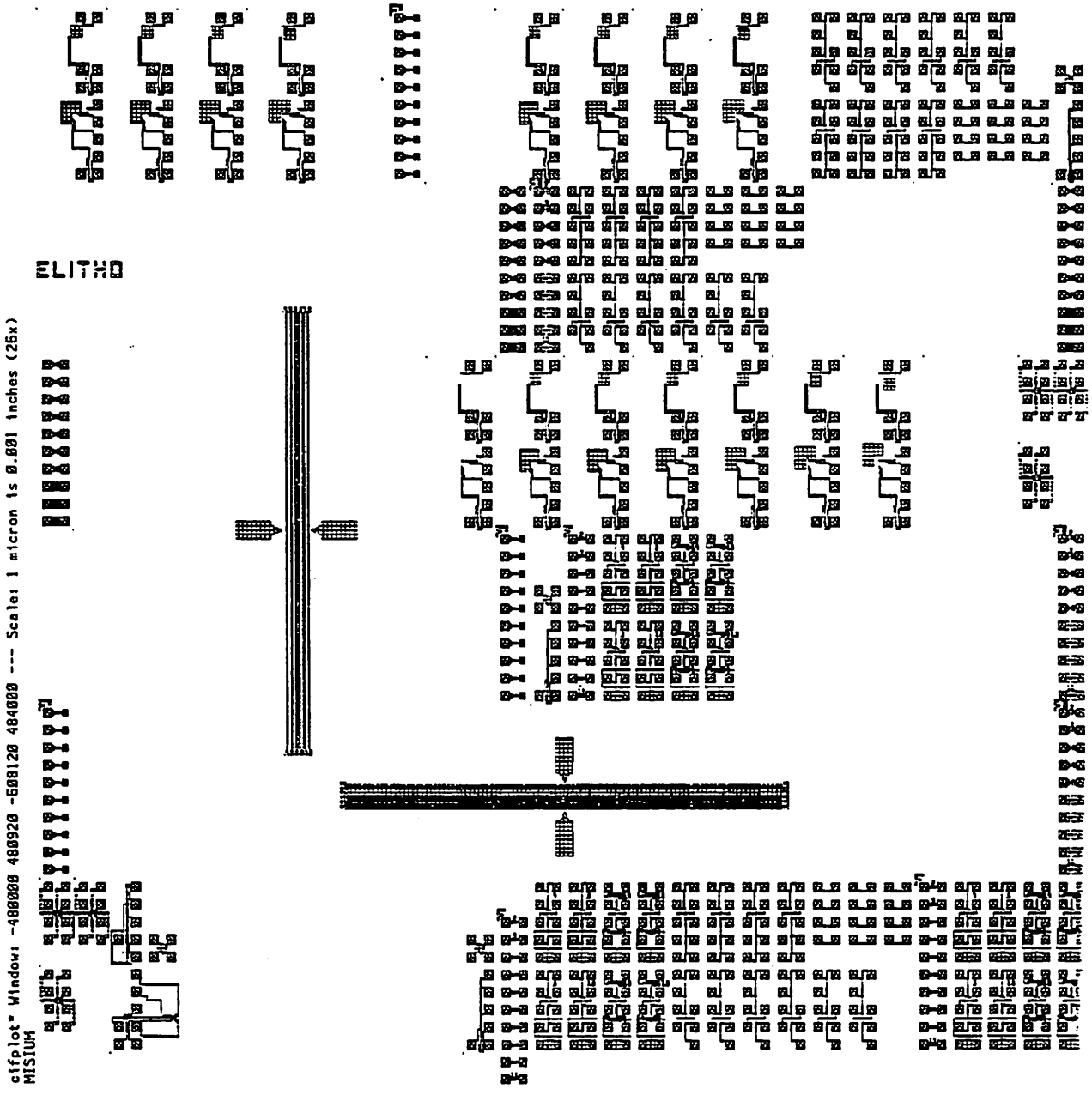
May 14, 1988

Abstract

A set of test strucures for electrical characterization of optical lithography are described. The main objectives of these structures are the characterization through electrical measurements of the optical tool -alignment, linewidth and contrast-, the optimization of optical processes -determination of best focus and exposure-, and the characterization of effects such as defects and flare.

Contents

1 ELITHO Chip Layout



2 Chip Floor Plan

Each chip is an arrangment of 6 rows by 30 columns of blocks. The coordinates shown between parenthesis are those of a measurement system based on a 2x5 test card.

(0,0) ALIGN1	FOCUS2D	(0,4) (0,5)	EXPOSURE	LABEL	(0,10) (0,11)
(1,0) ALIGN1					FLARESHORT
ALIGN2					
(3,0)					FLARESHORT
(4,0)					
(5,0)					FLARESHORT
(6,0)					
(7,0) SEM	SEM	SEM			FLARESHORT
(8,0)					
					FOCUS2D
(10,0)					
(11,0)					
VANDERP			FLARE		
(13,0)		FOCUS2D		EXPOSURE	
LINEWIDTH		VANDERP	FLARE	FOCUST	FLARESHORT
LINEWIDTH		FOCUS		DEF DEF2	
LINEWIDTH		LINEWIDTH	FLARE	DEF DEF2	FLARESHORT
LINEWIDTH		LINEWIDTH		DEF DEF2	
DEF DEF2			FLARE	DEF DEF2	FLARESHORT
DEF DEF2				DEF DEF3	
DEF DEF2		LINEWIDTH	FLARE	DEF DEF3	FLARESHORT
DEF DEF2				XXX DEF3	
DEF DEF3			FLARE		DEF2 DEF
DEF DEF3					DEF2 DEF
XXX DEF3			FLARE		DEF2 DEF
FOCUS					DEF2 DEF
LINEWIDTH					DEF3 DEF
LINEWIDTH			ALIGN1		DEF3 DEF
(28,0) LINEW					DEF3 (28,11)
(29,0) LINEW	FOCUST	FOCUST	ALIGN1	EXPOSURE	VAND (29,11)

The blocks are 320 μm by 1600 μm and each block consists of a 2x10 arrary of 80 μm pads on 160 μm centers. The devices can, however, be tested with a 2x5 card.

PAD GRID

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

3 Summary Table of Patterns in the Chip

NAME	BASIC STRUCTURE	PURPOSE	COORD[12]
ALIGN1	Modified Van der Pauw	Alignment of additive layers	(0,0)(28,7)
	Same	Aligned reference	(0,1)(28,6)
	Same	Missaligned reference	(1,1)(29,7)
ALIGN2	Linewidth with slits	Alignment of contacts and vias	(2,0)(2,11)
DEFECT	Lines, pinspots and pinholes	Effect of defects on linewidth	(15-20,8)(22-27,11) (18-23,0)
DEFECT2	Serpentine and defects	Effect of defects on linewidth	(15-18,9)(22-25,10) (18-21,1)
DEFECT3	Defects between close lines and on elbows	Shorts and opens due to defects	(19-21,7)(26-28,10) (22-24,1)
EXPOSURE	Checkerboard patterns	Exposure level detection	(13,8)(0,6)(29,8)
FLARE	Lines close to large features	Efect of flare on linewidth	(12-24,6)
FLARESHORT	Same	Same	(1-7,10)(14-20,10)
FOCUS	Thin lines	Defocus level detection	(15,4)(13,0)(25,0)
FOCUS2D	Poly pie capacitor	Defocus level detection	(13,4)(0,2)(9,10)
FOCUST	Broken metal film	Defocus level detection	(14,8)(29,2-4)
LINEWIDTH	Long lines	Smile plots	(16,4)(14,0)(26,0)
SEM	Set of SEM lines	Pattern cross sections	(7,0-5)
VANDERP	Van der Pauw pattern	Film resistance	(14,4)(12,0)(29,10)

12

[1]Most structures have been placed at the center, edge and corner of the field.

[2]For the HP testing system these coordinates should be read as (m_y, m_x), where $x = 800m_x, y = 320m_y$.

4 Discussion of Test Structures

ALIGN1

The purpose of these structures is to measure the missalignment of additive layers; for instance, of lift-off metal layers on a first conducting level. The basic structure is a modified Van der Pauw as described in[1], which has been modified in order to accomodate a 2x5 test probe card. A 40 μm sqare is corner-contacted to form a Van der Pauw resistor on the first layer. Sensor arms connecting the midpoints of the square are patterned on a second layer (see layout). The missalignment can be measured from the voltage offset between the sensor arm and the corners according to the formulas

$$D_x = 0.3159l \arcsin\left(\frac{V_1 - V_2}{V_1 + V_2}\right) \quad (1)$$

$$D_y = 0.3159l \arcsin\left(\frac{V_3 - V_4}{V_3 + V_4}\right), \quad (2)$$

where $D_x(D_y)$ is the missalignment in the $x(y)$ direction, l is the dimension of the central square, V_1 and V_2 (V_3 and V_4) are the voltage differences between two aligned corners in the $x(y)$ direction and the central arm.

ALIGN2

The purpose of these structures is to measure the missalignment of contacts and vias. Slits are open along a line and the linewidths of the resulting patterned lines are measured as described for the LINEWIDTH pattern. The structure was adapted from [2].

DEFECT

These structures are designed to investigate the effects of defects near line edges. Defects of different sizes and at different spacing from the line edges are used. The linewidths are calculated using the same formula as for the LINEWIDTH measurement.

DEFECT2

These structures are designed to investigate the effects of defects near elbows. The linewidths of the serpentine structures with and without defects are calculated by using the same formula as for the LINEWIDTH measurement. L, in this case, is the effective length of the structure and is equal to 273 μm.

DEFECT3A

These structures are designed to investigate under what conditions defects located between two lines at a minimal spacing induce shorts between the lines.

DEFECT3B

These structures are designed to investigate under what conditions defects located between corners of elbows induce shorts between them.

DEFECT3C

These structures are designed to investigate under what conditions transparent defects located in different critical locations on the elbows induce opens in them.

EXPOSURE

These strucures are used to determine the exposure level during the lithographic step by testing checkerboard patterns for opens and shorts. Different patterns are investigated in order to find structures capable of detecting different exposure levels.

FLARE

The linewidth of lines running close to large features is to be measured as a function of the distance between them. Lines are laid out at variable distances from and along the outer and inner corners of large dark features. The linewidth is measured as described elsewhere with L =170 μm.

FOCUS

These structures are used to determine the defocus level during mask exposure by testing thin lines with different linewidths for opens due to defocus. For a given dose, the best focus position is that of the chip at which a maximum number of sets of lines remains connected.

FOCUS2D

This is a structure designed to measure defocus levels based upon optical effects on two-dimensional features. A checkerboard is patterned on polysilicon and metal is sputtered on top of it in order to create a MOS capacitor whose capacitance is a function of the defocus level according to the following expression:

$$C = \epsilon_o \left[\frac{11.7 A_p}{x_p} + \frac{3.9(A_c - A_p)}{x_{ox}} \right] \tag{3}$$

where A_p is the patterned polysilicon area and is a function of defocus, A_c the capacitor area, and x_p and x_{ox} the corresponding thicknesses.

FOCUST

These structures are designed to determine the defocus level by testing thin lines for shorts due to defocus. A non-standard process is used (see §4, Process C) for this purpose. For a given dose, the best focus position is that of the chip at which a maximum number of sets of lines remains open.

LINEWIDTH

These structures are used for measuring linewidth in order to generate smile plots and to asses contrast. The linewidth is calculated by using the formula

$$W = \frac{R_{\square} L}{R_m} \tag{4}$$

where $R_{\square}$ is the sheet resistance measured on the Van der Pauw pattern, R_m is the measured resistance of the line, and L is equal to 150 μm for these structures.

SEM

A set of lines is provided in order to look at the cross sections of the patterned lines. They are described in §6.

Van der Pauw

Van der Pauw structures [3] are used to measure the film resistance according to the formula

$$R_{\square} = \frac{\pi}{\ln 2} \frac{\Delta V}{I} \tag{5}$$

where I is the current injected across a corner and ΔV is the voltage measured across the opposite corner.

5 Functional Description of Test Structures

Alignment of additive layers

- **Filename:** ALIGN1
- **References:** The basic structure was taken from [1] and modified to accomodate a 2 by 5 test card measurement.
- **Purpose:** To measure the missalignment of additive layers; for instance, the missalignment of a lift-off aluminum layer on top of a polysilicon layer.
- **Description:** A modified Van der Pauw structure as described in §5.

  In order to asses the testing method aligned and missaligned reference structures are added to the test pattern.
- **Testing:** Missalignment is measured according to the algorithm given by (1) and (2)

$$D_x = 0.3159l \arcsin \frac{V_1 - V_2}{V_1 + V_2} \tag{6}$$

$$D_y = 0.3159l \arcsin \frac{V_3 - V_4}{V_3 + V_4} \tag{7}$$

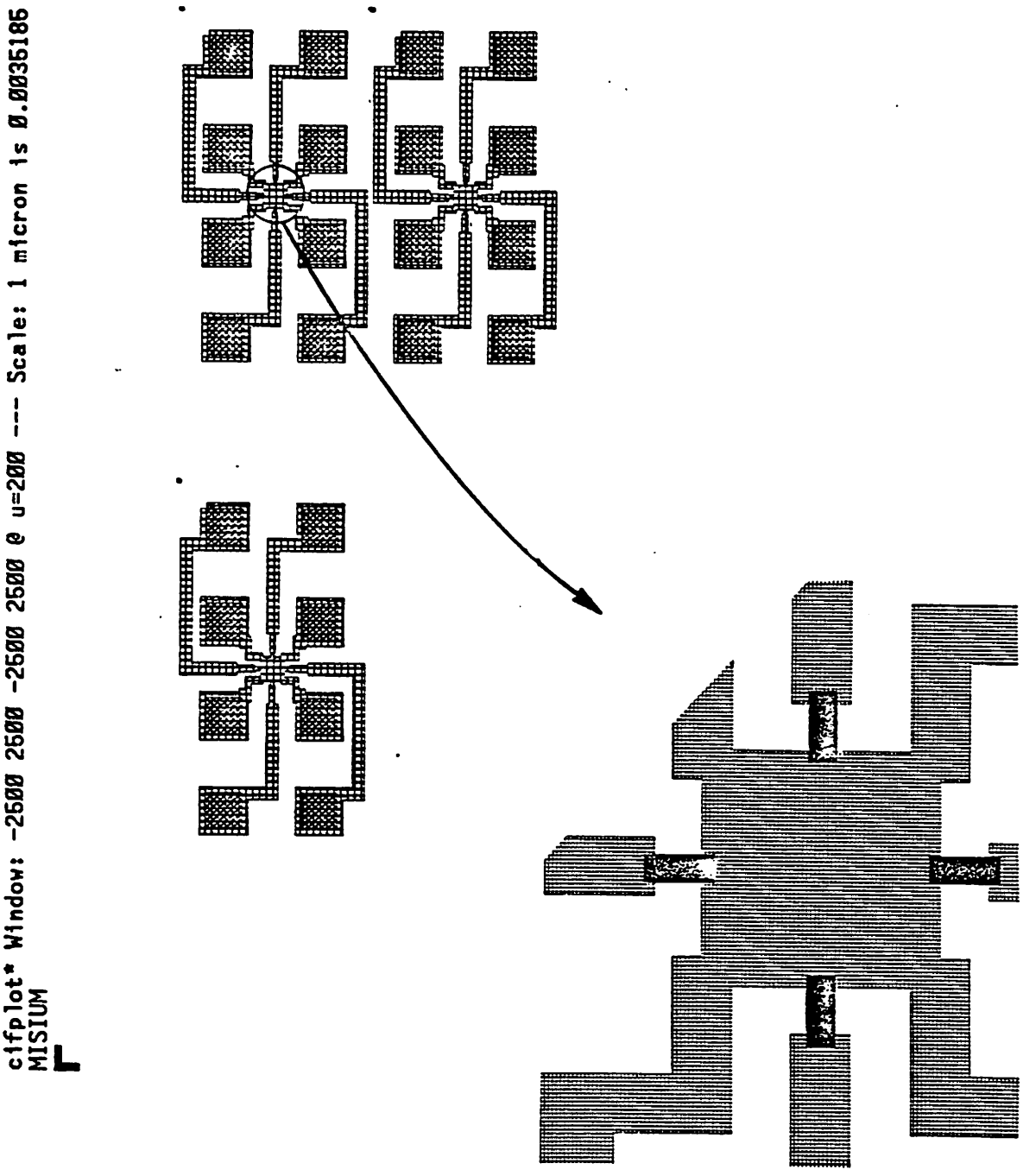
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (0,0), (28,6)

PAD #	DESCRIPTION	TEST FUNCTION
5,15	Arms at corners (y)	Inject current
2,11	Center and corner	Measure V_3
11,14	Center and corner	Measure V_4
2,3	Corners (second step x)	Inject current
12,14	Center and corner	Measure V_1
13,14	Center and corner	Measure V_2

- **ALIGN1 LAYOUT**



Alignment of substractive layers

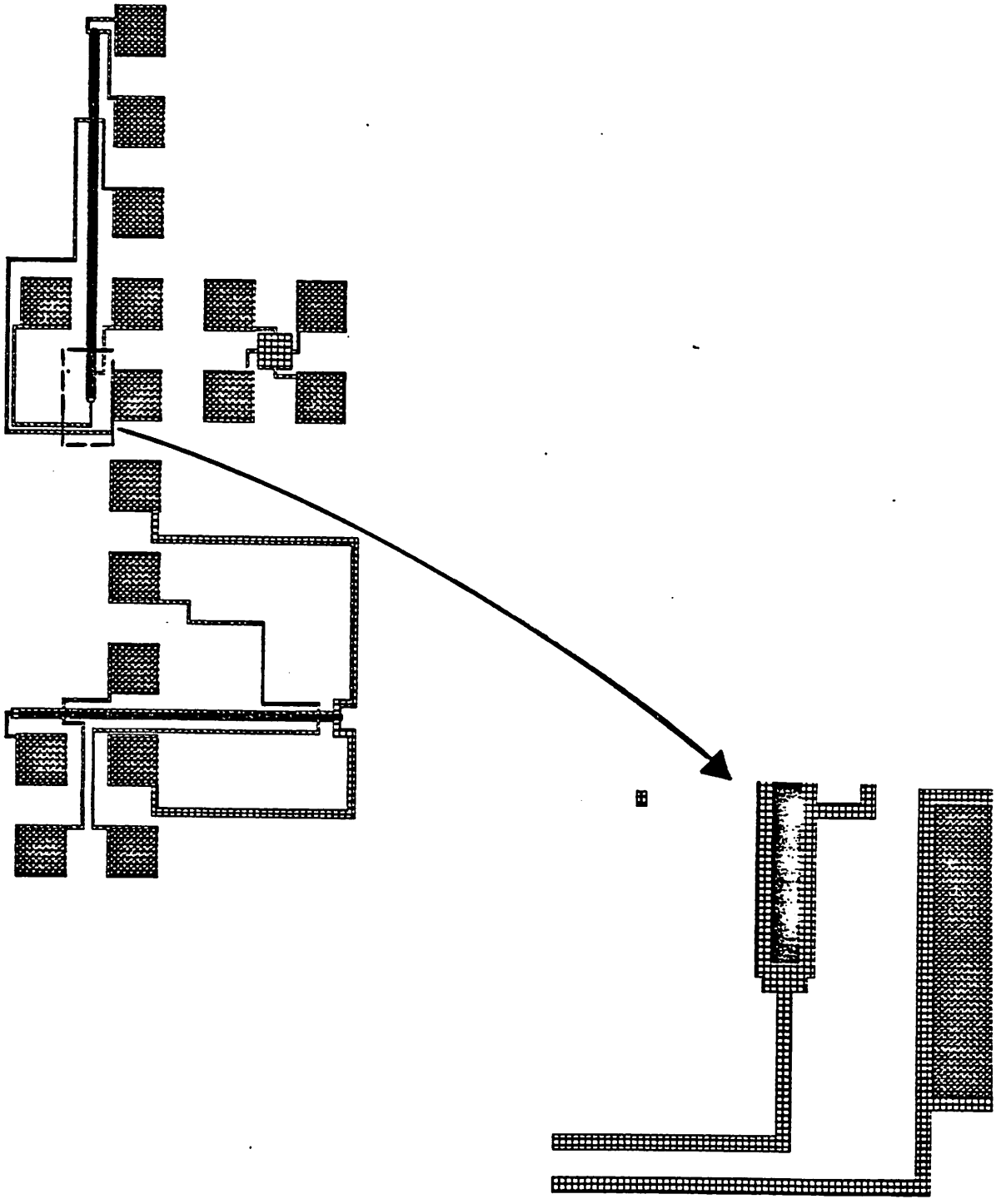
- **Filename:** ALIGN2
- **References:** None.
- **Purpose:** To measure the missalignment of contacts and vias.
- **Description:** Slits are patterned on lines by the contact/via mask.
- **Testing:** Linewidth measurement.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (2,0), (2,11)

PAD #	DESCRIPTION	TEST FUNCTION
4,11	Basic line (x dir)	Inject current
4,15		Measure voltage
13,14		Measure voltage
9,16	Basic line (y dir)	Inject current
10,20		Measure voltage
17,18		Measure voltage
4,5,14,15	Next pad block	Van der Pauw

- **ALIGN2 LAYOUT**



Defects

- **Filename:** DEFECT
- **References:** None
- **Purpose:** To investigate the effects of defects near line edges.
- **Description:** Fourteen equally spaced defects of the same size D are introduced at a distance S from a 1.3μm (.8λ/NA) line.

Coordinates:	(18,0)	(19,0)	(20,0)	(21,0)	(22,0)	(23,0)
D(μm)=	0.3	0.5	0.6	0.3	0.8	0.5(Transparent)
S(μm)=	0.2	0.2	0.2	0.0	0.0	0.0
D(μm)=	0.3	0.5	0.6	0.5	0.0	0.6(T)
S(μm)=	0.3	0.3	0.3	0.0	N/A	0.0
D(μm)=	0.3	0.5	0.6	0.6	0.3(T)	0.8(T)
S(μm)=	0.5	0.5	0.5	0.0	0.0	0.0

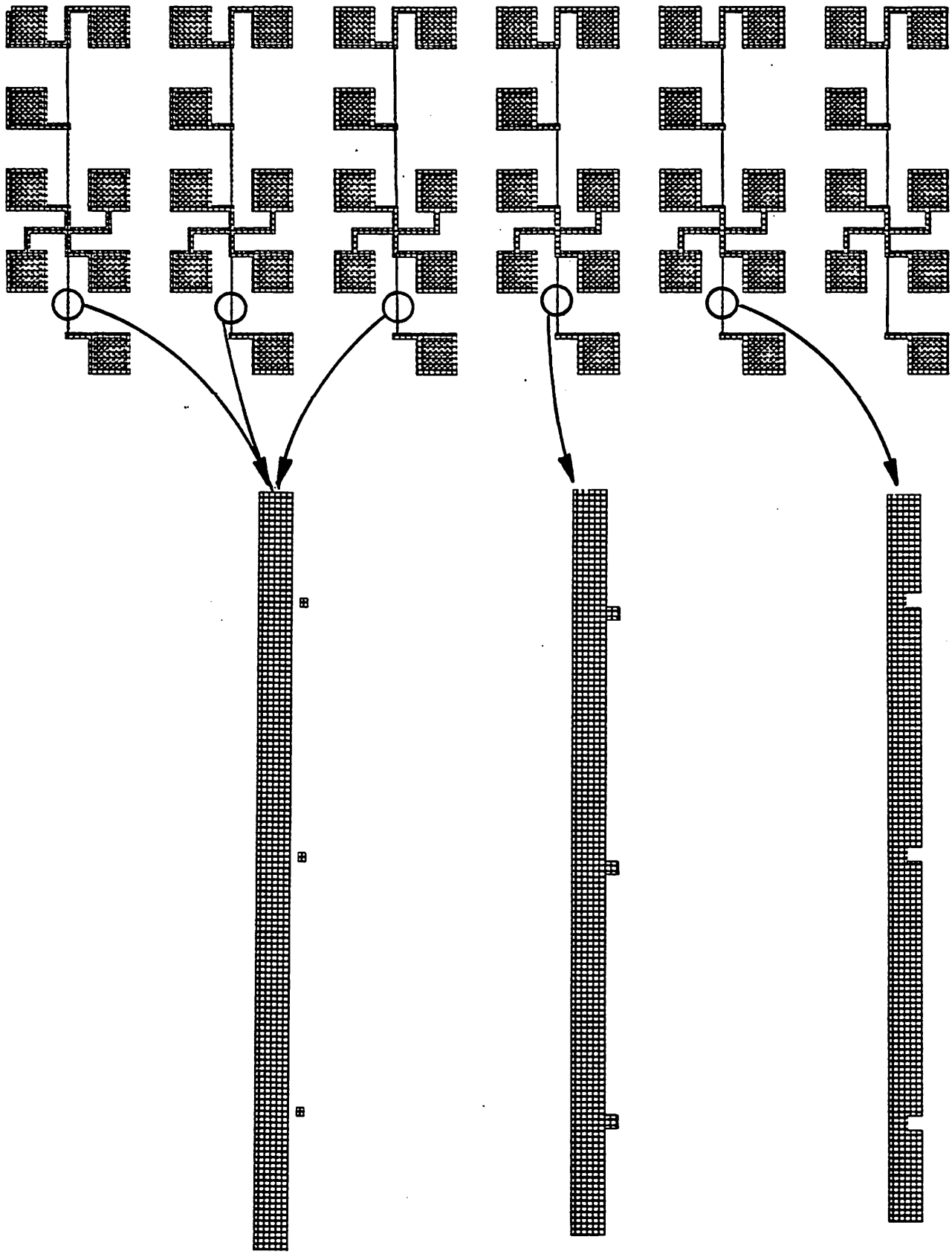
- **Testing:** Short/open detection.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (18,0),(19,0),(20,0),(21,0),(22,0),(23,0) (15,6), (16,8),(17,8),(1

PAD #	DESCRIPTION	TEST FUNCTION
16&20		Inject I
6&7	14 defects near a line edge	Sense V
7&8	14 defects near a line edge	Sense V
19&20	14 defects near a line edge	Sense V

- DEFECT LAYOUT



- **Filename:** DEFECT2
- **References:** None
- **Purpose:** To investigate the effects of defects near elbows.
- **Description:** Serpentine structures are used. Twenty eight defects of 0.5 μm are introduced near the corners of the elbows at a spacing S.

  Coordinate: (18,1)

  Defect: Defects are along the outer diagonals of the corners at a spacing of 0.2, 0.3, and 0.5μm from the vertical edges of the elbows.

  Coordinate: (19,1)

  Defect: Defects are lined up with the inner vertical edges of the elbows and are at a spacing of 0.2, 0.3, and 0.5μm from the horizontal edges of the elbows.

  Coordinate: (20,1)

  Defect: Defects are lined up with the outer vertical edges of the elbows and are at a spacing of 0.2, 0.3, and 0.5μm from the horizontal edges of the elbows.

  Coordinate: (21,1)

  Defect: No defect is introduced in the serpentine structure. It is used as a reference.

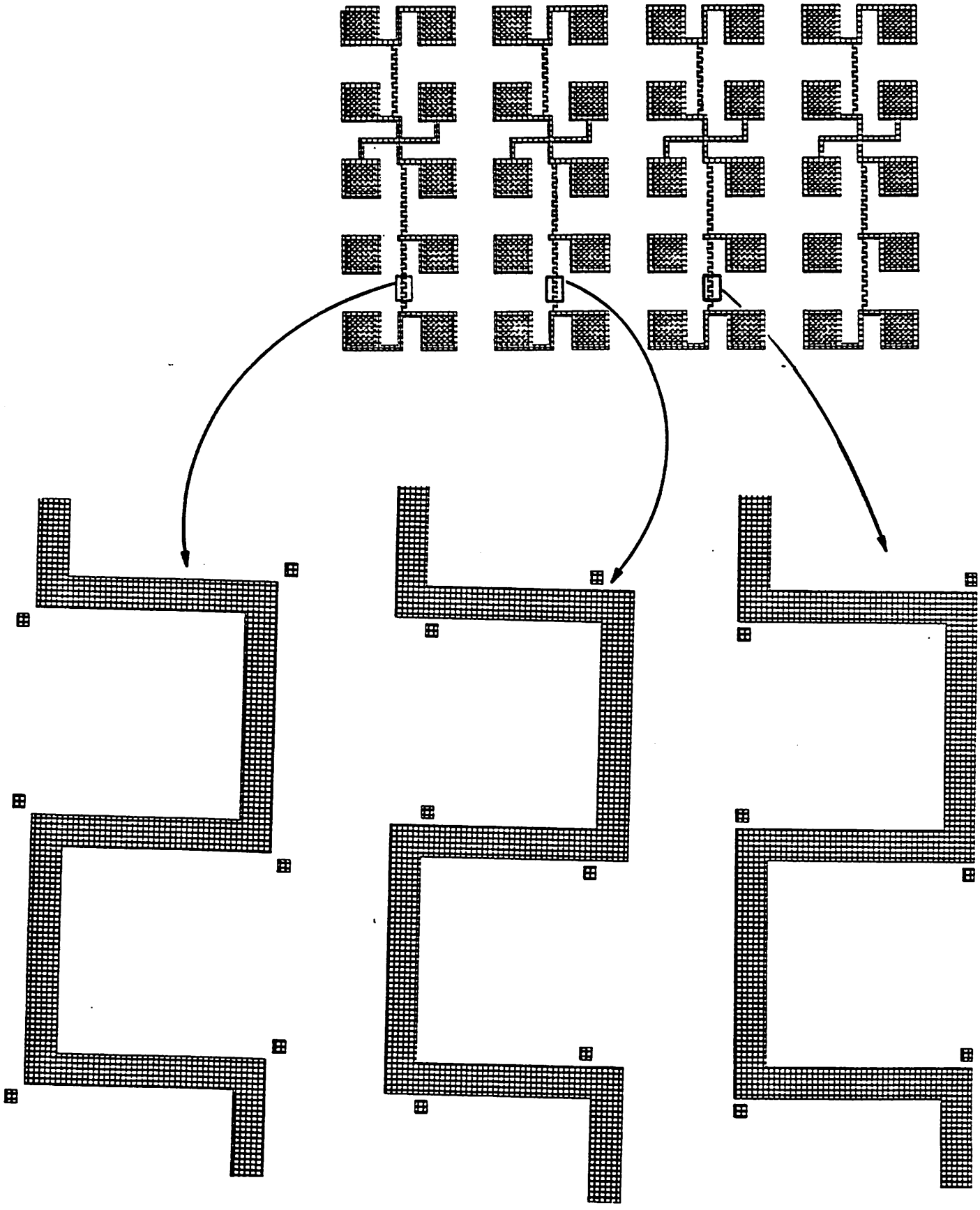
- **Testing:** Short/open detection.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (18,0), (19,0), (20,0), (21,0) (15,9), (16,9), (17,9), (18,9) (22,10), (23,10), (24,10), (25,10)

PAD #	DESCRIPTION	TEST FUNCTION
5&11		Inject I
1&2	Serpentine structure with 28 defects	Sense V
13&14	Serpentine structure with 28 defects	Sense V
14&15	Serpentine structure with 28 defects	Sense V

- **DEFECT2 LAYOUT**



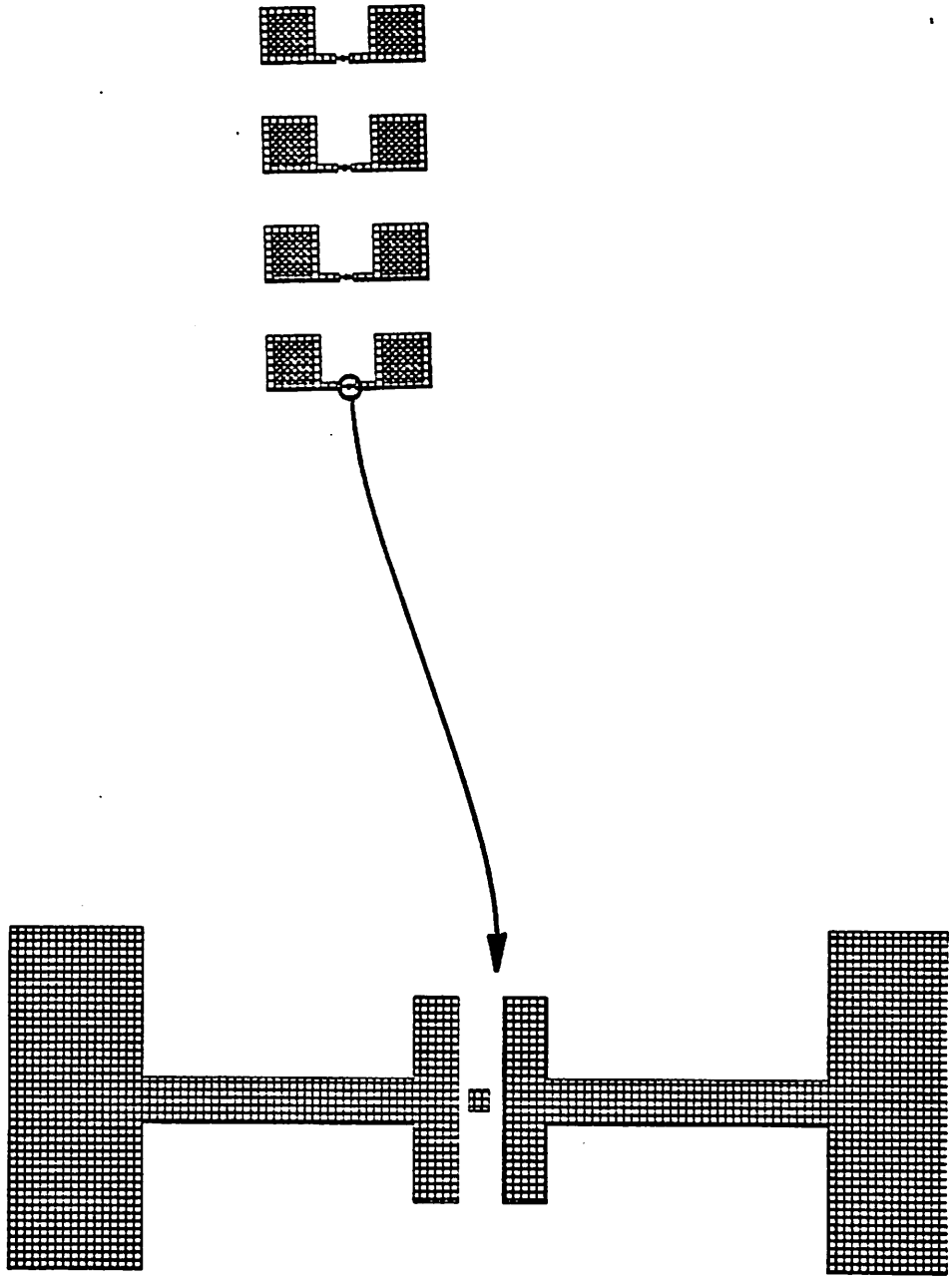
- **Filename/Structure:** DEFECT3/DEFECT3A
- **References:** None
- **Purpose:** To investigate under what conditions defect located between two lines at a minimal spacing induce a short between the lines.
- **Description:** Centered defects of 0.3, 0.5, 0.6, 0.8 μm are introduced between two 1.3 μm lines at a 1.3 μm spacing.
- **Testing:** Short/open detection.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (22,0), (19,6), (26,9)

PAD #	DESCRIPTION	TEST FUNCTION
1&11	Defect between two lines	Apply V, Sense I
2&12	Defect between two lines	Apply V, Sense I
3&13	Defect between two lines	Apply V, Sense I
4&14	Defect between two lines	Apply V, Sense I

- **DEFECT3 STRUCTURE DEFECT3A LAYOUT**



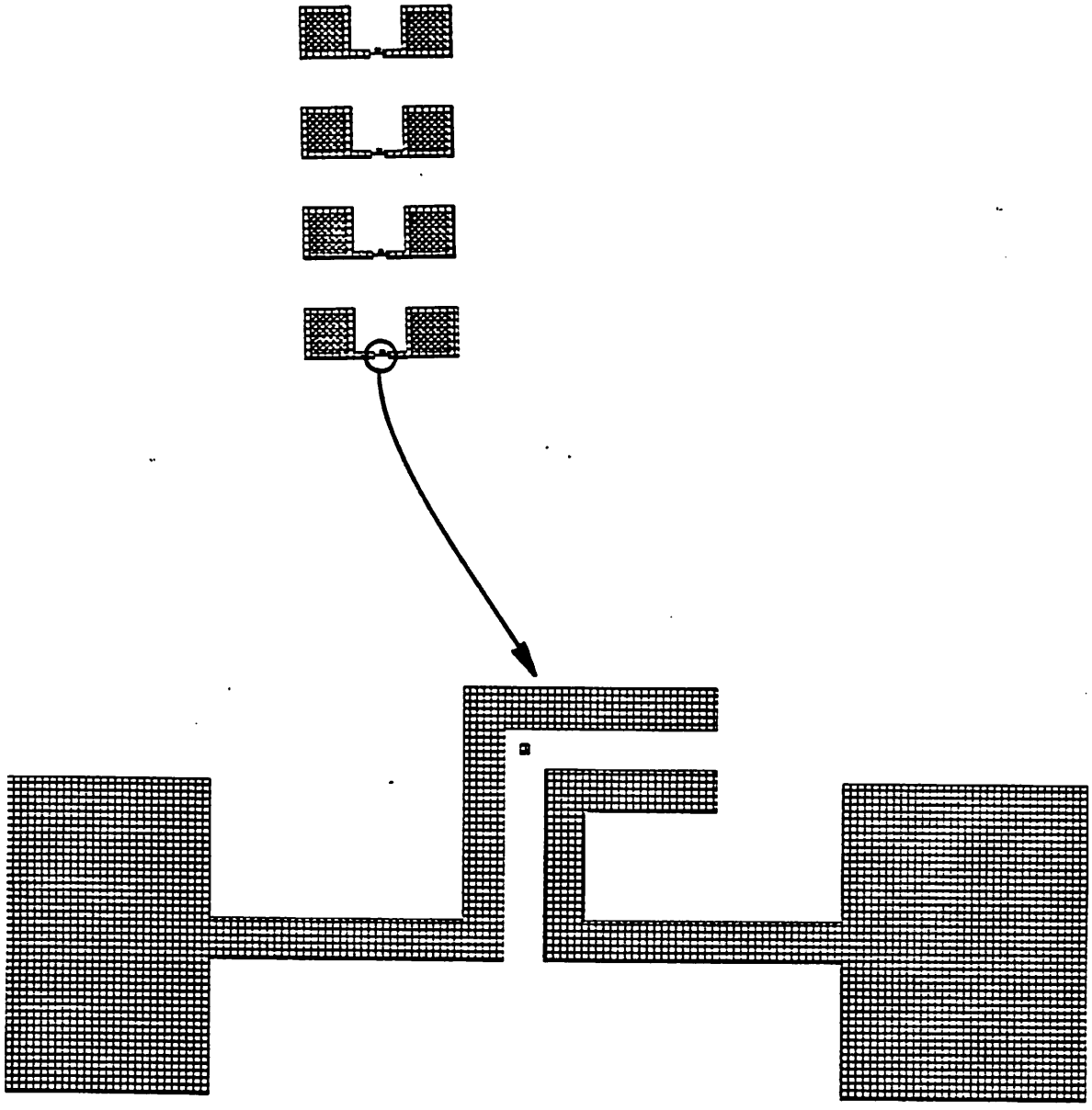
- **Filename/Structure:** DEFECT3/DEFECT3B
- **References:** None
- **Purpose:** To investigate the effects of defects in between corners of elbows.
- **Description:** A defect (of size 0.3, 0.5, 0.6, 0.8 μm for different cases) is introduced at the corner between two 1.3 μm elbows. Testing for a short between the elbows is done.
- **Testing:** Resistance measurement.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (23,0), (20,6), (27,9)

PAD #	DESCRIPTION	TEST FUNCTION
1&11	Defect between elbows	Apply V, Sense I
2&12	Defect between elbows	Apply V, Sense I
3&13	Defect between elbows	Apply V, Sense I
4&14	Defect between elbows	Apply V, Sense I

- **DEFECT3 STRUCTURE DEFECT3B LAYOUT**



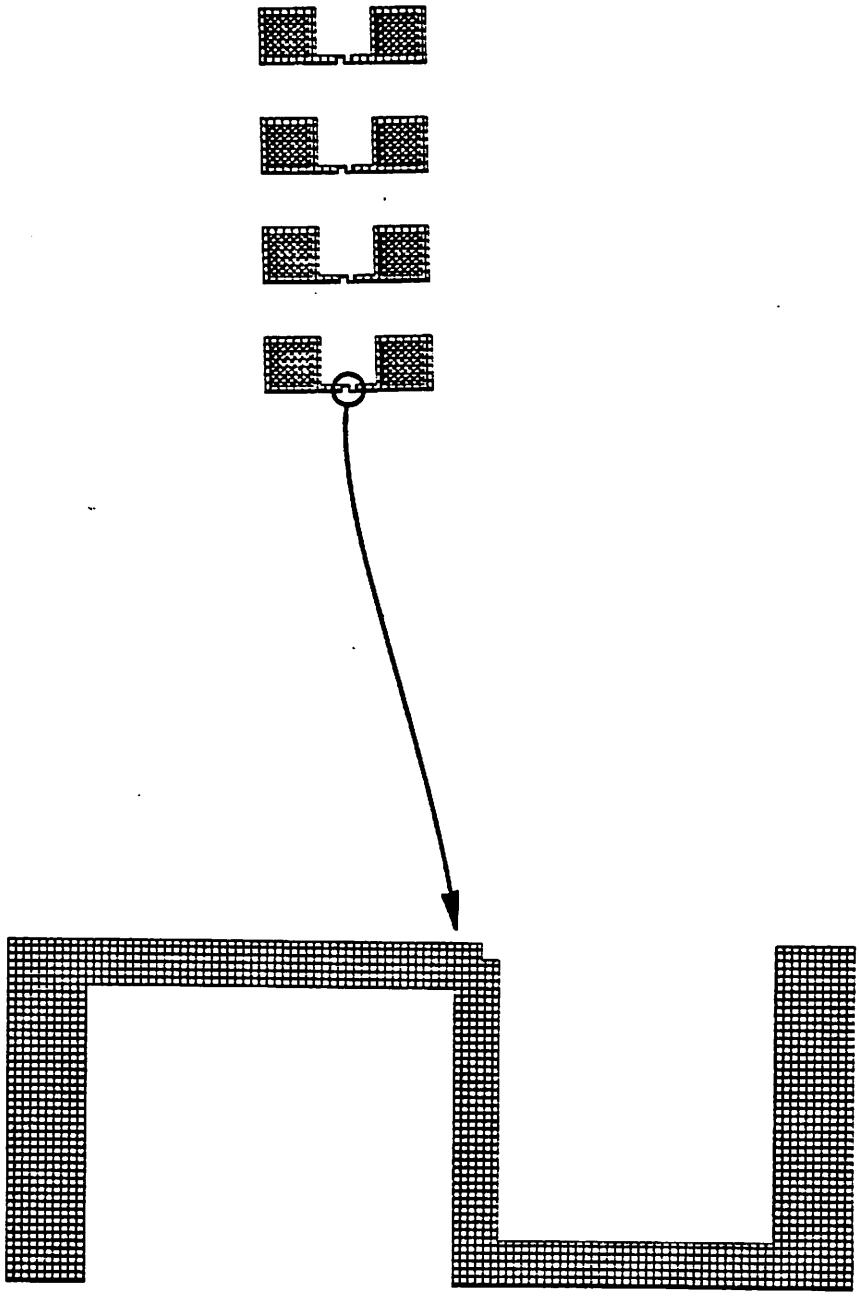
- **Filename/Structure:** DEFECT3/DEFECT3C
- **References:** None
- **Purpose:** To investigate the effects of defects in different critical locations on the elbows.
- **Description:** 1.3μm elbows are used. A 0.5μm transparent defect is placed at different locations on the elbows. Testing of opens of the elbows are done. The locations are the following:
  1. At the outer corner of the elbow.
  2. Lined up with the inner vertical and outer horizontal edge of the elbow.
  3. Lined up with the inner vertical and inner horizontal edge of the elbow.
  4. Lined up with the outer horizontal edge and at a spacing of 2.6μm from the outer vertical edge of the elbow.
- **Testing:** Resistance measurement.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (24,0), (21,6), (28,9)

PAD #	DESCRIPTION	TEST FUNCTION
1&11	Transparent defect in elbow	Inject I, Sense V
2&12	Transparent defect in elbow	Inject I, Sense V
3&13	Transparent defect in elbow	Inject I, Sense V
4&14	Transparent defect in elbow	Inject I, Sense V

- **DEFECT3 STRUCTURE DEFECT3C LAYOUT**



Exposure test patterns

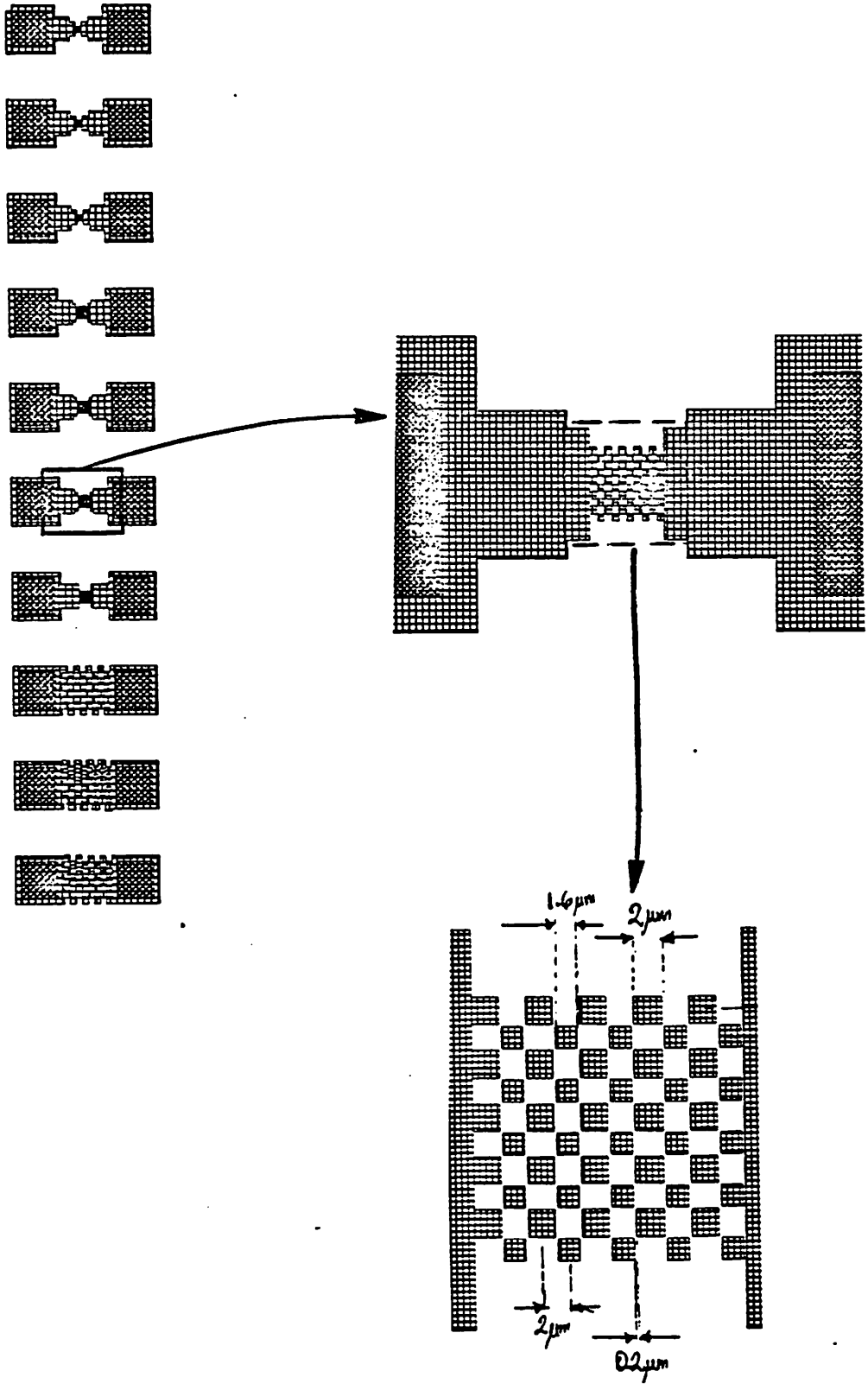
- **Filename:** EXPOSURE
- **References:** The use of checkerboard patterns for measuring exposure was taken from [5].
- **Purpose:** To measure exposure levels during lithographic steps.
- **Description:** Ten different checkerboard patterns are used to measure exposure levels. See §7 for detailed description of some patterns.
- **Testing:** Resistance measurement.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (13,8), (0,6), (29,8)

PAD #	DESCRIPTION	TEST FUNCTION
1,11	Checkerboard pattern	Inject I, sense V
2,12	Same	Same
3,13		
4,14		
5,15		
6,16		
7,17		
8,18		
9,19		
10,20		

- **EXPOSURE LAYOUT**



Flare effects

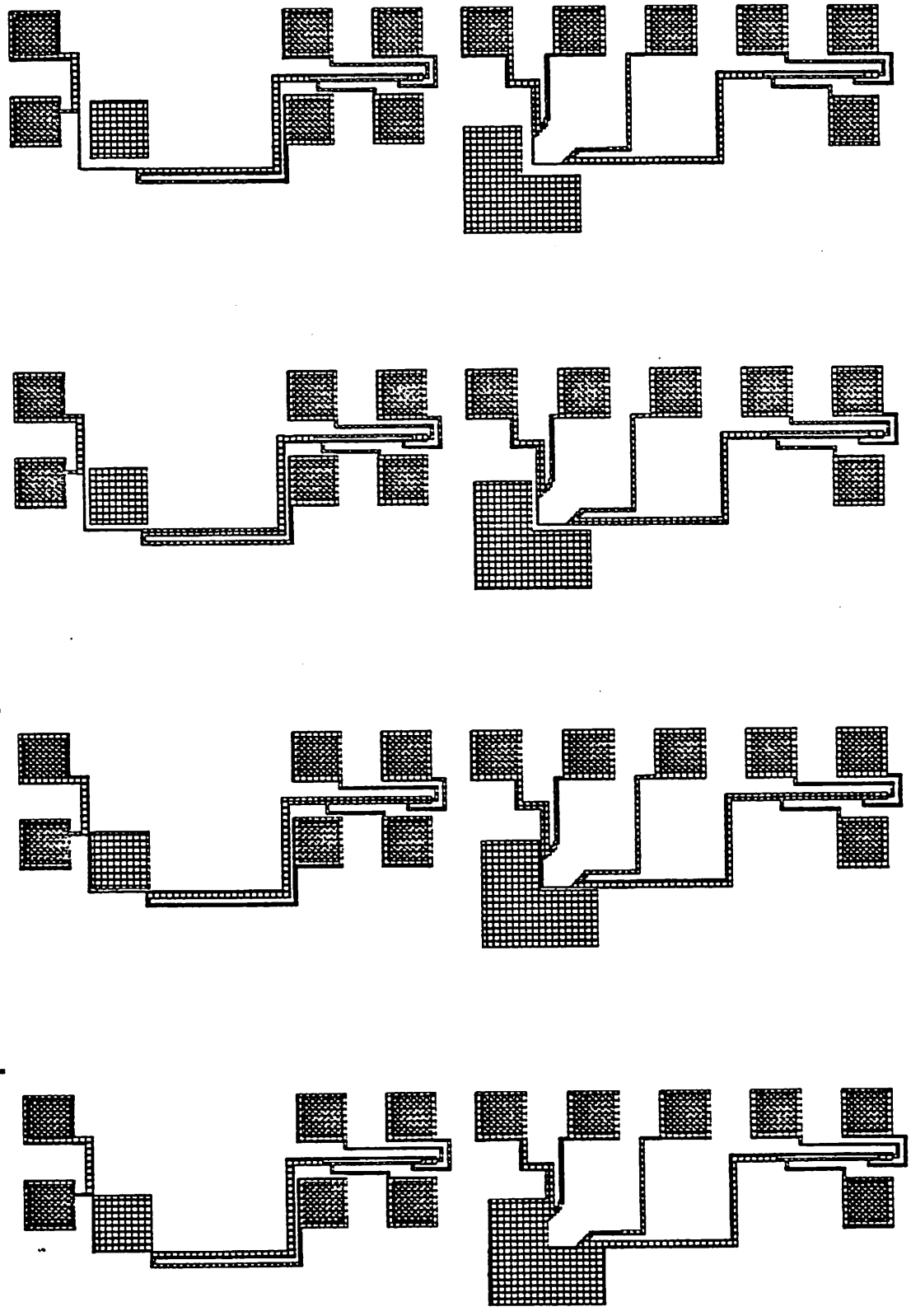
- **Filenames:** FLARE and FLARESHORT
- **References:** None.
- **Purpose:** To measure the effect of flare on linewidth.
- **Description:** 1 μm lines are laid out close to large dark features. FLARE consists of seven structures (an isolated line and lines at 1, 2, 5, 10, 20 and 50 μm from a dark field) and FLARESHORT (see layout) of four (1, 2, 5 and 10 μm).
- **Testing:** Linewidth measurement.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: FLARE (12-24,6) FLARESHORT (1-7,10) and (14-20,10)

PAD #	DESCRIPTION	TEST FUNCTION
11,14	Inner dark feature	Inject current
1,4		Sense voltage
16,19	Outer dark field	Inject current
17,18		Sense voltage

- **FLARE LAYOUT**



Focus A(1 D)

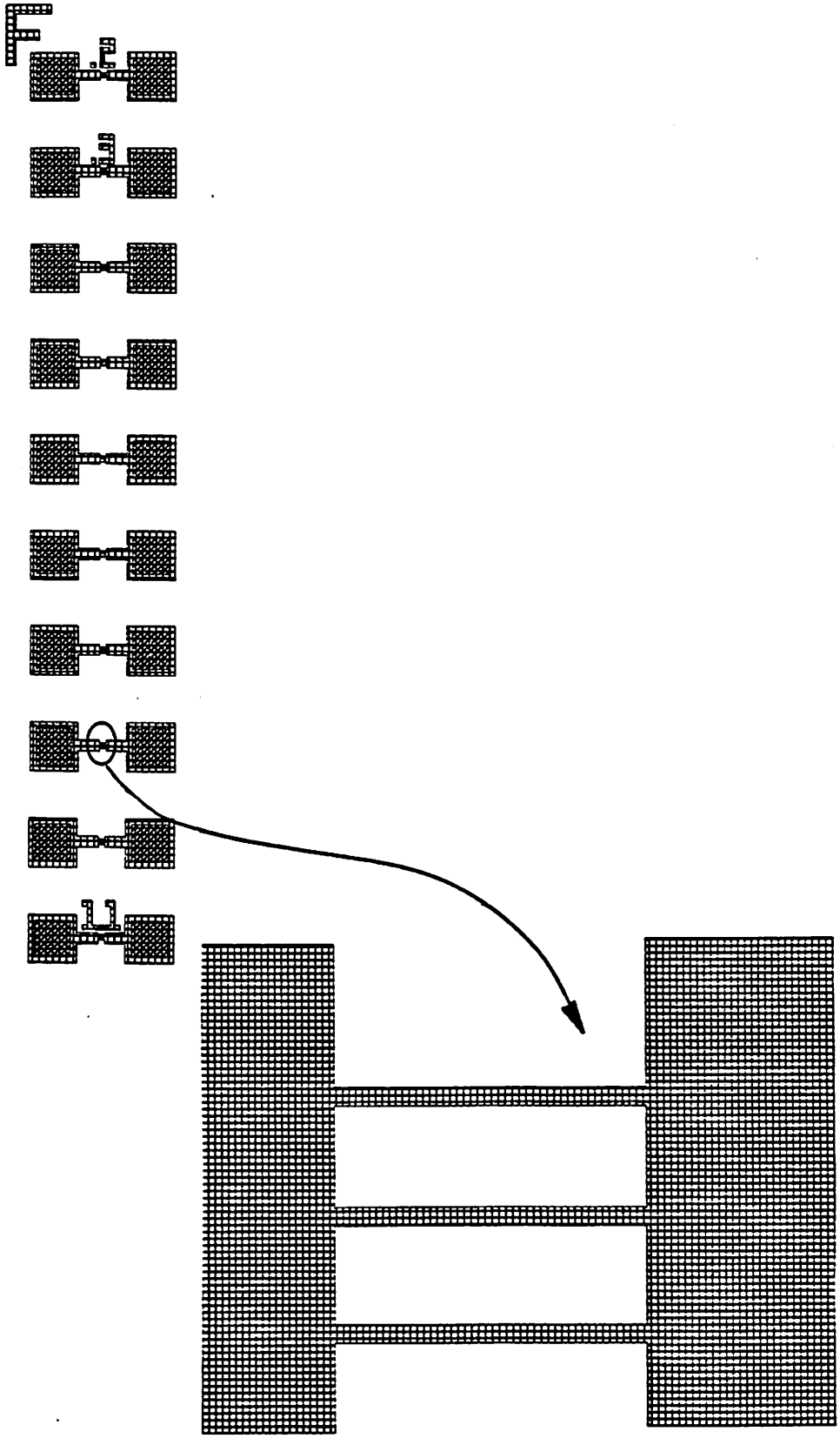
- **Filename:** FOCUS
- **References:** None
- **Purpose:** To measure defocus by testing thin lines for opens due to defocus.
- **Description:** Ten sets of lines with widths of 0.2,0.3,0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1 μm are used. Each set is composed of three lines 12.0 μm long with a pitch of 4 μm.
- **Testing:** Short/open detection.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (15,0), (15,4), (27,0)

PAD #	DESCRIPTION	TEST FUNCTION
1&11	Three lines in parallel	Inject I, Sense V
2&12	Three lines in parallel	Inject I, Sense V
3&13	Three lines in parallel	Inject I, Sense V
4&14	Three lines in parallel	Inject I, Sense V
5&15	Three lines in parallel	Inject I, Sense V
6&16	Three lines in parallel	Inject I, Sense V
7&17	Three lines in parallel	Inject I, Sense V
8&18	Three lines in parallel	Inject I, Sense V

- **FOCUS LAYOUT**



Two-dimensional defocus structures

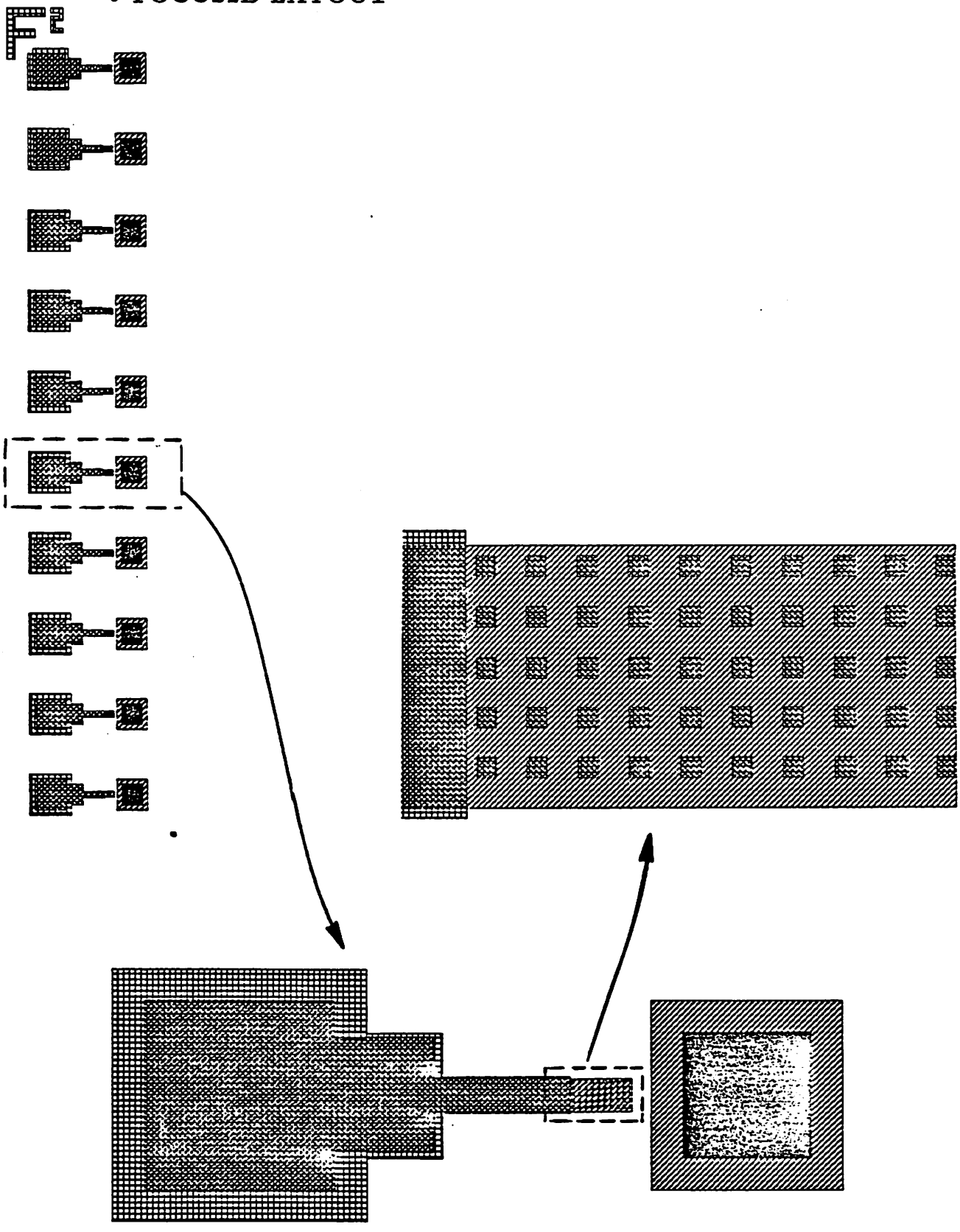
- **Filename:** FOCUS2D
- **References:** None.
- **Purpose:** To determine defocus through capacitance measurements.
- **Description:** See §5.
- **Testing:** Capacitance measurement.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (13,4), (0,2), (9,10)

PAD #	DESCRIPTION	TEST FUNCTION
1,11	Patterned capacitor	Measure capacitance
2,12	Same	Same
3,13		
4,14		
5,15		
6,16		
7,17		
8,18		
9,19		
10,20		

- **FOCUS2D LAYOUT**



Focus B(1 D)

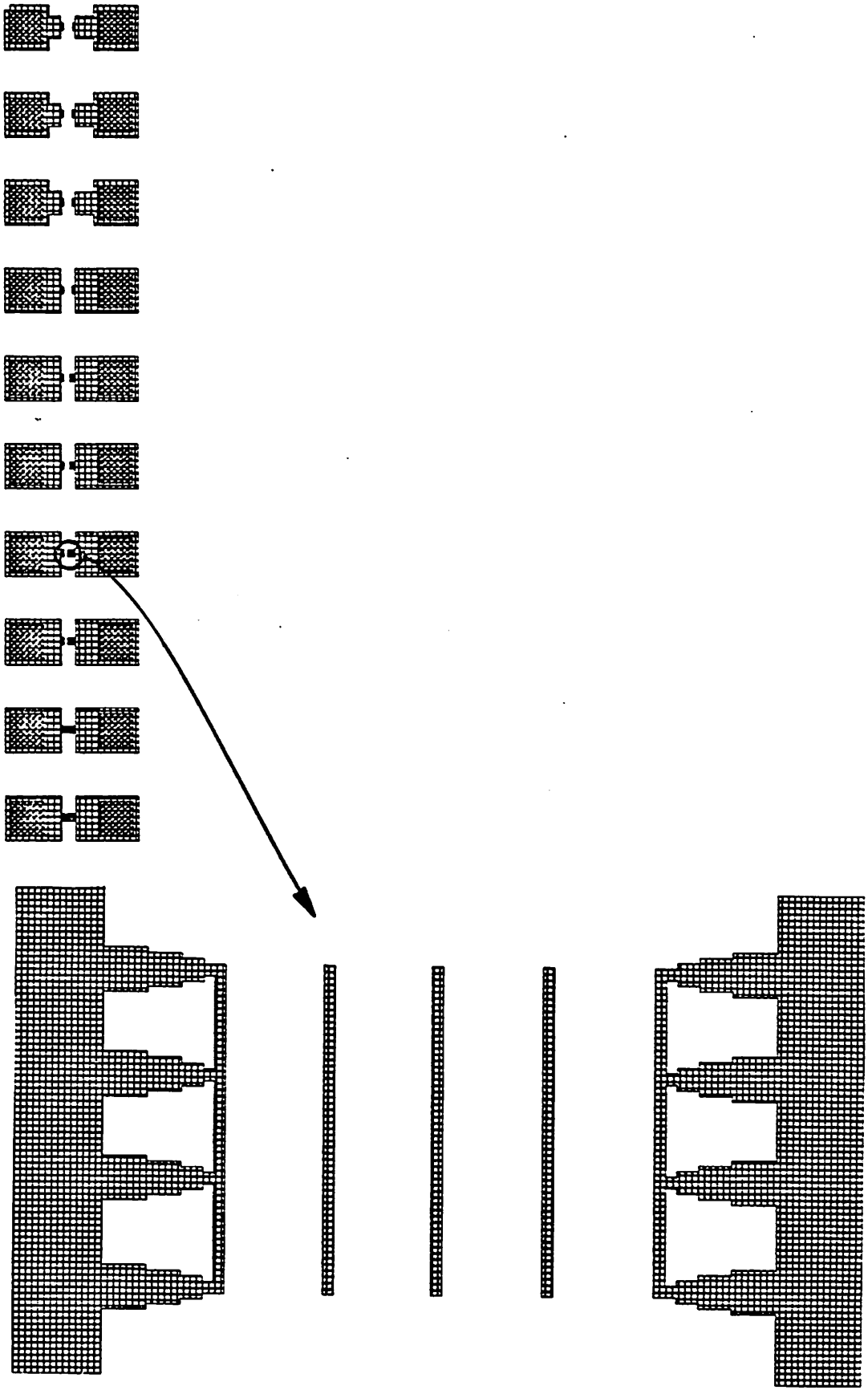
- **Filename:** FOCUST
- **References:** None
- **Purpose:** To measure defocus by testing thin broken (see description of process C) lines for shorts due to defocus.
- **Description:** Ten sets of lines with widths of 0.2,0.3,0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, and 1.1 μm are used. Each set is composed of five lines with a pitch of 4 μm. A non-standard process should be used.
- **Testing:** Resistance measurement.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (14,6),(29,2), (29,4)

PAD #	DESCRIPTION	TEST FUNCTION
1&11	Five lines in parallel	Apply V, Sense I
2&12	Five lines in parallel	Apply V, Sense I
3&13	Five lines in parallel	Apply V, Sense I
4&14	Five lines in parallel	Apply V, Sense I
5&15	Five lines in parallel	Apply V, Sense I
6&16	Five lines in parallel	Apply V, Sense I
7&17	Five lines in parallel	Apply V, Sense I
8&18	Five lines in parallel	Apply V, Sense I
9&19	Five lines in parallel	Apply V, Sense I
10&20	Five lines in parallel	Apply V, Sense I

- **FOCUST LAYOUT**



Linewidth, smile plots and contrast

- **Filename:** LINEWIDTH
- **References:** The basic structure was taken from [4] and modified to fit the described purpose.
- **Purpose:** To generate smile plots from linewidth measurements and to assess the effect of contrast.
- **Description:** Lines with linewidth W are used. Isolated and non-isolated lines can be measured, the non-isolated line is part of a pattern of equal lines and spaces. Two different sets of structures have been designed to measure vertical and horizontal lines.

  Vertical Lines

Coordinates	(14,1)	(14,0)	(15,1)	(15,0)
W	0.4μm	0.6μm	0.8μm	1.0μm

  Horizontal Lines

Coordinates	(16,1)	(16,0)	(17,1)	(17,0)
W	0.4μm	0.6μm	0.8μm	1.0μm

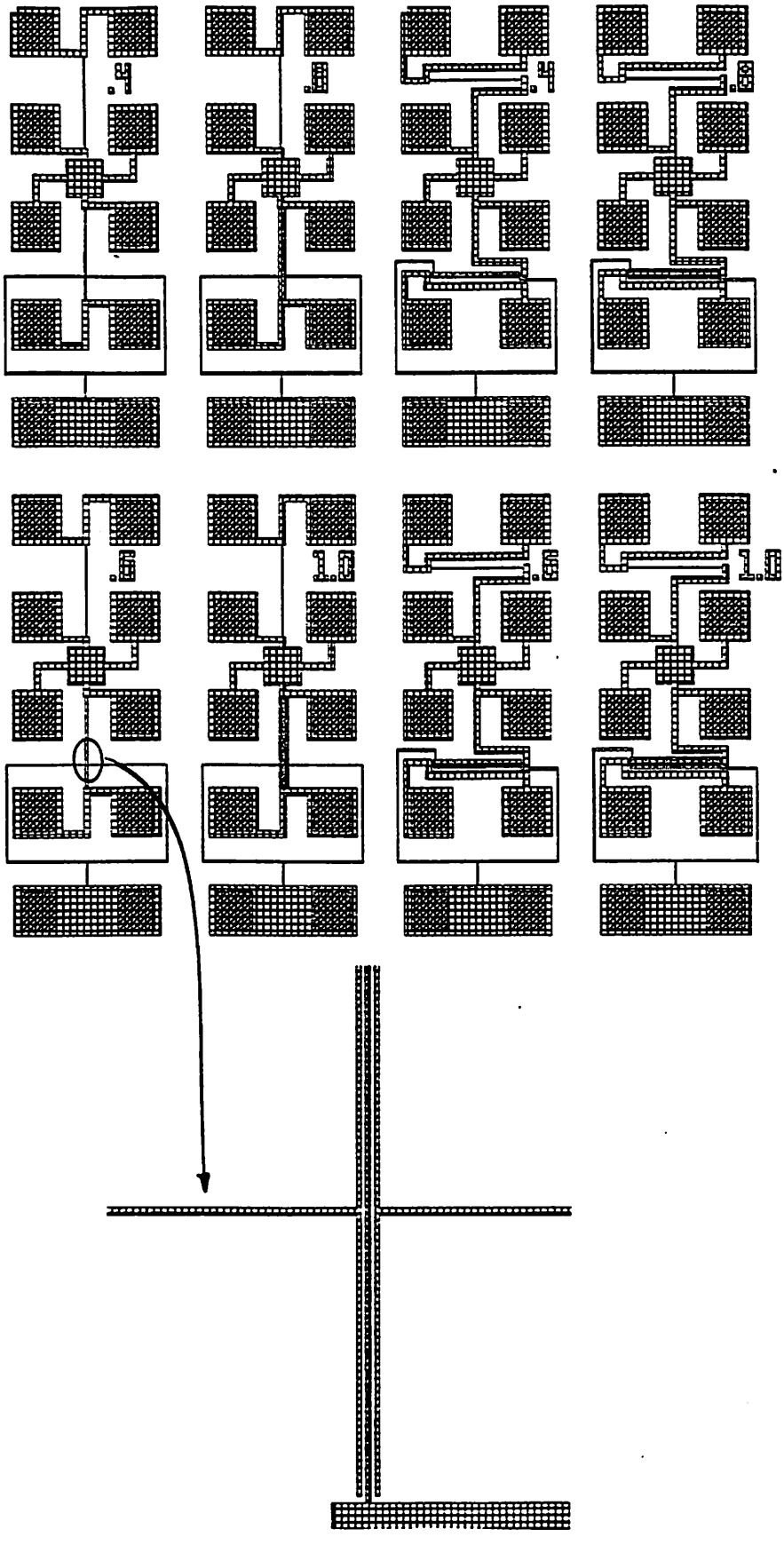
- **Testing:** Resistance measurement.
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (14,0)-(17,0), (16,4)-(17,4), (26,0)-(29,0)

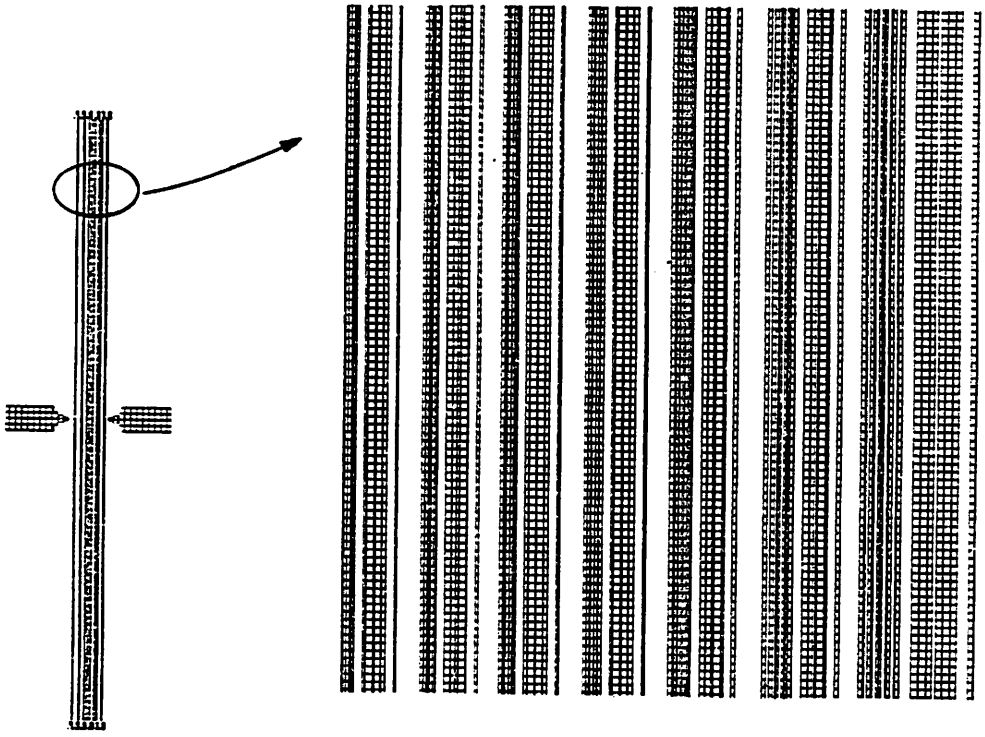
PAD #	DESCRIPTION	TEST FUNCTION
4&11		Inject I
1&2	Isolated line	Sense V
13&14	Line/space	Sense V
9&16		Inject I
6&7	Isolated line	Sense V
18&19	Line/space	Sense V
2,3,12,13	Van der Pauw reference	See Van der Pauw description

- LINEWIDTH LAYOUT



SEM measurement lines

- **Filename:** SEM
- **References:** None.
- **Purpose:** Cross-section evaluation.
- **Description:** Five sets of SEM lines (0.4, 0.5, 0.6, 0.8, and 1.0 μm) have been designed. Each set consists of the following lines -from left to right: Five equal line/spaces, one isolated line and one isolated space.
- **Testing:** No electrical testing.
- TEST COORDINATES: (7,0-5)
- **SEM LAYOUT**



Van der Pauw pattern

- **Filename:** VANDERP
- **References:** See for instance [3].
- **Purpose:** Measurement of sheet resistance.
- **Description:** See §5.
- **Testing:** Current is injected across a corner of the central square and voltage is measured across the opposite corner. The sheet resistance can be calculated from (5)

$$R_{\square} = \frac{\pi}{\ln 2}\frac{\Delta V}{I} \tag{8}$$

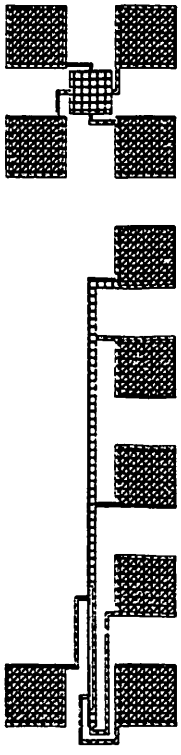
- **Pad Assignments**

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

TEST COORDINATES: (14,4), (12,0), (29,10)

PAD #	DESCRIPTION	TEST FUNCTION
4,14		Inject current (I)
5,15		Sense voltage (ΔV)

- **VANDERP LAYOUT**



6 Cell Hierarchy

The cell hierarchy for mask layout is very simple and it is organized according to the following elements. Vem (version 5) was the CAD tool used and the graphic files are OCT files, which in turn were converted to cif files for the mask generation. The entire layout is named ELITHO and consists of instances of the patterns previously described. The filenames for these patterns are the same than those in the summary table shown in §3. Most patterns were laid out using a basic PADSET instance, which in turn consists of twenty instances of PAD. Finally, the VANDERP pattern uses the vp-poly instance.

References

[1] T. F. Hasan, S. U. Katzman, D. S. Perloff, IEEE Trans. Elect. Dev. ED-27 (1980) 2304.

[2] Memorandum No. UCB/ERL M84/26, University of California, Berkeley (1984).

[3] L. J. van der Pauw, Philips Res. Rep. **13** (1958) 1.

[4] D. Yen, L. W. Linholm, W. B. Glendinning, J. Electrochem. Soc. **132** (1985) 1726.

[5] R. Holwill et al, IEEE VLSI Workshop on Test Structures (1986) 67.

See also the following two references for information on electrical characterization of optical lithography:

[6] W. H. Arnold, SPIE **722** (1987) 21.

[7] Cristopher P. Ausschnitt. *Electrical Measurements for Characterizing Lithography.* In N.G. Einspruch and R.K. Watts, editors, *VLSI Electronics Microstructure Science Vol. 16*, Academic Press, Inc., 1987.