

SEMI M21-0998

SPECIFICATION FOR ASSIGNING ADDRESSES TO RECTANGULAR ELEMENTS IN A CARTESIAN ARRAY

NOTE: This specification reflects input from equipment producers and users; from SEMI Standards groups in the U.S. and Japan with interest in silicon wafers (including epi), equipment automation, and micropatterning metrology; and from individuals in the U.S., Japan, and Europe.

1 Scope

1.1 This specification defines an element addressing convention which can be used to locate and identify rectangular elements in a Cartesian array. The array may be regular or tiled in one direction. Such arrays are useful in locating sites for site flatness characterization, defect mapping, determination of parametric distributions, etc. on unpatterned semiconductor wafers. The position of the array on the wafer may be established through use of the wafer coordinate system defined in SEMI M20. For complex patterns, more than one array on a wafer may be defined and related to the same coordinate axes.

1.2 This specification provides a unique identification (address) for each element in the array.

1.3 The element addressing convention in this specification is consistent with that of the polar array specified in SEMI M17. In addition, element addresses can be readily transformed to addresses in other types of addressing conventions for cartesian arrays.

1.4 The element addressing convention in this specification provides an orderly progression along perpendicular directions with addresses of adjacent elements in any direction differing by 1. Consequently, distances may be calculated in a unified way.

2 Applicable Documents

2.1 SEMI Standards

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M2 — Specification for Silicon Epitaxial Wafers

SEMI M11 — Specification for Silicon Epitaxial Wafers for Advanced Applications

SEMI M17 — Specification for a Universal Wafer Grid

SEMI M20 — Specification for Establishing a Wafer Coordinate System

2.2 ASTM Standard¹

F 1241 — Terminology of Silicon Technology

3 Terminology

3.1 Many terms used in silicon wafer technology are defined in ASTM Terminology F 1241.

3.2 Definitions of additional terms may be found in SEMI M1, SEMI M2, or SEMI M11.

3.3 Selected definitions are also listed (for information only) in the glossary, Definitions for Semiconductor Materials, at the end of this volume.

4 Array Element Layout

4.1 The array is constructed from m vertical columns and n horizontal rows of identical elements of dimension a horizontally and b vertically. The number of elements in different rows and columns may vary to suit the application.

4.2 The address of an element is given by two numbers separated by a comma: (i,j) . The first number, i , indicates the column and the second, j , the row.

4.3 The longest row and the longest column are used in identifying the Starting Element, which is assigned the address $(0,0)$.

4.4 The array may have a tiled appearance, either with one or more rows offset relative to the row containing the Starting Element (row tiling) or with one or more columns offset relative to the column containing the Starting Element (column tiling).

4.4.1 For row tiling, the offset, t_r , is a fraction (p_r/q_r) of the horizontal element dimension, a , where p_r and q_r are small whole numbers.

4.4.2 For column tiling, the offset, t_c , is a fraction (p_c/q_c) of the vertical element dimension, b , where p_c and q_c are small whole numbers.

4.4.3 In either case, the offset may be constant or it may vary from row to row or column to column. When the offset is constant, the array pattern is repeated every q_r rows or q_c columns.

¹ American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

5 Element Addresses

5.1 Define the array center as the intersection of the vertical and horizontal array centerlines, found as follows:

5.1.1 If the array is regular (not tiled):

5.1.1.1 Count the number of elements, m , in the longest row.

5.1.1.2 If m is even, start at the leftmost element, count $m/2$ elements to the right, and construct a line along the right vertical boundary of this element. This line is the vertical array centerline (see Figure 1a).

5.1.1.3 If m is odd, start at the leftmost element, count the integer of $m/2$ elements to the right, continue to the next element to the right, and construct a line through the center of this element. This line is the vertical array centerline (see Figure 1b).

5.1.1.4 Count the number of elements, n , in the longest column.

5.1.1.5 If n is even, start at the topmost element, count down $n/2$ elements, and construct a line along the bottom horizontal boundary of this element. This line is the horizontal array centerline (see Figure 1c).

5.1.1.6 If n is odd, start at the topmost element, count down the integer of $n/2$ elements, continue down to the next element, and construct a line through the center of this element. This line is the horizontal array centerline (see Figure 1d).

5.1.2 If the columns of the array are tiled (see Figure 2a):

5.1.2.1 Count the number of columns, m , in the widest part of the array from left to right.

5.1.2.2 If m is even, start at the leftmost column, count $m/2$ columns to the right, and construct a line along the right vertical boundary of this column. This line is the vertical array centerline.

5.1.2.3 If m is odd, start at the leftmost column, count the integer of $m/2$ columns to the right, continue to the next column to the right, and construct a line through the center of this column. This line is the vertical array centerline.

5.1.2.4 Count the number of elements, n' , in the column which contains or is immediately to the right of the vertical array centerline, depending on whether m is odd or even, respectively.

NOTE 1 The number, n' , is usually equal to but may be less than n .

5.1.2.5 If n' is even, start at the topmost element, count down $n'/2$ elements, and construct a line along

the bottom horizontal boundary of this element. This line is the horizontal array centerline.

5.1.2.6 If n' is odd, start at the topmost element, count down the integer of $n'/2$ elements, continue down to the next element, and construct a line through the center of this element. This line is the horizontal array centerline.

5.1.3 If the rows of the array are tiled (see Figure 2b):

5.1.3.1 Count the number of rows, n , in the widest part of the array from top to bottom.

5.1.3.2 If n is even, start at the topmost row, count down $n/2$ rows, and construct a line along the bottom horizontal boundary of this row. This line is the horizontal array centerline (see Figure 1c).

5.1.3.3 If n is odd, start at the topmost row, count down the integer of $n/2$ rows, continue down to the next row, and construct a line through the center of this row. This line is the horizontal array centerline (see Figure 1d).

5.1.3.4 Count the number of elements, m' , in the row which contains or is immediately above the vertical array centerline, depending on whether n is odd or even, respectively.

NOTE 2 The number, m' , is usually equal to but may be less than m .

5.1.3.5 If m' is even, start at the leftmost element, count $m'/2$ elements to the right, and construct a line along the right vertical boundary of this element. This line is the vertical array centerline.

5.1.3.6 If m' is odd, start at the leftmost element, count the integer of $m'/2$ elements to the right, continue to the next element to the right, and construct a line through the center of this element. This line is the vertical array centerline.

5.2 Locate the Starting Element (0,0) as follows:

5.2.1 If the array center falls within an element, designate that element as the Starting Element (see Figure 3a).

5.2.2 If the array is regular and the array center lies at an element corner, designate the element to the right and immediately above the array center as the Starting Element (see Figure 3b).

5.2.3 If the array is regular and the array center lies on a vertical element boundary, designate as the Starting Element that element which contains the horizontal array centerline and is immediately to the right of the vertical array centerline (see Figure 3c).

5.2.4 If the array is regular and the array center lies on a horizontal element boundary, designate as the Starting

Element that element which contains the vertical array centerline and is immediately above the horizontal array centerline (see Figure 3d).

5.2.5 If columns of the array are tiled and the array center lies on a vertical boundary between columns, designate that element immediately to the right of the vertical centerline and containing the horizontal array centerline as the Starting Element. If the horizontal array centerline also falls on an element boundary in the column immediately to the right of the vertical array centerline, designate the element in this column and immediately above the horizontal array centerline as the Starting Element (see Figure 4a).

5.2.6 If rows of the array are tiled and the array center lies on a horizontal boundary between rows, designate that element immediately above the horizontal array centerline and containing the vertical array centerline as the Starting Element. If the vertical array centerline also falls on an element boundary in the row immediately above the horizontal array centerline, designate the element in this row and immediately to the right of the vertical array centerline as the Starting Element (see Figure 4b).

5.3 Assign addresses to the array elements as follows:

5.3.1 Elements along the horizontal array centerline:

5.3.1.1 If the horizontal array centerline passes through an element, assign that element the address $(i,0)$, where i is the column number. The first column to the right of the vertical array centerline is numbered 1, the next column to the right is numbered 2, the next column to the right is numbered 3, etc. Similarly, the first column to the left of the vertical array centerline is numbered -1, the next column to the left is numbered -2, the next column to the left is numbered -3, etc. (see Figure 3a).

5.3.1.2 If the horizontal array centerline falls along an element boundary in any column, i , assign the address $(i,0)$ to the element in that column which lies immediately above the horizontal array centerline (see Figure 3b).

5.3.2 Elements along the vertical array centerline:

5.3.2.1 If the vertical array centerline passes through an element, assign that element the address $(0,j)$, where j is the row number. The first row above the horizontal array centerline is numbered 1, the next row up is numbered 2, the next row up is numbered 3, etc. Similarly the first row below the horizontal array centerline is numbered -1, the next row down is numbered -2, the next row down is numbered -3, etc. (see Figure 3a).

5.3.2.2 If the vertical array centerline falls along an element boundary in any row, j , assign the address $(0,j)$ to the element in that row which lies immediately to the right of the vertical array centerline (see Figure 3b).

5.3.3 Remaining elements:

5.3.3.1 Assign addresses (i,j) to the remaining elements based on their position relative to the elements along the horizontal and vertical array centerlines. For example the address of the element immediately above $(1,0)$ is $(1,1)$ and the element immediately below $(1,0)$ is $(1,-1)$ (see Figure 5).

6 An Example

6.1 An example of a regular 29-column by 9-row array, truncated for application to a wafer, is shown in Figure 6. The Starting Element includes the array center because there are odd numbers of both columns and rows. In addition, Figure 6 shows the element addresses for elements along the right half of the horizontal array centerline, for elements along column 1, and for selected other elements in the array. Also shown are the left hand corner elements (which lie outside the truncated array).

6.2 Figure 7 shows the same truncated array fitted onto a wafer. Because the truncation is not symmetrical around the vertical array centerline, the array center is located to the left of the wafer center.

7 Extensions to Other Element Addressing Conventions

7.1 Element addressing conventions other than that covered by this specification are also widely used in engineering. Two of these are illustrated in Figure 8 with the use of the same truncated array discussed in the previous section.

7.2 First-Quadrant Convention

7.2.1 Addresses in this convention start at the lower left corner of the array and increase to the right and upward in the same way as in the convention covered by this specification. The lower left corner of the array is defined by the intersection of the bottom boundary of the lowest row and the left boundary of the leftmost column. In the case of tiling, the boundaries are those of the lowest elements and the leftmost elements in the array. The lower left corner may fall outside the useful portion of the array. The lower left element of the array is the element immediately to the right and above the lower left corner of the array.

7.2.2 The First-Quadrant Convention uses a column, row address but does not have a zero row or a zero column.

7.2.3 The addresses of the corners of an array with m columns and n rows in the First-Quadrant Convention are as follows:

lower left (Starting Element)	(1,1)
lower right	(m ,1)
upper left	(1, n)
upper right	(m , n)

7.2.4 The general formulas for obtaining the addresses of any element (i_f, j_f) in the First-Quadrant Convention from the addresses (i, j) in the convention covered by this specification are as follows:

$$i_f = i + \text{integer}(m/2) + 1$$

$$j_f = j + \text{integer}(n/2) + 1$$

7.2.5 These equations also apply to arrays with column or row tiling if $n' = n$ or $m' = m$, respectively. If this condition is not met, the displacement of the row or column which defines the array centerline with respect to the boundary of the array must be known to transform the addresses.

7.3 Row, Column (Matrix) Convention

7.3.1 Addresses in this convention start at the upper left corner of the array and increase to the right and downward. The upper left corner of the array is defined by the intersection of the top boundary of the highest row and the left boundary of the leftmost column. In the case of tiling, the boundaries are those of the highest elements and the leftmost elements in the array. The upper left corner may fall outside the useful portion of the array. The upper left element of the array is the element immediately to the right and below the upper left corner of the array.

7.3.2 The Row, Column (Matrix) Convention uses a row, column address and, like the First-Quadrant Convention, does not have a zero row or a zero column.

7.3.3 The addresses of the corners of an array with m columns and n rows in the Row, Column (Matrix) Convention are as follows:

upper left (Starting Element)	(1,1)
upper right	(1, m)
lower left	(n ,1)
lower right	(n , m)

7.3.4 The general formulas for obtaining the addresses of any element (i_m, j_m) in the Row, Column (Matrix) Convention from the addresses (i, j) in the convention covered by this specification are as follows:

$$i_m = \text{integer}(n/2) + 1 + j$$

$$j_m = \text{integer}(m/2) + 1 + i$$

7.3.5 These equations also apply to arrays with column or row tiling if $n' = n$ or $m' = m$, respectively. If this condition is not met, the displacement of the row or column which defines the array centerline with respect to the boundary of the array must be known to transform the addresses.