

# SEMI P23-0200 (Reapproved 1107) GUIDELINES FOR PROGRAMMED DEFECT MASKS AND BENCHMARK PROCEDURES FOR SENSITIVITY ANALYSIS OF MASK DEFECT INSPECTION SYSTEMS

This standard was technically approved by the global Micropatterning Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on September 5, 2007. It was available at [www.semi.org](http://www.semi.org) in October 2007. Originally published in 1993; previously published in February 2000.

**NOTICE:** This Standard or Safety Guideline has an Inactive Status because the conditions to maintain Current Status have not been met. Inactive Standards or Safety Guidelines are available from SEMI and continue to be valid for use.

## 1 Purpose

1.1 The purpose of this guideline is to propose a test mask to be used for evaluation of the sensitivity of Mask Defect Inspection Systems. This test mask consists of test chips including programmed pattern defects and reference test chips without programmed defects. Since the test chip is an assembly of cells, the test chips are defined in this guideline by cell patterns, programmed defects in cell patterns, and the layout of the cells. Also, the test mask is defined by defining the test chips arrangement. Furthermore, the use of this mask is described. It is desirable that these test masks and benchmark procedures be used when the sensitivity of a Mask Defect Inspection System is evaluated.

1.2 *Background* — Different masks have been used by many equipment manufacturers and users in the past, and sensitivity has been tested by various methods decided independently by each manufacturer and user. In some cases, no common measurement methods or sensitivity analysis methods have been agreed upon. Therefore, confusion exists concerning the sensitivity comparison of equipment between manufacturers, the definition for specifications between users and suppliers, and the definition for specifications between users. Also, due to the fact that several problems were found when using the previous guideline in actual manufacturing, the document has been reviewed and content has been changed throughout. It was also the goal of this revision, while considering ease of manufacturing of test masks first, to fully cover the evaluation of mask defect inspection systems.

## 2 Scope

2.1 This guideline defines the content and methods for use of test masks used in the evaluation of mask defect inspection systems. Although it is possible to use this test mask to evaluate transcription of defects etc., this standard does not attempt to define these processes.

2.2 This guideline shall be revised when a new effective measurement technology for defect sizing becomes commonly available in the market.

**NOTICE:** SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

## 3 Referenced Standards and Documents

### 3.1 SEMI Standards and Safety Guidelines

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI P22 — Guideline for Photomask Defect Classification and Size Definition

SEMI P33 — Provisional Specification for Developmental 230 mm Square Hard Surface Photomask Substrates

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

## 4 Terminology

### 4.1 Definitions

4.1.1 Many terms relating to photomask technology are defined in SEMI P22 and SEMI P33.

4.1.2 *design pattern* — pattern of intended design data.

4.1.3 *photomask pattern* — pattern on photomask surface.

## 5 Mask (See Figure 1)

5.1 Masks will be either 5 inch or 6 inch which meet SEMI P1; both the 5 inch and 6 inch will be the same layout.

5.2 Masks will be limited to two types, namely Conventional and Attenuated (Half Tone). Note that Levenson and optical proximity correction (OPC) types will not be included.

5.3 There are two types of patterns: Wiring and Contact Hole pattern.

5.4 In one mask, there will be one type of pattern, either Wiring or Contact Hole.

5.5 One defect chip will be placed in the center of the mask.

5.6 Eight reference chips (non-defective) will be placed at 25,000 micron intervals to make sure that inspection can occur even if the mask is set in the inspection equipment in different directions (e.g., 0°, 90°, 180°, 270°).

### 5.7 Mask Naming

5.7.1 Wiring Pattern Mask is “SEMI STANDARD P23-0200-1500W”.

5.7.2 Contact Hole Pattern Mask is “SEMI STANDARD P23-0200-1500C”.

5.7.3 “P23-0200” is the registered number of this guideline.

5.7.4 “1500” expressed in nanometers, is the photomask pattern design rule. The following explanations in this guideline are based on a 1,500 nm (1.50 micron) design rule.

5.7.5 The mask naming should be written in characters which can be confirmed by the naked eye, and should be displayed in a place recognized by either the manufacturer or user of the mask.

5.8 Four light intensity adjustment patterns will be placed at 12,500 micron intervals from the center of the mask.

5.9 It is feasible to place stepper alignment marks and other patterns in such a way as not to affect the mask pattern described above.

## 6 Chip (See Figure 2 for illustration)

6.1 One chip of wiring patterns will be made up of 17 types of defects, each at 20 different defect sizes for a total of 340 cells.

6.2 One chip of contact hole patterns will be made up of 14 types of defects, each at 20 different defect sizes for a total of 280 cells.

6.3 Place defects changing types along the X-axis.

6.3.1 Display the defect type from the left side of the chip, toward the right, in capital English letters.

6.3.1.1 Wiring patterns are listed from A to Q.

6.3.1.2 Contact Hole patterns are listed from A to N.

6.4 Place defects changing size along the Y-axis.

6.4.1 Place the defects, from top to bottom, in range of size from 0.05 microns to 1.00 microns at 0.05 micron intervals.

NOTE 1: Display all sizes as they pertain to the mask (on the mask).

## 7 Cell

7.1 One cell will be 250 microns square. (See Figure 3.)

7.2 Sub-cells will be placed  $5 \times 5$  (Total=25).

7.3 Defects will be placed in the center of the cell ( $\pm 5.0$  micron).

7.4 Cells will be broken up into 9 types, depending on the content of the pattern and defect.

7.4.1 Seven types are used for Wiring Patterns. (See Figures 4 and 15 through 21.)

7.4.2 Two types are used for Contact Hole Patterns. (See Figures 6 and 7.)

## 8 Sub-Cell

8.1 One sub-cell is 50 microns square.

8.2 Place a pattern which shows the boundaries of the cell at the sub-cell coordinates (x1,y1), (x5,y1), (x1,y5) and (x5,y5). (See Figures 8 through 12.)

8.2.1 Figure 13 shows an example of these patterns placed together.

8.2.2 The pattern placed at (x5,y1) should be a pattern from which coordinates can be measured.

8.3 Place the defect type ID (cell coordinates) and the abbreviated pattern for the defect type in sub-cell coordinates (x1,y5). (See Figures 8 and 12.)

8.3.1 Defect type ID (cell coordinates) are written as one capital English letter, representing the defect type and a two-digit number representing defect size. (Example: A01). Character line width is set at 2.00 micron. (See Figure 14.)

8.3.2 The abbreviated pattern which denotes the defect content should keep the defect shape and direction consistent with the shape and direction of the program defect in the design.

8.4 The recommended values for pattern dimensions under the design rule (dimensions on mask) are as follows:

| <i>Dimension on Mask</i> | <i>Mask Name</i> |
|--------------------------|------------------|
| 5.00 micron              | 5000             |
| 3.00 micron              | 3000             |
| 2.50 micron              | 2500             |
| 2.00 micron              | 2000             |
| 1.50 micron              | 1500             |
| 1.00 micron              | 1000             |
| 0.80 micron              | 800              |
| 0.50 micron              | 500              |

8.4.1 The above list of design rule dimensions is recommended values, and it is feasible to use a different size.

8.4.2 When changing the design rule, chip spacing (25.0 mm) should not change.

8.5 For the Wiring Pattern Chip, place a pattern with uniform sub-cell coordinates: (x2,y1), (x4,y1), (x1,y2), (x2,y2), (x4,y2), (x5,y2), (x1,y4), (x2,y4), (x4,y4), (x5,y4), (x2,y5), (x4,y5). (See Figure 4.)

8.5.1 Patterns in a sub-cell using the uniform Wiring Pattern should be as follows:

| <i>Sub-cell Coordinates</i> | <i>Pattern to Be Used</i> |
|-----------------------------|---------------------------|
| (x2,y1) and (x4,y5)         | Wiring Type A (Figure 15) |
| (x4,y1) and (x2,y5)         | Wiring Type B (Figure 16) |
| (x1,y4) and (x5,y2)         | Wiring Type A rotated 90° |
| (x1,y2) and (x5,y4)         | Wiring Type B rotated 90° |
| (x2,y2)                     | Wiring Type C (Figure 17) |
| (x4,y2)                     | Wiring Type D (Figure 18) |
| (x2,y4)                     | Wiring Type E (Figure 19) |
| (x4,y4)                     | Wiring Type F (Figure 20) |

8.5.2 Uniform patterns are placed inside a 50 micron-square sub-cell.

8.5.3 For patterns in the Wiring Pattern which change depending on the defect type ID, the same patterns should be placed, without borders, in sub-cell coordinates (x3,y1), (x3,y2), (x1,y3), (x2,y3), (x3,y3), (x4,y3), (x5,y3), (x3,y4) and (x3,y5).

8.5.4 Pattern content will change as follows, depending on the defect type ID:

| <i>Defect Type ID</i> | <i>Pattern to Be Used</i> |
|-----------------------|---------------------------|
| A, B, C, D            | Wiring Type A (Figure 15) |
| G, H, K, L, Q         | Wiring Type C (Figure 17) |
| I, J                  | Wiring Type D (Figure 18) |
| E, F                  | Wiring Type E (Figure 19) |
| M, N                  | Wiring Type F (Figure 20) |
| O, P                  | Wiring Type G (Figure 21) |

8.5.4.1 Adjust the pattern position so that the defect is placed in the center of sub-cell coordinates (x3,y3). There may be instances where the placement of the uniform patterns and the defect-inserted patterns vary slightly.

8.5.4.2 Figure 5 is an example of placement of a Type A Wiring Pattern.

8.6 For Contact Hole Pattern Chips, contact hole patterns should be placed at all sub-cells except coordinates (x1,y1), (x5,y1), (x1,y5) and (x5,y5). (See Figures 6 and 22.)

8.6.1 For misplacement defects, in order to be evaluated as an isolated field, place just one contact hole pattern in the center of sub-cell coordinates (x3,y3) and only in cells where the contact hole pattern defect type ID is "M". (See Figure 7.)

8.6.2 Adjust the whole pattern for contact hole patterns so that the defect is placed in the center of sub-cell coordinates (x3,y3).

8.7 Use a common spacing for placement of wiring patterns and contact hole patterns.

8.7.1 For placement of patterns in design rule 1.50 microns (on mask), use a spacing of 14.0 microns in the X-direction and 7.0 microns in the Y-direction.

8.7.2 The values for spacing should change accordingly with a change in the design rule.

## 9 Defect (See Figures 23 and 24 for illustration)

### 9.1 Defect Type

#### 9.1.1 Dot

#### 9.1.2 Hole

#### 9.1.3 Edge Extension

- 0°
- 45°
- $\arctan(1/2) = 26.565^\circ$

#### 9.1.4 Edge Intrusion

- 0°
- 45°
- $\arctan(1/2) = 26.565^\circ$

#### 9.1.5 Corner Extension

#### 9.1.6 Corner Intrusion

#### 9.1.7 Over size

#### 9.1.8 Under size

#### 9.1.9 Elongation

#### 9.1.10 Truncation

#### 9.1.11 Misplacement

#### 9.1.12 Missing Pattern

### 9.2 Defect Design Method

9.2.1 Design the following defects, in squares, for wiring patterns and contact hole patterns. For edge defects on diagonal lines, use a pattern designed in a square and rotated to the angle of the diagonal. (In this case, the shape of the defect may change in the design data.) For corner defects, design using the edge length as a design dimension and not the diagonal.

#### 9.2.1.1 Dot

#### 9.2.1.2 Hole

#### 9.2.1.3 Edge Extension

- $0^\circ$
- $45^\circ$
- $\arctan(1/2) = 26.565^\circ$

#### 9.2.1.4 Edge Intrusion

- $0^\circ$
- $45^\circ$
- $\arctan(1/2) = 26.565^\circ$

#### 9.2.1.5 Corner Extension

#### 9.2.1.6 Corner Intrusion

9.2.2 The following defects change only in the pattern size along the Y-direction.

#### 9.2.2.1 Wiring Pattern Over Size

#### 9.2.2.2 Wiring Pattern Under Size

9.2.3 The following defects change in pattern size along both X and Y.

#### 9.2.3.1 Contact Hole Pattern Over Size

#### 9.2.3.2 Contact Hole Pattern Under size

9.2.4 The following defects change only in pattern length along the Y-direction in both wiring and contact hole patterns.

#### 9.2.4.1 Elongation

#### 9.2.4.2 Truncation

9.2.5 For the following defects, in both wiring and contact hole patterns, move the right half of the pattern in the Y-direction only to form a step.

#### 9.2.5.1 Misplacement Defect with ID “K”

9.2.6 In the following defects, the pattern shape and size are the same, with one whole isolated pattern moving only in the Y-direction.

#### 9.2.6.1 Misplacement defects, in both wiring and contact hole patterns, which have the defect ID “L”.

#### 9.2.6.2 Misplacement defects, in contact hole patterns, with the defect ID “M”.

9.2.7 The following single isolated pattern is completely destroyed in both wiring and contact hole patterns.

#### 9.2.7.1 Missing Pattern

### 9.3 Fabricating Position for Program Defect

9.3.1 Fabricate according to Figure detailed drawing.

## 10 Program Defect Size

10.1 According to SEMI P22, mainly, two values are to be used in defining size of defects. However, for the following reason, one value will be used to describe program defect size on this SEMI Standard P23 mask.

10.1.1 Defects used in evaluation are all program defects and mainly designed in square shape.

10.1.2 When describing the capabilities of mask defect inspection systems, it has become typical to describe defect size which one value.

10.2 Due to various reasons (influences) in mask manufacturing, it is not always possible to form all program defects with the shape and size described in the design.

10.3 SEMI Standard mask defect size is defined as follows. (See Figures 23 and 24.) Follow SEMI P22 for the values used below (S1, S2, X, Y, a, b, c, d).

#### 10.3.1 Dot and Hole

10.3.1.1 Defect Size is S1 or S2, whichever is larger.

#### 10.3.2 Edge Extension and Intrusion

10.3.2.1 Defect Size is S2.

#### 10.3.3 Corner Extension

10.3.3.1 Defect Size is the difference between the reference pattern S1[Reference] and the defect pattern S1[Defect] ( $|S1[Reference] - S1[Defect]|$ ).

#### 10.3.4 Corner Intrusion

##### 10.3.4.1 Wiring Pattern

10.3.4.1.1 Defect Size is the difference between the reference pattern S1[Reference] and the defect pattern S1[Defect] ( $|S1[Reference] - S1[Defect]|$ ).

##### 10.3.4.2 Contact Hole Pattern

10.3.4.2.1 As with Edge Intrusion in § 10.3.2, Defect Size is S2.

#### 10.3.5 Over Size

##### 10.3.5.1 Wiring Pattern

10.3.5.1.1 Since size only changes in the Y-direction, Defect Size is (d-c).

##### 10.3.5.2 Contact Hole Pattern

10.3.5.2.1 With “a” and “c” as the reference pattern size, Defect Size is (b-a) or (d-c), whichever is larger.

#### 10.3.6 Under Size

##### 10.3.6.1 Wiring Pattern

10.3.6.1.1 Since size only changes in the Y-direction, Defect Size is (d-c).

##### 10.3.6.2 Contact Hole Pattern

10.3.6.2.1 With “a” and “c” as the reference pattern size, Defect Size is (b-a) or (d-c), whichever is larger.

#### 10.3.7 Elongation and Truncation

10.3.7.1 Since, in a program defect, the size only changes in the Y-direction (S1), Defect Size is S1.

#### 10.3.8 Misplacement

10.3.8.1 Since the program defect is only moving along the Y-axis, Defect Size is Y.

### 10.3.9 *Missing Pattern*

10.3.9.1 With S1 and S2 as the reference pattern size, Defect Size is S1 or S2, whichever is larger.

## 11 **Light Intensity Adjustment Pattern**

11.1 Light intensity adjustment patterns will be placed in four areas in mask defect inspection systems. (See Figure 1.)

11.2 A glass pattern will be placed in the center.

11.3 Around the circumference of the glass pattern, a line and space pattern will be placed, 1 for 1, with the same line width as the design rule (dimensions on mask).

11.3.1 With 500 by 1,250 microns as one block, place horizontal patterns on the left and right sides, perpendicular patterns on the top and bottom. Also, place a horizontal pattern on the lower left corner. (See Figure 25.)

11.4 The circumference of the glass pattern and line and space pattern should have at least 6,000 microns of shade film.

## 12 **Method for Use of Test Masks in Evaluating Mask Defect Inspection System**

12.1 Inspect all defect cells, or a portion of them according to the inspection conditions of the mask defect inspection system to be evaluated.

12.2 Perform at least 20 inspections.

12.3 Perform the inspection at least with a set direction of 0°. It is also preferable that the inspection be performed after rotating the set at 90°, 180°, and 270°.

12.4 When displaying the defect inspection sensitivity for mask defect inspection system, display the defect size of the smallest defect of each type which was detected 100%. (See Figures 26 and 27.)

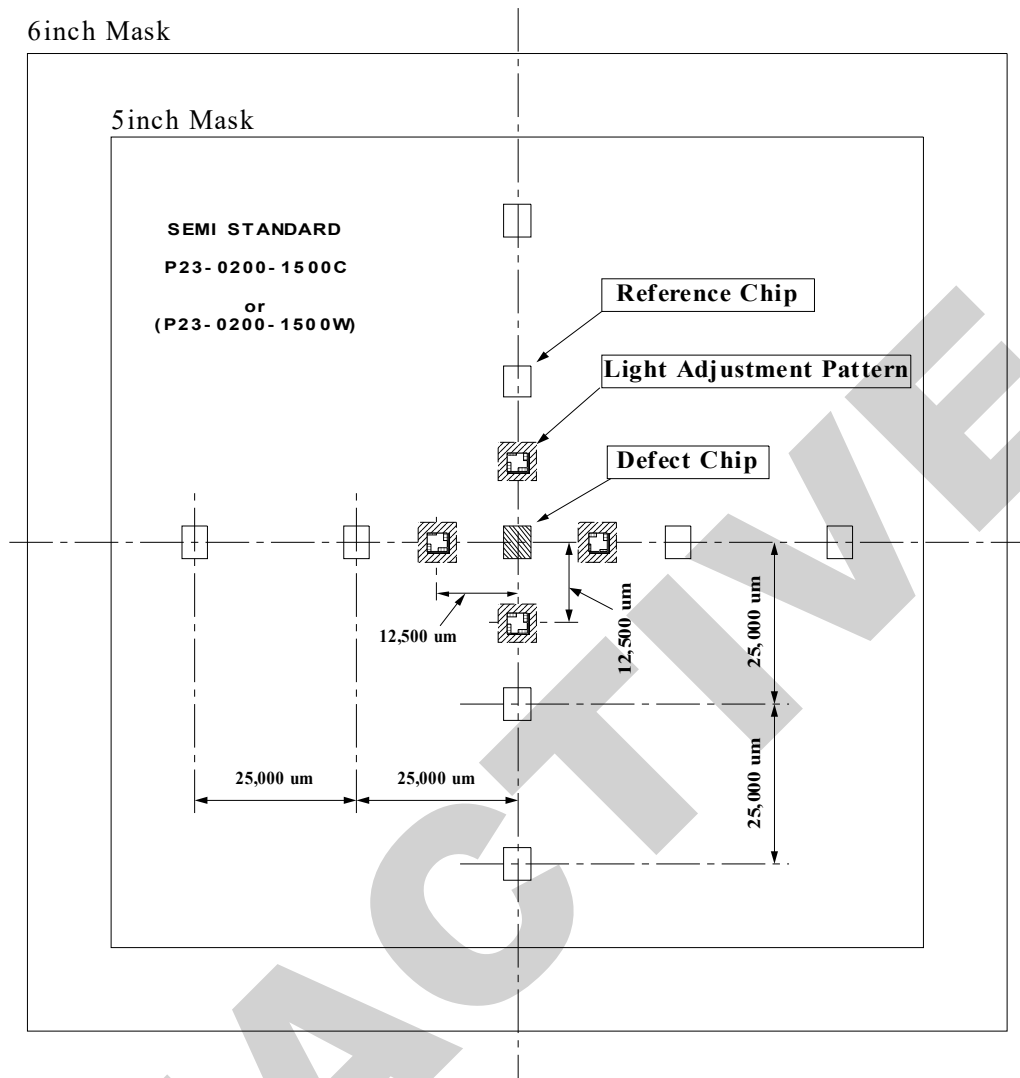
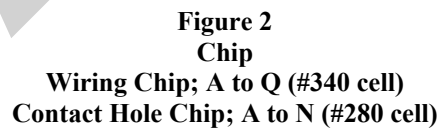


Figure 1  
Mask



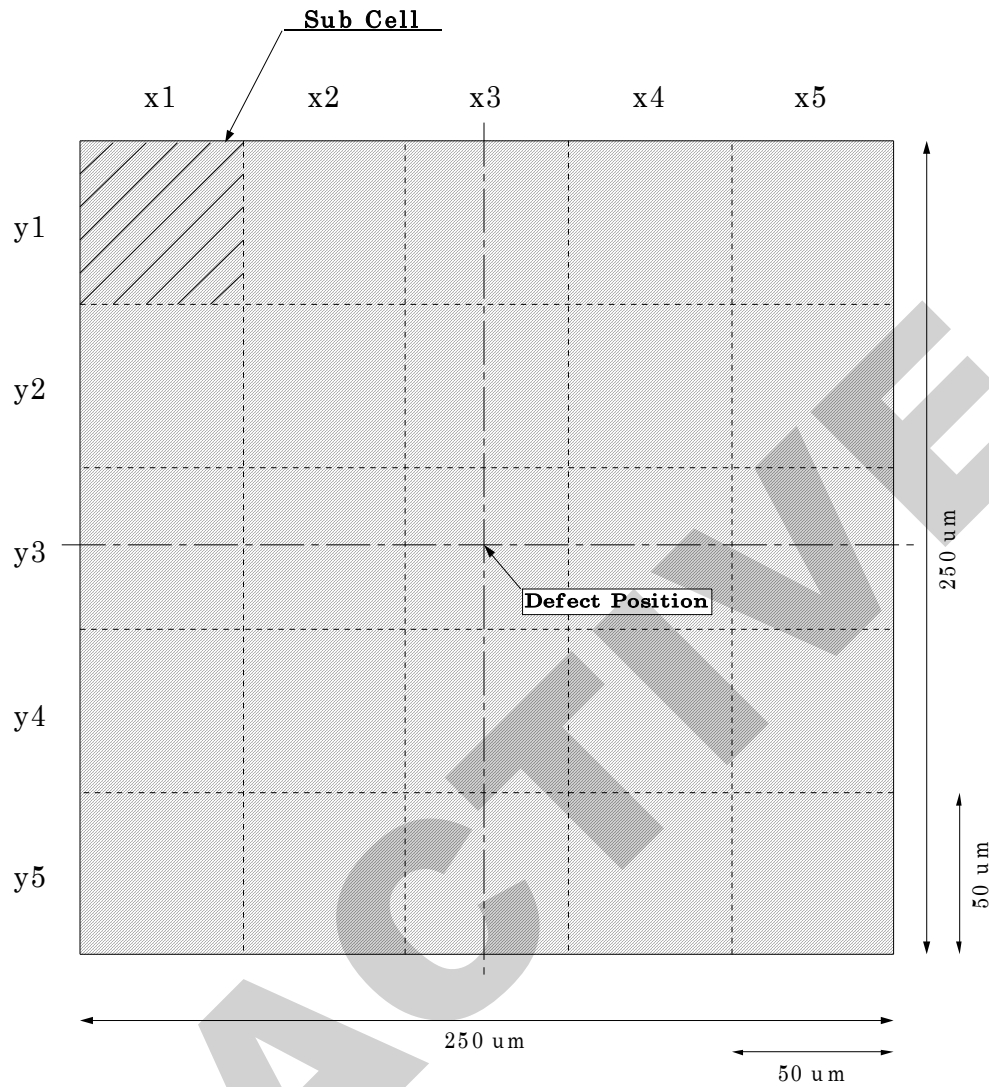


**Figure 3**  
**Cell**

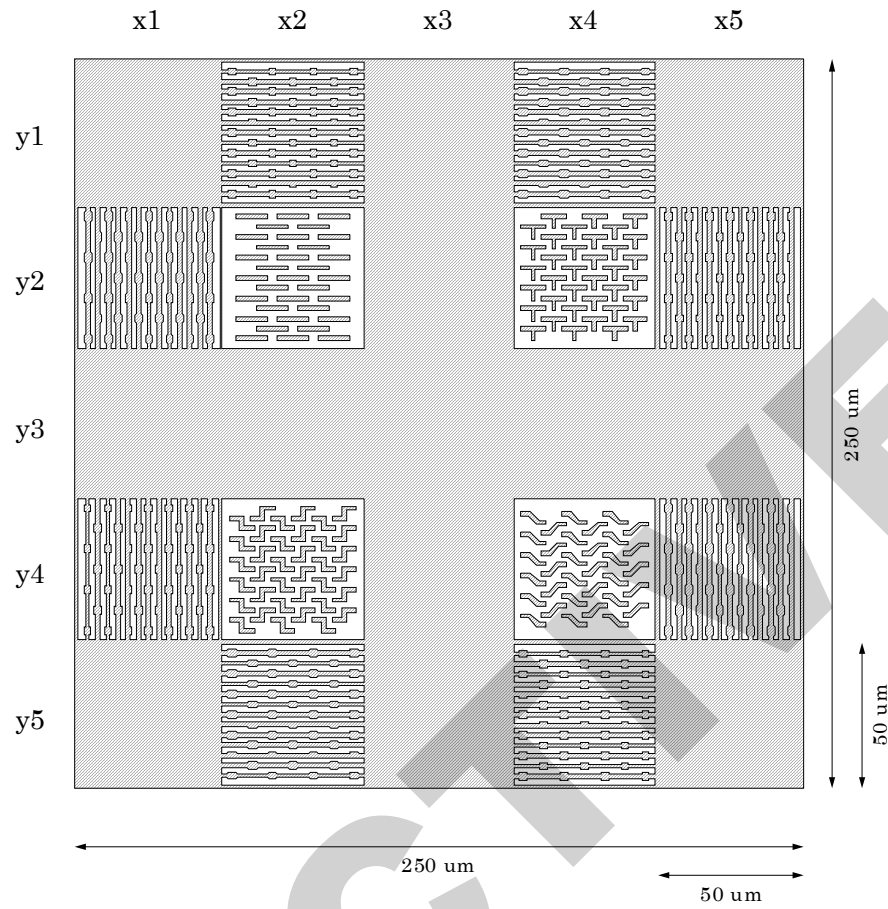


**Figure 4**  
**Cell Wiring Standard Pattern**