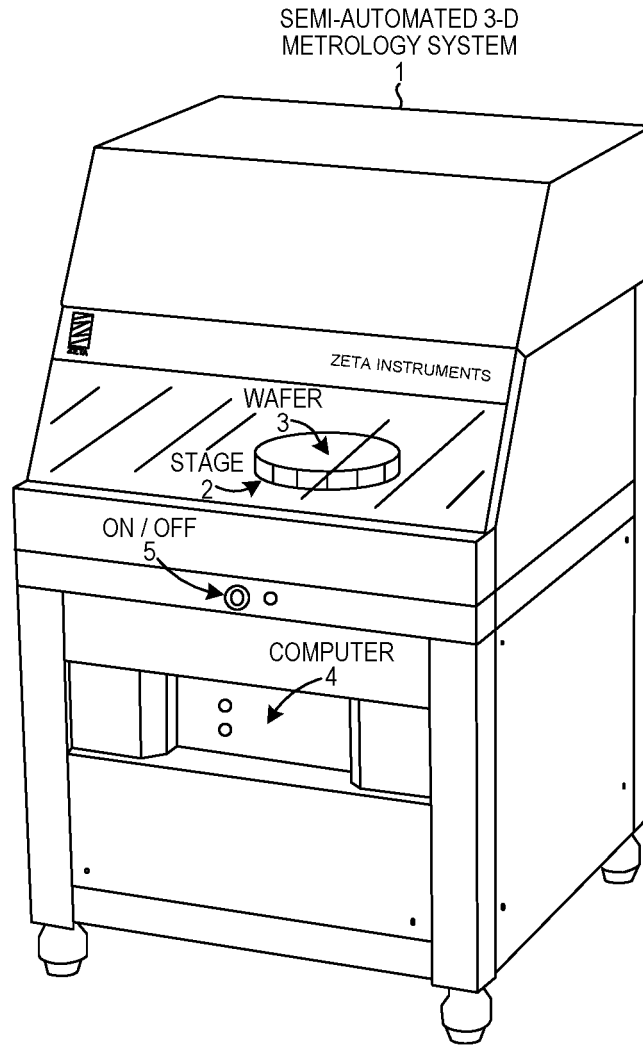


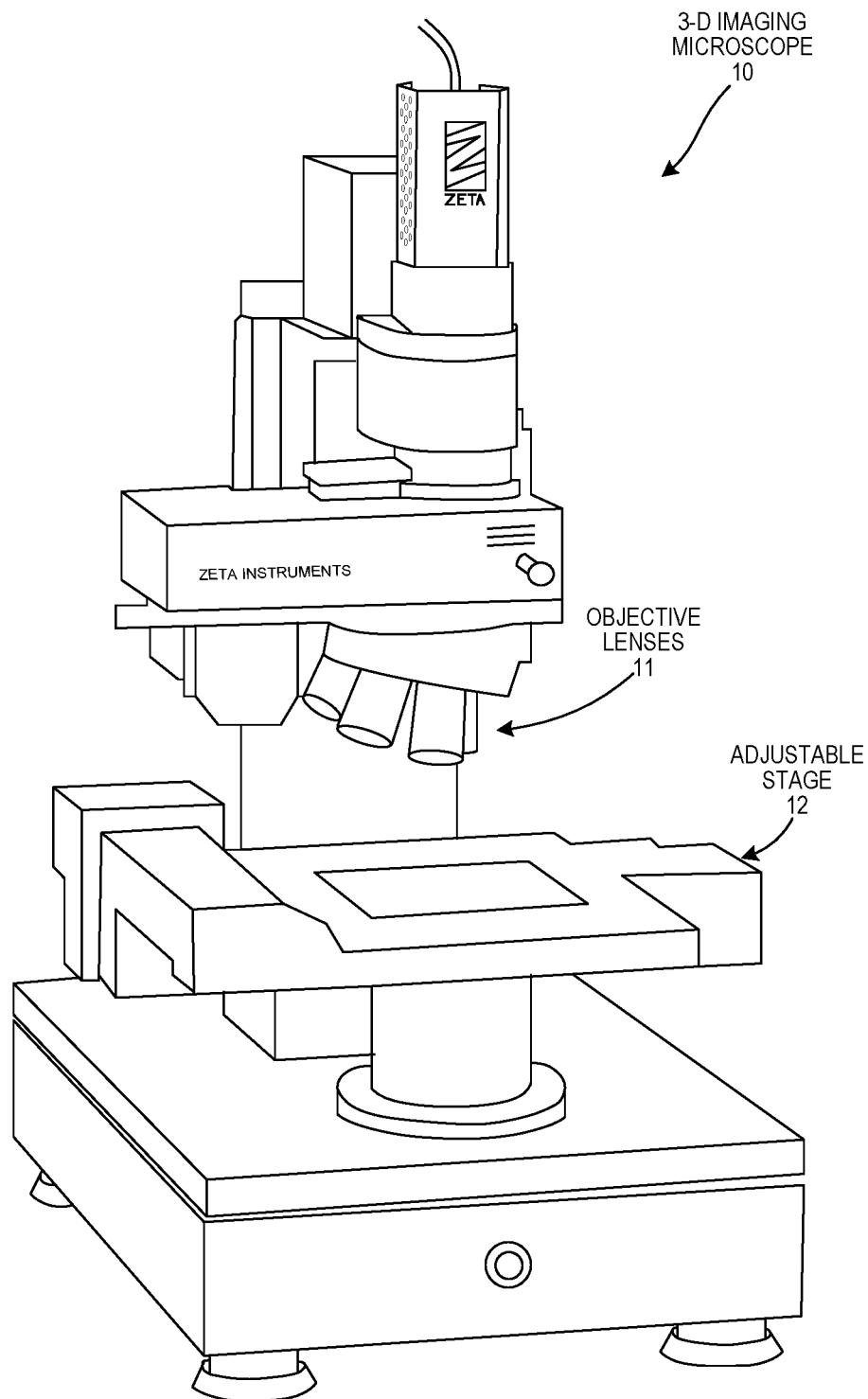
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SEMI-AUTOMATED 3-D METROLOGY SYSTEM

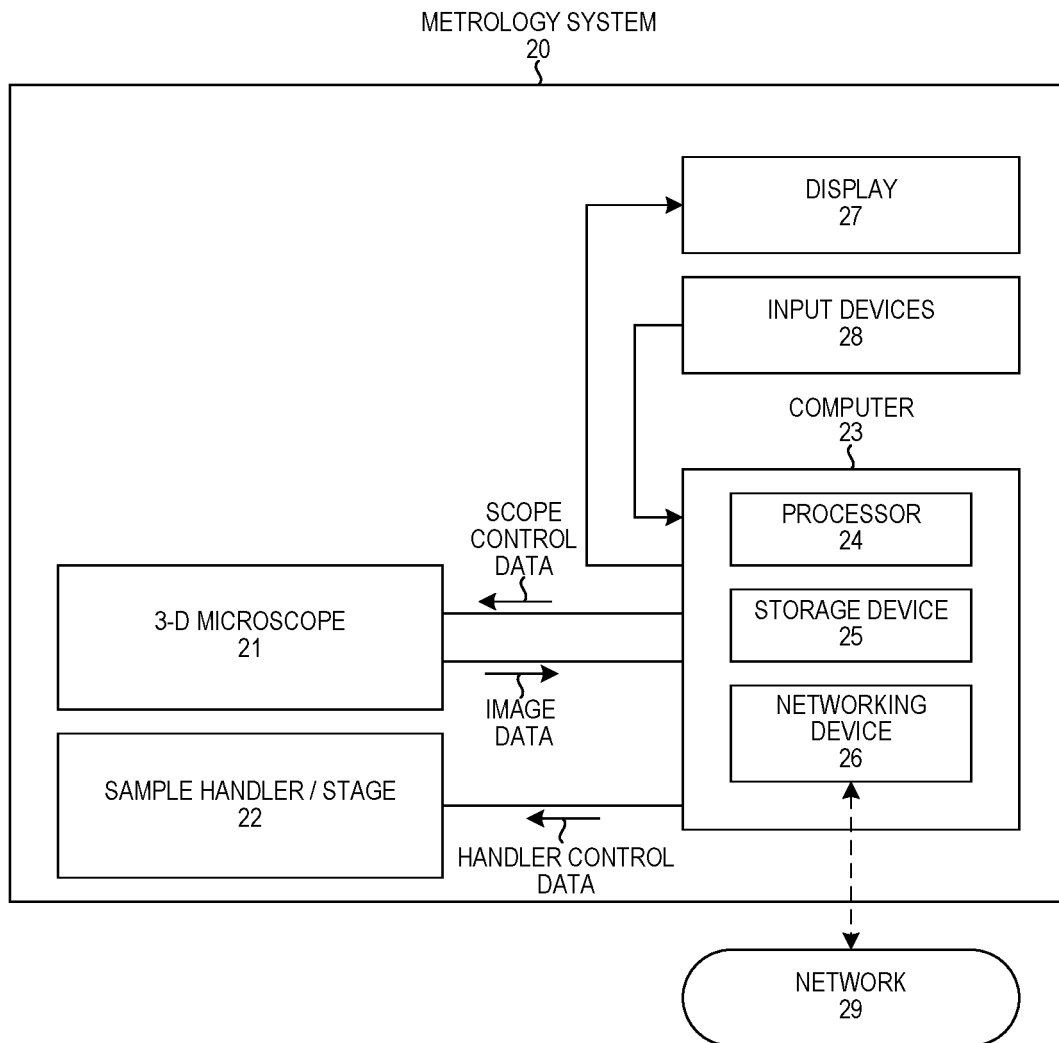
FIG. 1

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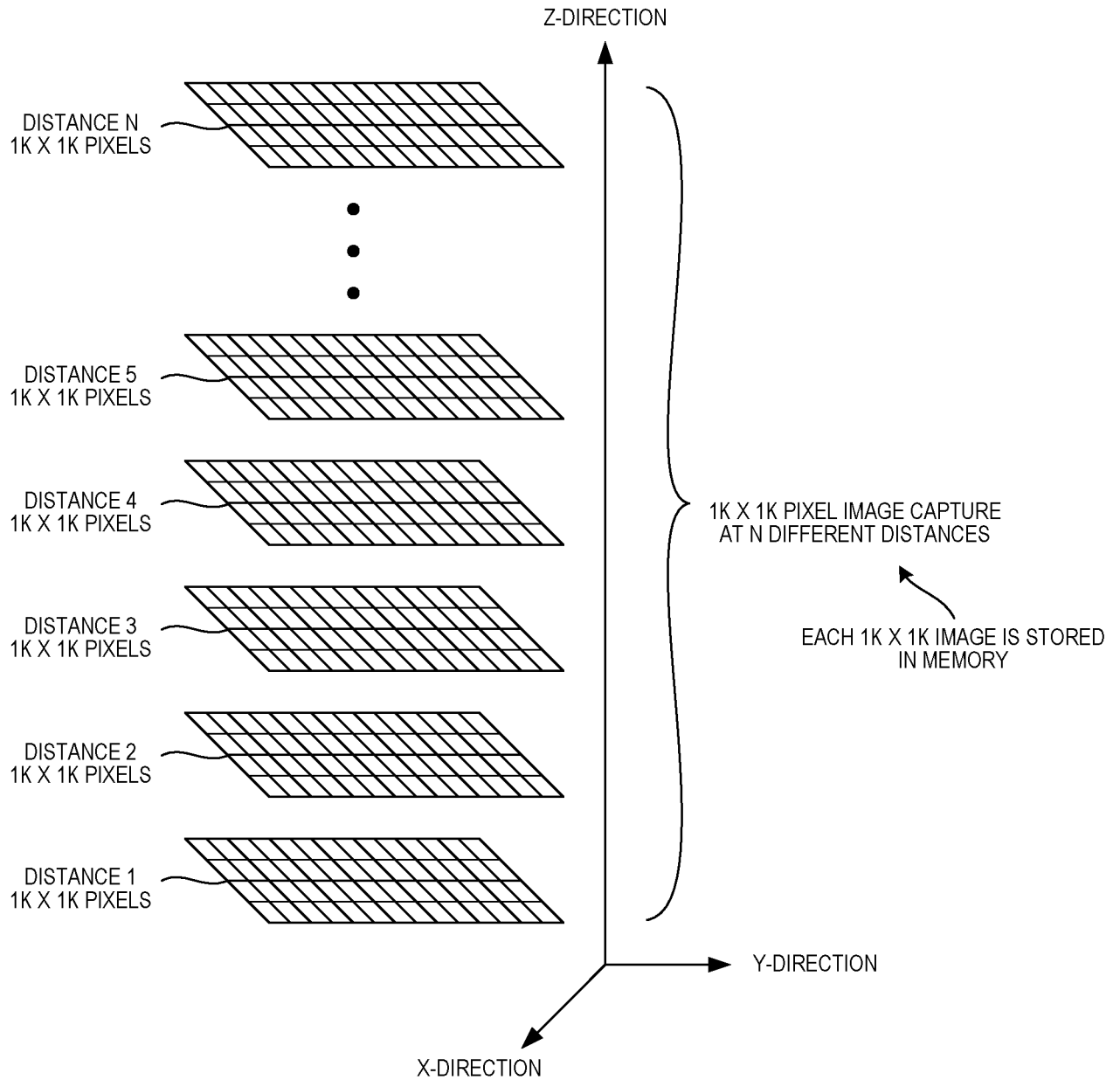
3-D IMAGING MICROSCOPE  
FIG. 2

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METROLOGY SYSTEM  
**FIG. 3**

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MULTIPLE IMAGES CAPTURED AT DIFFERENT DISTANCES

FIG. 4

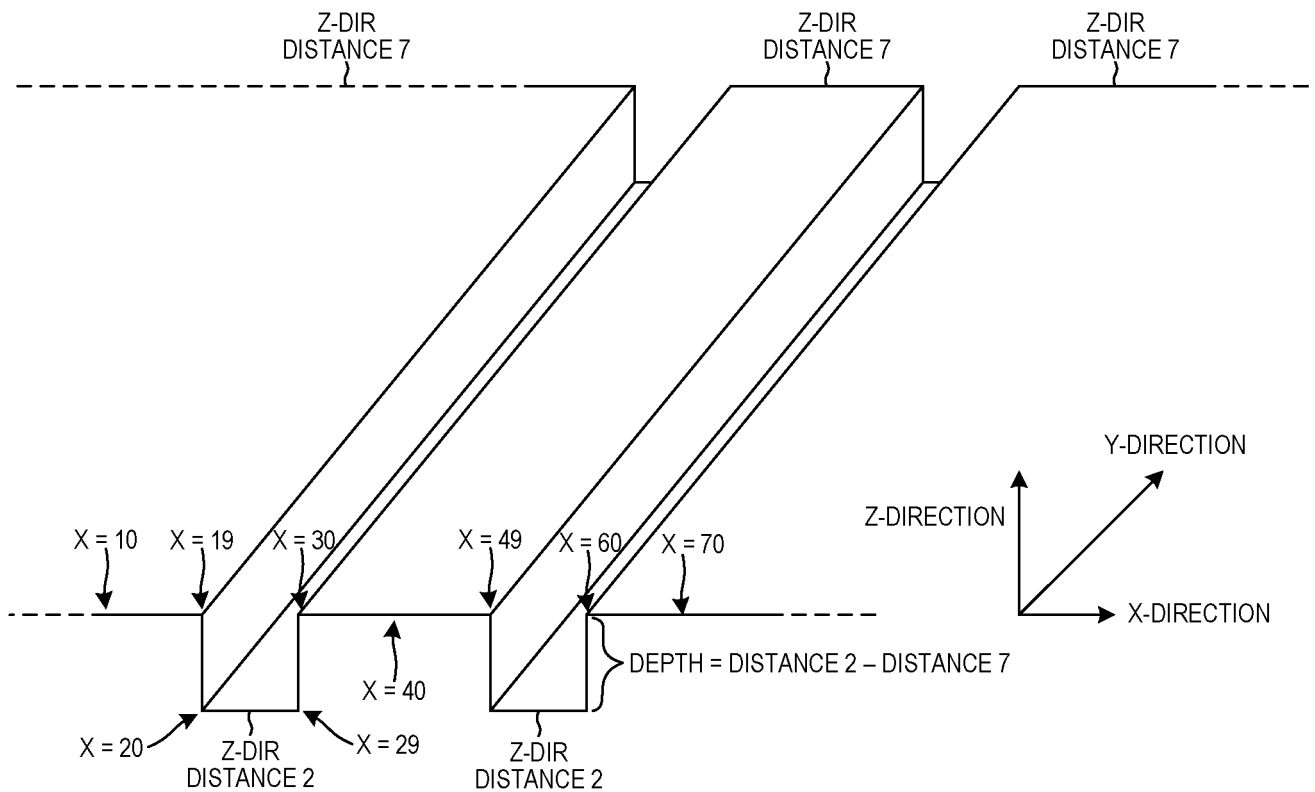
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|        |                     |                     |                     |                     |                     |                     |                     |
|--------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
|        | Y-DIRECTION ↑       |                     |                     |                     |                     |                     |                     |
| Y = 12 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
| Y = 11 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
| Y = 10 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
| Y = 9  | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
| Y = 8  | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
| Y = 7  | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
| Y = 6  | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
| Y = 5  | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
| Y = 4  | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
| Y = 3  | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
| Y = 2  | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
| Y = 1  | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 2 | Z-DIR<br>DISTANCE 7 | Z-DIR<br>DISTANCE 7 |
|        | X = 1 ~ 19          | X = 20 ~ 29         | X = 30 ~ 39         | X = 40 ~ 49         | X = 50 ~ 59         | X = 60 ~ 69         | X-DIRECTION →       |

MAXIMUM CHARACTERISTIC VALUES FOR EACH PIXEL  
LOCATION ACROSS ALL CAPTURED IMAGES

FIG. 5

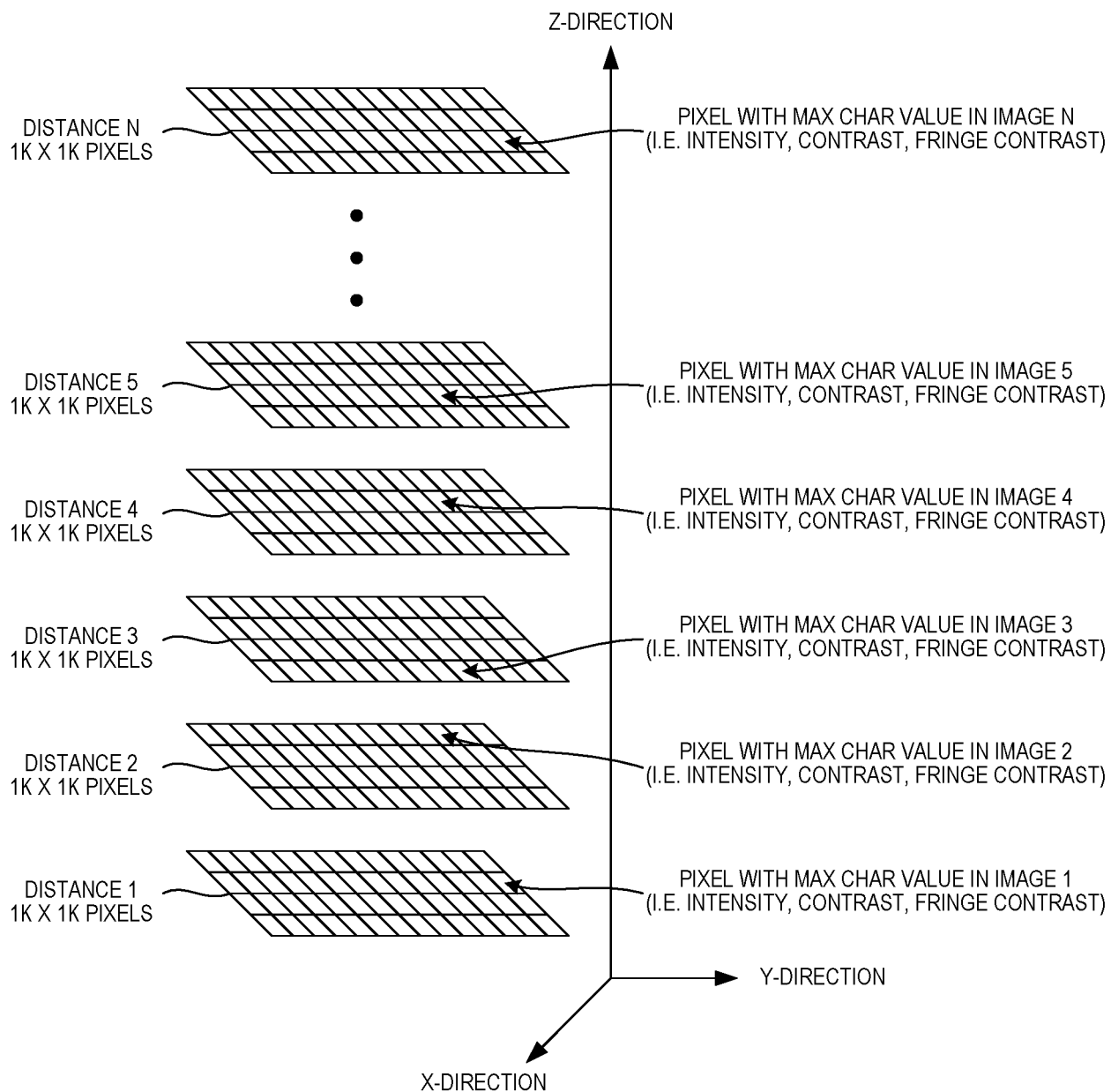
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3-D IMAGE RESULTING FROM SELECTING MAXIMUM VALUES FOR EACH X-Y PIXEL LOCATION ACROSS ALL Z-DIRECTION DISTANCES

FIG. 6

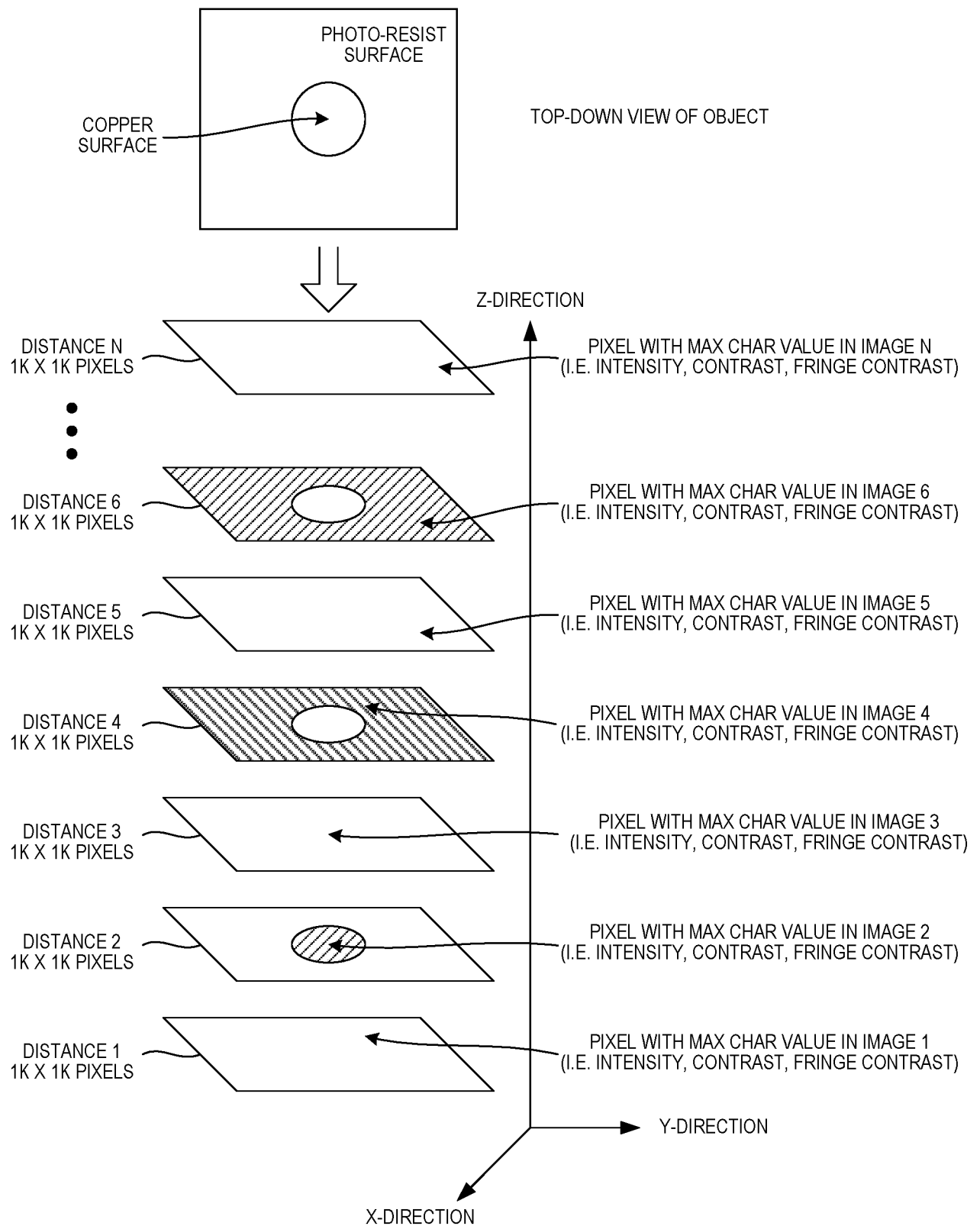
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PEAK MODE OPERATION  
(SELECT MAXIMUM CHARACTERISTIC VALUE FOR  
EACH CAPTURED IMAGE)

FIG. 7

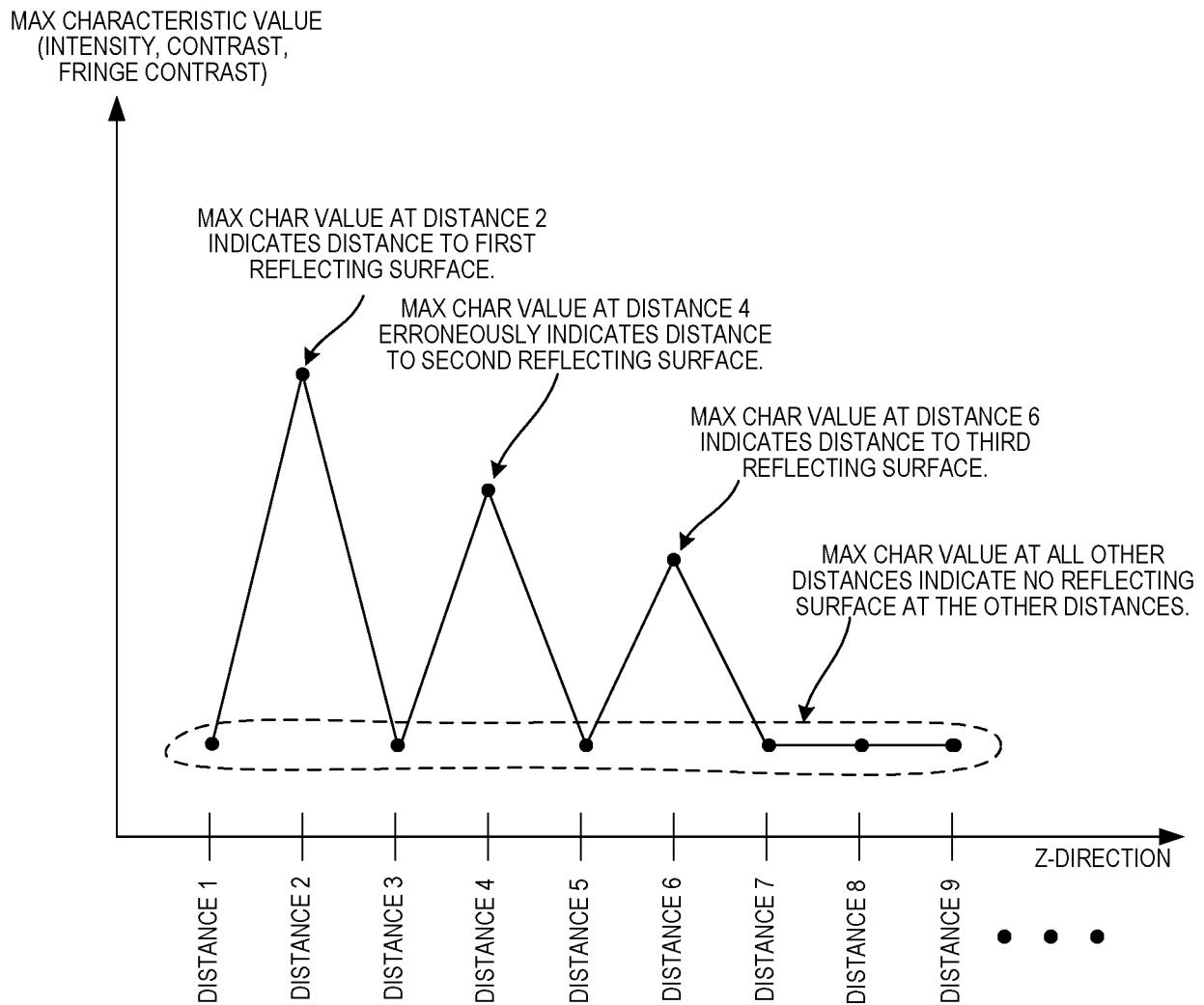
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PEAK MODE OPERATION  
(MAXIMUM CHARACTERISTIC VALUE FOR EACH CAPTURED IMAGE)

**FIG. 8**

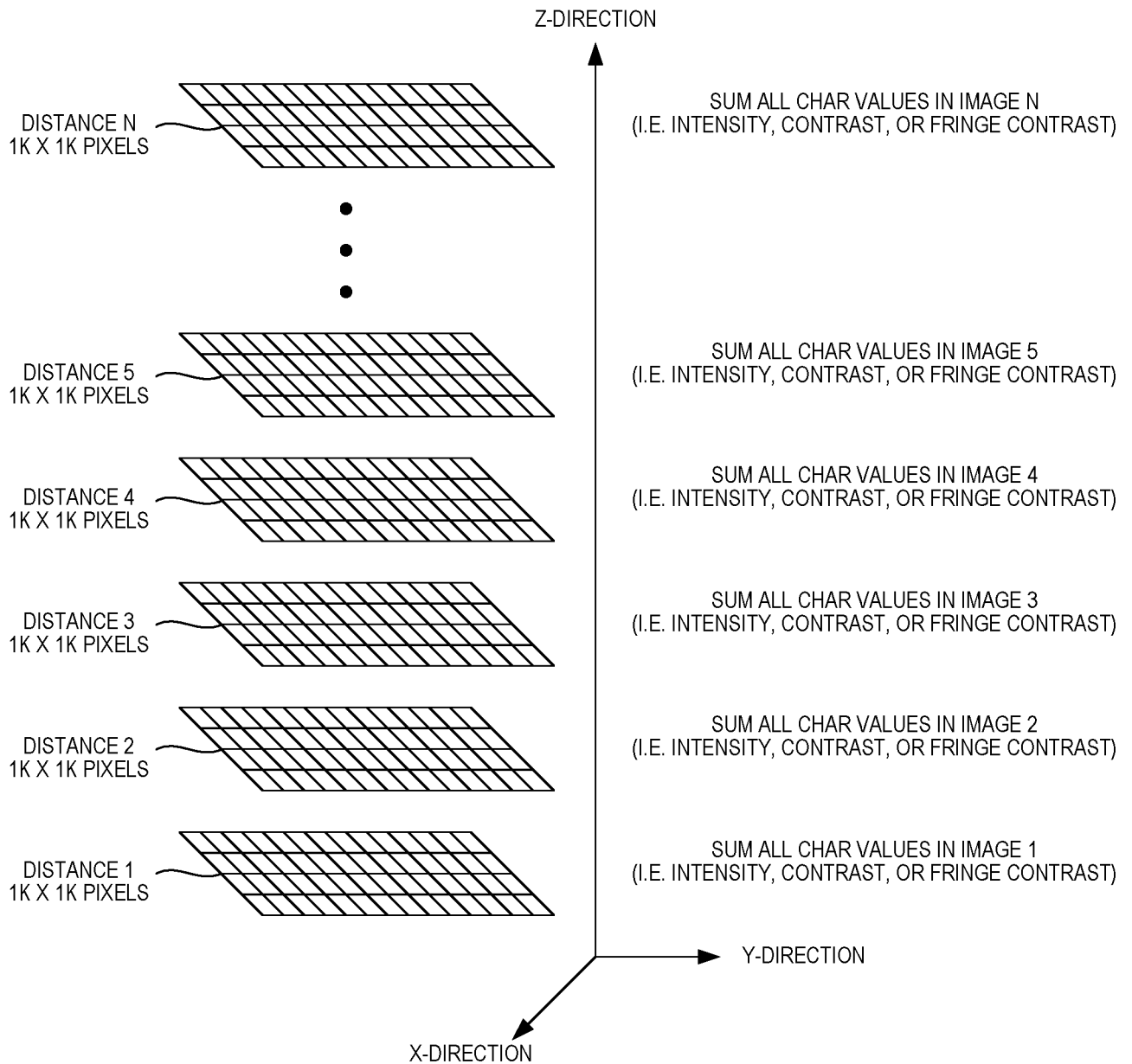
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MAXIMUM CHARACTERISTIC VALUE  
ACROSS ALL CAPTURED IMAGES

FIG. 9

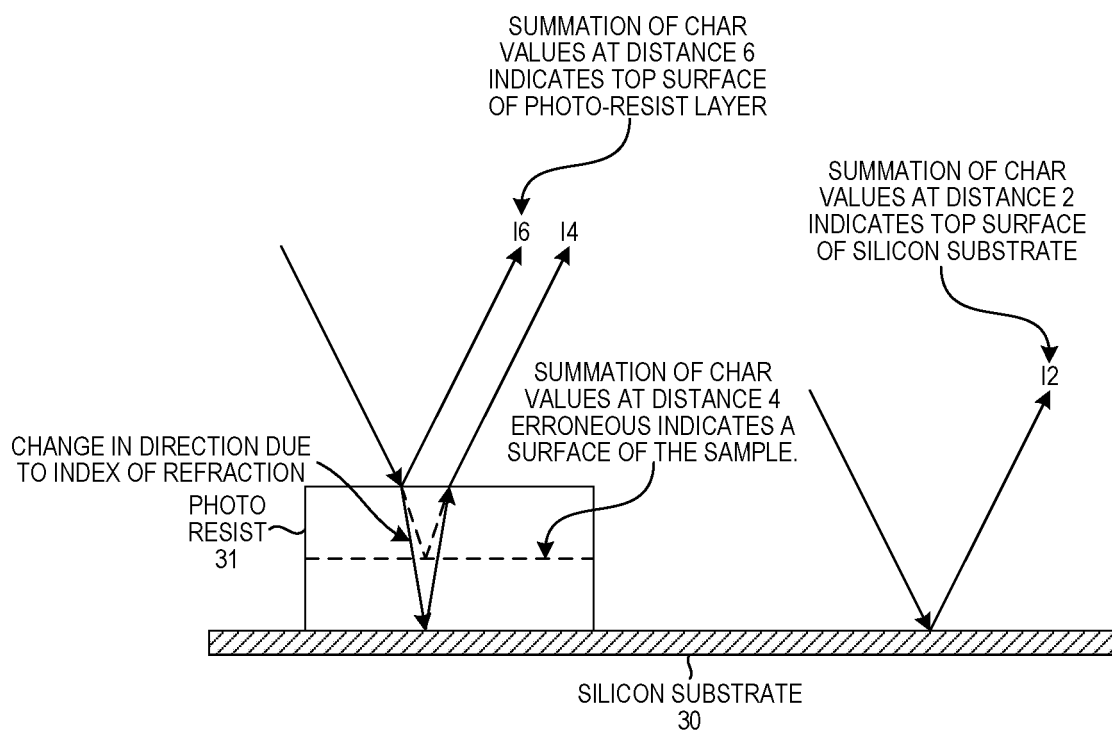
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SUMMATION MODE OPERATION  
(SUM ALL CHARACTERISTIC VALUES FOR EACH CAPTURED IMAGE)

FIG. 10

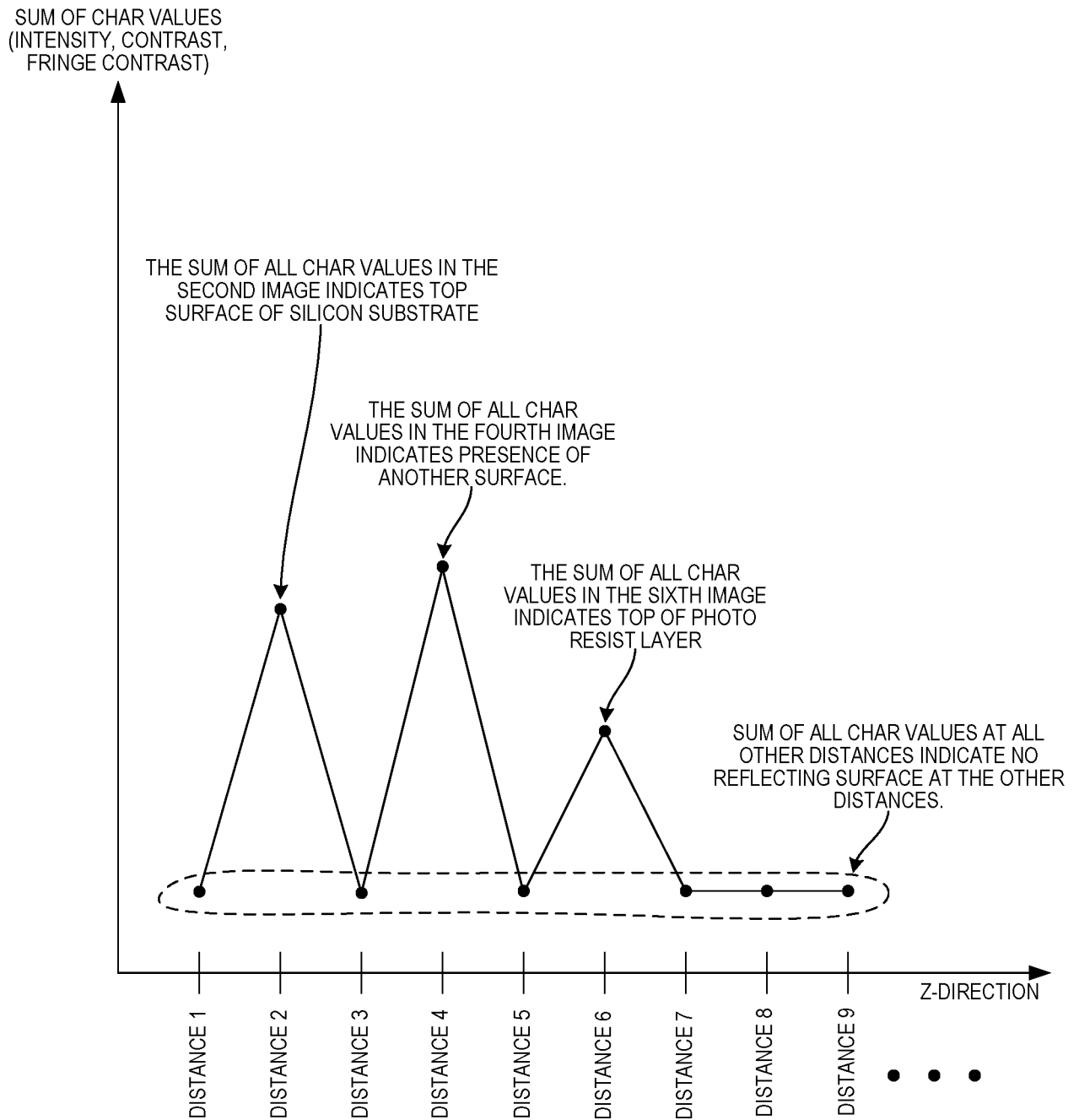
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ERRONEOUS SURFACE DETECTION  
DUE TO TRANSPARENT MATERIALS

FIG. 11

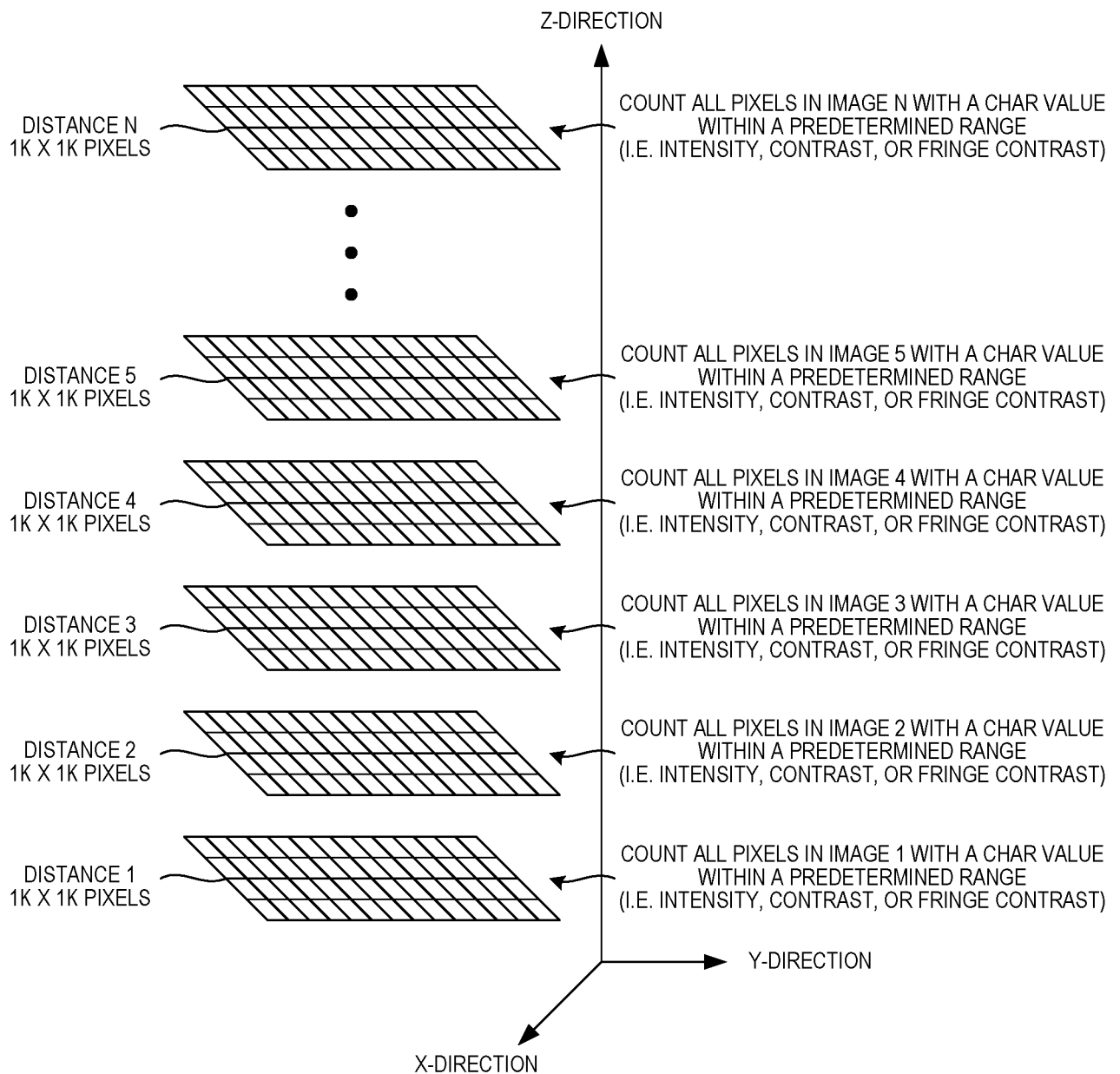
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SUMMATION OF ALL CHARACTERISTIC VALUES  
FOR EACH IMAGE

FIG. 12

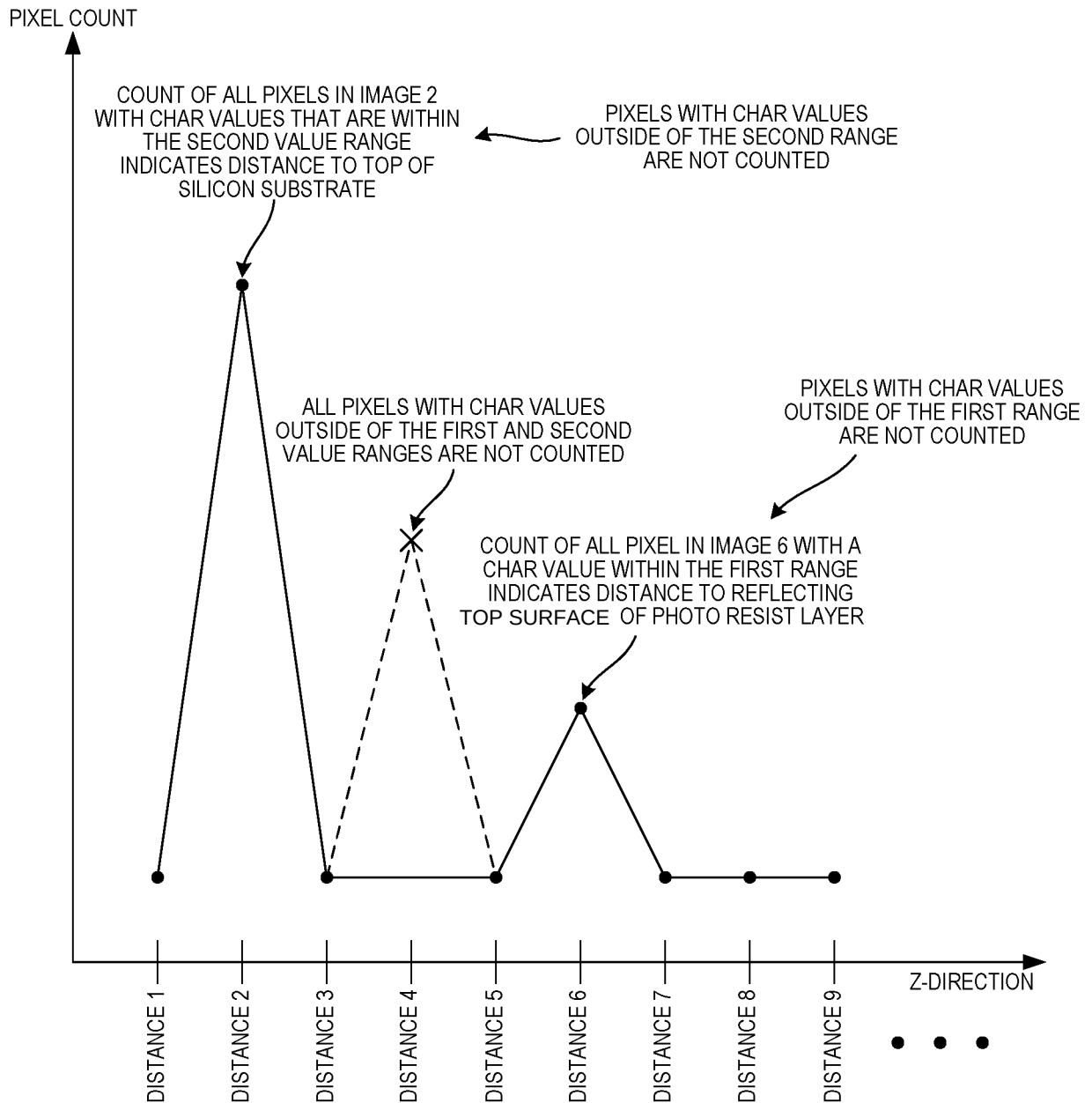
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RANGE MODE OPERATION  
(COUNT ALL PIXELS WITH A CHARACTERISTIC VALUE  
WITHIN A RANGE)

**FIG. 13**

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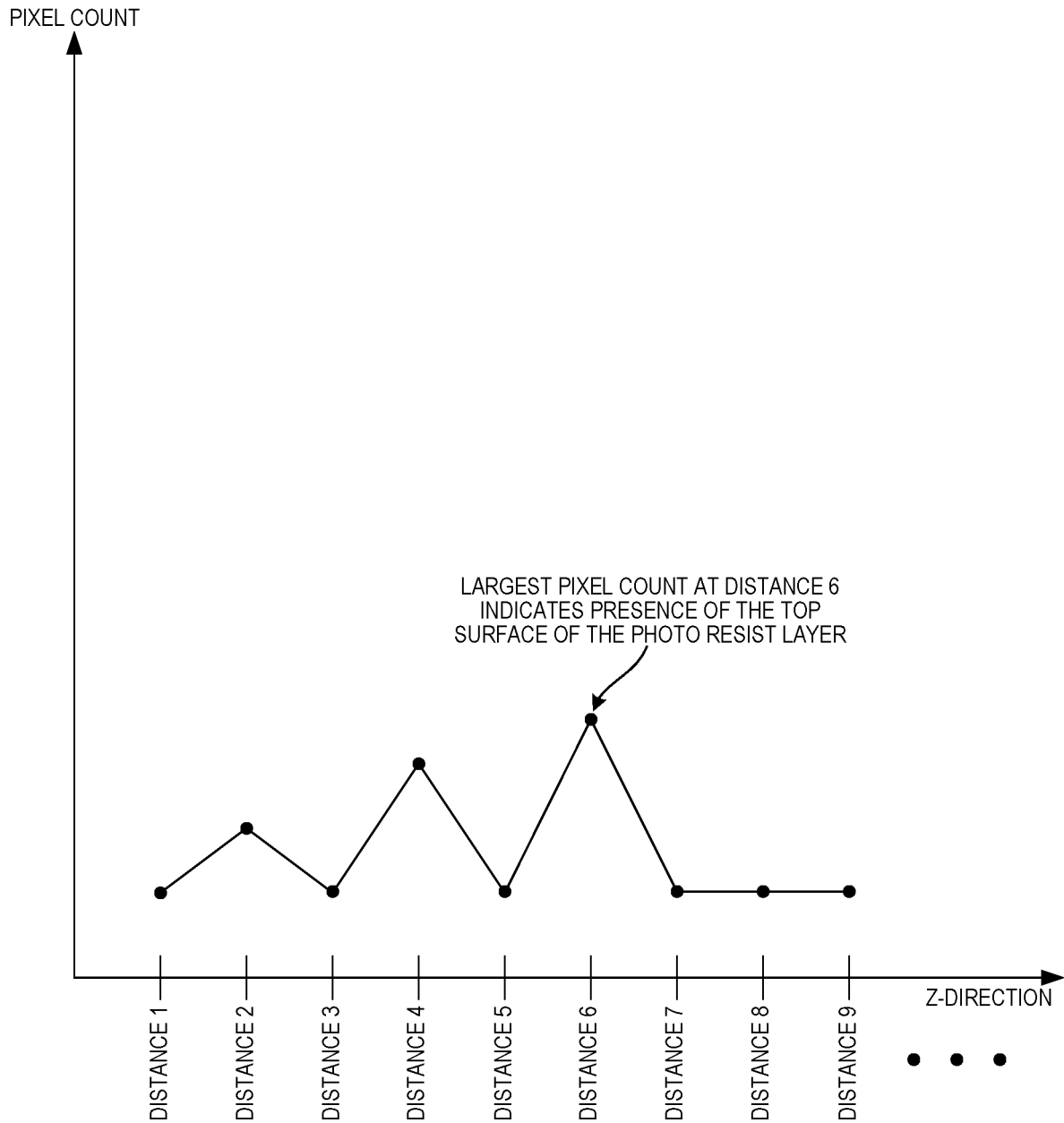


ALL PIXELS WITH A VALUE OUTSIDE THE FIRST AND SECOND RANGES ARE FILTERED OUT, THEREBY REMOVING THE ERRONEOUS INDICATION OF A THIRD SURFACE THAT DOESN'T EXIST AT DISTANCE 4.

COUNT OF ALL PIXELS WITH CHARACTERISTIC VALUES  
WITHIN A SPECIFIC RANGE

FIG. 14

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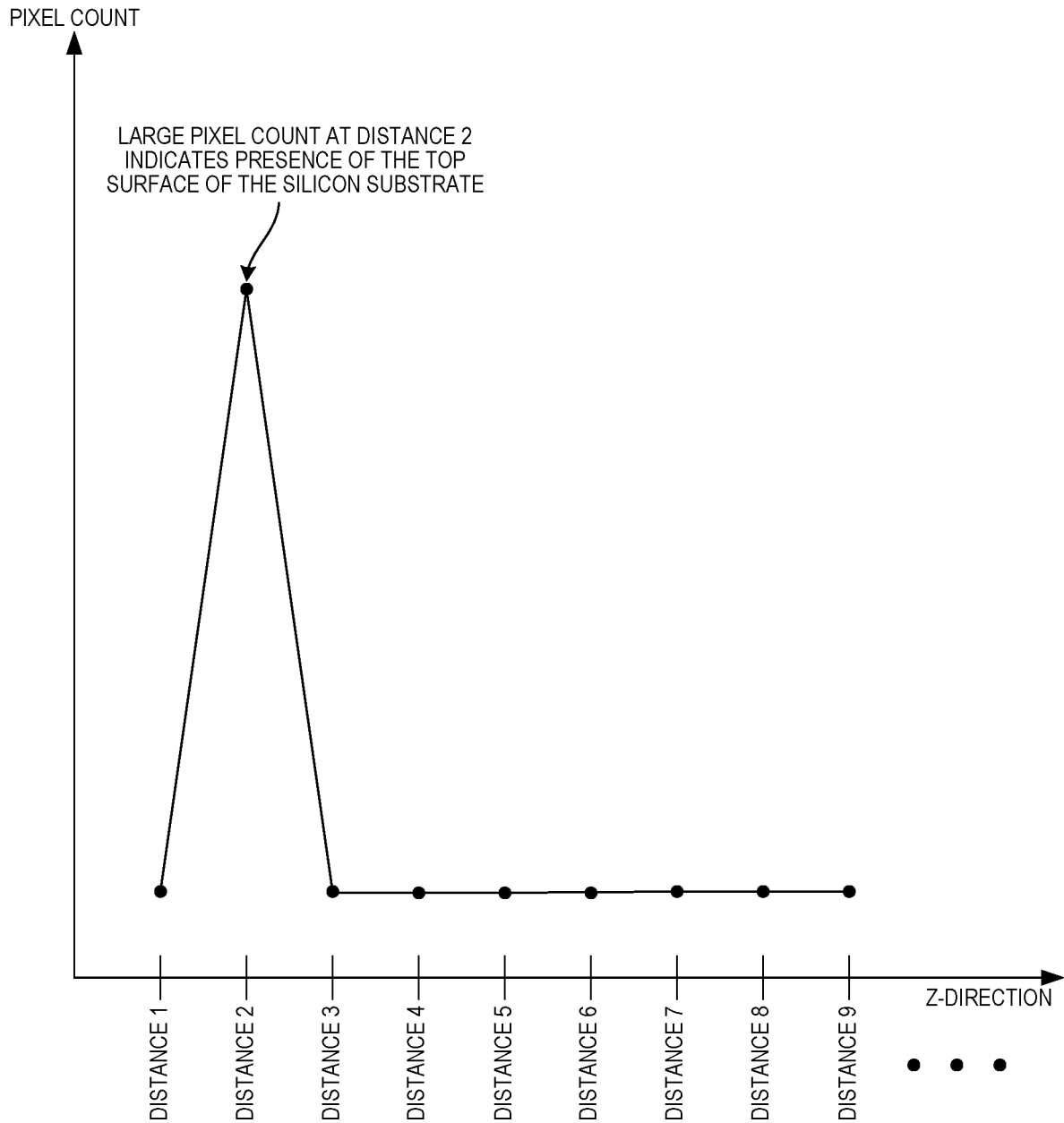


ALL PIXELS WITH A VALUE OUTSIDE THE FIRST RANGE ARE FILTERED OUT, THEREBY ONLY INDICATING A COUNT OF PIXELS THAT INDICATE THE PRESENCE OF THE TOP SURFACE OF THE PHOTO-RESIST LAYER.

COUNT OF ALL PIXELS WITH CHARACTERISTIC VALUES  
WITHIN A FIRST RANGE

FIG. 15

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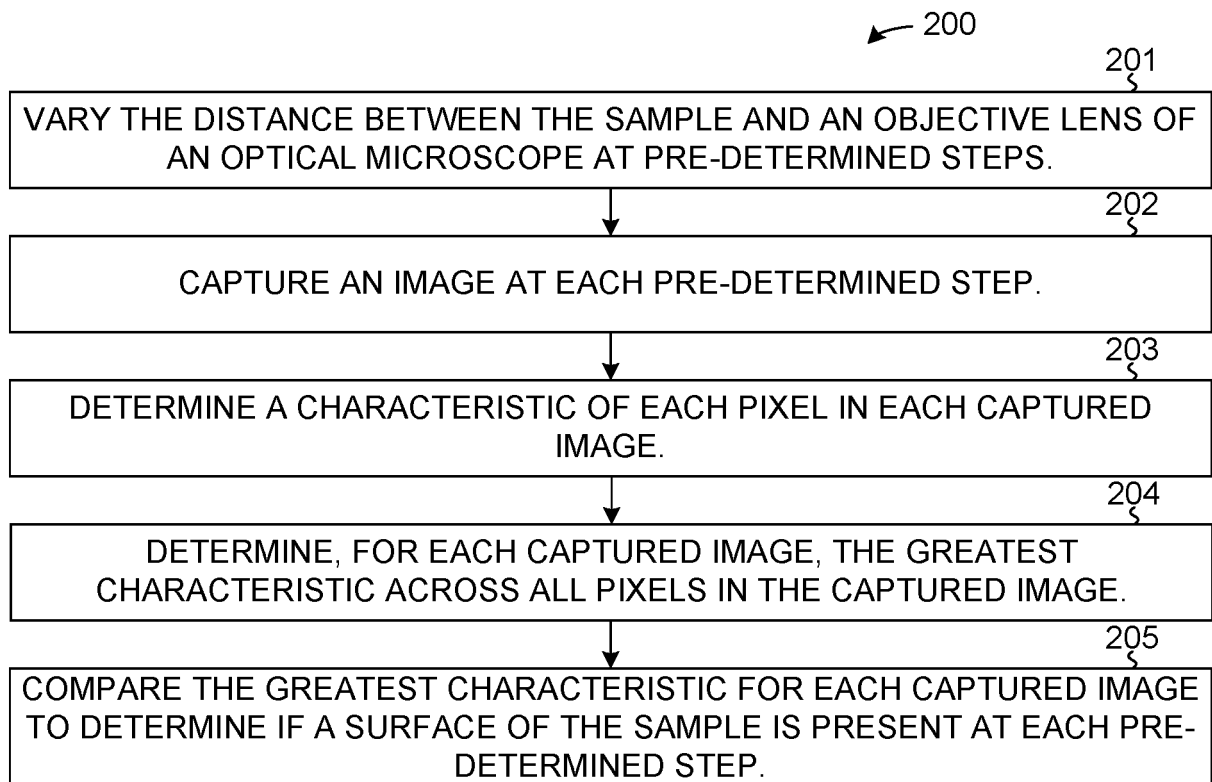


ALL PIXELS WITH A VALUE OUTSIDE THE SECOND RANGE ARE FILTERED OUT, THEREBY ONLY INDICATING A COUNT OF PIXELS THAT INDICATE THE PRESENCE OF THE TOP SURFACE OF THE SILICON LAYER.

COUNT OF ALL PIXELS WITH CHARACTERISTIC VALUES  
WITHIN A SECOND RANGE

FIG. 16

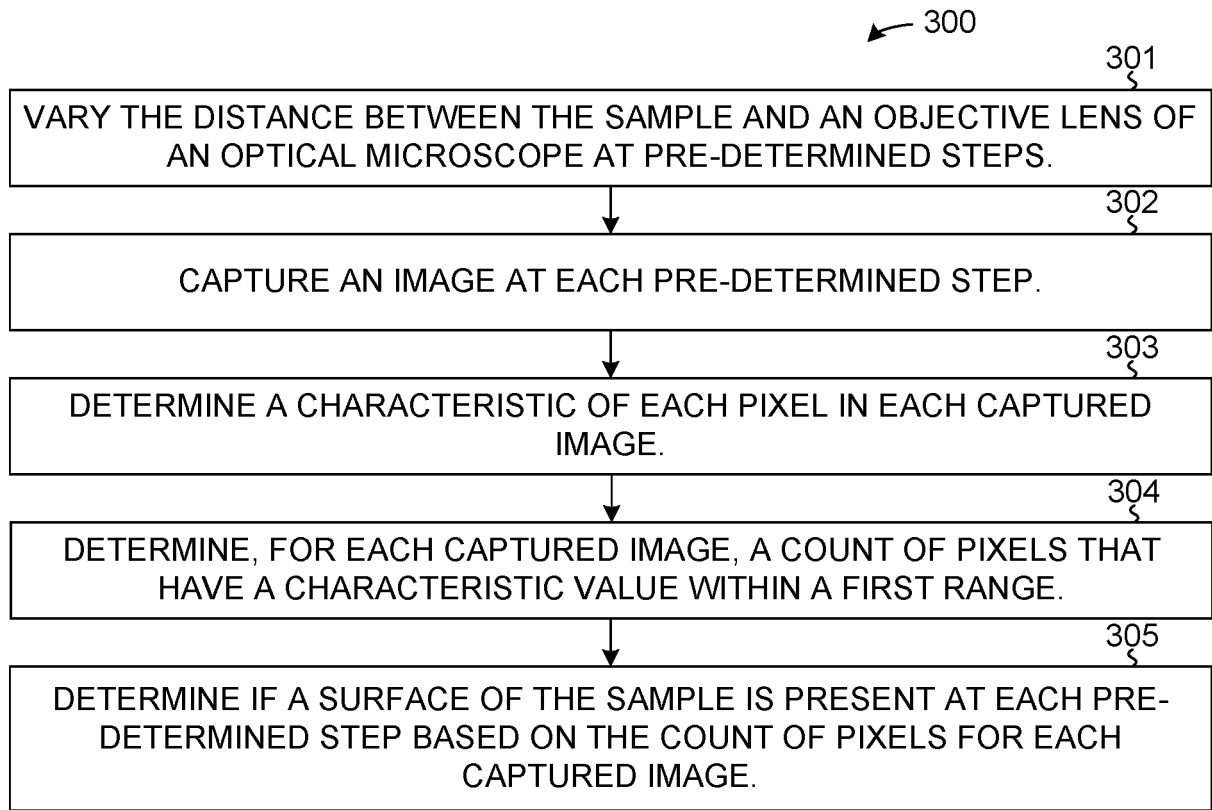
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PEAK MODE FLOWCHART

FIG. 17

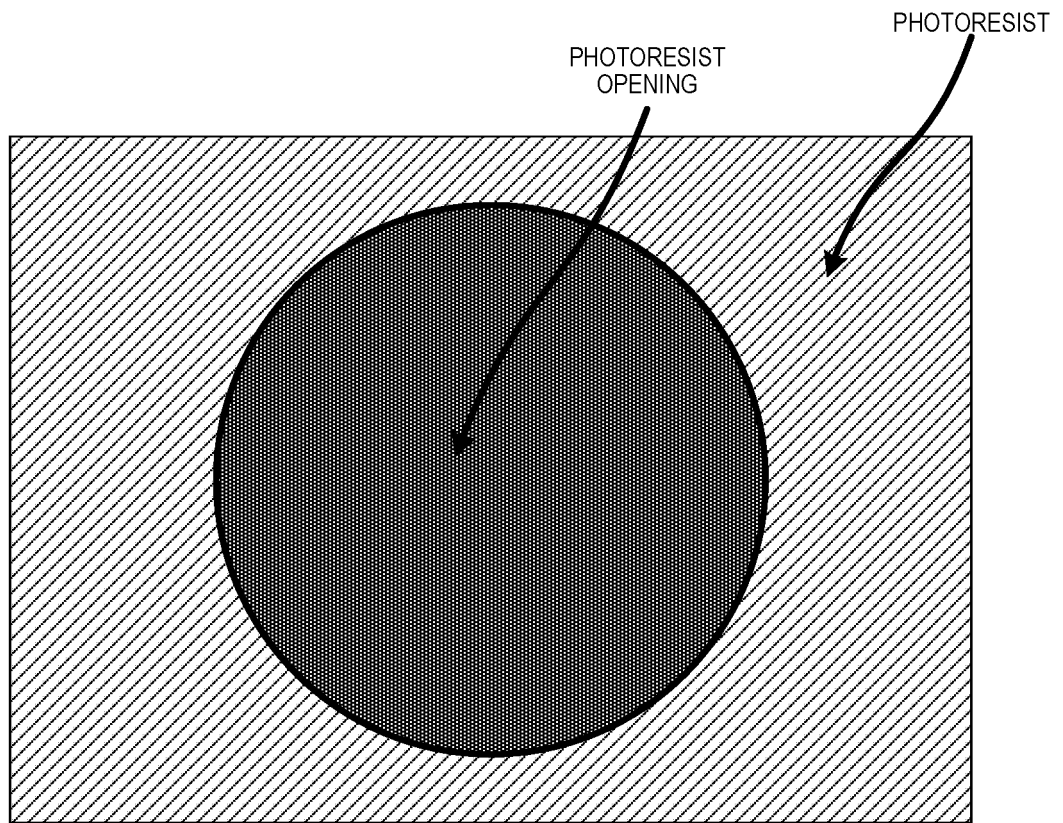
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RANGE MODE FLOWCHART

FIG. 18

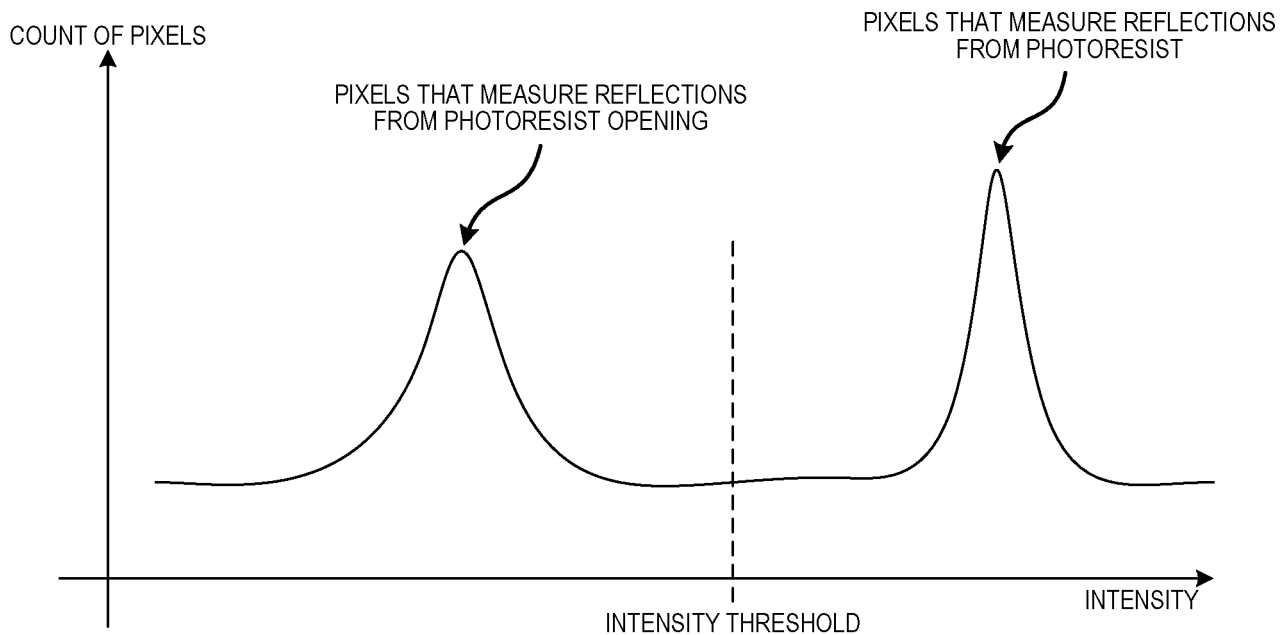
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CAPTURED IMAGE

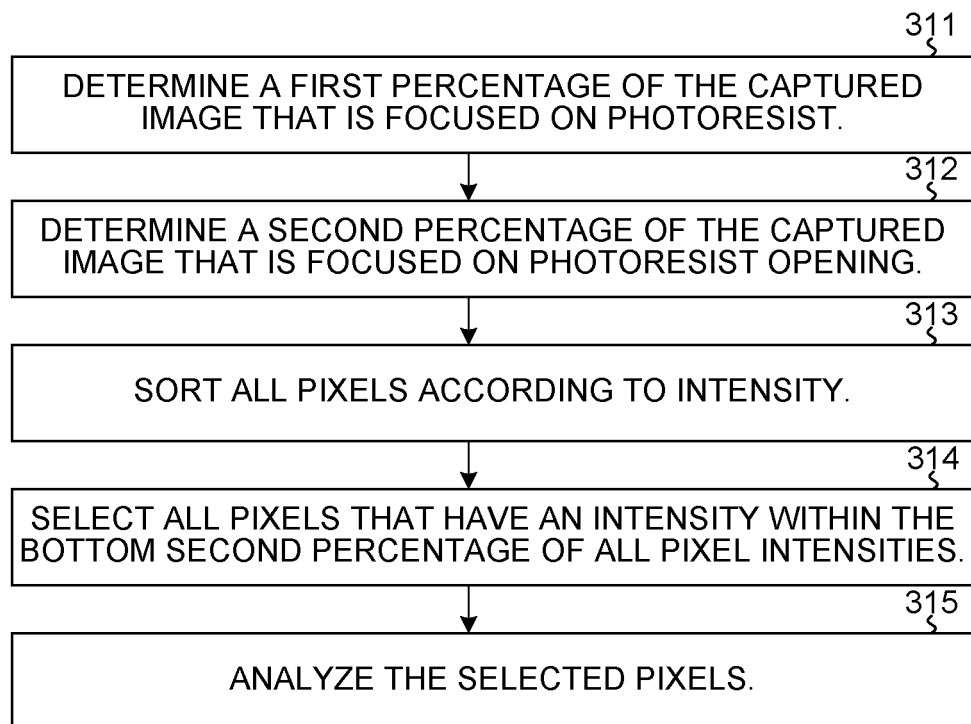
FIG. 19

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FIRST METHOD OF GENERATING INTENSITY THRESHOLD

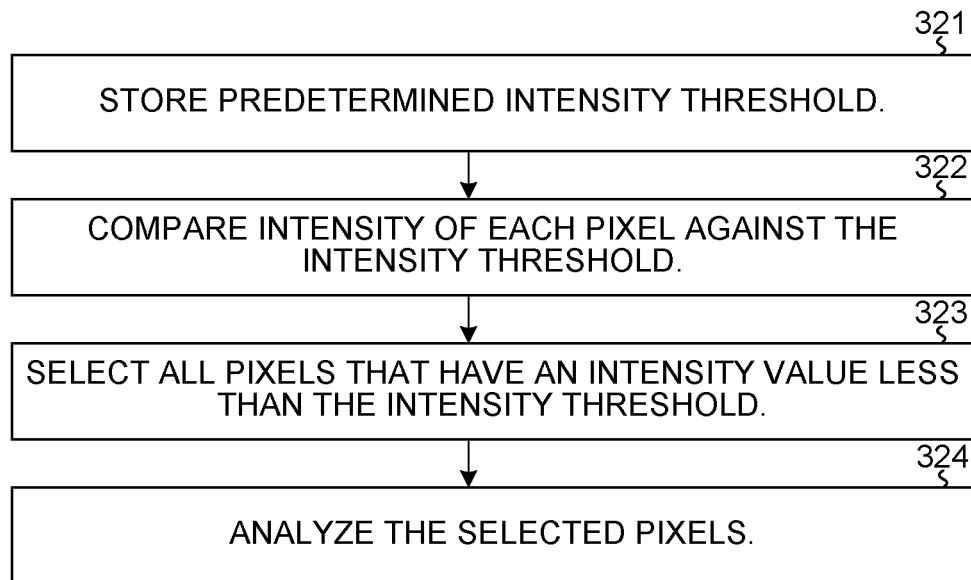
FIG. 20



SECOND METHOD OF GENERATING INTENSITY THRESHOLD

FIG. 21

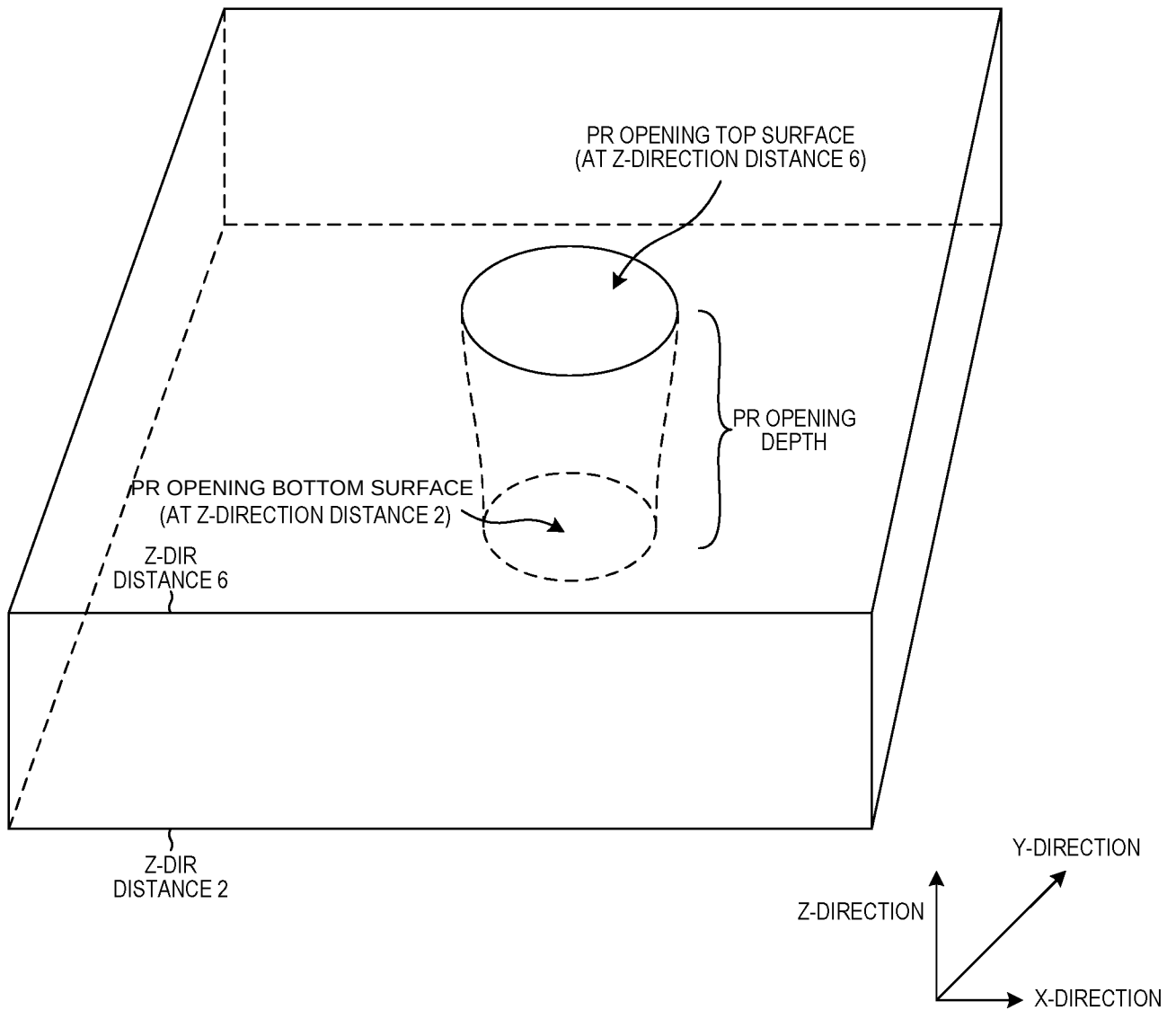
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THIRD METHOD OF GENERATING INTENSITY THRESHOLD

FIG. 22

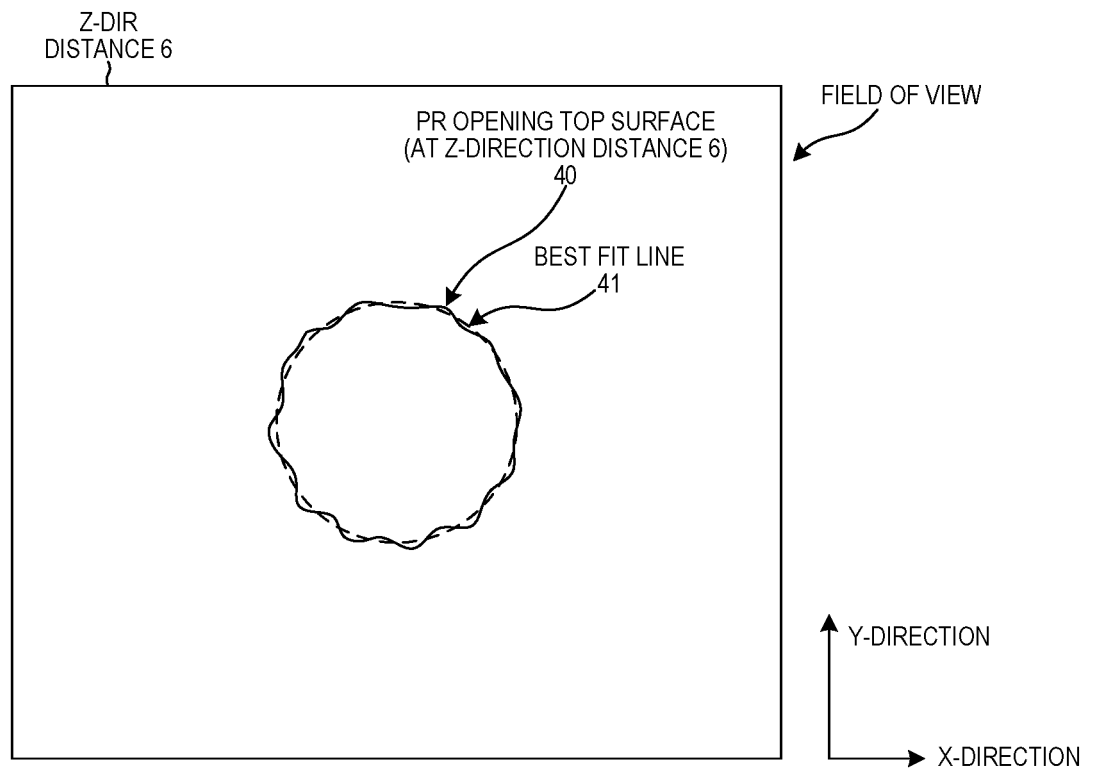
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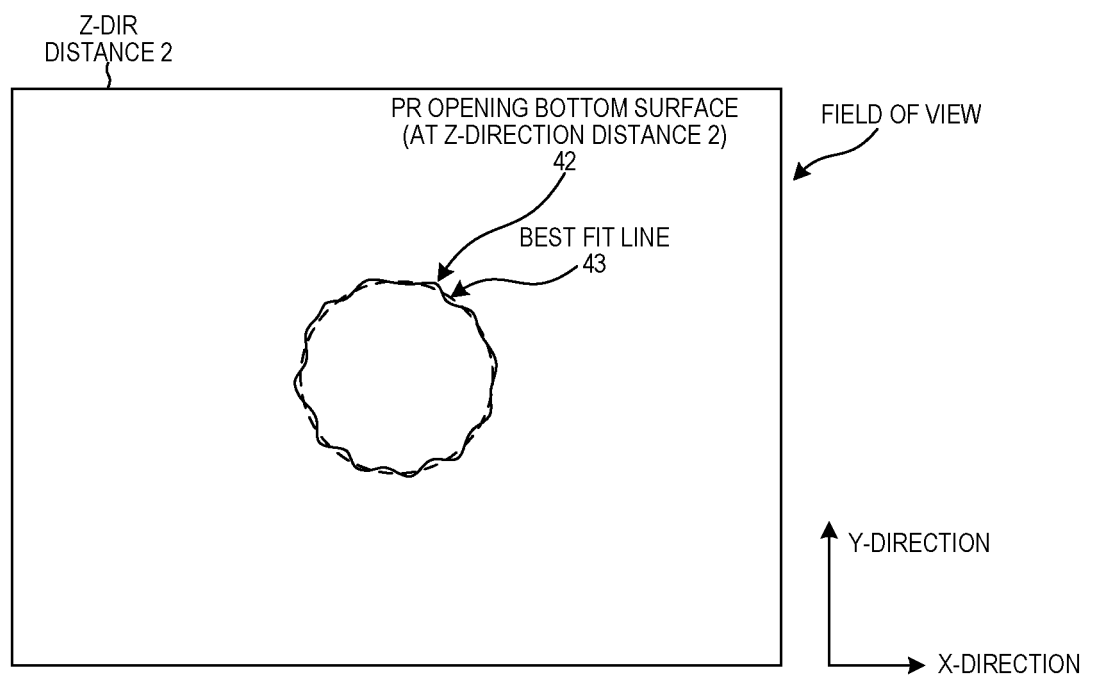
3-D VIEW OF PR OPENING

FIG. 23

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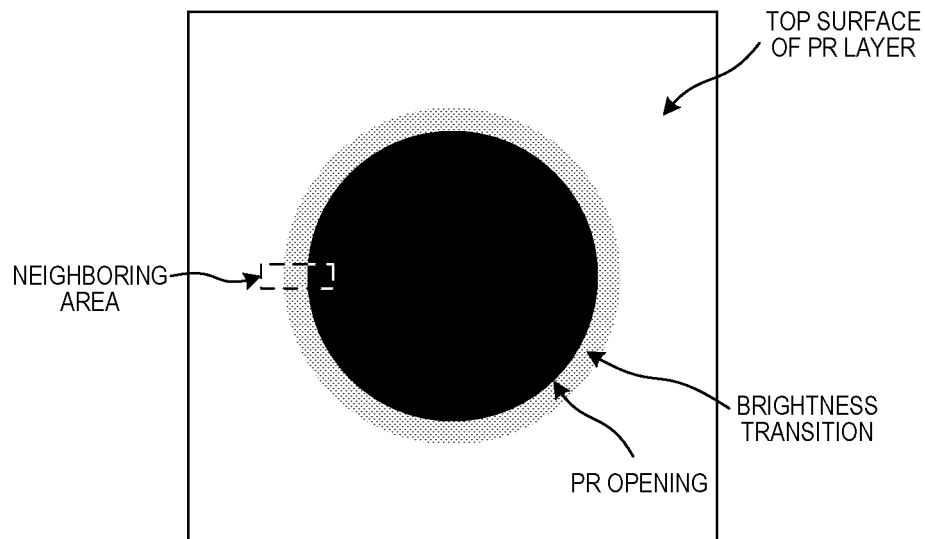


2-D VIEW OF PR OPENING TOP SURFACE  
**FIG. 24**

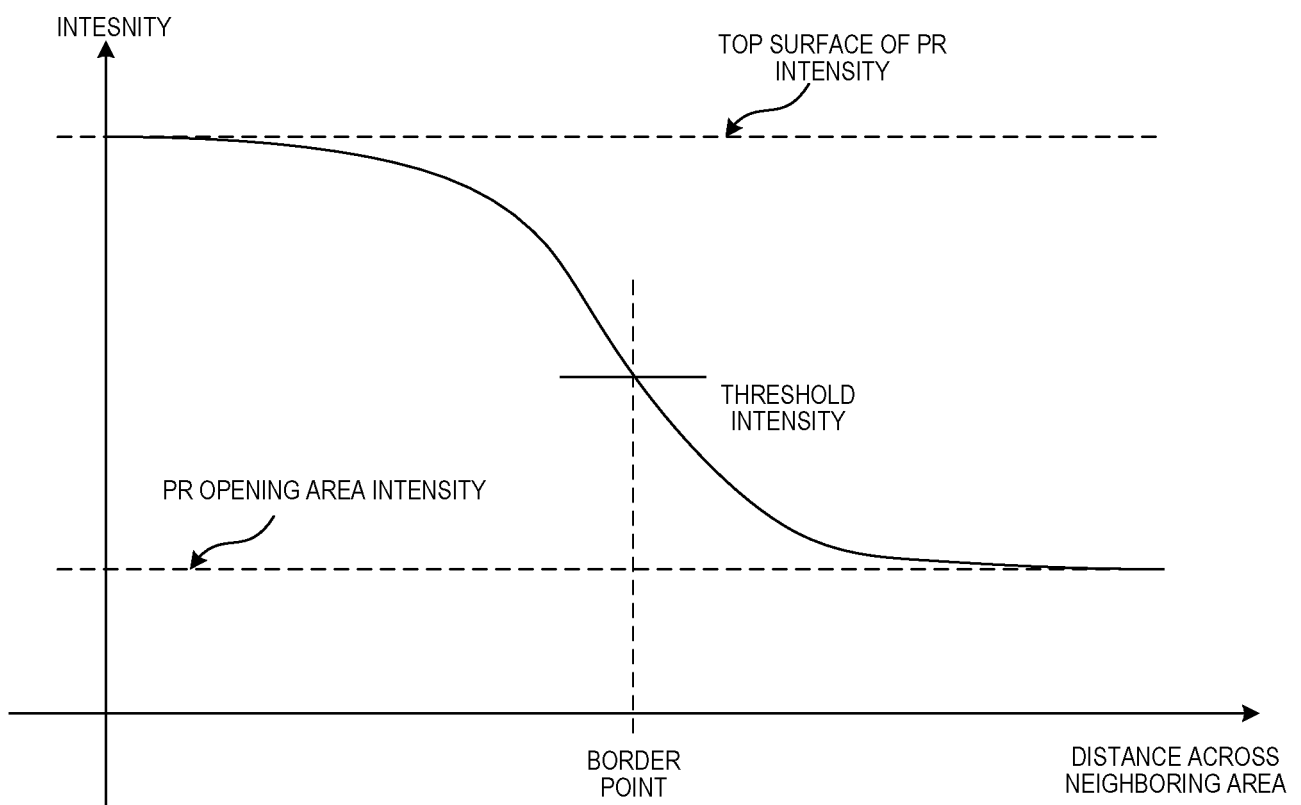


2-D VIEW OF PR OPENING BOTTOM SURFACE  
**FIG. 25**

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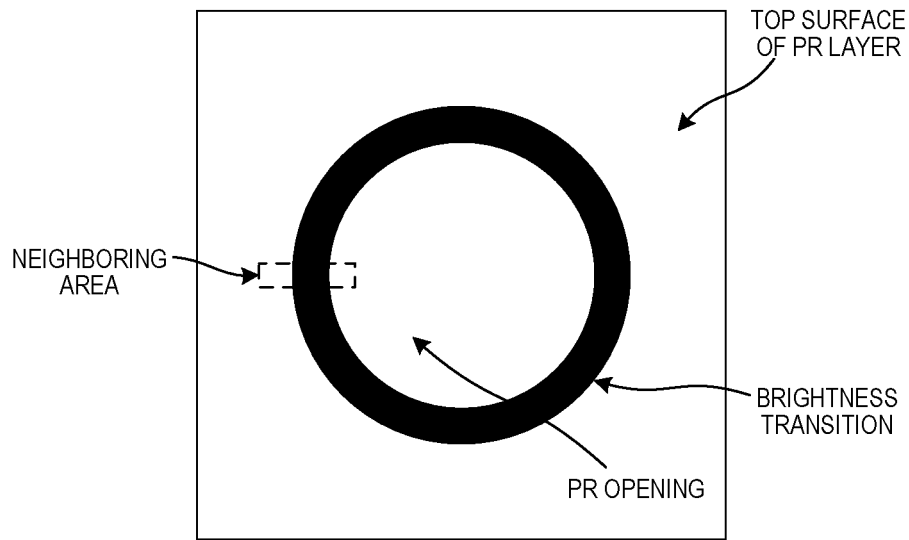


CAPTURED IMAGE FOCUSED ON TOP SURFACE OF PR LAYER  
**FIG. 26**



**FIG. 27**

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CAPTURED IMAGE FOCUSED ON BOTTOM SURFACE OF PR LAYER

FIG. 28

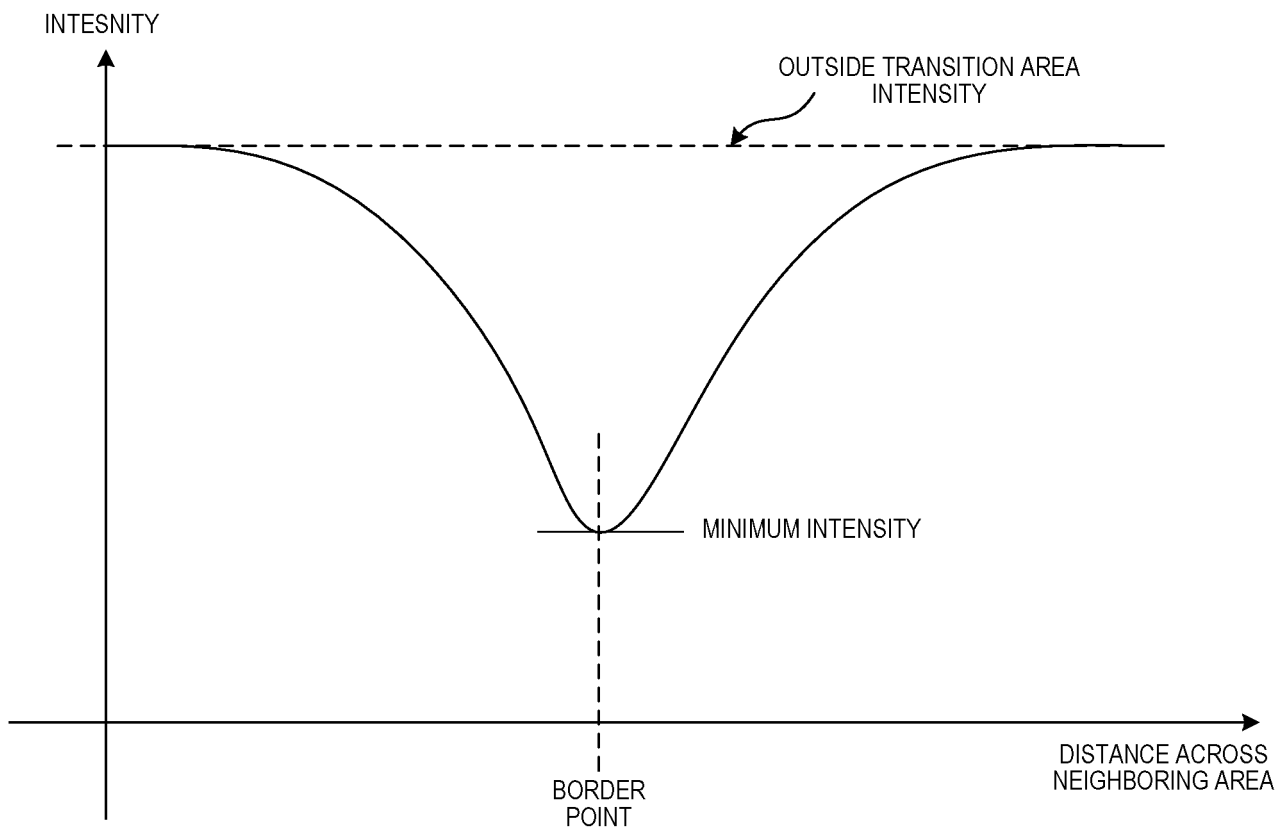
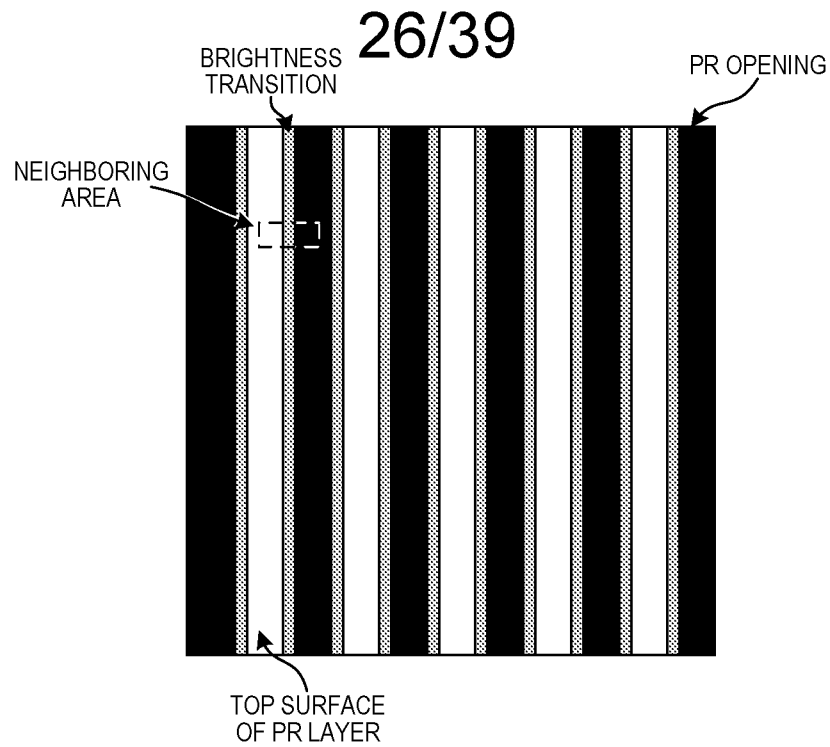


FIG. 29



CAPTURED IMAGE FOCUSED ON TOP SURFACE OF PHOTORESIST TRENCH

FIG. 30

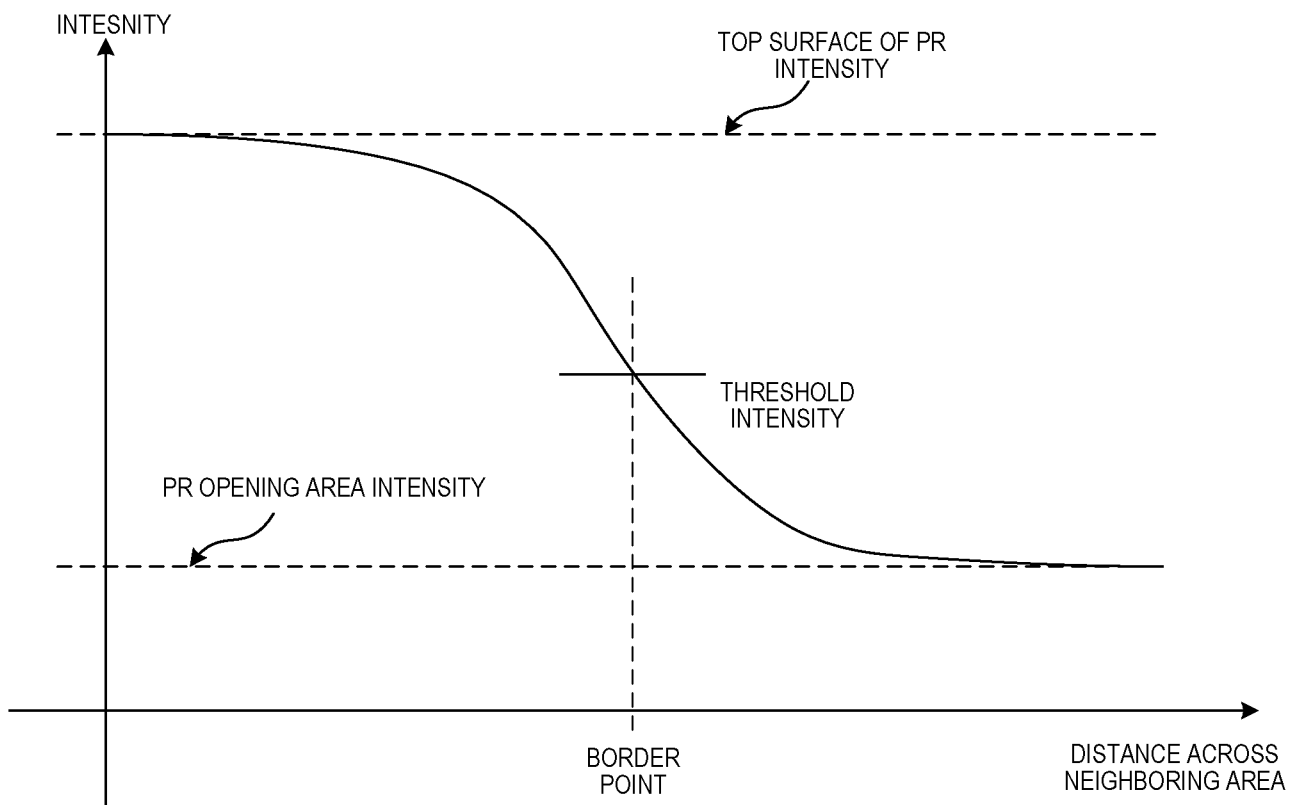
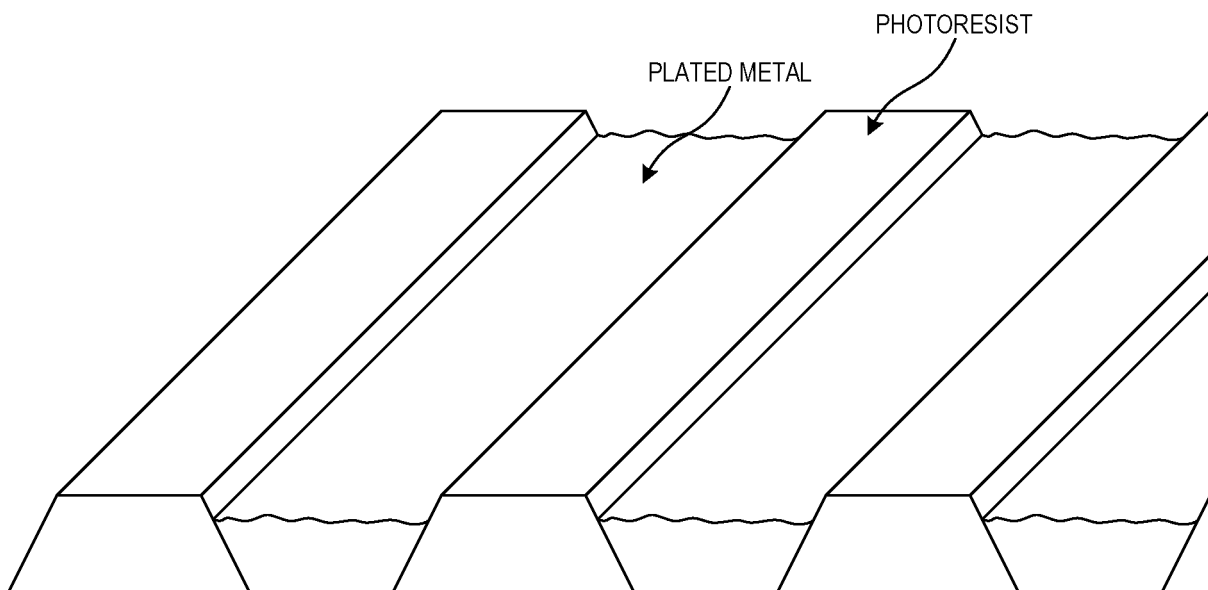


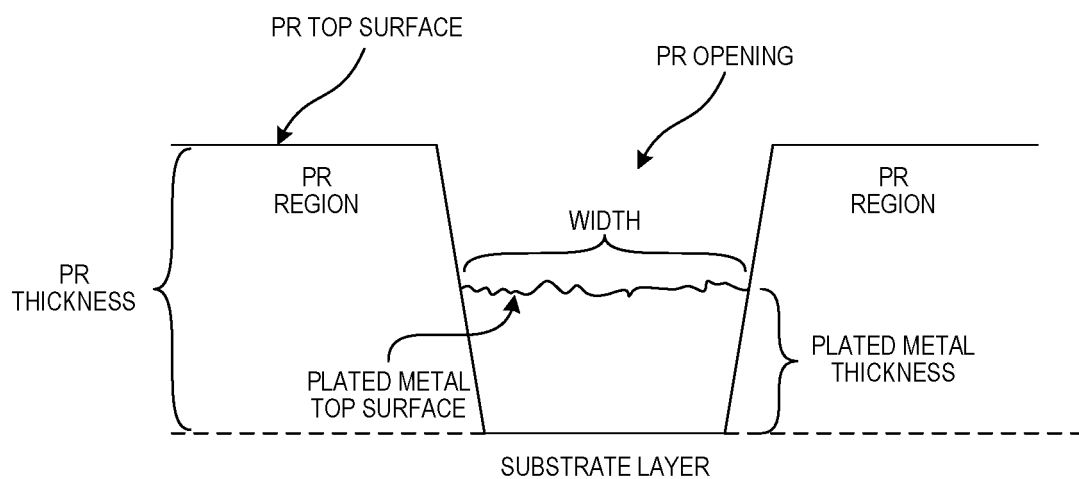
FIG. 31

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3-D VIEW OF PHOTORESIST OPENING WITH PLATED METAL

FIG. 32

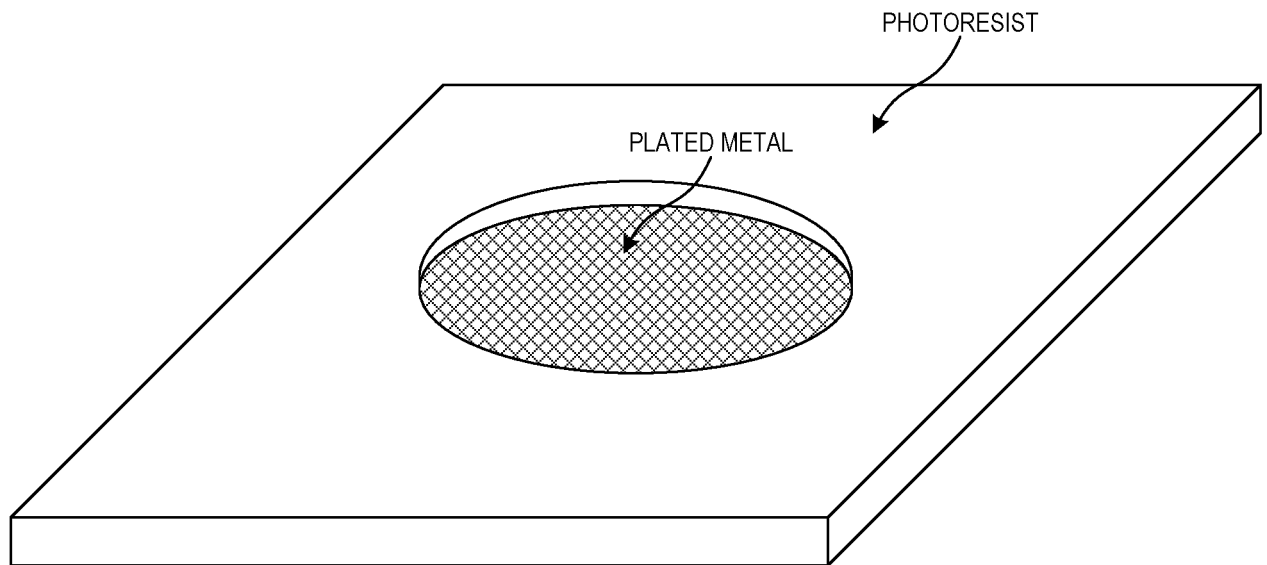


\*PLATED METAL THICKNESS = PR REGION THICKNESS - (PR TOP SURFACE - PLATED METAL TOP SURFACE)

CROSS-SECTIONAL VIEW OF PHOTORESIST OPENING WITH PLATED METAL

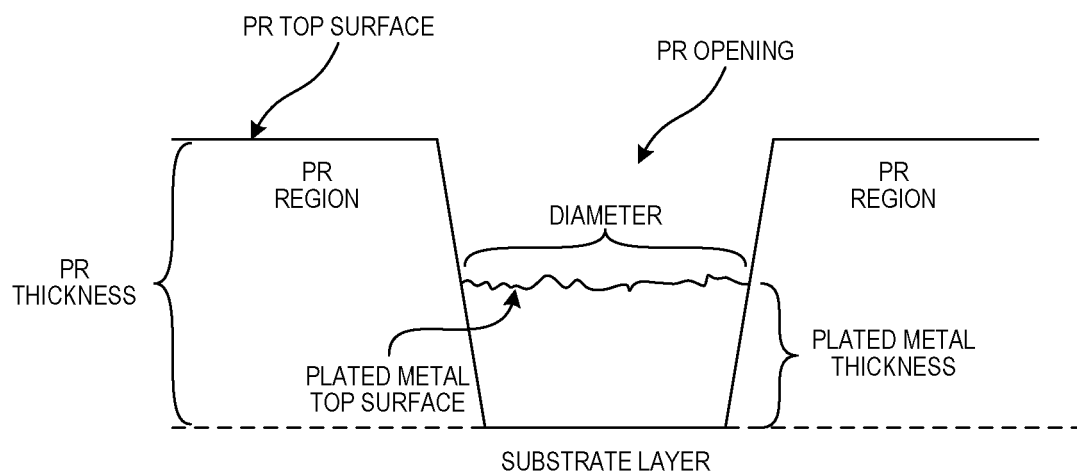
FIG. 33

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3-D VIEW OF PHOTORESIST OPENING WITH PLATED METAL

FIG. 34

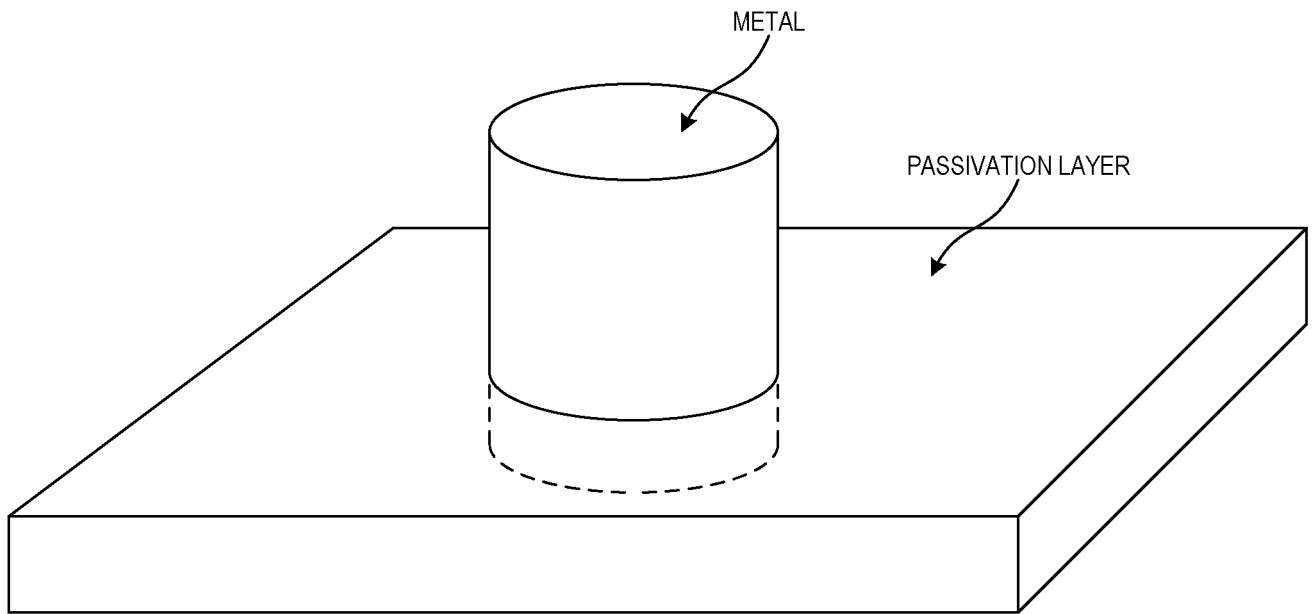


\*PLATED METAL THICKNESS = PR REGION THICKNESS - (PR TOP SURFACE - PLATED METAL TOP SURFACE)

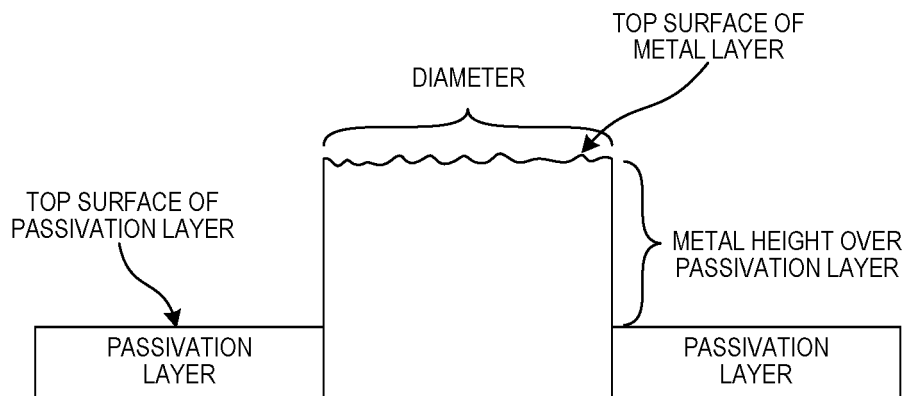
CROSS-SECTIONAL VIEW OF PHOTORESIST OPENING WITH PLATED METAL

FIG. 35

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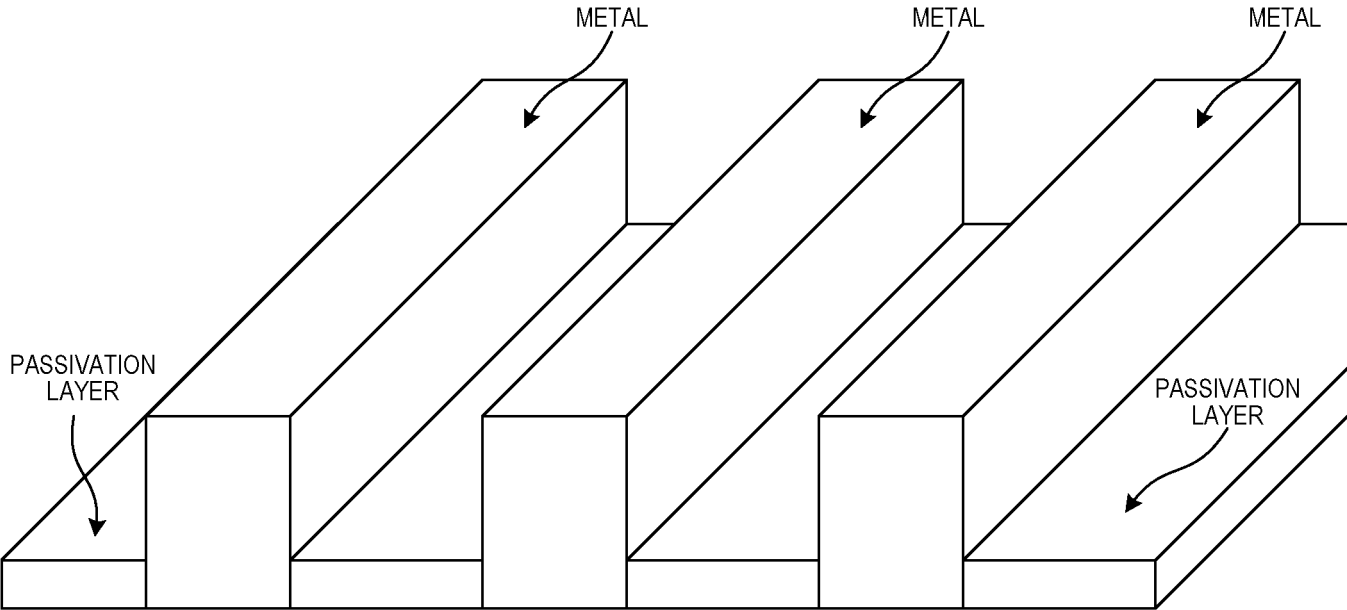
3-D VIEW OF METAL OVER PASSIVATION  
**FIG. 36**



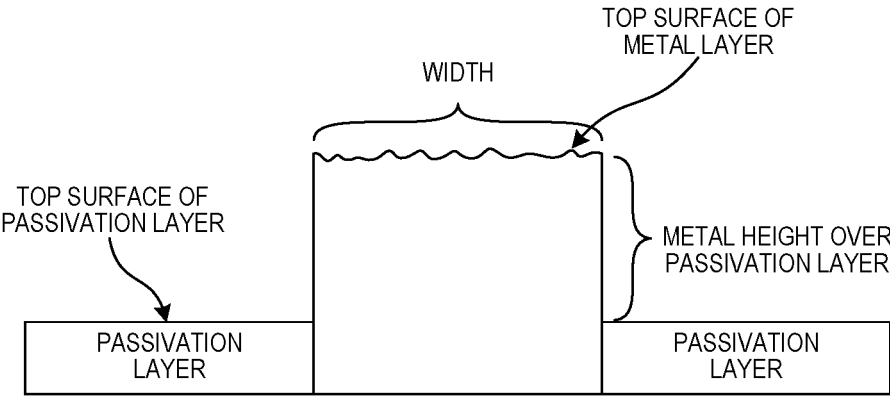
METAL HEIGHT OVER PASSIVATION = TOP SURFACE OF METAL LAYER – TOP SURFACE OF PASSIVATION LAYER

CROSS-SECTIONAL VIEW OF METAL OVER PASSIVATION  
**FIG. 37**

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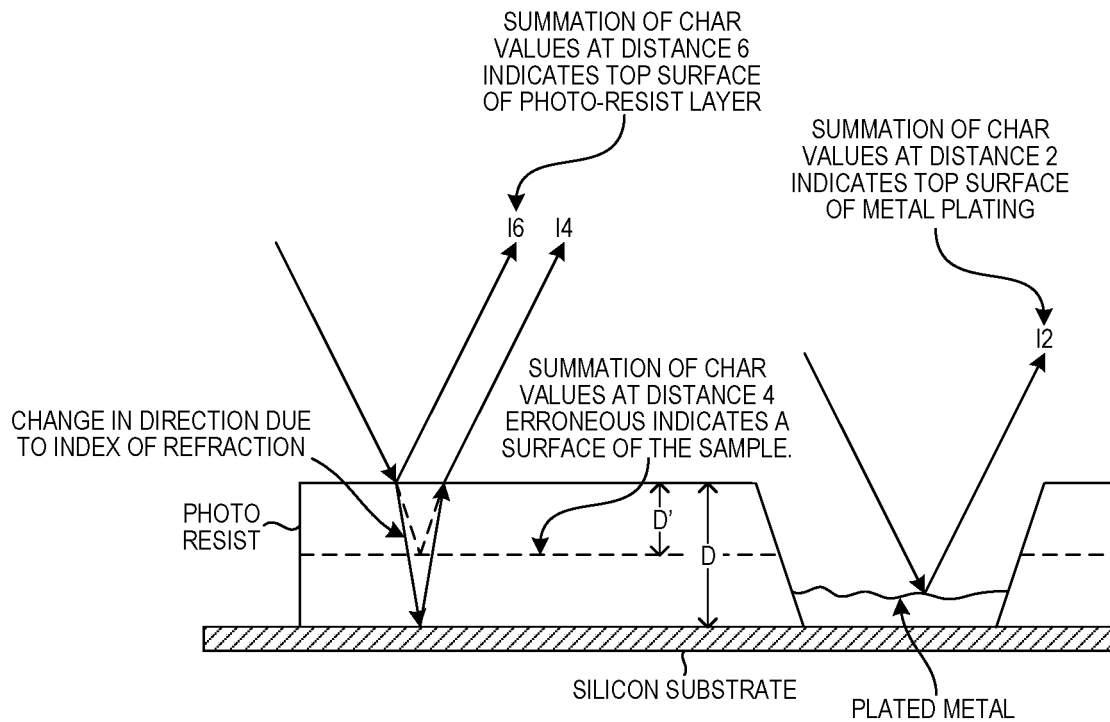
3-D VIEW OF METAL OVER PASSIVATION  
FIG. 38



METAL HEIGHT OVER PASSIVATION = TOP SURFACE OF METAL LAYER – TOP SURFACE OF PASSIVATION LAYER

CROSS-SECTIONAL VIEW OF METAL OVER PASSIVATION  
FIG. 39

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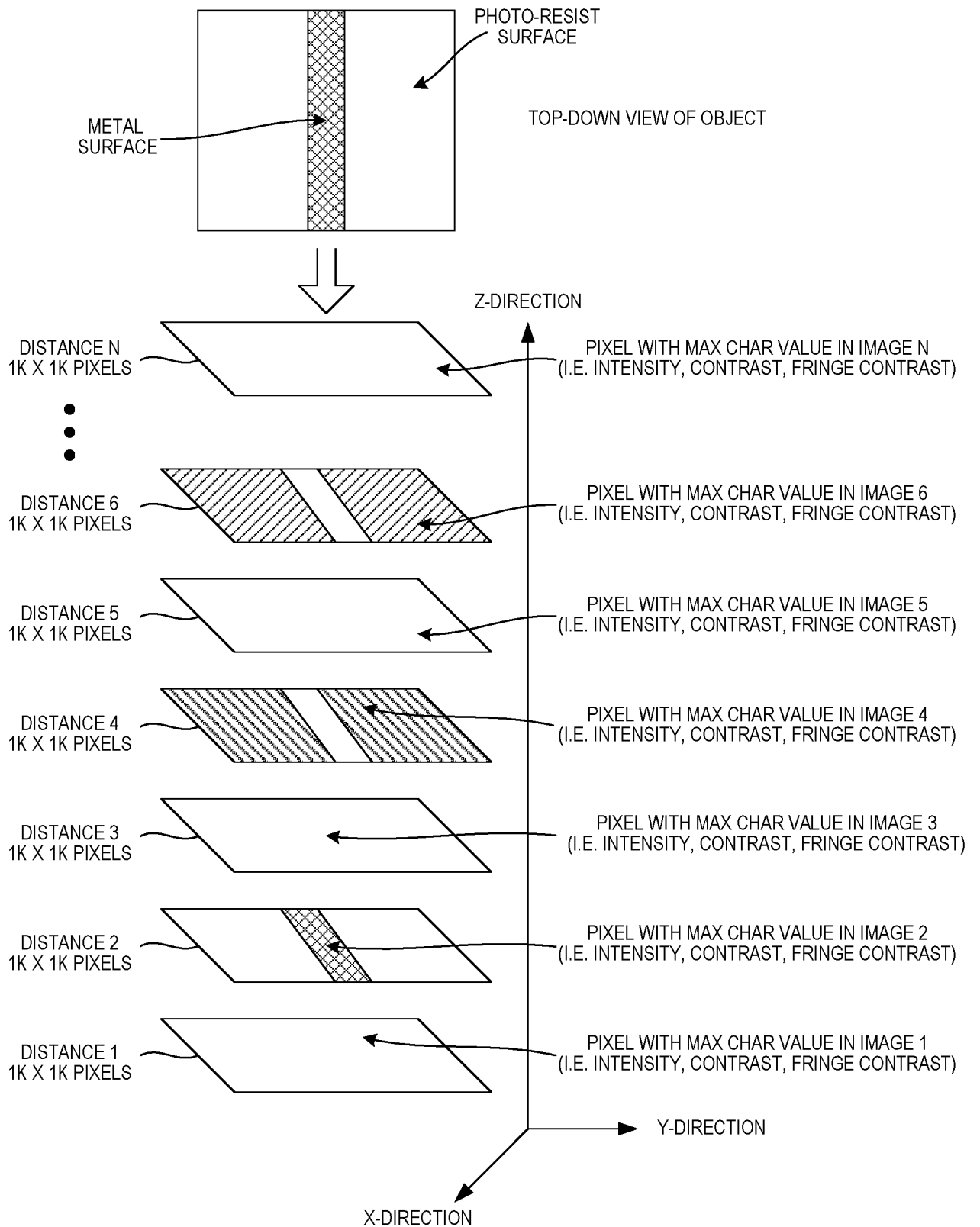
PHOTORESIST THICKNESS (D) = MEASURED THICKNESS (D') X INDEX OF REFRACTION OF PHOTORESIST

PHOTORESIST THICKNESS (D) = MEASURED THICKNESS (D') X INDEX OF REFRACTION OF PHOTORESIST + OFFSET

MEASUREMENT OF TRANSPARENT MATERIAL THICKNESS

FIG. 40

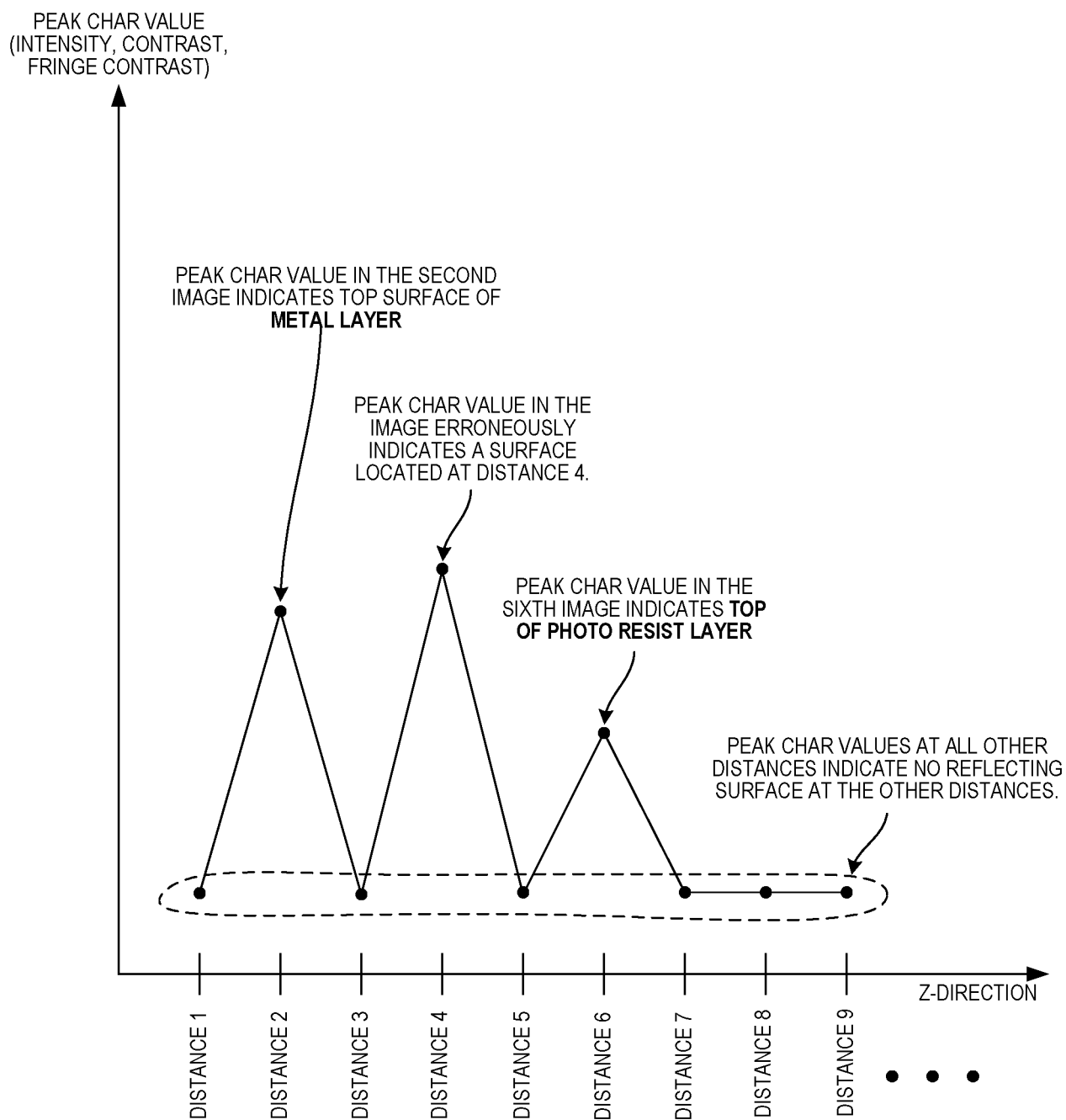
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PEAK MODE OPERATION  
(MAXIMUM CHARACTERISTIC VALUE FOR EACH CAPTURED IMAGE)

FIG. 41

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PEAK CHARACTERISTIC VALUES  
FOR EACH IMAGE

FIG. 42

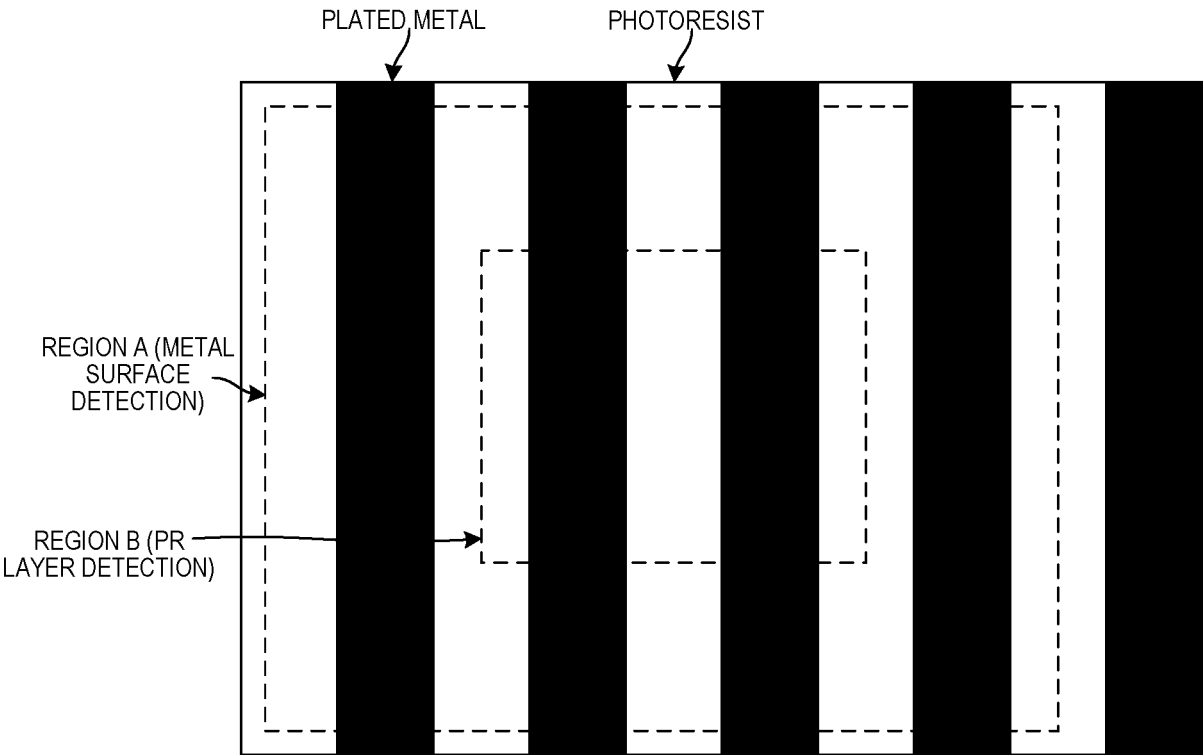
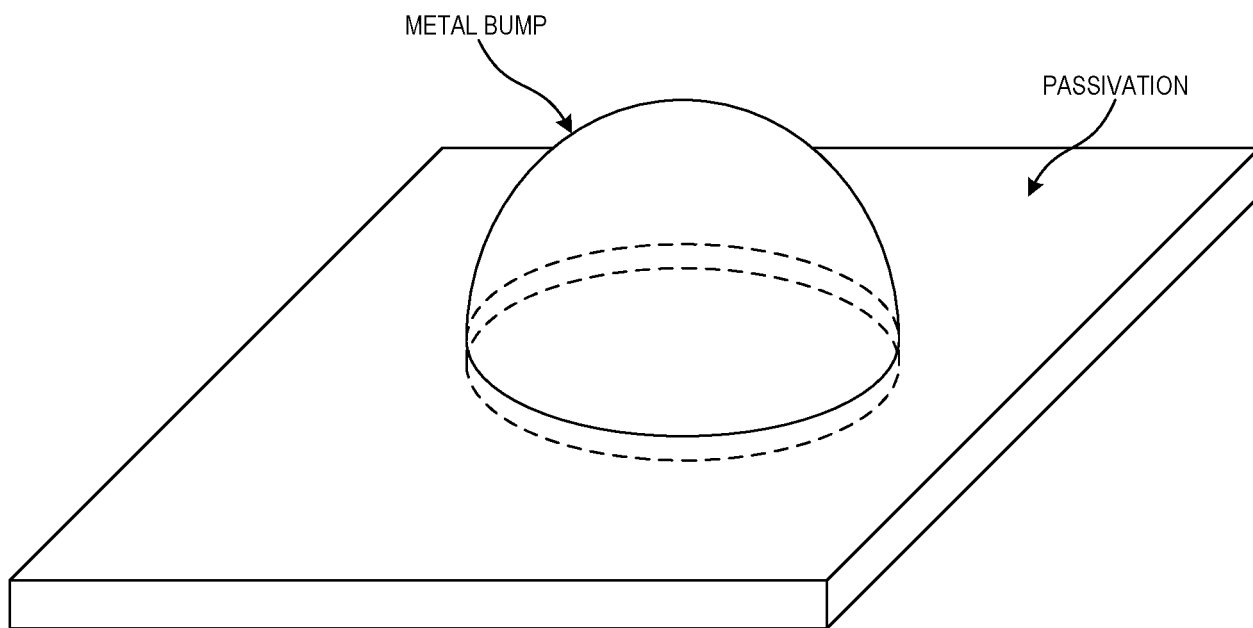


FIG. 43

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3-D VIEW OF METAL BUMP OVER PASSIVATION

FIG. 44

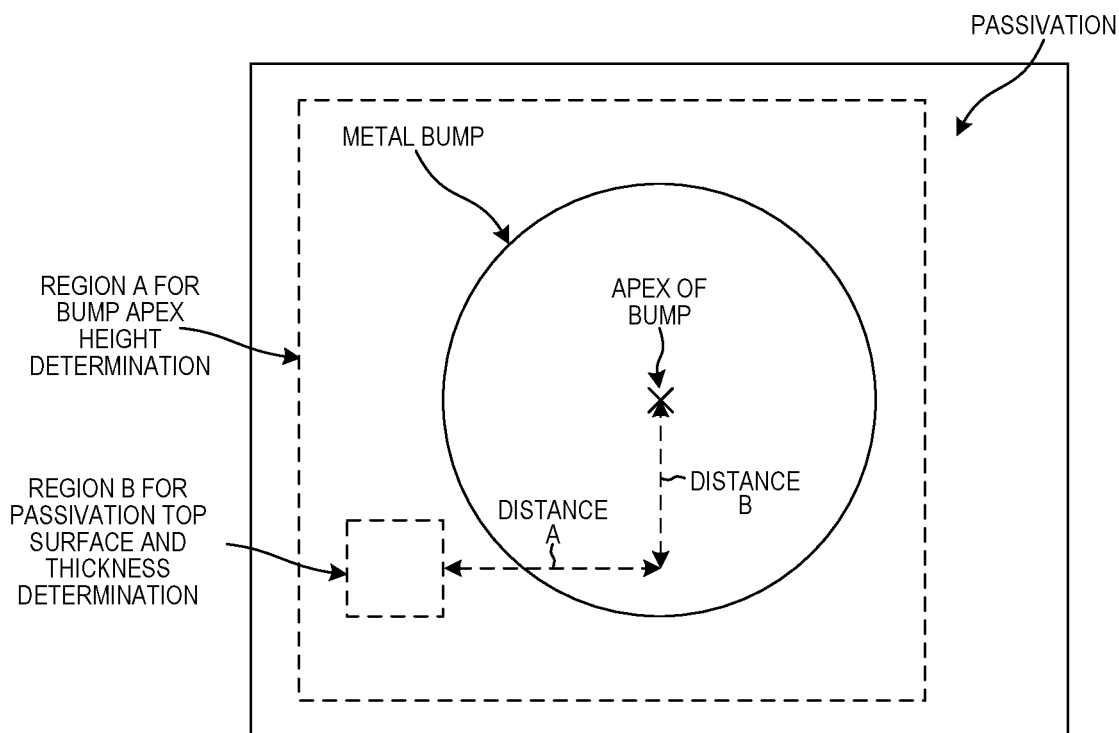


FIG. 45

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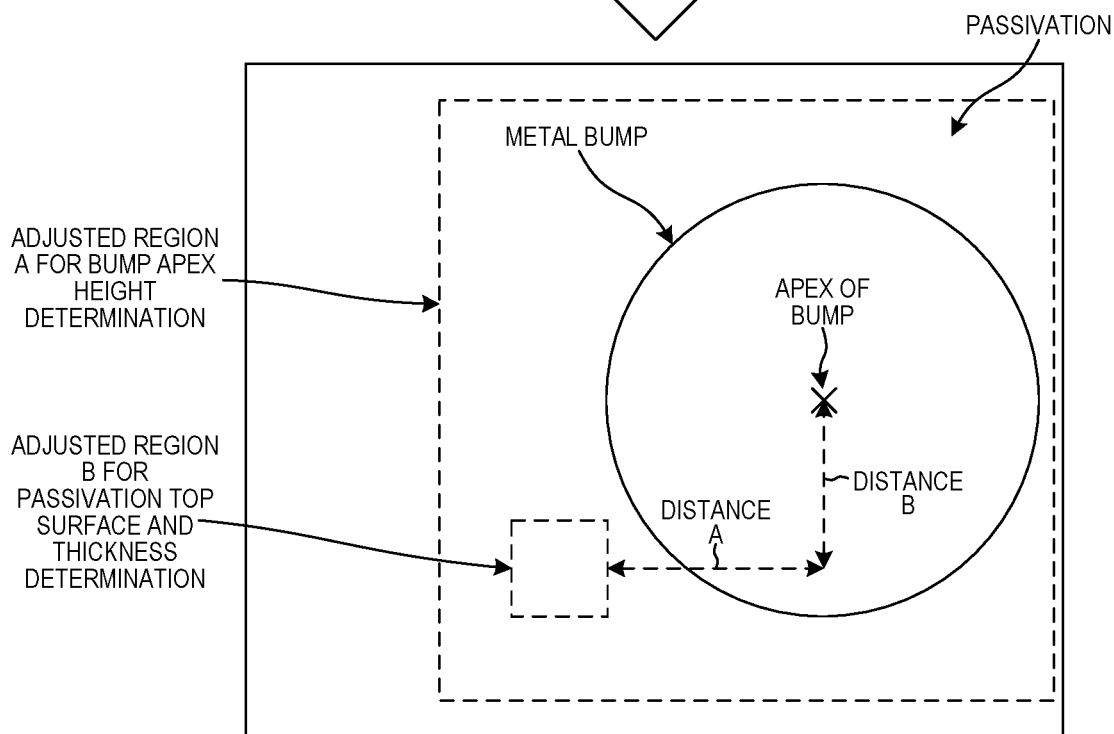
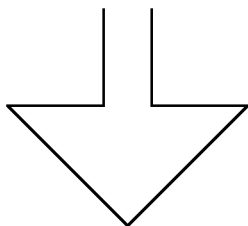
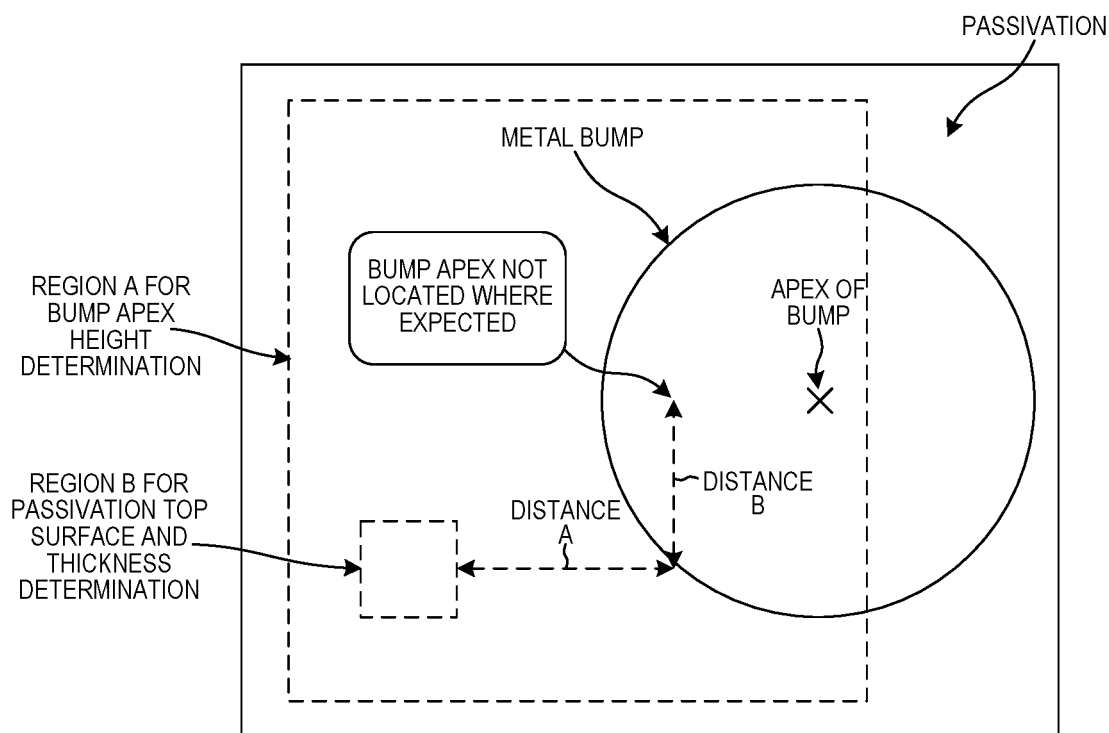
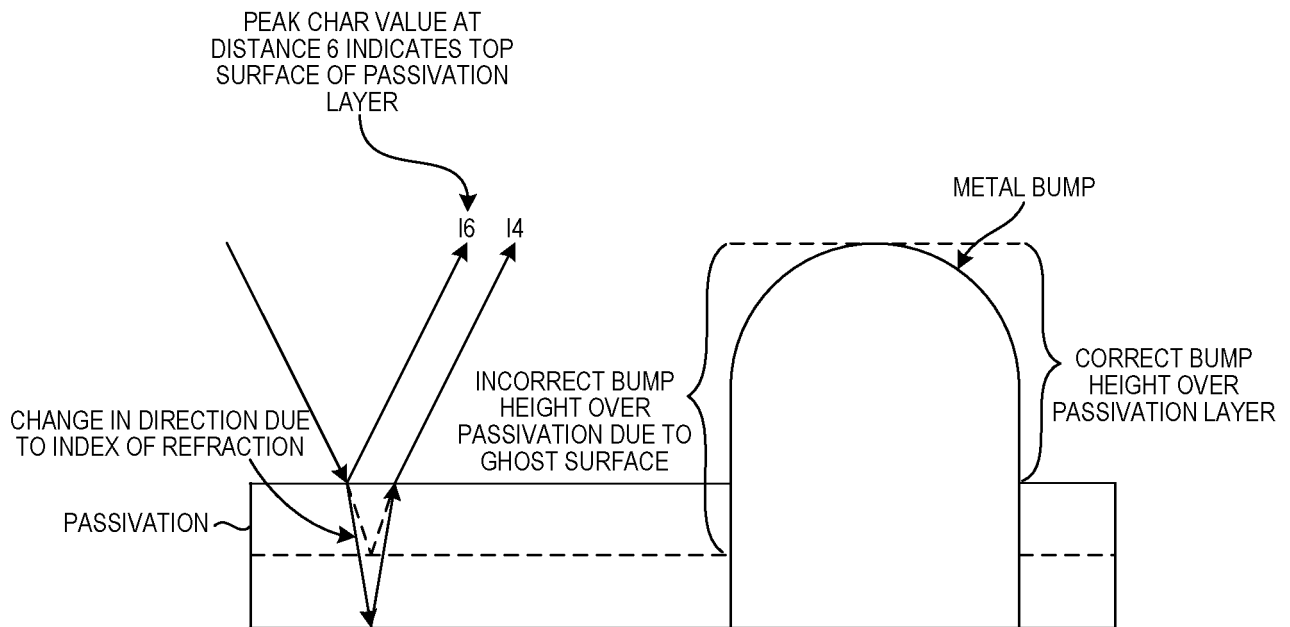


FIG. 46

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PASSIVATION THICKNESS (D) = MEASURED THICKNESS (D') X INDEX OF REFRACTION OF PASSIVATION

PASSIVATION THICKNESS (D) = MEASURED THICKNESS (D') X INDEX OF REFRACTION OF PASSIVATION + OFFSET

## MEASUREMENT OF TRANSPARENT MATERIAL THICKNESS FIG. 47

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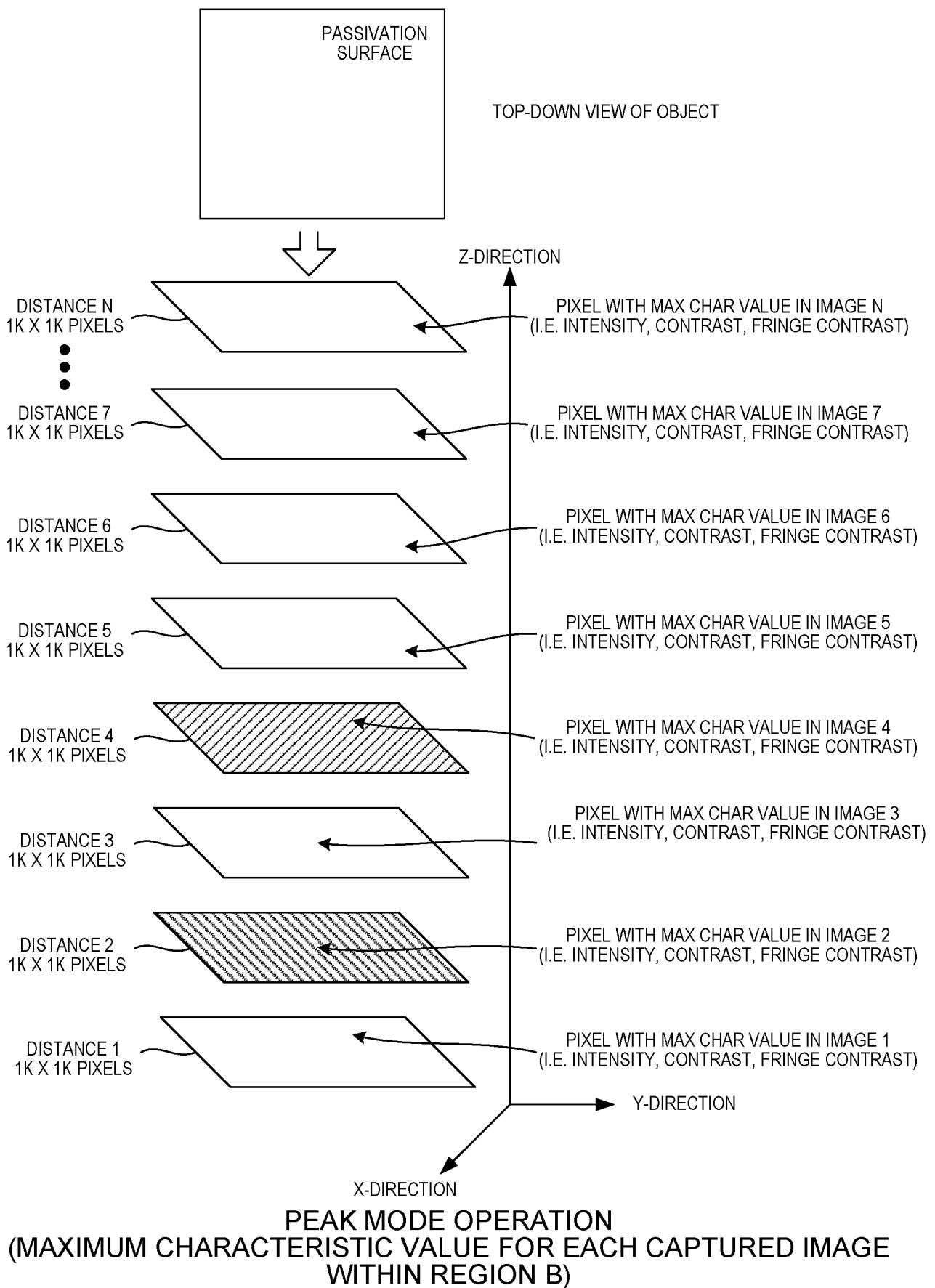
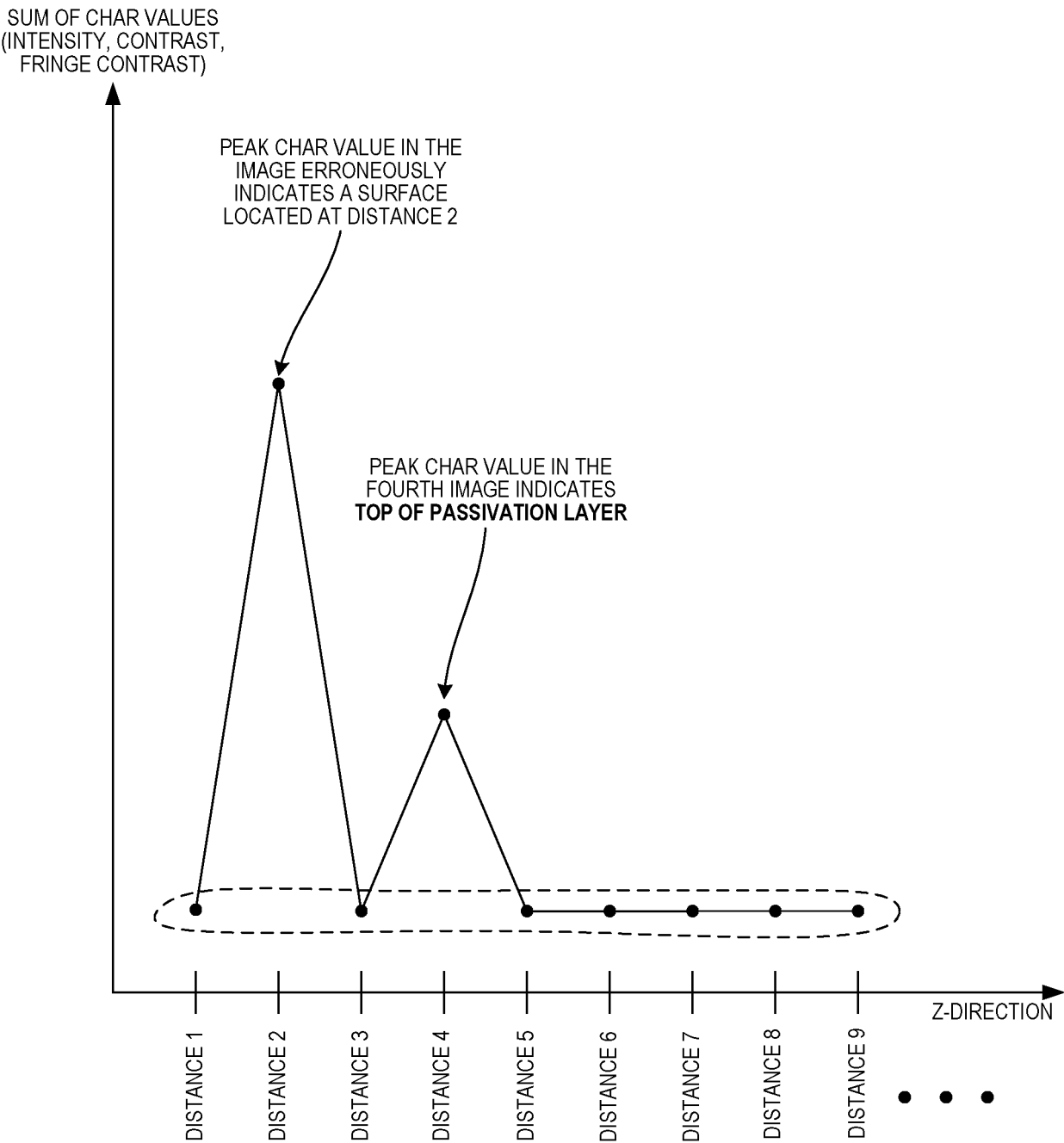


FIG. 48



PEAK CHARACTERISTIC VALUES  
FOR EACH IMAGE IN REGION B

FIG. 49