

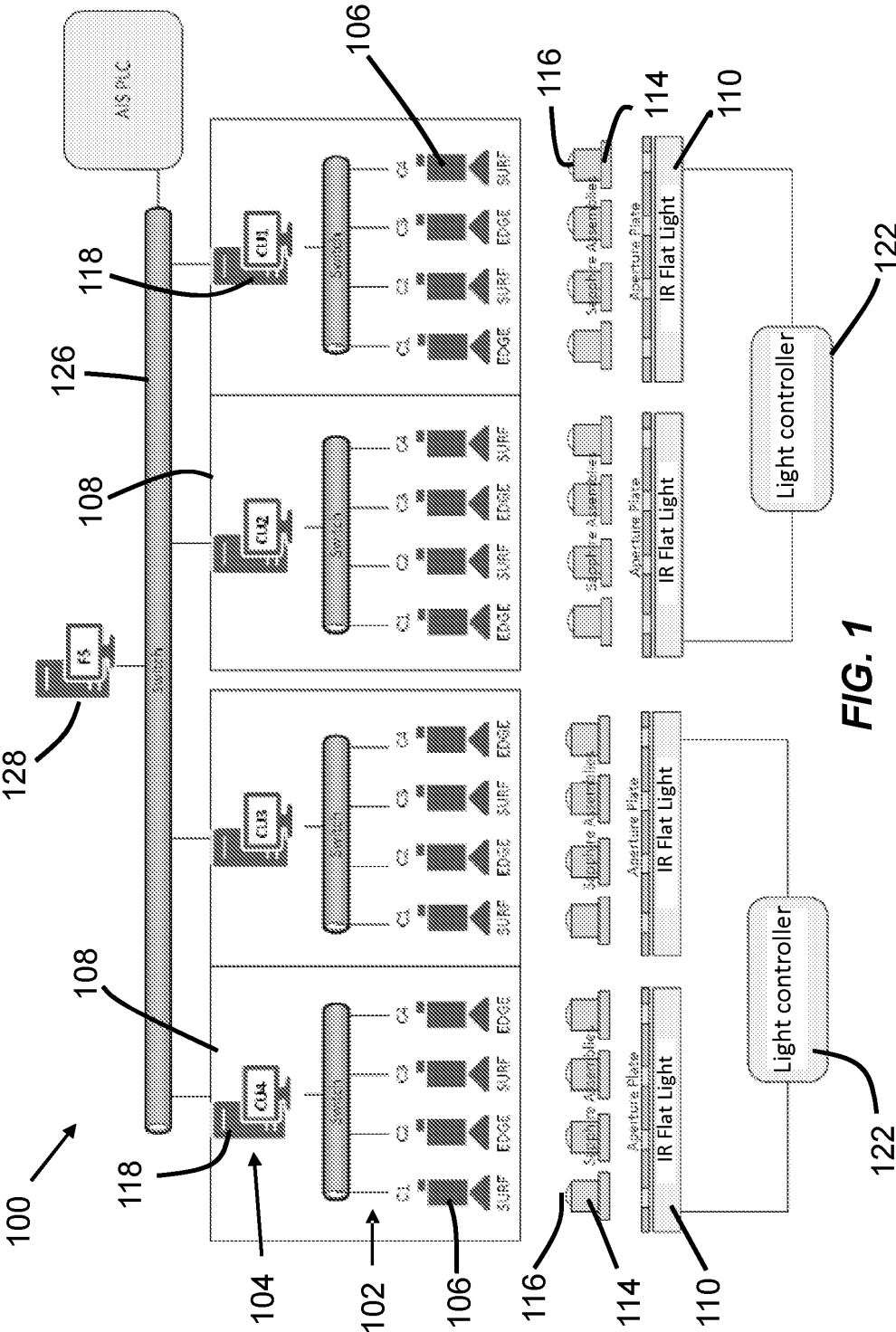


FIG. 1

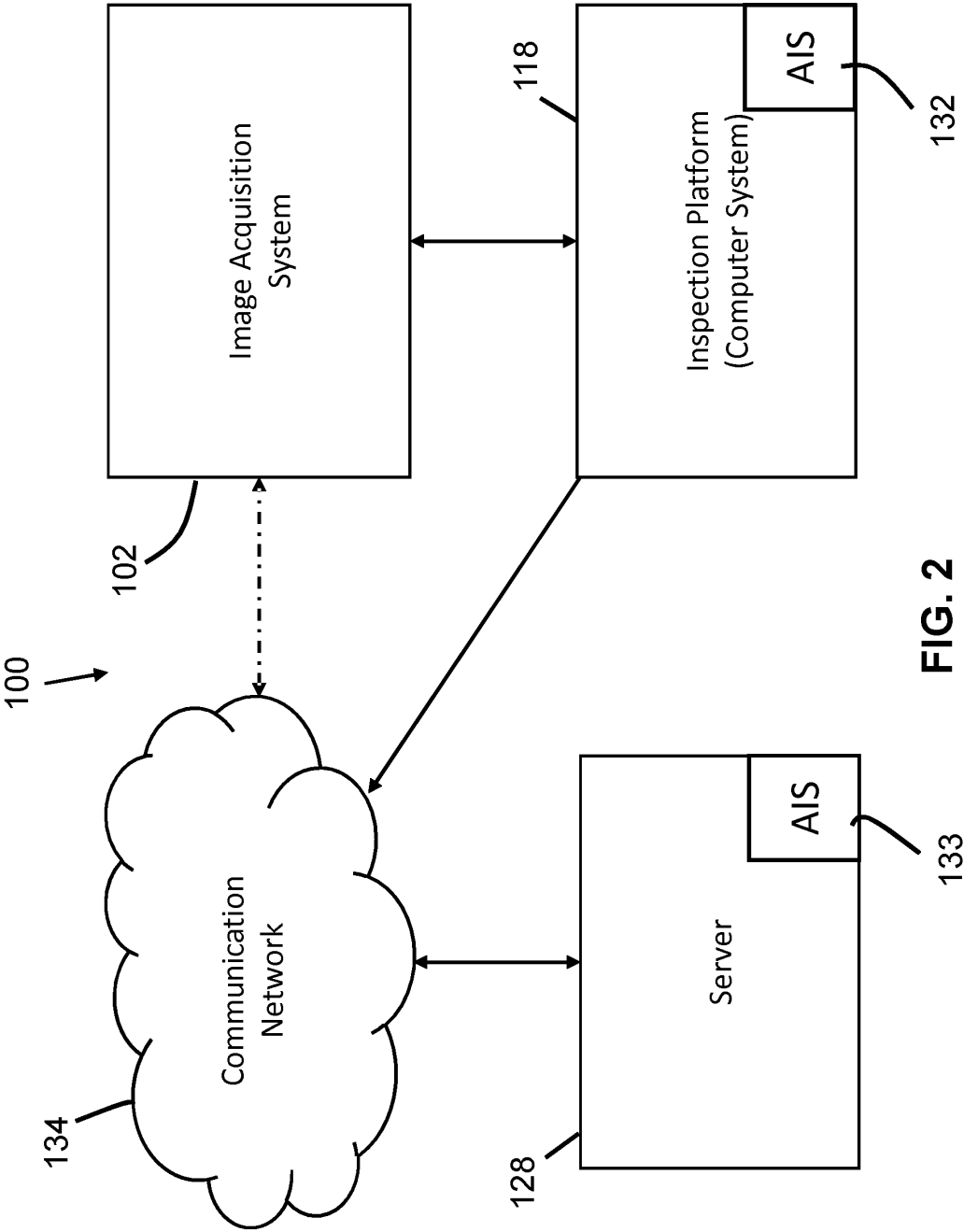


FIG. 2

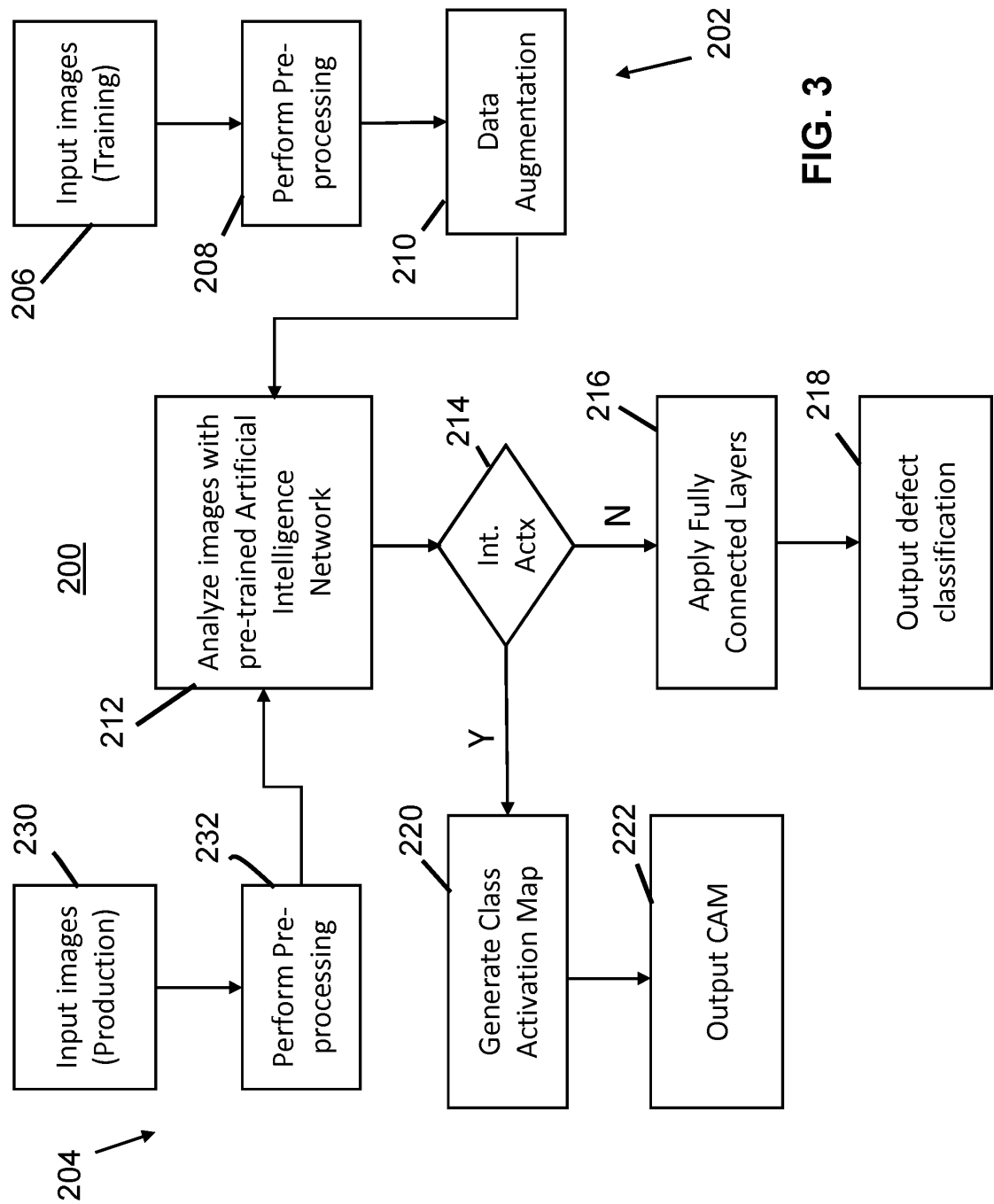


FIG. 3

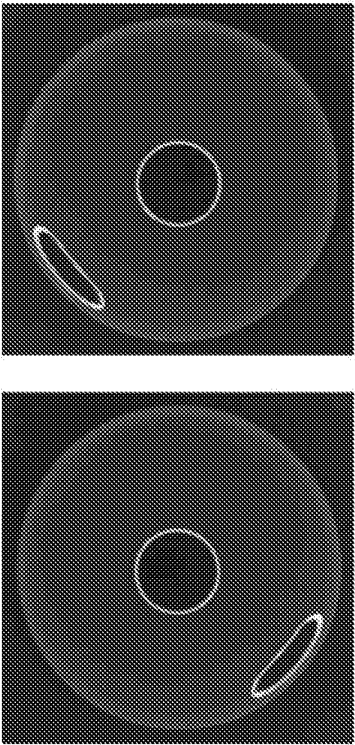


FIG. 4A

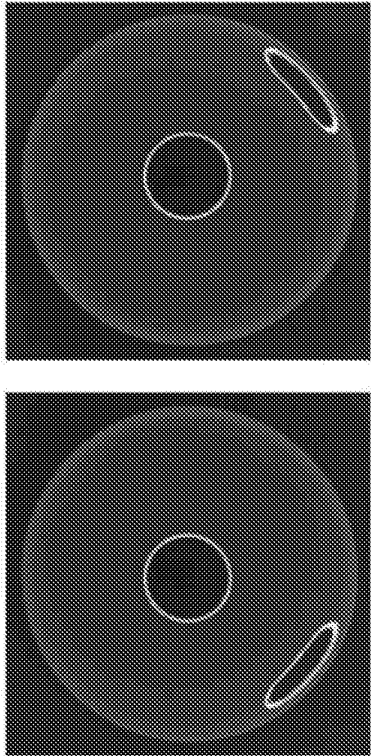
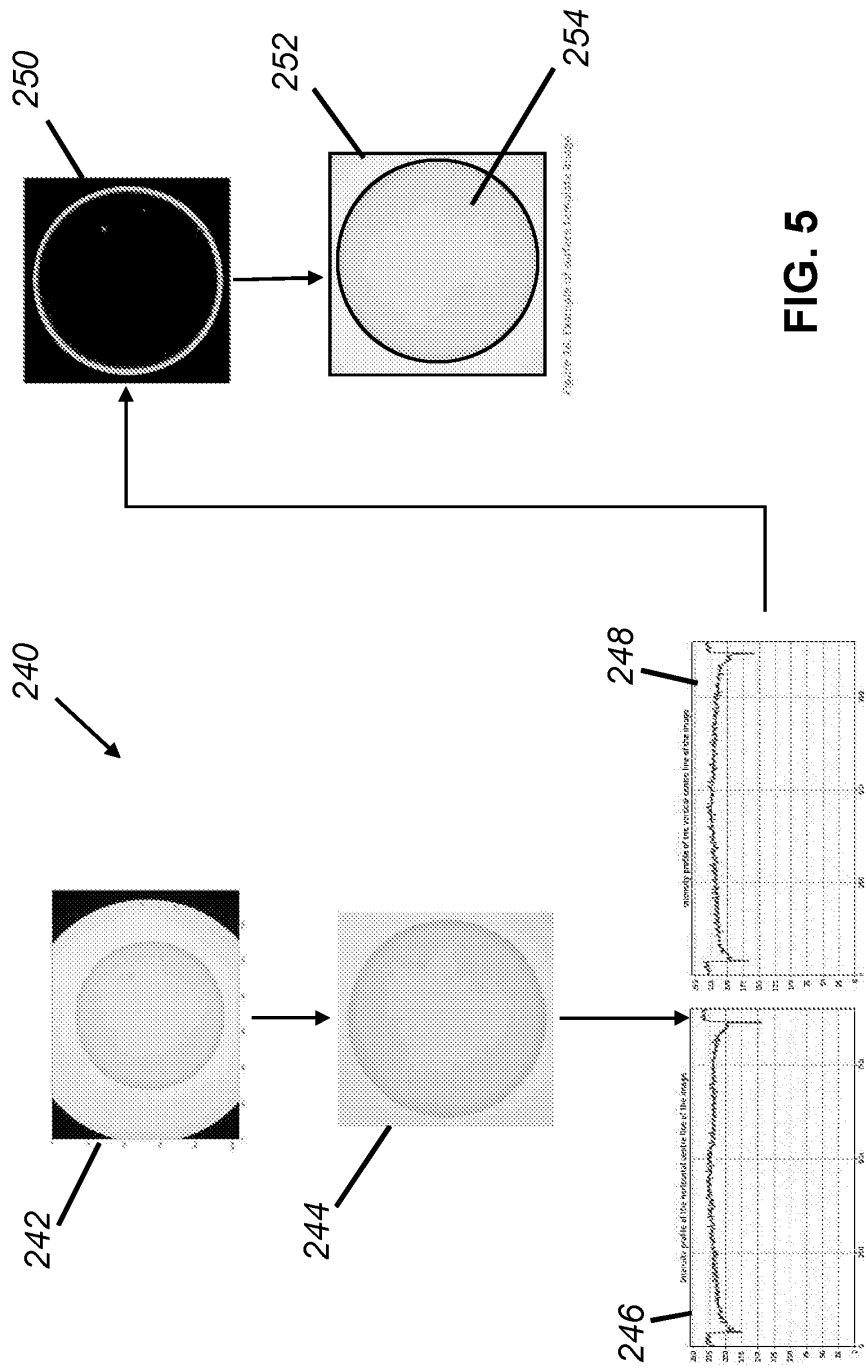


FIG. 4B



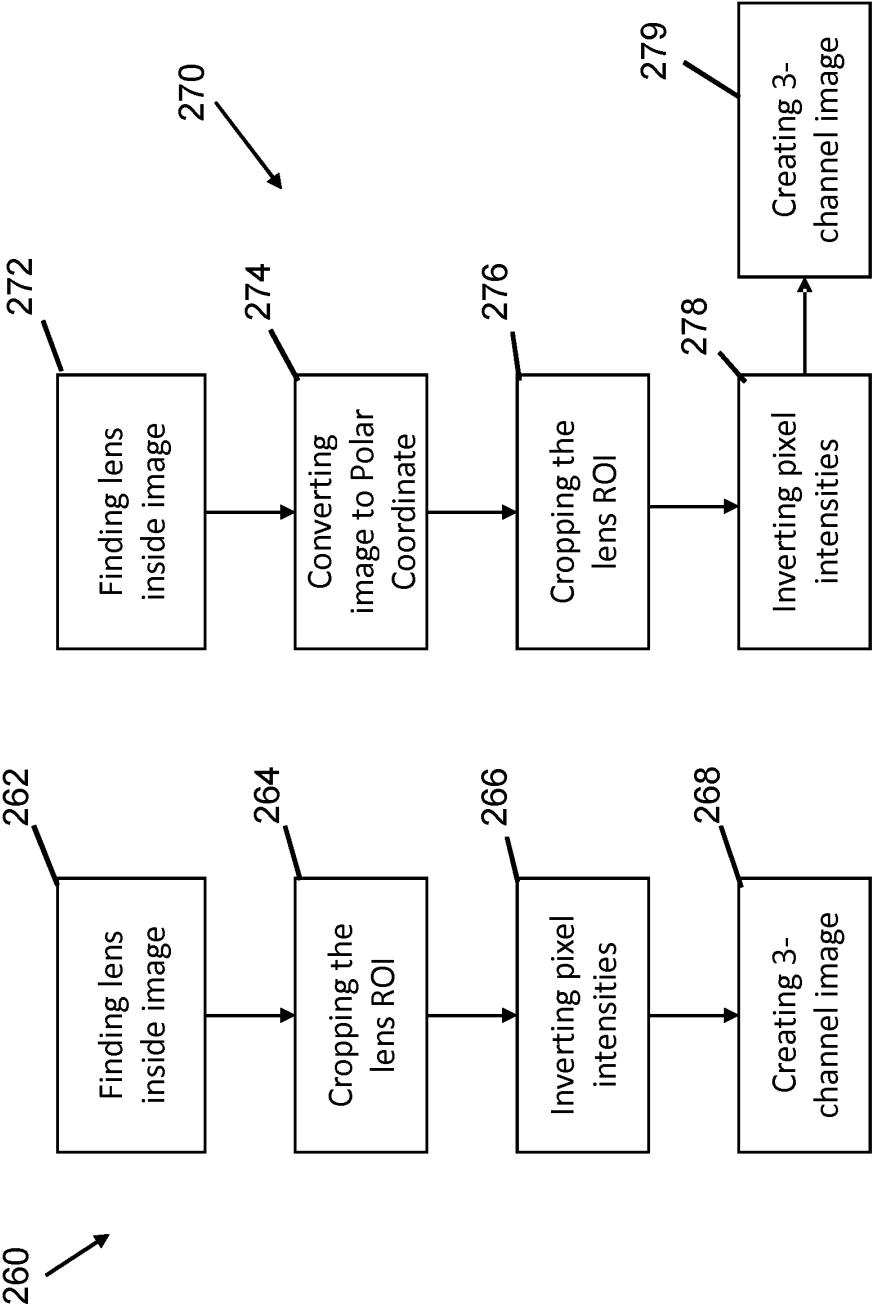


FIG. 6

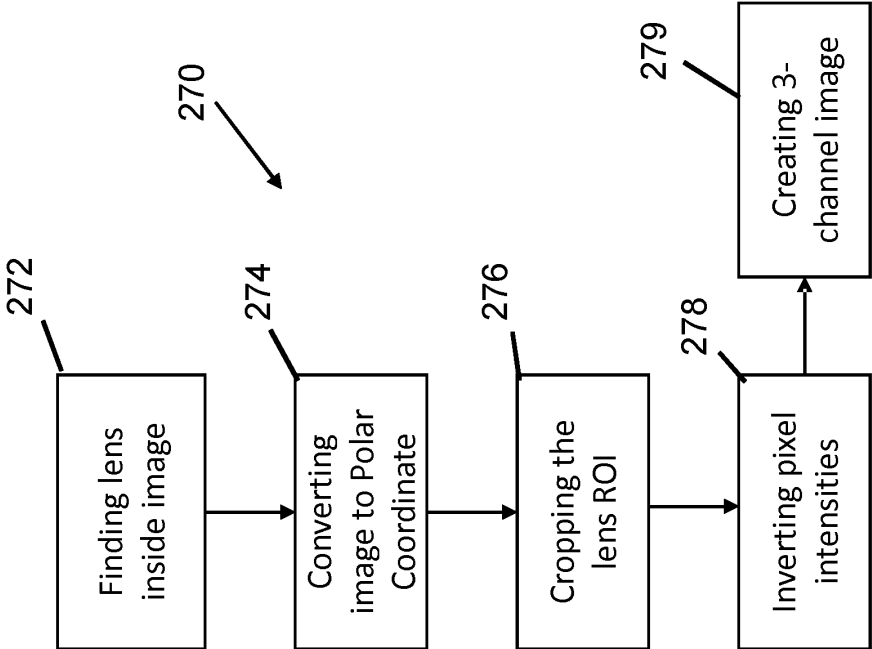


FIG. 7

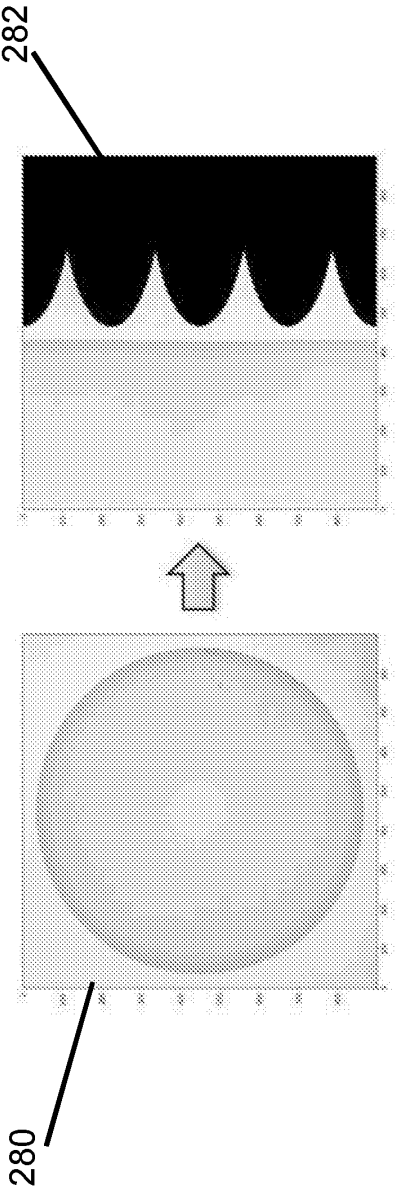


Figure 22: From cartesian to polar coordinates

FIG. 8

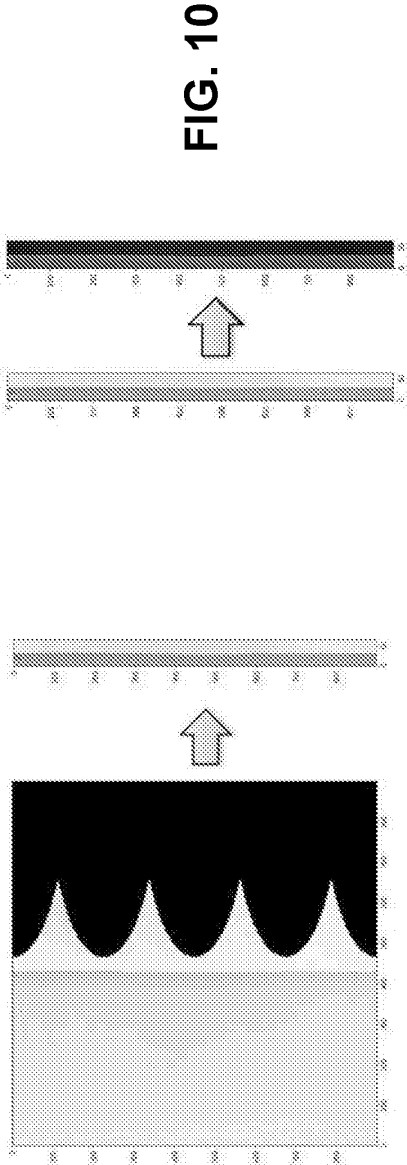


Figure 23: Cropping the ROI of the EDGE

FIG. 9

FIG. 10

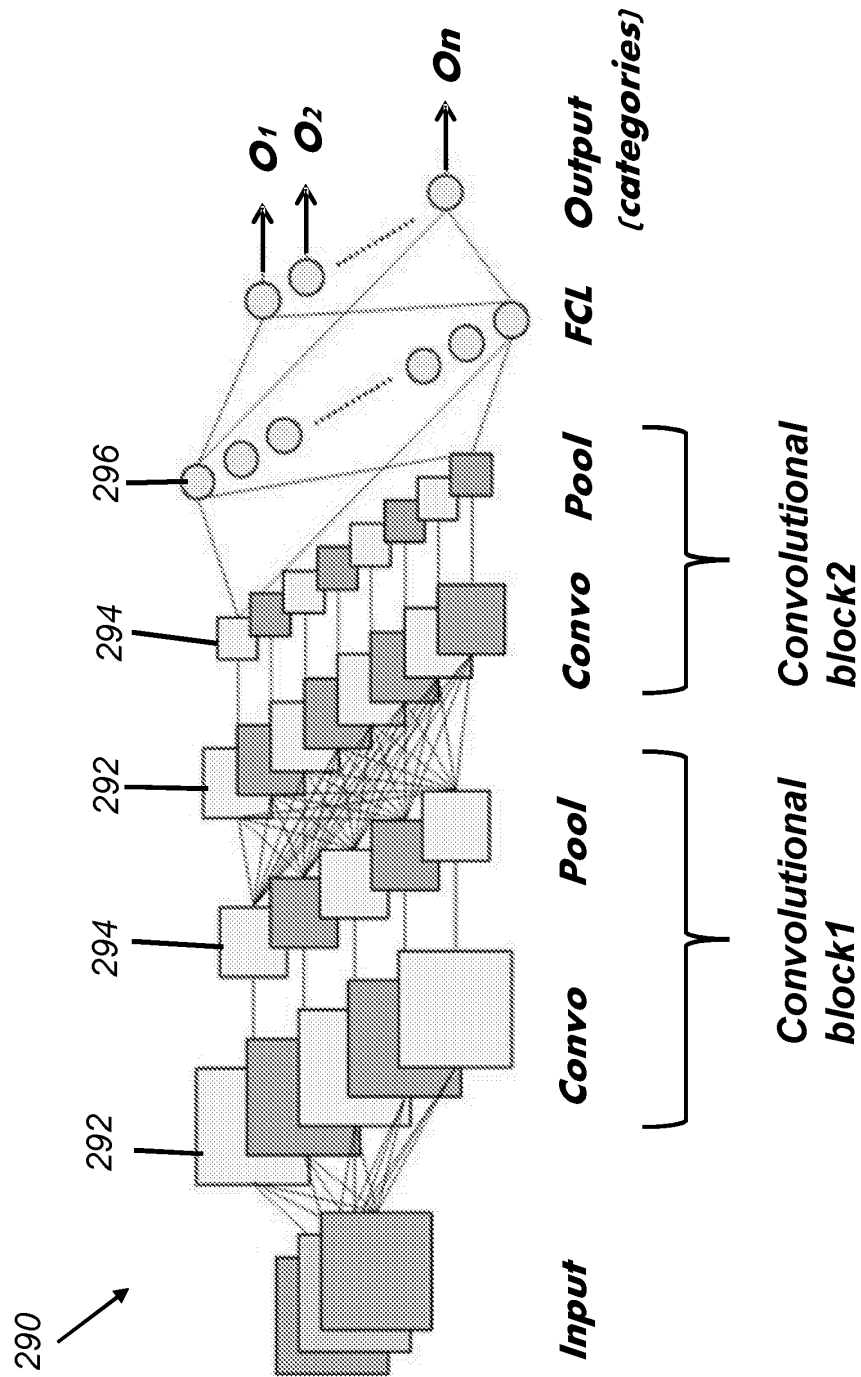


FIG. 11

Library	Convolutional Block	Layer name	Layer Input Shape	Layer Output shape
VGG19		Input	(900, 900, 3)	(900, 900, 3)
	block1	block1_conv1	(900, 900, 3)	(900, 900, 64)
		block1_conv2	(900, 900, 64)	(900, 900, 64)
		block1_pool	(900, 900, 64)	(450, 450, 64)
	block2	block2_conv1	(450, 450, 64)	(450, 450, 128)
		block2_conv2	(450, 450, 128)	(450, 450, 128)
		block2_pool	(450, 450, 128)	(225, 225, 128)
	block3	block3_conv1	(225, 225, 128)	(225, 225, 256)
		block3_conv2	(225, 225, 256)	(225, 225, 256)
		block3_conv3	(225, 225, 256)	(225, 225, 256)
		block3_conv4	(225, 225, 256)	(225, 225, 256)
		block3_pool	(225, 225, 256)	(112, 112, 256)
	block4	block4_conv1	(112, 112, 256)	(112, 112, 512)
		block4_conv2	(112, 112, 512)	(112, 112, 512)
		block4_conv3	(112, 112, 512)	(112, 112, 512)
		block4_conv4	(112, 112, 512)	(112, 112, 512)
		block4_pool	(112, 112, 512)	(56, 56, 512)
	block5	block5_conv1	(56, 56, 512)	(56, 56, 512)
		block5_conv2	(56, 56, 512)	(56, 56, 512)
		block5_conv3	(56, 56, 512)	(56, 56, 512)
		block5_conv4	(56, 56, 512)	(56, 56, 512)
		block5_pool	(56, 56, 512)	(28, 28, 512)
Densely connected layers	N/A	flatten_1	(28, 28, 512)	(401408, 1)
	N/A	dense_1	(401408, 1)	(256, 1)
	N/A	dense_2	(256, 1)	(8, 1)

FIG. 12

Library	Convolutional Block	Layer name	Layer Output shape	Layer Output shape
VGG19	block1	Input	(900, 50, 3)	(900, 50, 3)
		block1_conv1	(900, 50, 3)	(900, 50, 64)
		block1_conv2	(900, 50, 64)	(900, 50, 64)
		block1_pool	(900, 50, 64)	(450, 25, 64)
	block2	block2_conv1	(450, 25, 64)	(450, 25, 128)
		block2_conv2	(450, 25, 128)	(450, 25, 128)
		block2_pool	(450, 25, 128)	(225, 12, 128)
	block3	block3_conv1	(225, 12, 128)	(225, 12, 256)
		block3_conv2	(225, 12, 256)	(225, 12, 256)
		block3_conv3	(225, 12, 256)	(225, 12, 256)
		block3_conv4	(225, 12, 256)	(225, 12, 256)
		block3_pool	(225, 12, 256)	(112, 6, 256)
	block4	block4_conv1	(112, 6, 256)	(112, 6, 512)
		block4_conv2	(112, 6, 512)	(112, 6, 512)
		block4_conv3	(112, 6, 512)	(112, 6, 512)
		block4_conv4	(112, 6, 512)	(112, 6, 512)
		block4_pool	(112, 6, 512)	(56, 3, 512)
	block5	block5_conv1	(56, 3, 512)	(56, 3, 512)
		block5_conv2	(56, 3, 512)	(56, 3, 512)
		block5_conv3	(56, 3, 512)	(56, 3, 512)
		block5_conv4	(56, 3, 512)	(56, 3, 512)
		block5_pool	(56, 3, 512)	(28, 1, 512)
Densely connected layers	N/A	flatten_1	(28, 1, 512)	(14336, 1)
	N/A	dense_1	(14336, 1)	(256, 1)
	N/A	dense_2	(256, 1)	(3, 1)

FIG. 13

FIG. 14

Setting	Value
Training steps per epoch	100
Validation steps per epoch	50
Train batch size	40
Validation batch size	40
Training metrics	accuracy
Learning rate	2×10^{-5}
Loss function	Categorical cross-entropy

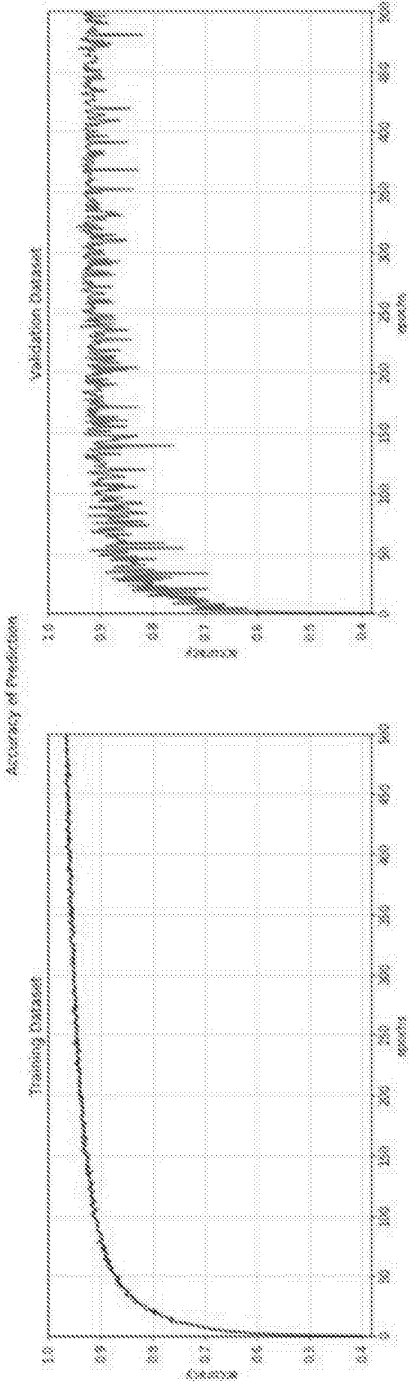


FIG. 15

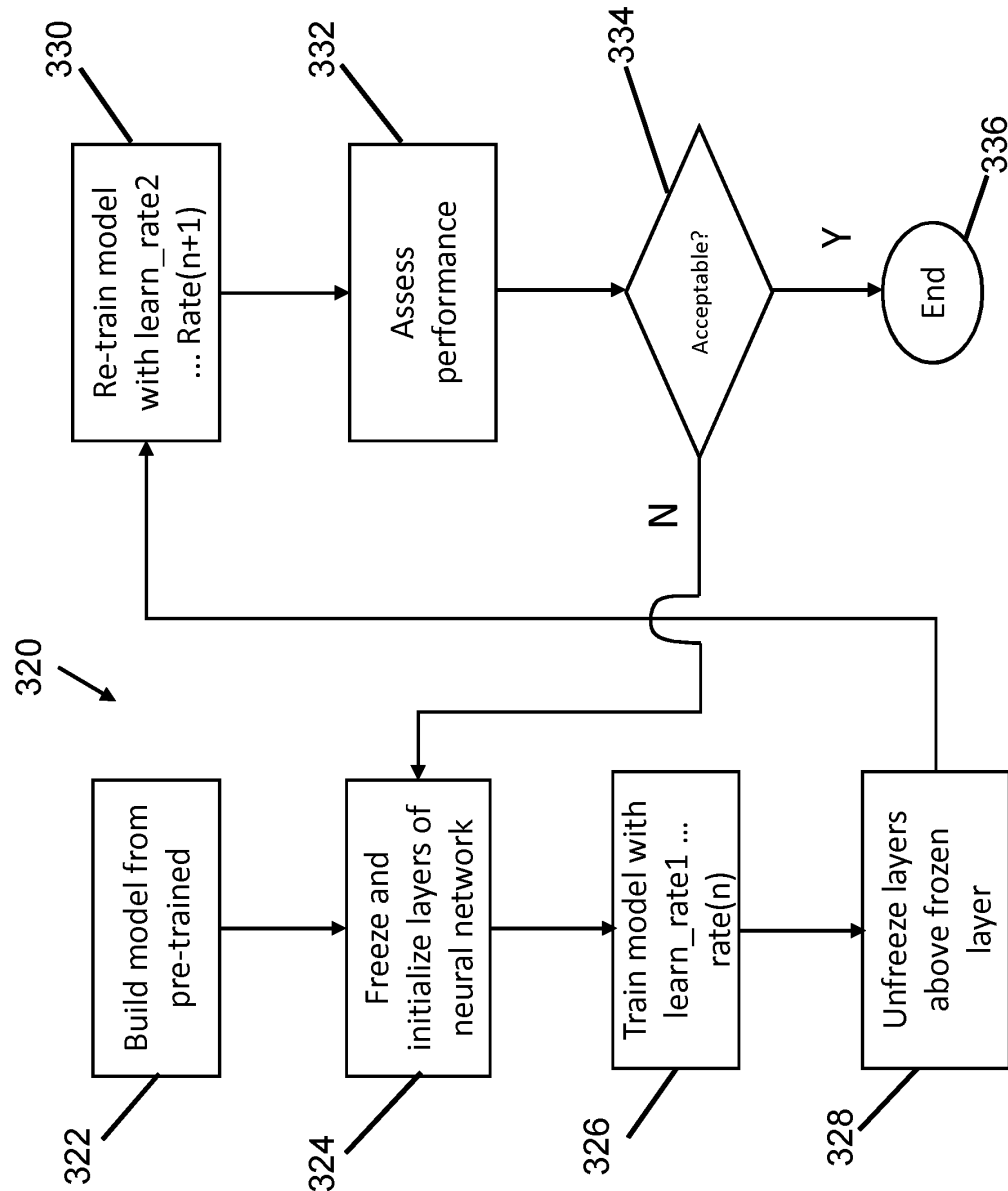


FIG. 14A

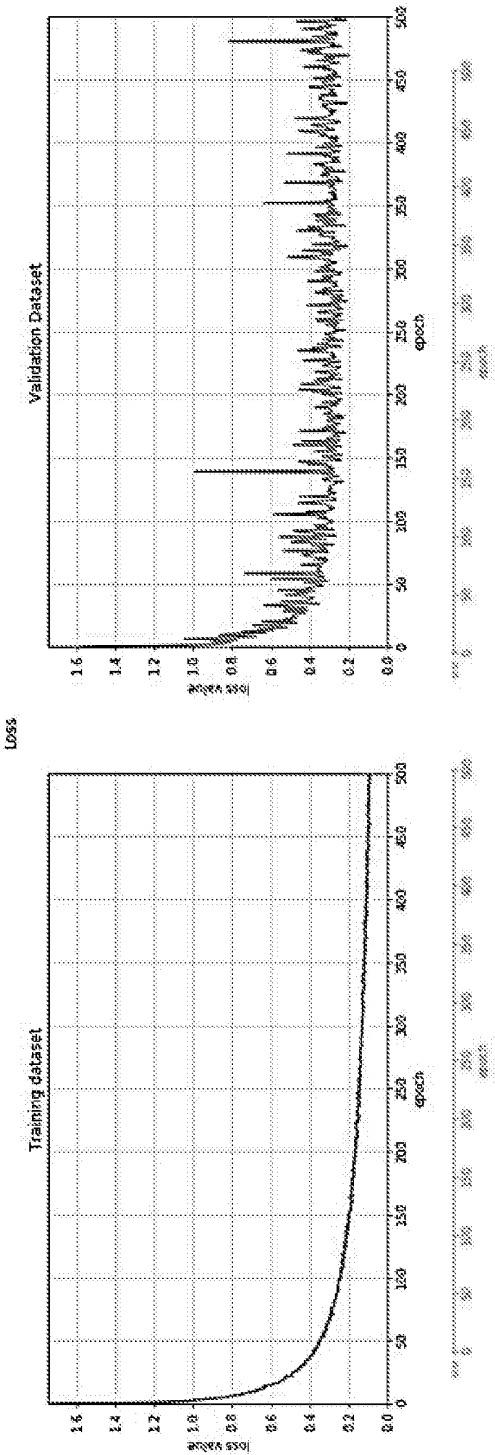


FIG. 16

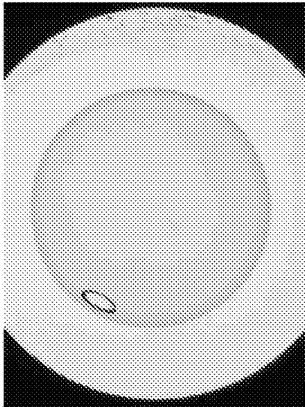


Figure 1: Example of "Bubble"
FIG. 18

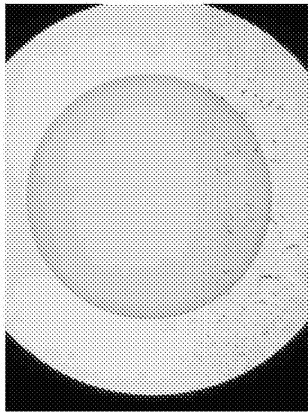


Figure 2: Example of soften defect category "Too Softened"
FIG. 20

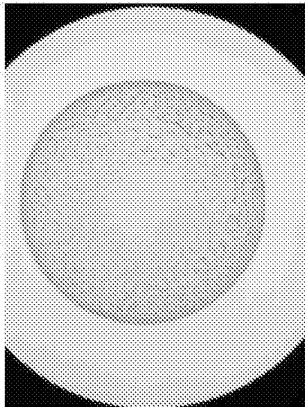


Figure 3: Example of "Crease"
FIG. 17

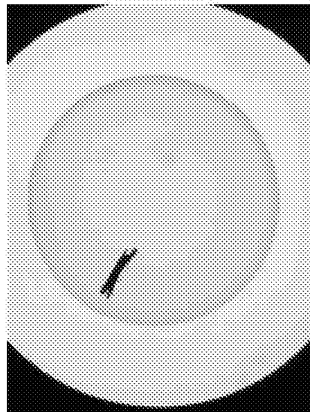


Figure 4: Example of "Crease"
FIG. 19

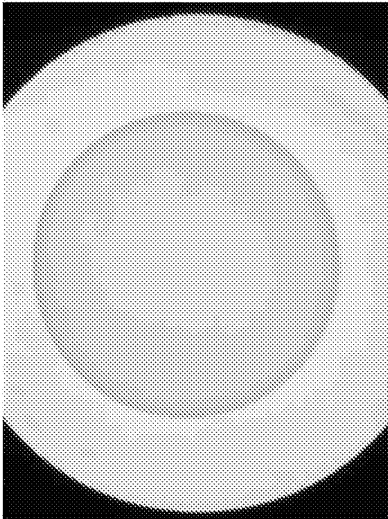


Figure 21: Example of surface defect "Double lens"

FIG. 21

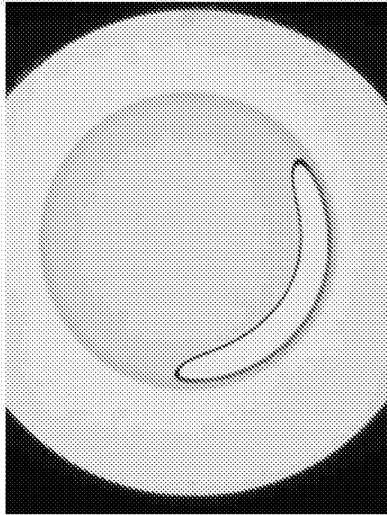


Figure 22: Example of a lens with good surface

FIG. 22

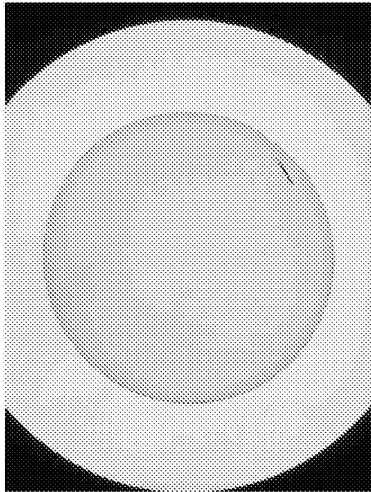


Figure 23: Example of surface defect category "No defect"

FIG. 23

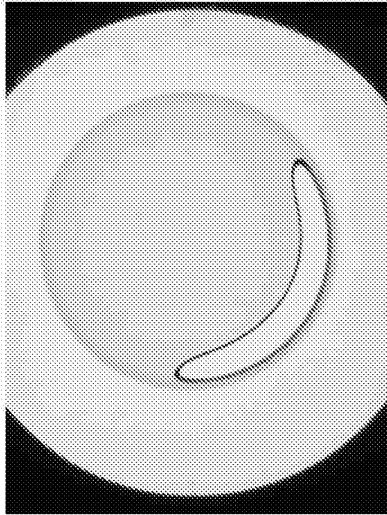


Figure 24: Example of surface defect "Void"

FIG. 24

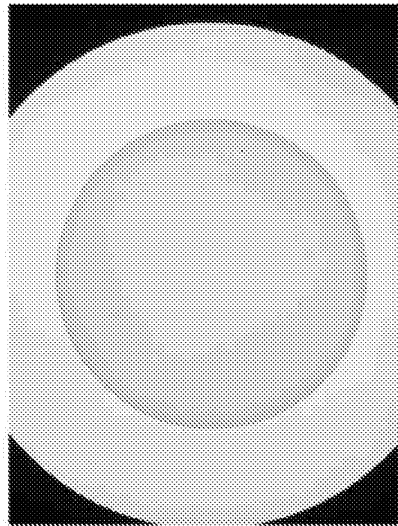


Figure 12. Example of a good edge image

FIG. 26

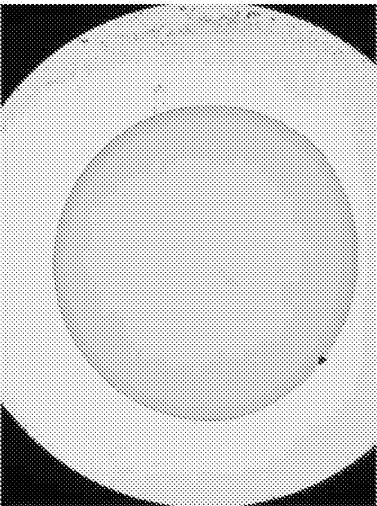


Figure 12. Example of edge-defect category "Deline"

FIG. 25

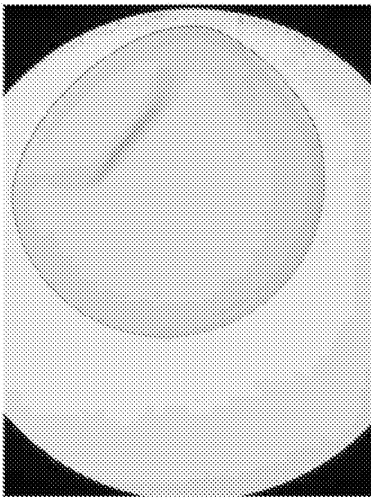


Figure 14. Example of edge-defect "Pinholes"

FIG. 27

Category	Total	TP	FP	FN	TN	Accuracy	Precision	Recall
Brains	498	498	0	0	3475	1.00	1.000	1.000
Bubble	496	496	0	0	3477	1.00	1.000	1.000
Debris	497	496	2	1	3475	1.00	0.996	0.998
Dirty Sapphire	497	440	22	57	3419	0.98	0.952	0.885
Double Lens	502	479	3	23	3448	0.99	0.994	0.954
Good Lens	499	496	49	3	3970	0.99	0.910	0.994
Scratch	500	499	9	1	3472	1.00	0.982	0.998
Void	484	484	0	0	3489	1.00	1.000	1.000

FIG. 29

Ground Truth	Predicted		
	Debris	Goodlens	Pinched
	Debris	486	41
	Goodlens	6	494
Pinched	502	0	502

FIG. 30

Category	Total	TP	FP	FN	TN	Accuracy	Precision	Recall
Debris	527	486	6	41	996	0.97	0.99	0.92
Goodlens	500	494	41	6	988	0.97	0.92	0.99
Pinched	502	502	0	0	1027	1.00	1.00	1.00

FIG. 31

Library	Convolutional Block	Layer name	Layer Output shape
VGG16		Input	(780, 590, 3)
	block1	block1_conv1	(780, 590, 64)
		block1_conv2	(780, 590, 64)
		block1_pool	(390, 295, 64)
	block2	block2_conv1	(390, 295, 128)
		block2_conv2	(390, 295, 128)
		block2_pool	(195, 147, 128)
	block3	block3_conv1	(195, 147, 256)
		block3_conv2	(195, 147, 256)
		block3_conv3	(195, 147, 256)
		block3_pool	(97, 73, 256)
	block4	block4_conv1	(97, 73, 512)
		block4_conv2	(97, 73, 512)
		block4_conv3	(97, 73, 512)
		block4_pool	(48, 36, 512)
	block5	block5_conv1	(48, 36, 512)
		block5_conv2	(48, 36, 512)
		block5_conv3	(48, 36, 512)
		block5_pool	(24, 18, 512)
Densely connected layers	NA	conv2d_1	(26, 26, 512)
	N/A	flatten_1	(221184, 1)
	N/A	dense_1	(256, 1)
	N/A	dense_2	(3, 1)

FIG. 32

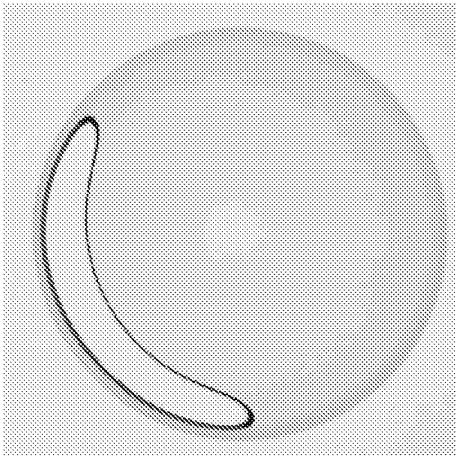
	Lyer Name	Output Shape	Parameter #
N/A	flatten_1	(221184, 1)	0
N/A	dropout_1	(221184, 1)	0
N/A	dense_1	(256, 1)	56623360
N/A	dense_2	(1, 1)	257

FIG. 33

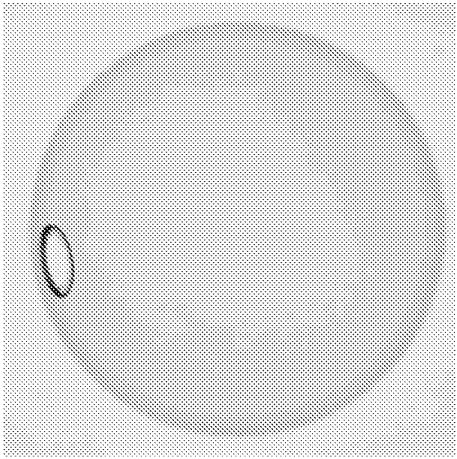
	Layer Name	Output Shape	Parameter #
N/A	conv2d_1	(26, 26, 512)	2359808
N/A	flatten_1	(346112, 1)	0
N/A	dense_1	(256, 1)	88604928
N/A	dense_2	(8, 1)	2056

FIG. 34

Bubble 3



Bubble 2



Bubble 1

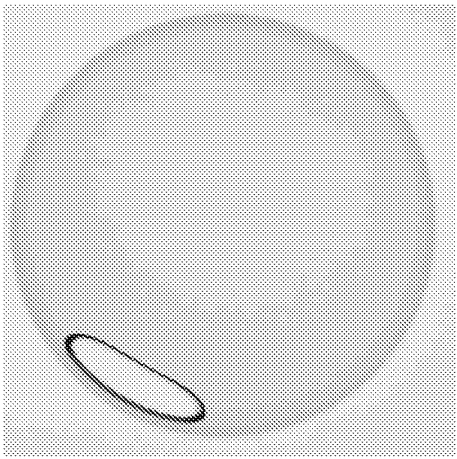
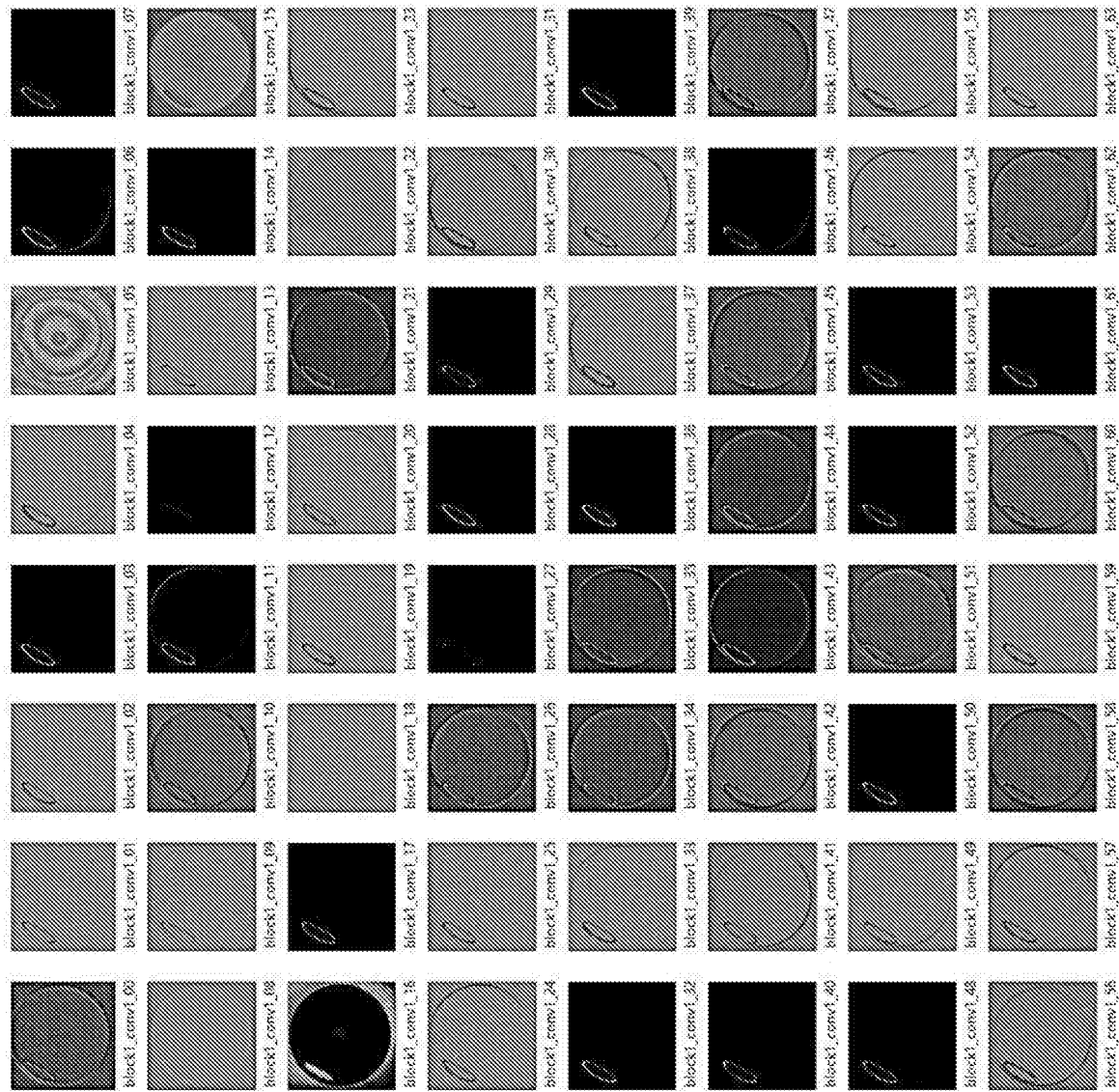


FIG. 35

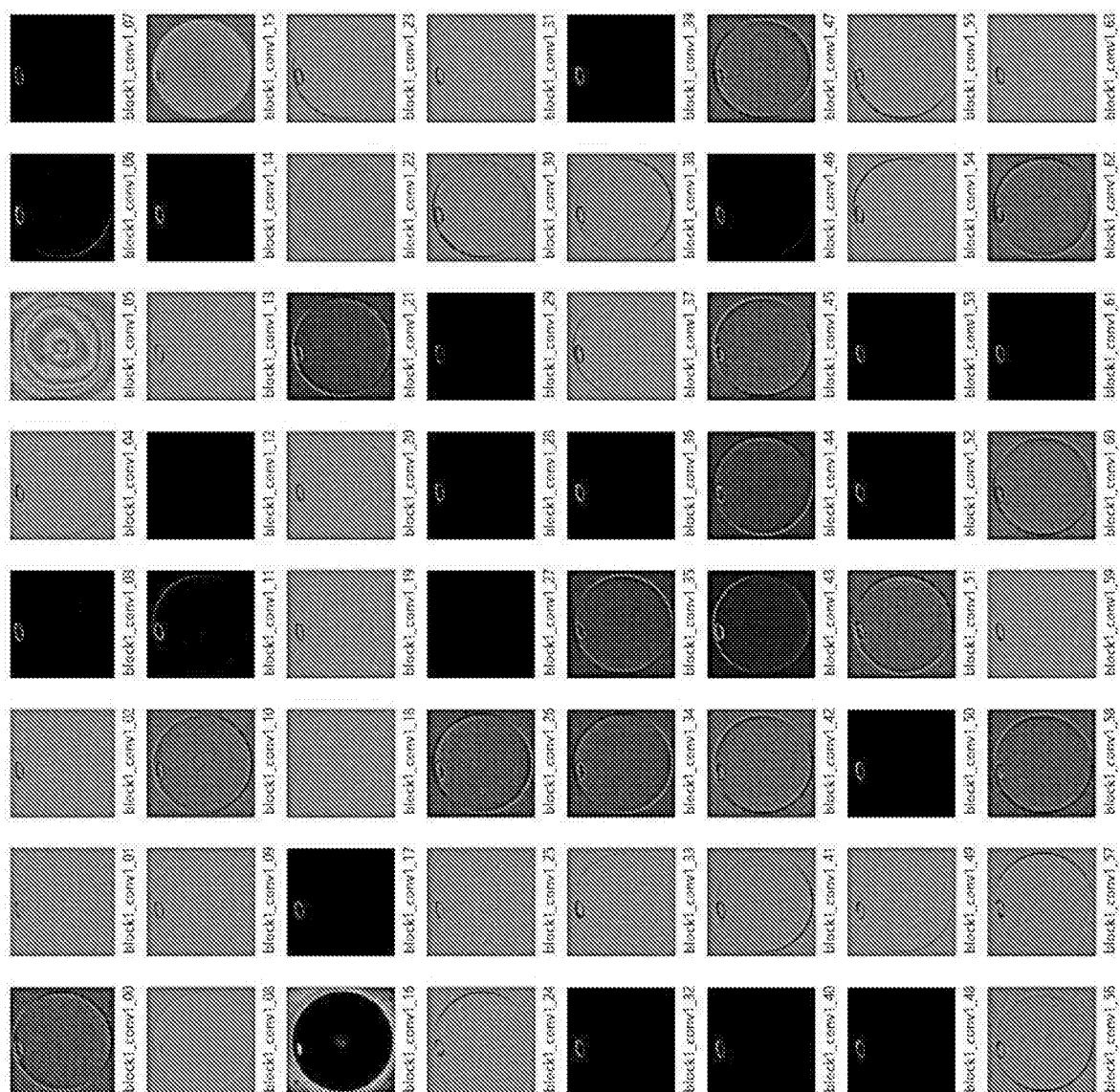
Bubble 1

FIG. 36A



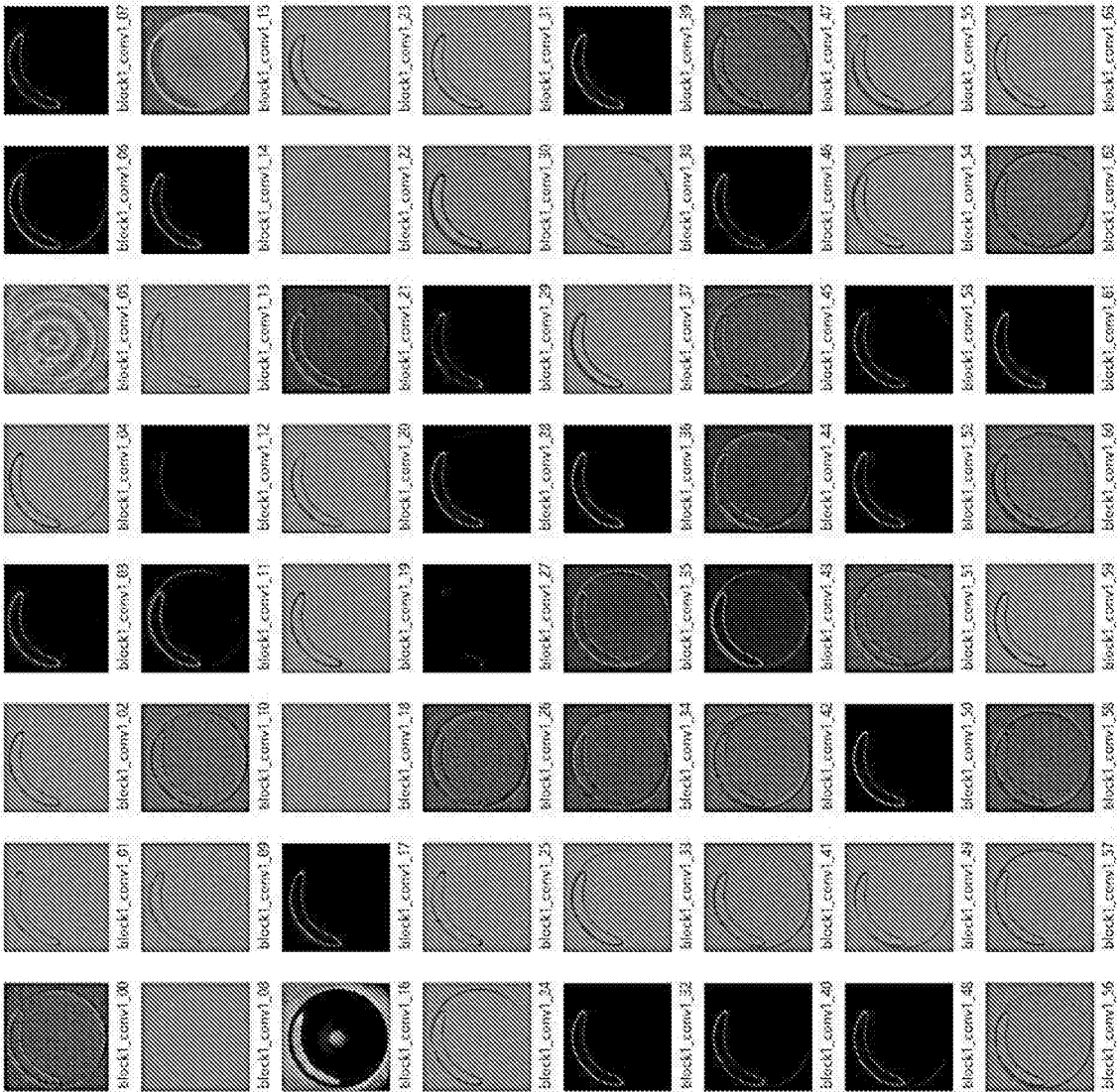
Bubble 2

FIG. 36B



Bubble 3

FIG. 36C



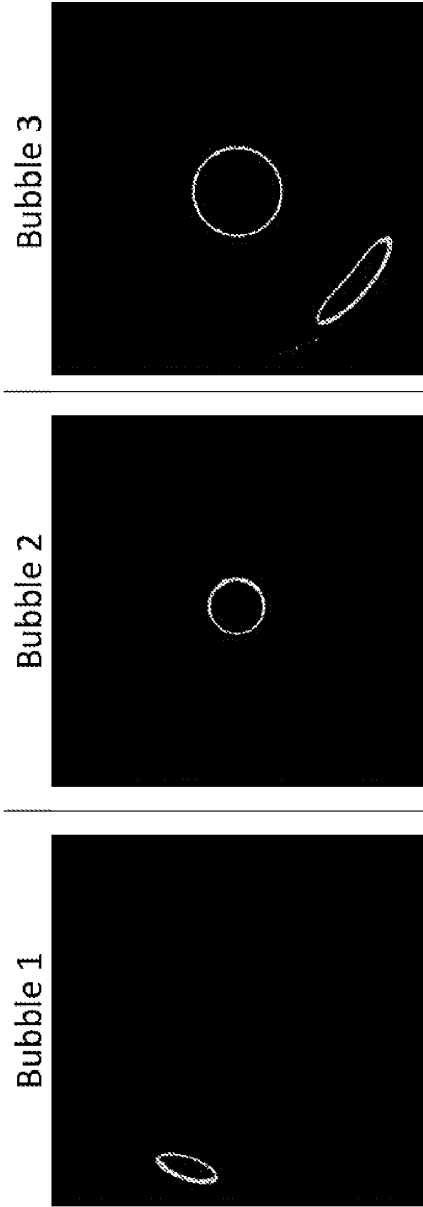


FIG. 37

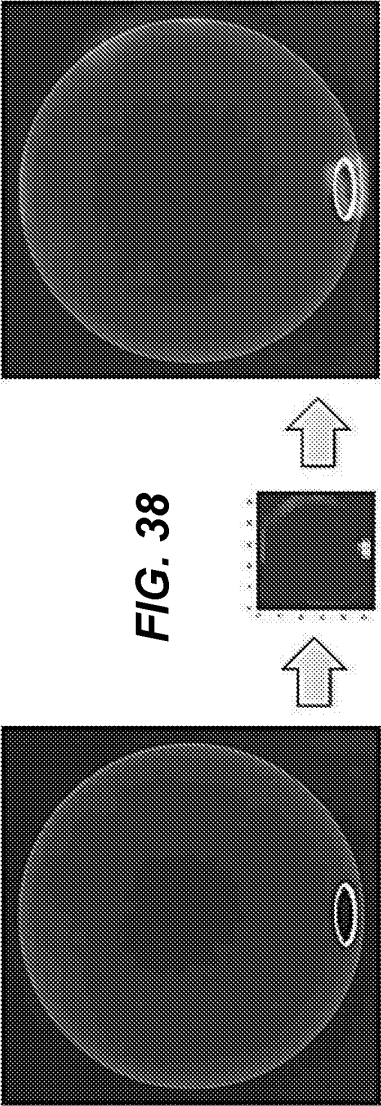


FIG. 38

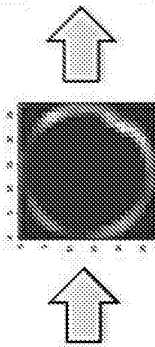
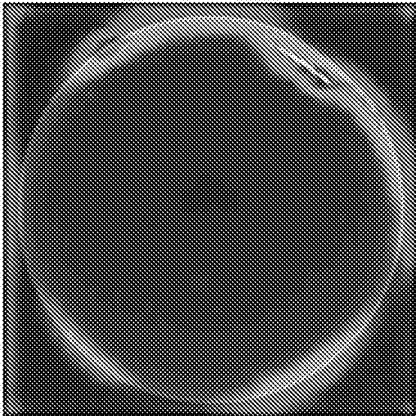


FIG. 39

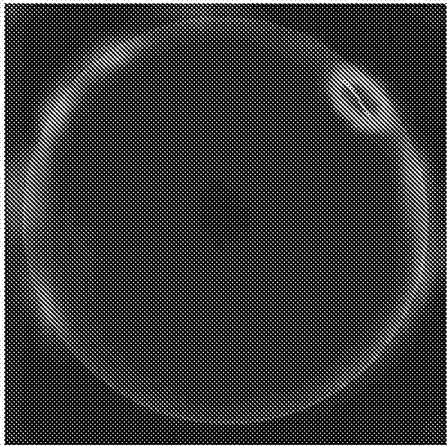
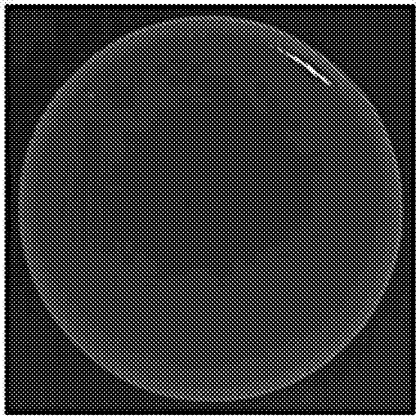


FIG. 40B

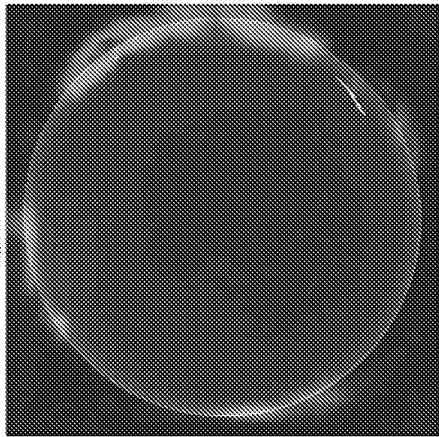
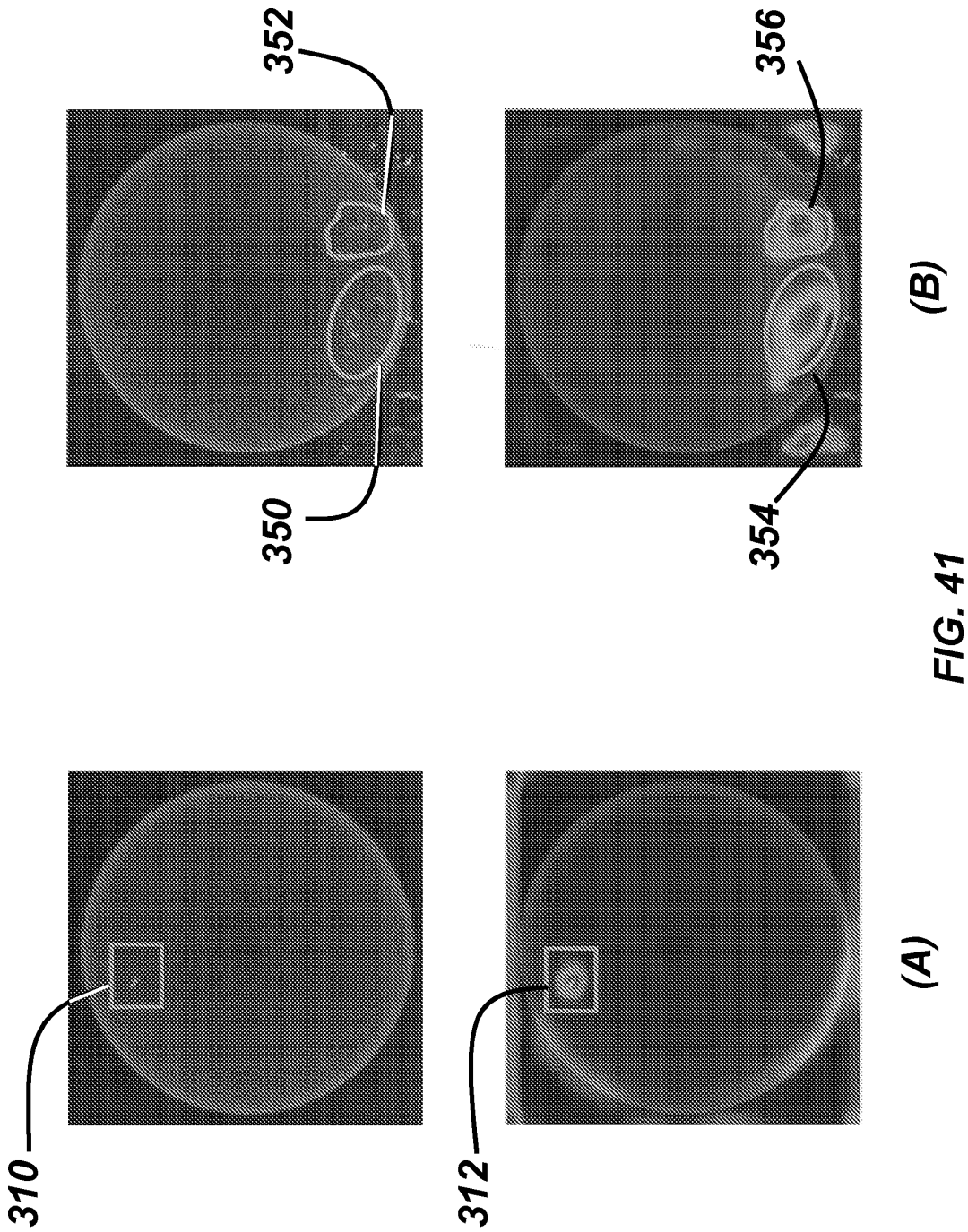


FIG. 40A



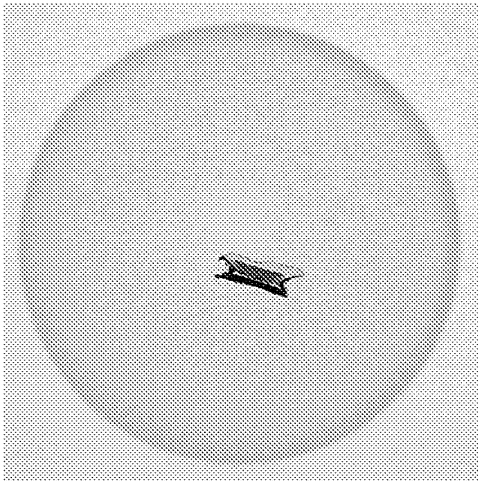


FIG. 42

Class	Brains	Bubble	Debris	Dirty Sapphire	Double Lens	Good Lens	Scratch	Void
Probability	0.20	0.00	0.74	0.00	0.06	0.00	0.00	0.00

FIG. 43