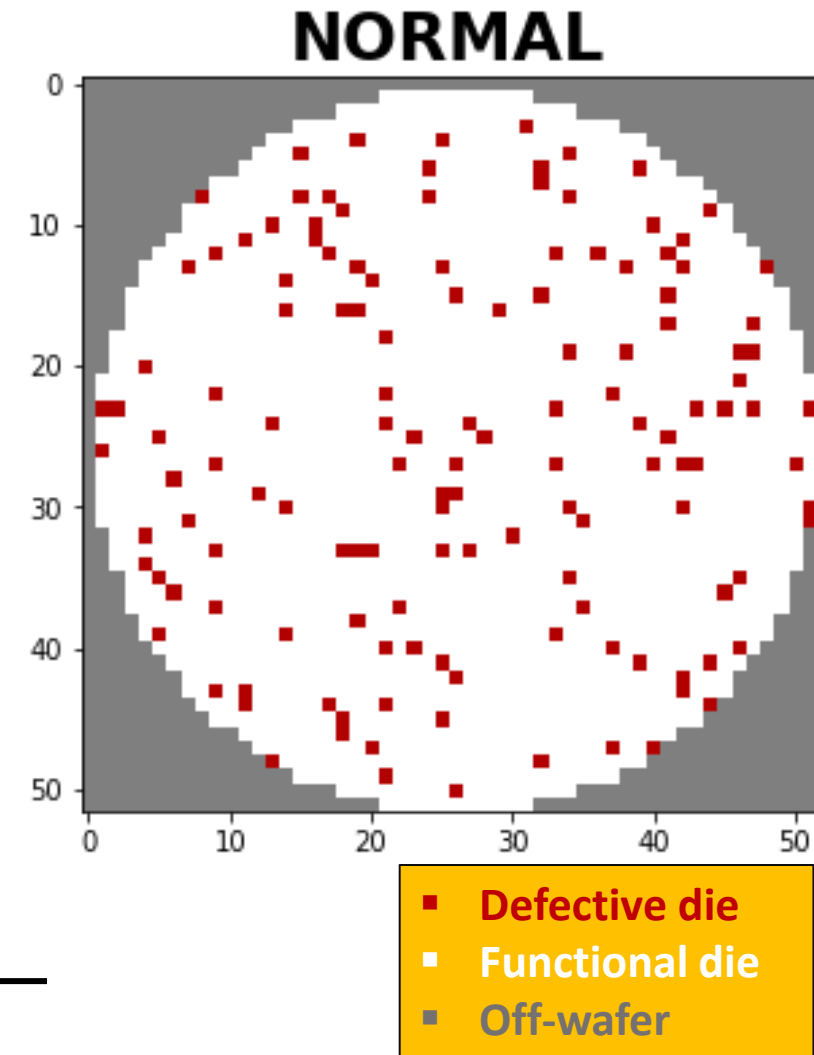


# Intro

- Silicon wafers that comprise an array of chips are susceptible to defects.
- While some defects are expected (yield < 100%), systematic patterns of defective chips in a wafer are indicative of problems in the process line.
- The 'pattern' of defective chips in a wafer is indicative of the nature/location of the problem.
- Typically wafer maps are reviewed manually and dispositioned into error types.
- This project looks at training a conv-net to identify and classify defects in semiconductor wafers

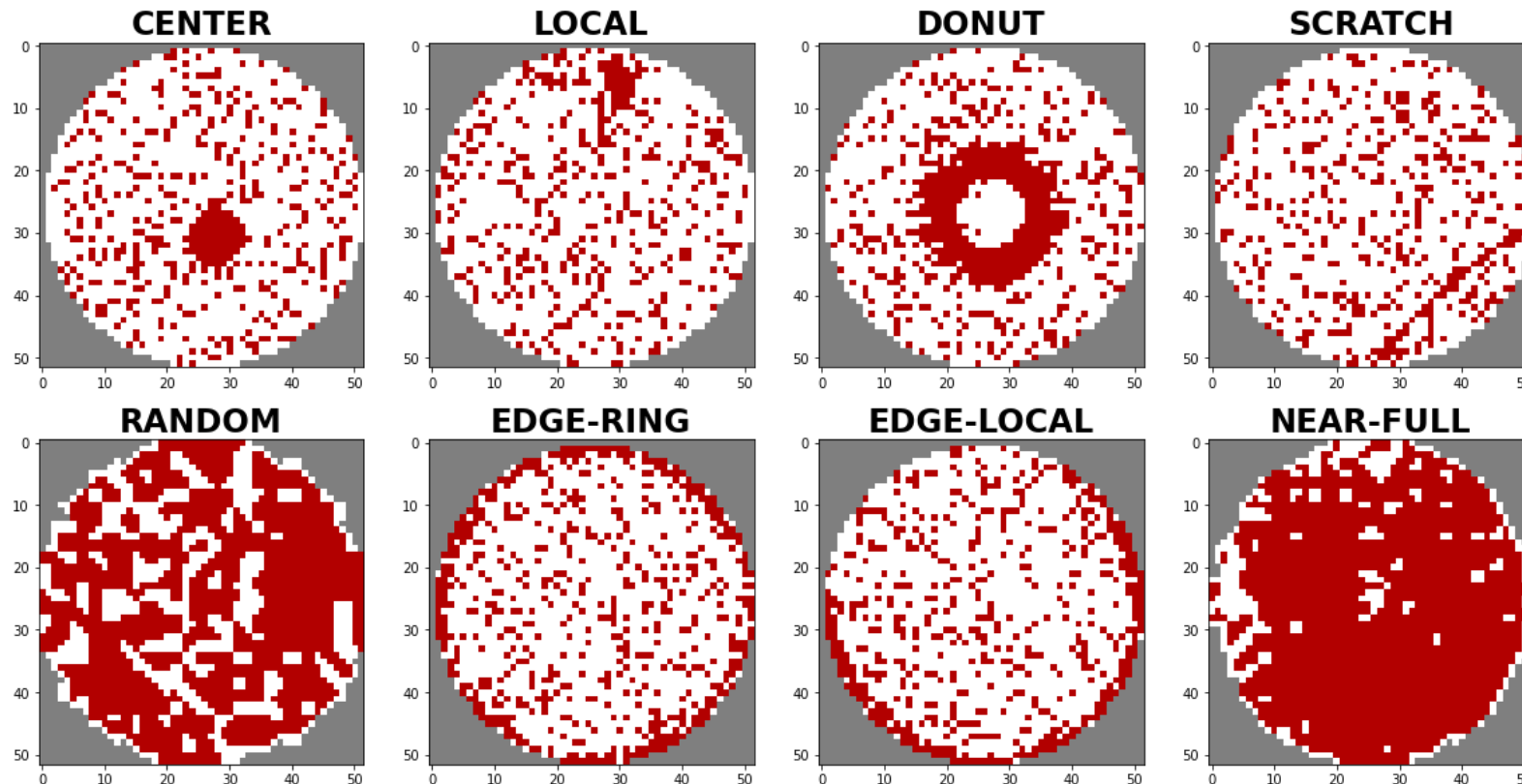


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• Wang *et al*, *IEEE Transactions on Semiconductor Manufacturing*, 2020

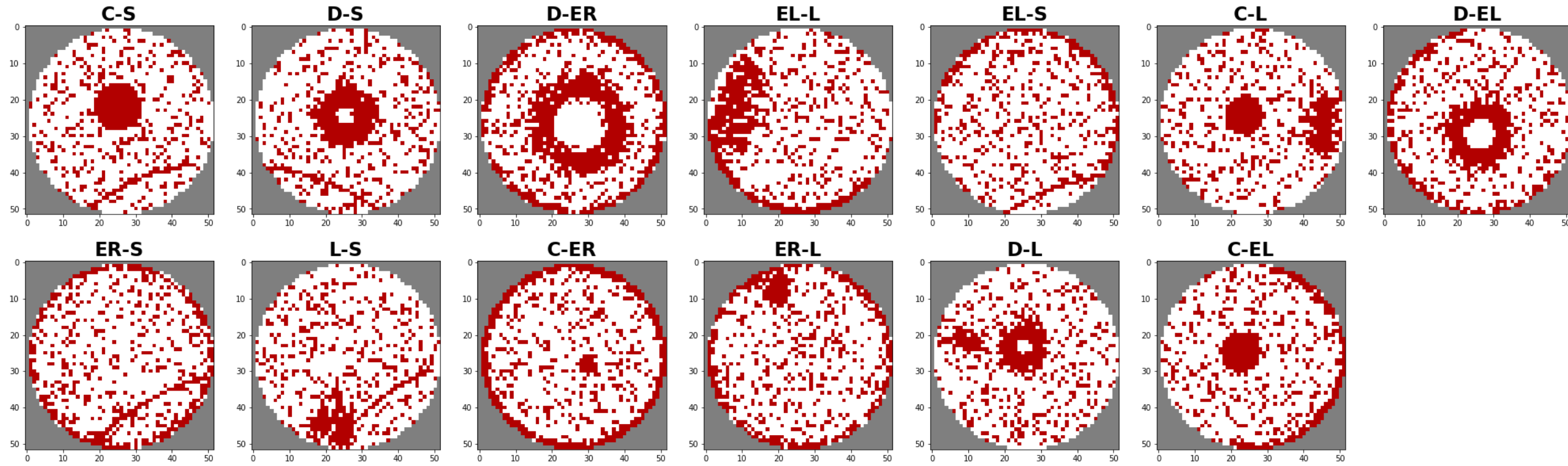
# Dataset – Defect Types

- Public dataset from fab in China
- Each wafer map is a 54x54 array of values identifying each location as a functional die, defective die or off-wafer. Each label is a one-hot encoded vector indicating the presence (or absence) of 8 different defect types.
- There are wafers with 0, 1, 2, 3 and 4 defect types.



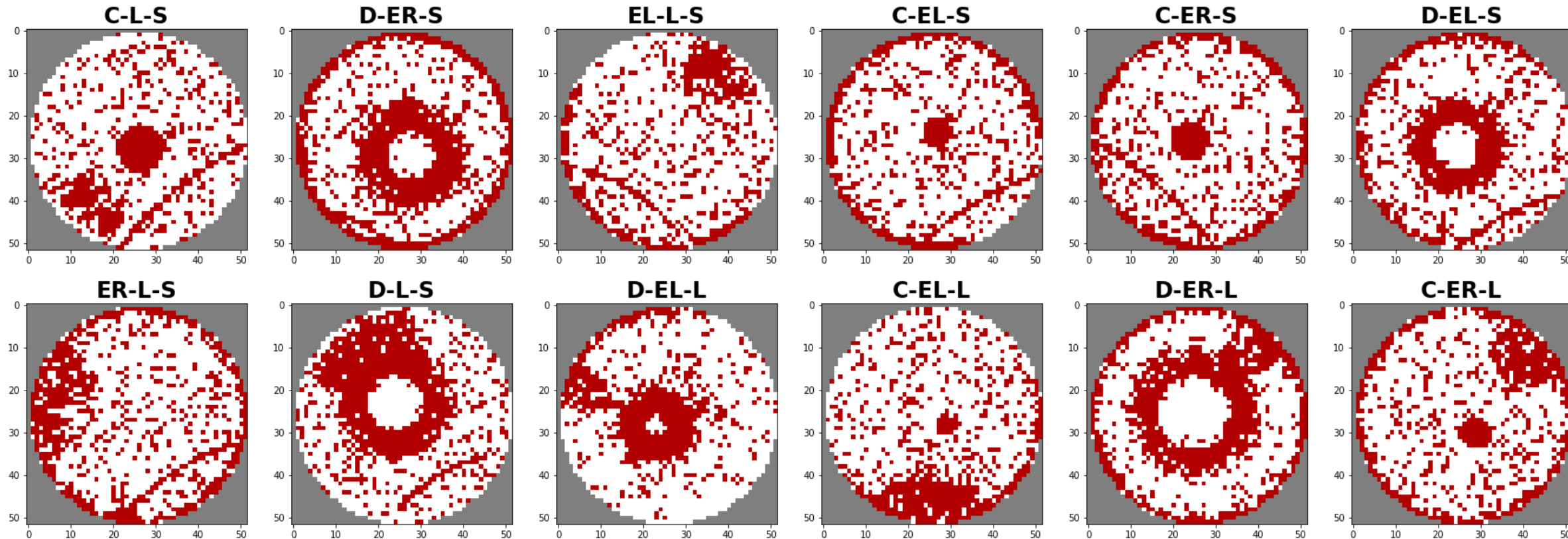
# Dataset – 2 Defects Types in a Wafer

- Public dataset from fab in China
- Each wafer map is a 54x54 array of values identifying each location as a functional die, defective die or off-wafer. Each label is a one-hot encoded vector indicating the presence (or absence) of 8 different defect types.
- There are wafers with 0, 1, 2, 3 and 4 defect types.



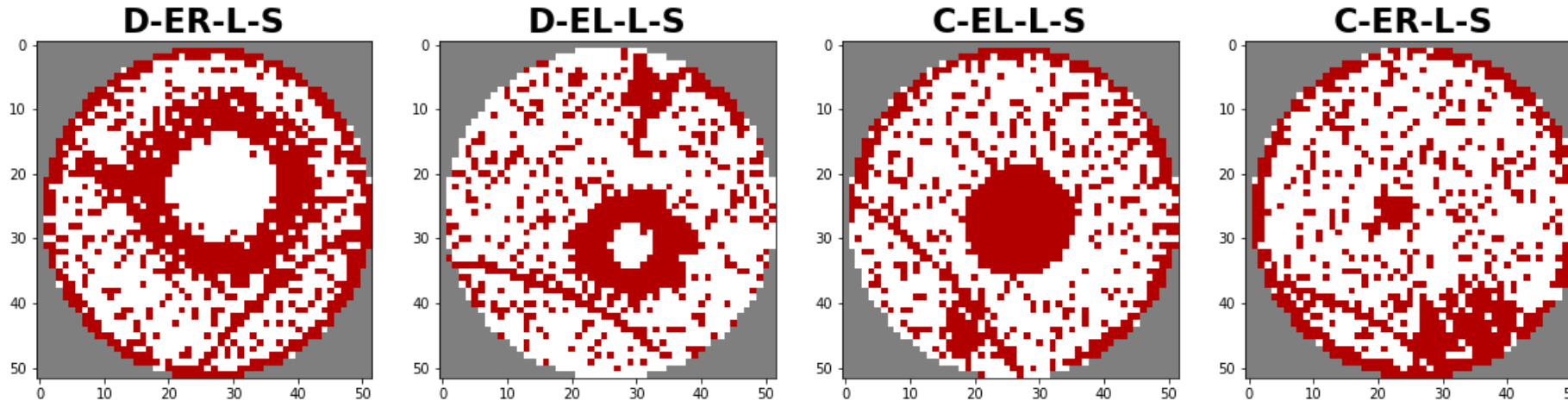
# Dataset – 3 Defects Types in a Wafer

- Public dataset from fab in China
- Each wafer map is a 54x54 array of values identifying each location as a functional die, defective die or off-wafer. Each label is a one-hot encoded vector indicating the presence (or absence) of 8 different defect types.
- There are wafers with 0, 1, 2, 3 and 4 defect types.

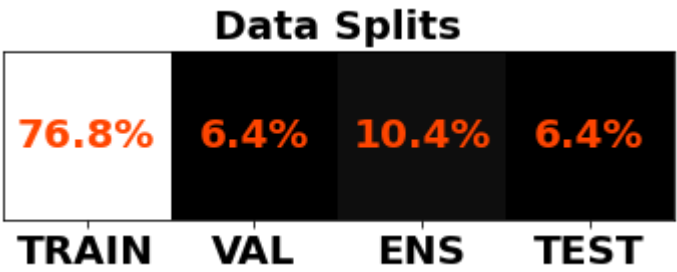
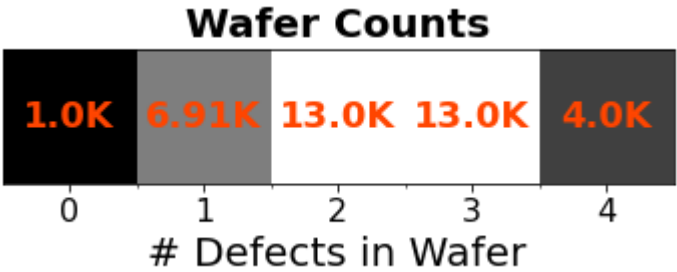


# Dataset – 4 Defects Types in a Wafer

- Public dataset from fab in China
- Each wafer map is a 54x54 array of values identifying each location as a functional die, defective die or off-wafer. Each label is a one-hot encoded vector indicating the presence (or absence) of 8 different defect types.
- There are wafers with 0, 1, 2, 3 and 4 defect types.



# Dataset – Counts and Splits

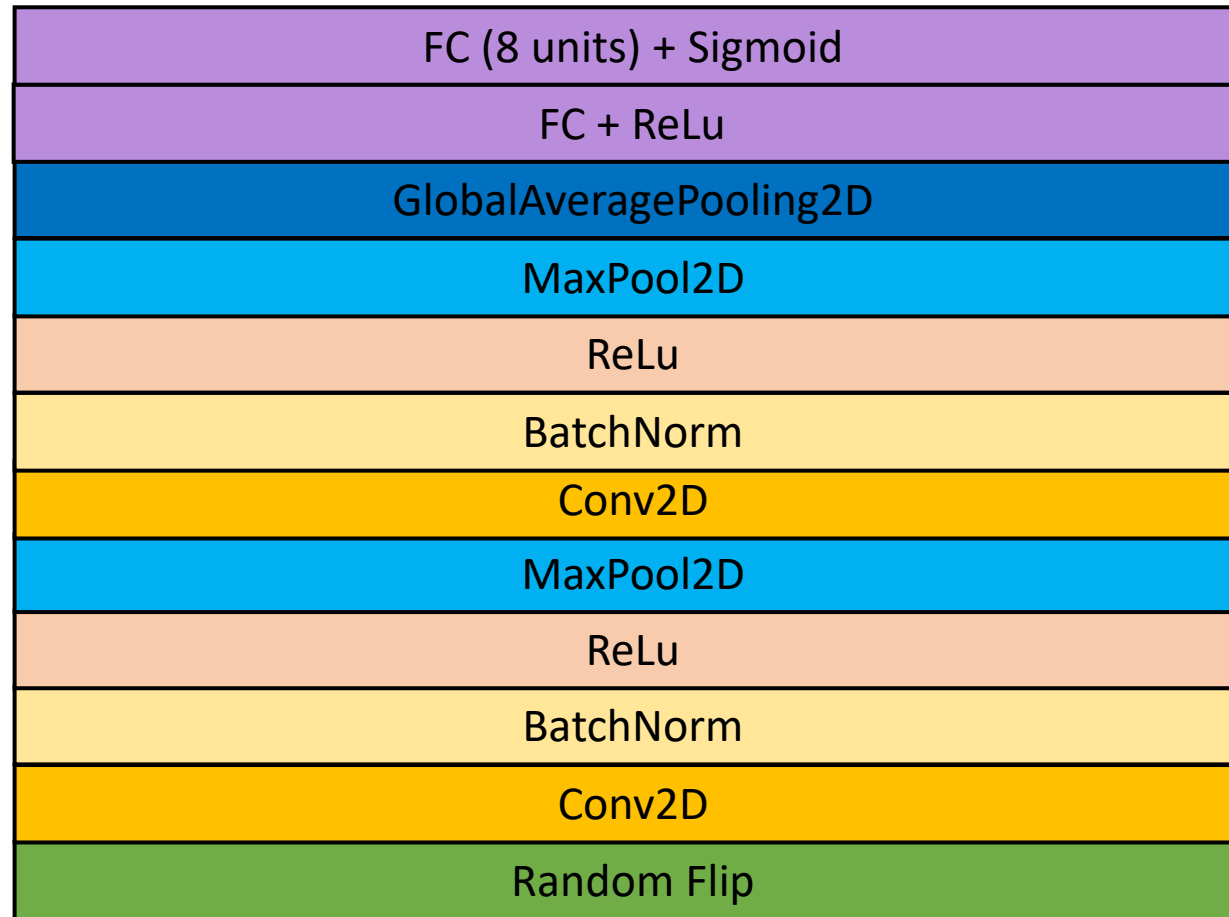


Defect Type	# Defects in Wafer				Any	
	1	2	3	4		
	Center	1K	4K	6K	2K	13K
	Donut	1K	4K	5K	2K	12K
	Edge-Local	1K	4K	6K	2K	13K
	Edge-Ring	1K	4K	5K	2K	12K
	Local	1K	5K	8K	4K	18K
	Near-Full	141	0	0	0	141
	Scratch	1K	5K	9K	4K	19K
	Random	769	0	0	0	769

# Model Architecture

**LOSS**

Binary Crossentropy



- Ioffe & Szegedy (2015) *arXiv: 1502.03167v3*
- Li et al (2018) *arXiv: 1801.05134v1*

# Hyperparameter Exploration

## Hyperparameter Values Explored

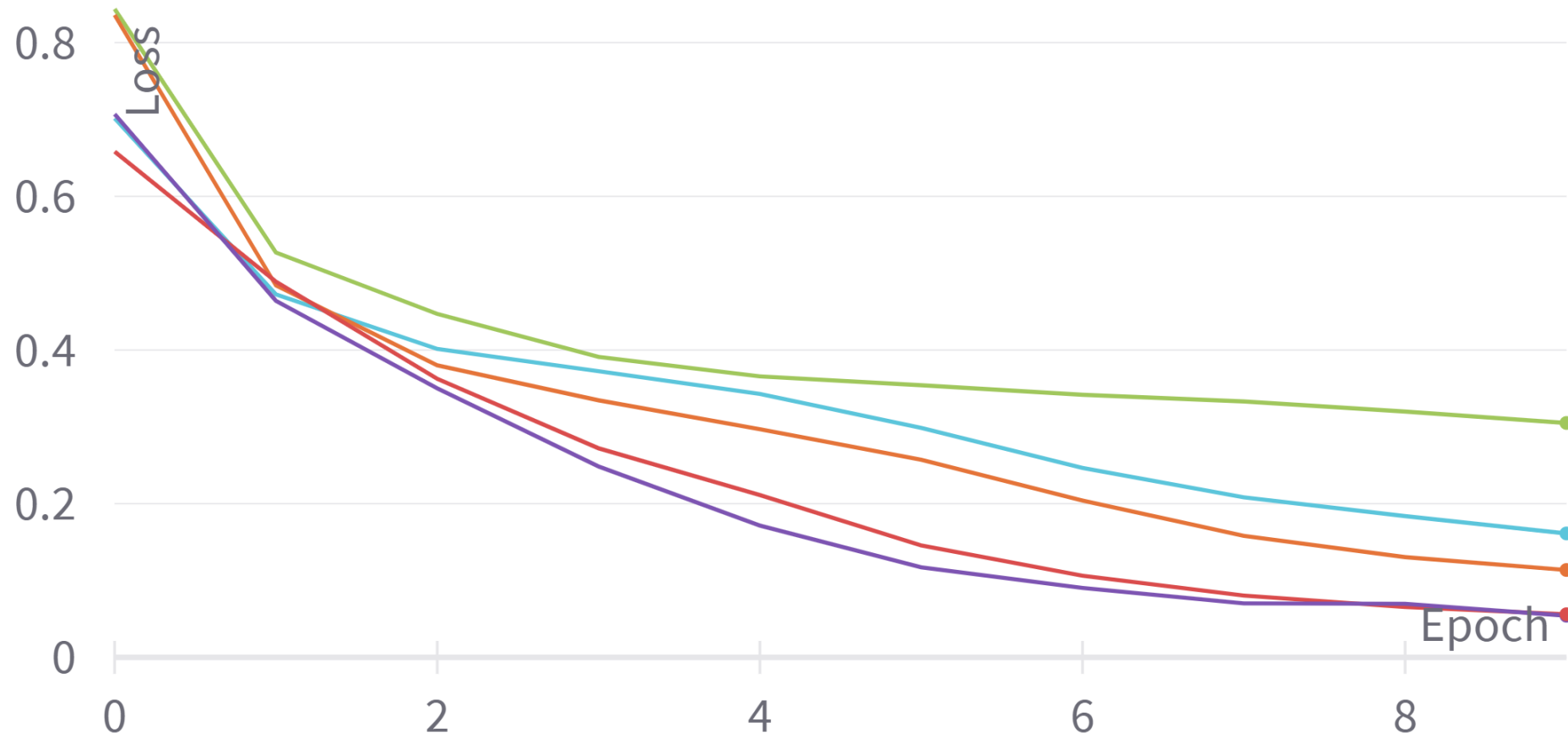
<b>C1_filterSize</b>	3, 5, 7
<b>C1_numFilters</b>	16, 32, 64
<b>C1_stride</b>	1, 2
<b>P1_filterSize</b>	2
<b>P1_stride</b>	2
<b>C2_filterSize</b>	3, 5
<b>C2_numFilters</b>	64, 128
<b>C2_stride</b>	1, 2
<b>P2_filterSize</b>	2
<b>P2_stride</b>	2
<b>FC1_numUnits</b>	32, 64
<b>FC2_numUnits</b>	8
<b>Total Combinations</b>	<b>288</b>

## Training Parameters

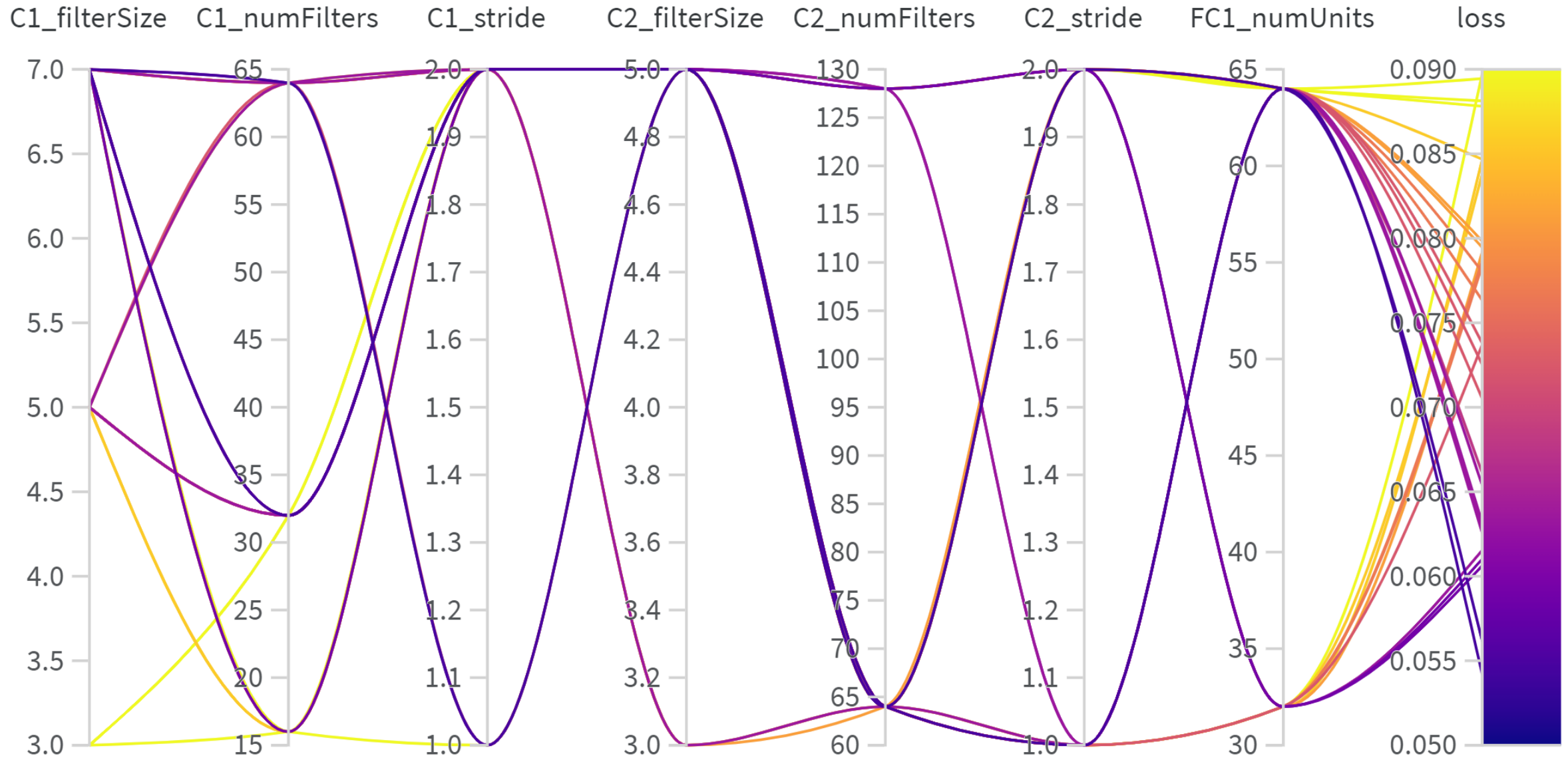
<b>Optimizer</b>	Adam (parm vals)
<b>Batch Size</b>	512
<b>Learning Rate</b>	0.01
<b>Epochs</b>	<b>10</b>



# Hyperparameter Exploration: Selected Training Curves



# Hyperparameter Exploration: Loss v.s. HP values



# Hyperparameter Exploration: **Selected HP Values**

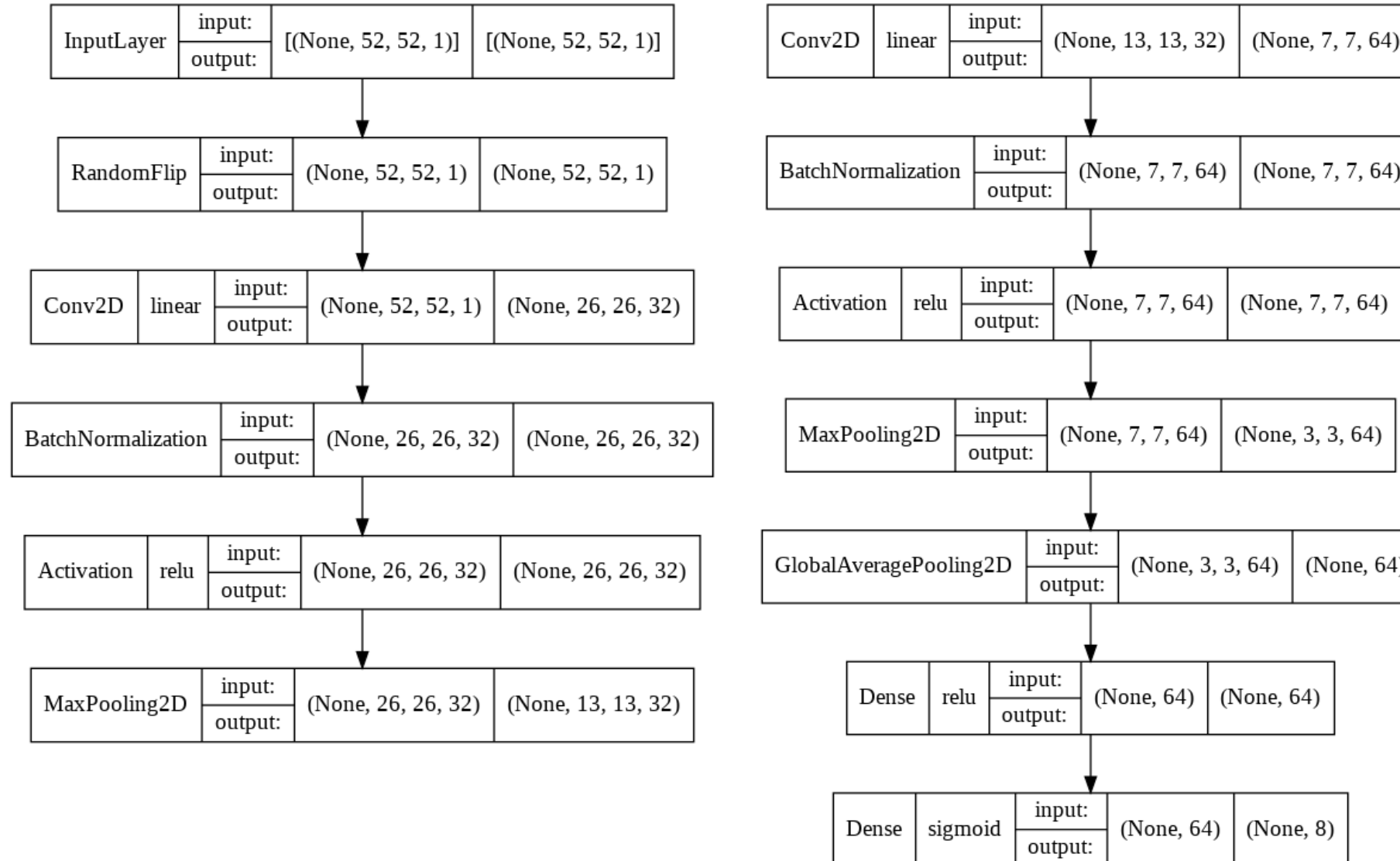
The 2 Lowest Loss Hyperparameter Combinations

Loss	0.0541	0.0561
C1_filterSize	7	7
C1_numFilters	64	32
C1_stride	2	2
P1_filterSize	2	2
P1_stride	2	2
C2_filterSize	5	5
C2_numFilters	64	64
C2_stride	2	2
P2_filterSize	2	2
P2_stride	2	2
FC1_numUnits	64	64
FC2_numUnits	8	8
Total Parameters	110,472	57,460

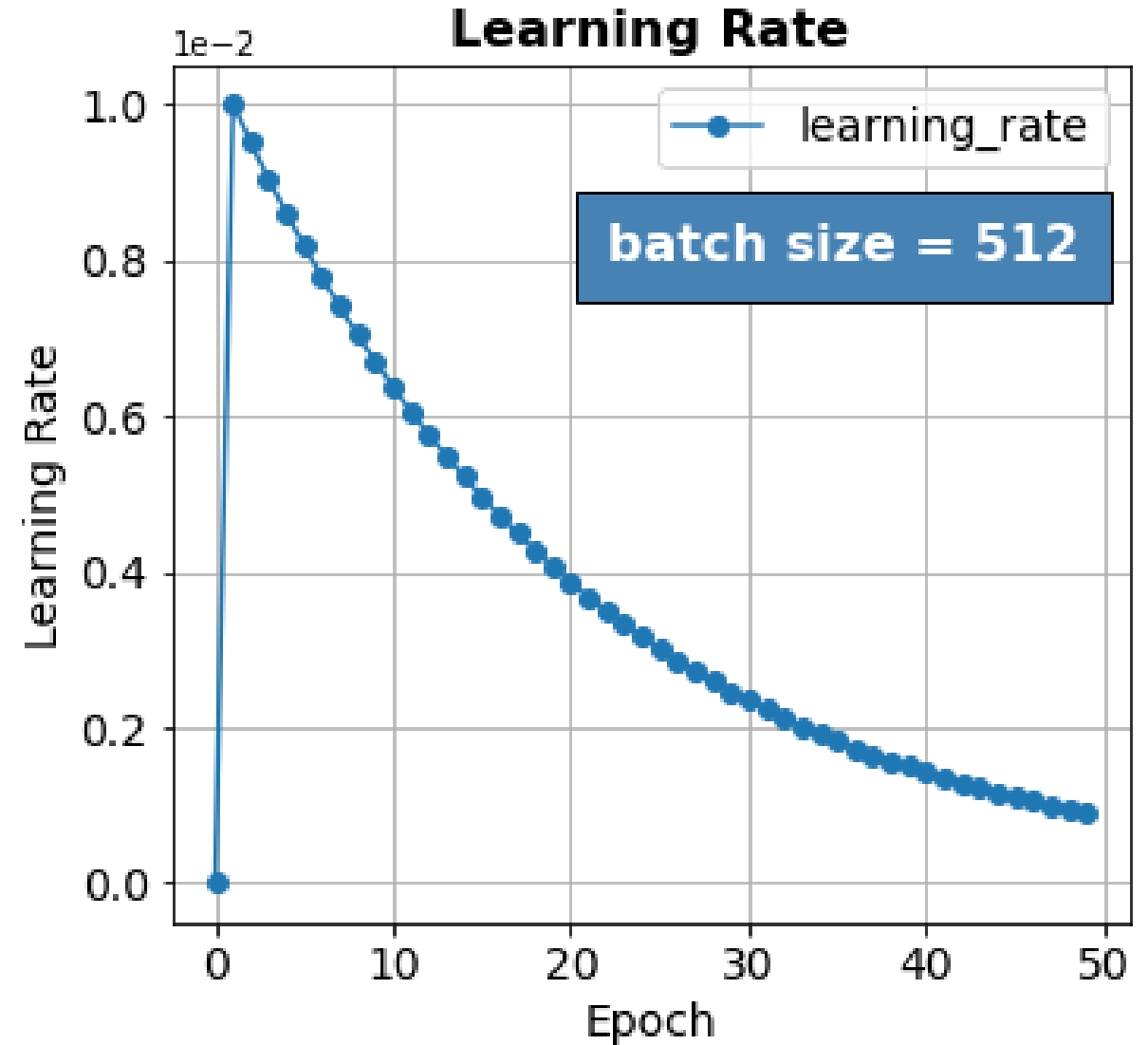
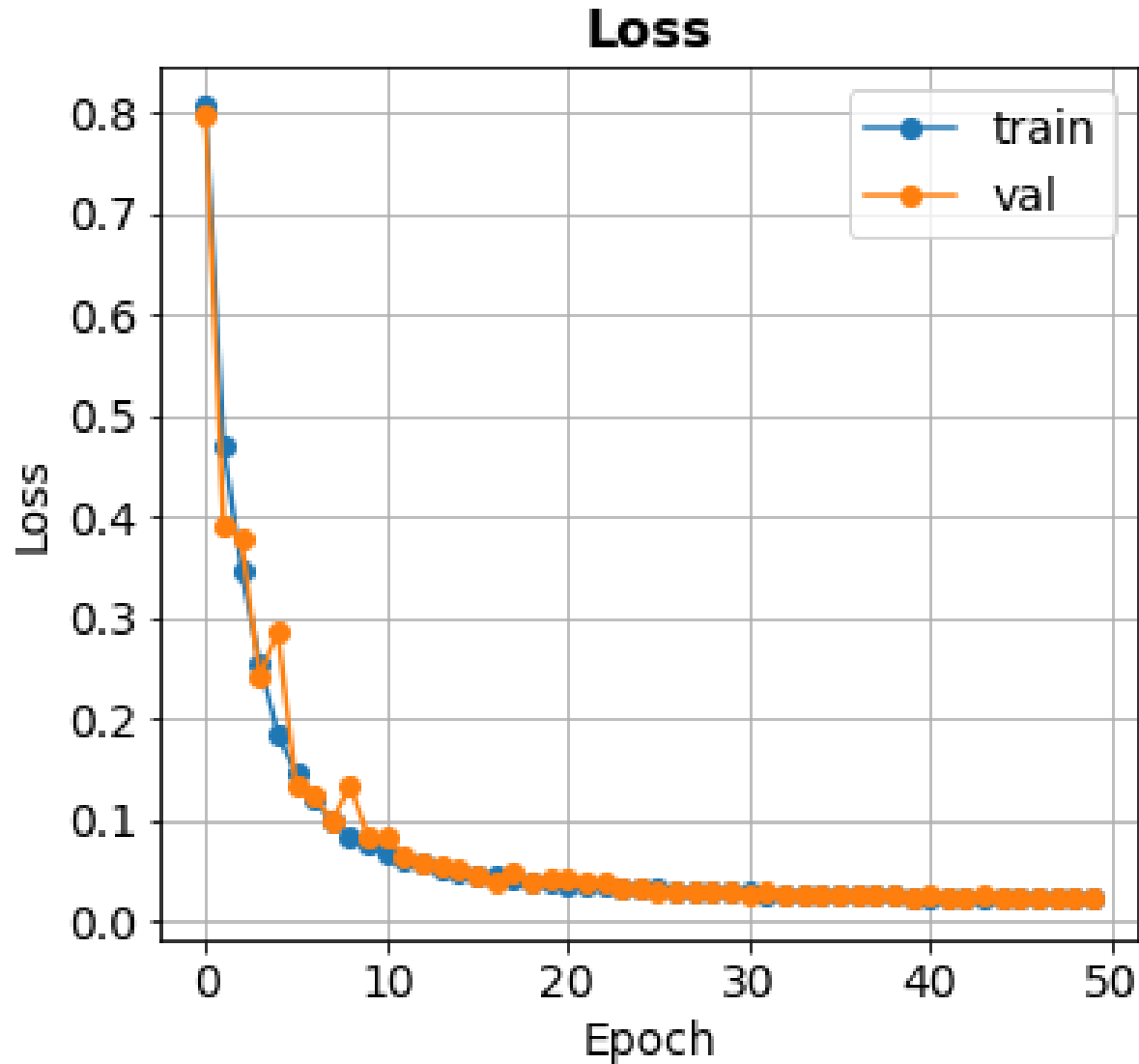
**Selected  
This One**



# Final Model Shapes



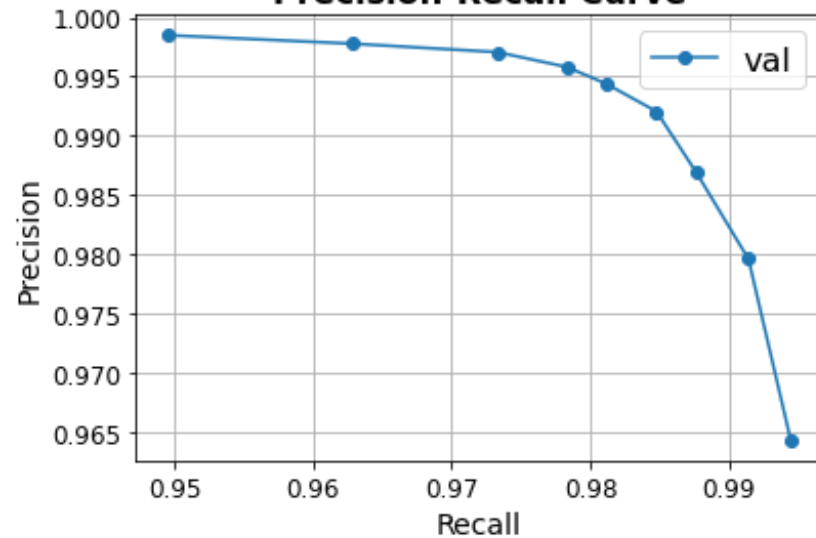
# Full Training



# Performance

ACCURACY	99.3%	99.3%
RECALL	98.3%	98.1%
PRECISION	99.4%	99.4%
F1	98.9%	98.8%
	TRAIN	VAL

Precision-Recall Curve



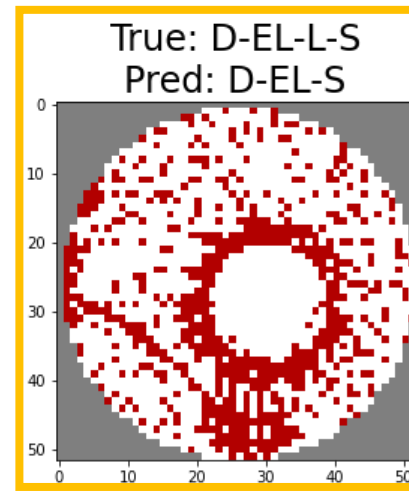
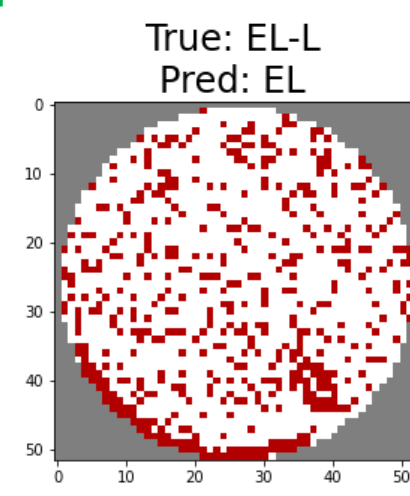
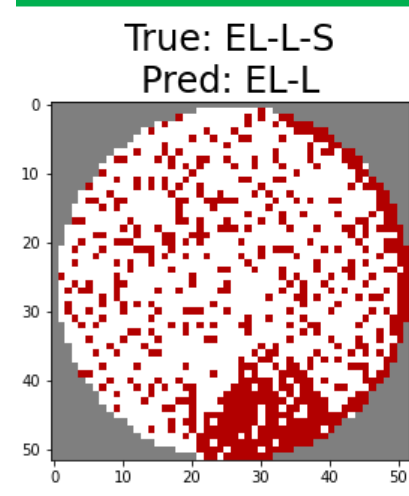
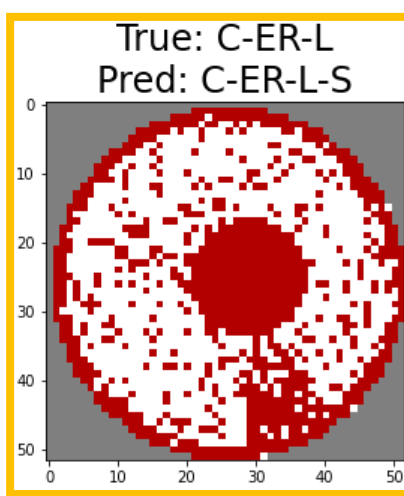
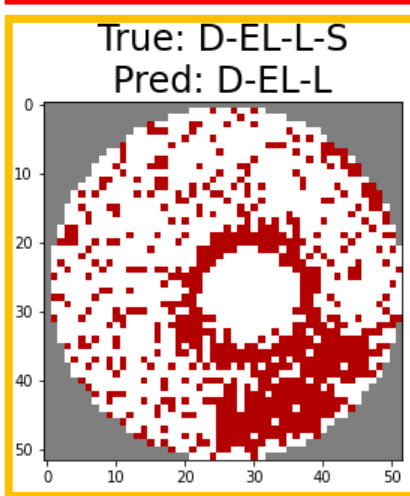
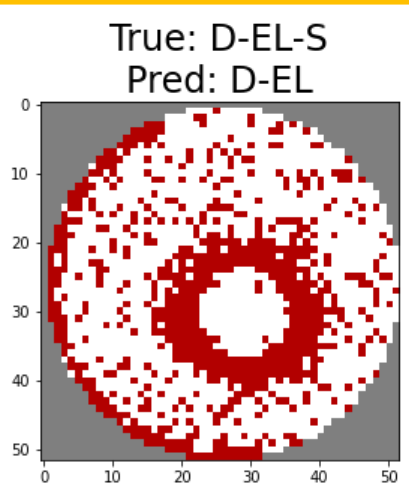
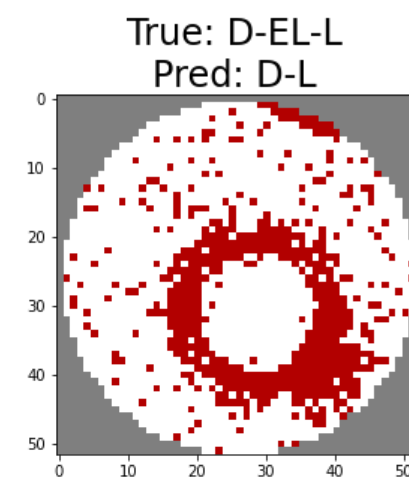
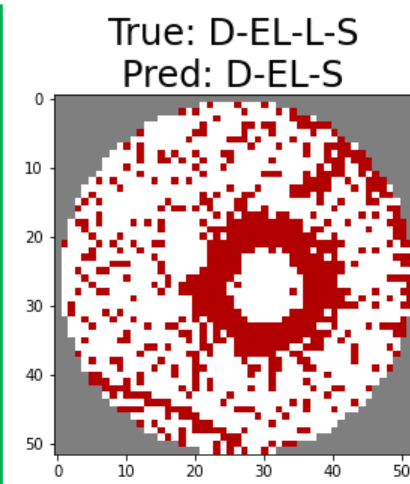
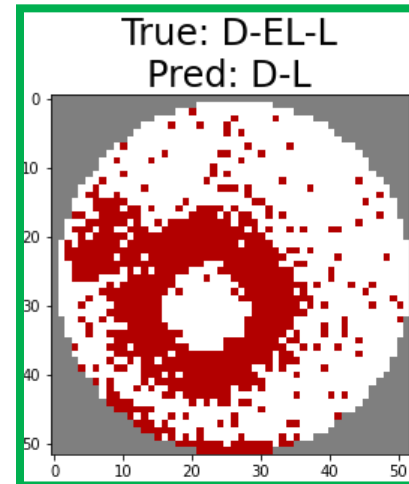
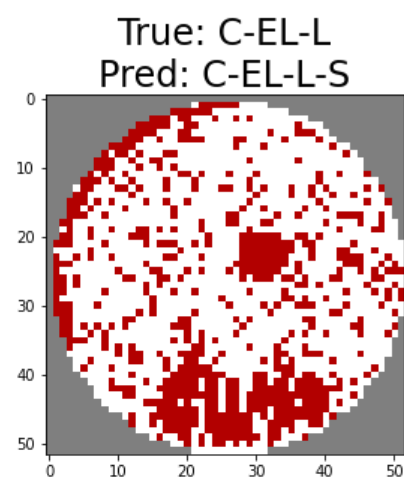
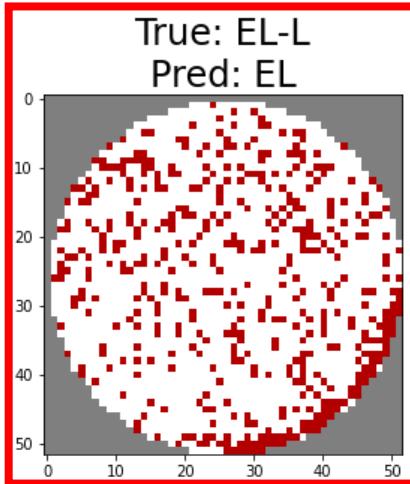
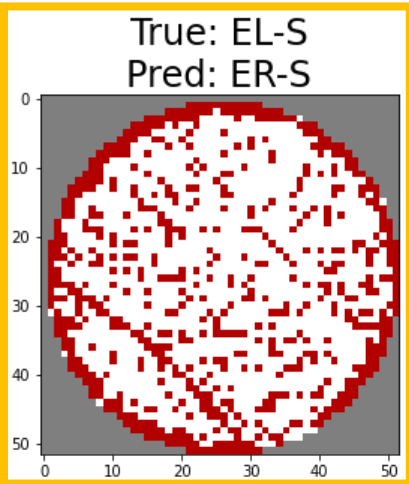
Defect Type

	VAL RECALL				
Any	98.6	98.8	97.8	97.6	
Center	100	100	99.2	100	99.6
Donut	100	100	99.7	100	99.9
Edge-Local	93.8	98.8	95.7	93.8	96.2
Edge-Ring	100	99.6	99.4	99.2	99.5
Local	96.9	97.5	97.5	97.7	97.5
Near-Full	100	NA	NA	NA	100
Scratch	100	97.5	96.6	96.1	96.9
Random	100	NA	NA	NA	100
	1	2	3	4	Any
	# Defects in Wafer				

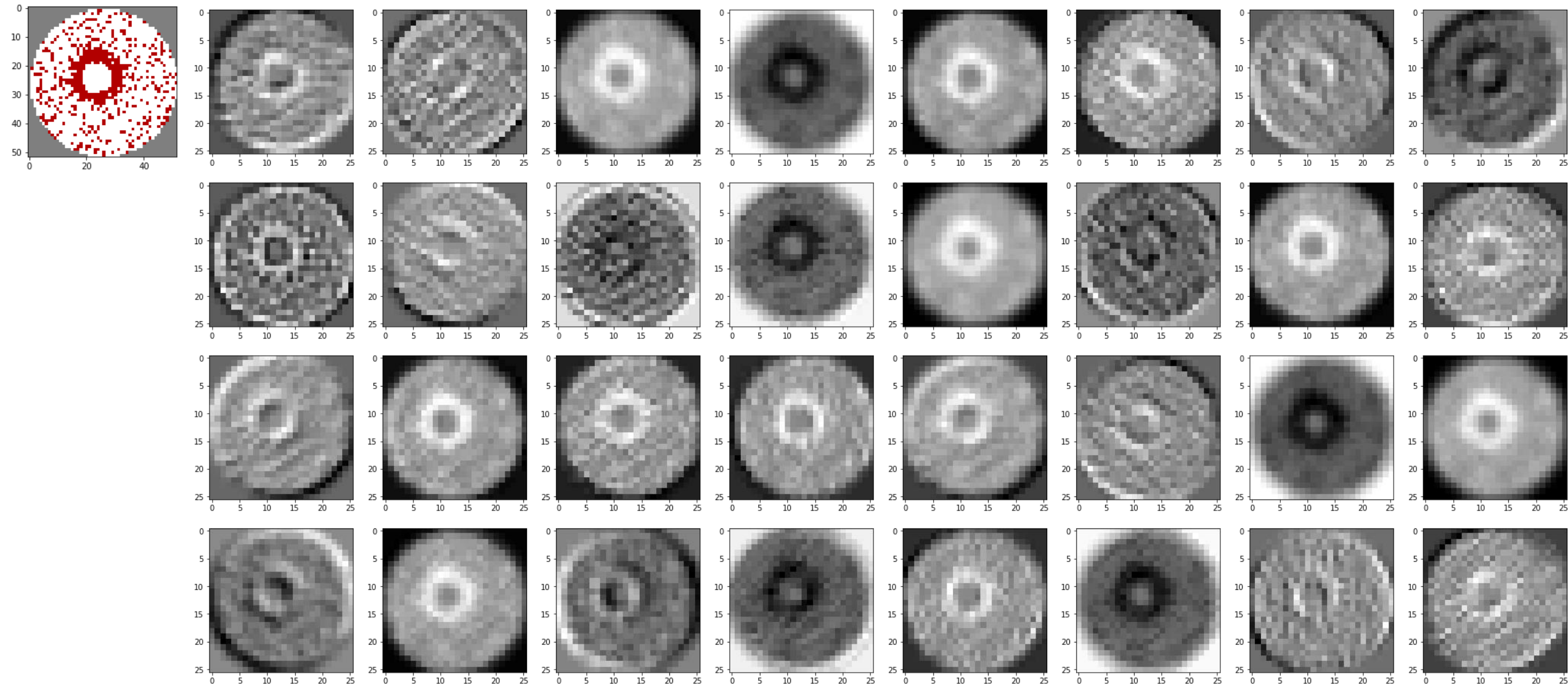
Defect Type

	VAL PRECISION				
Any	98.9	99.4	99.5	99.7	
Center	100	100	100	100	100
Donut	100	100	100	100	100
Edge-Local	98.4	99.6	99.4	100	99.5
Edge-Ring	98.5	99.6	98.5	97.7	98.7
Local	98.4	100	99.8	100	99.8
Near-Full	90.0	NA	NA	NA	90.0
Scratch	98.5	97.5	99.1	100	98.8
Random	100	NA	NA	NA	100
	1	2	3	4	Any
	# Defects in Wafer				

# Examples of Mis-labeled Wafers

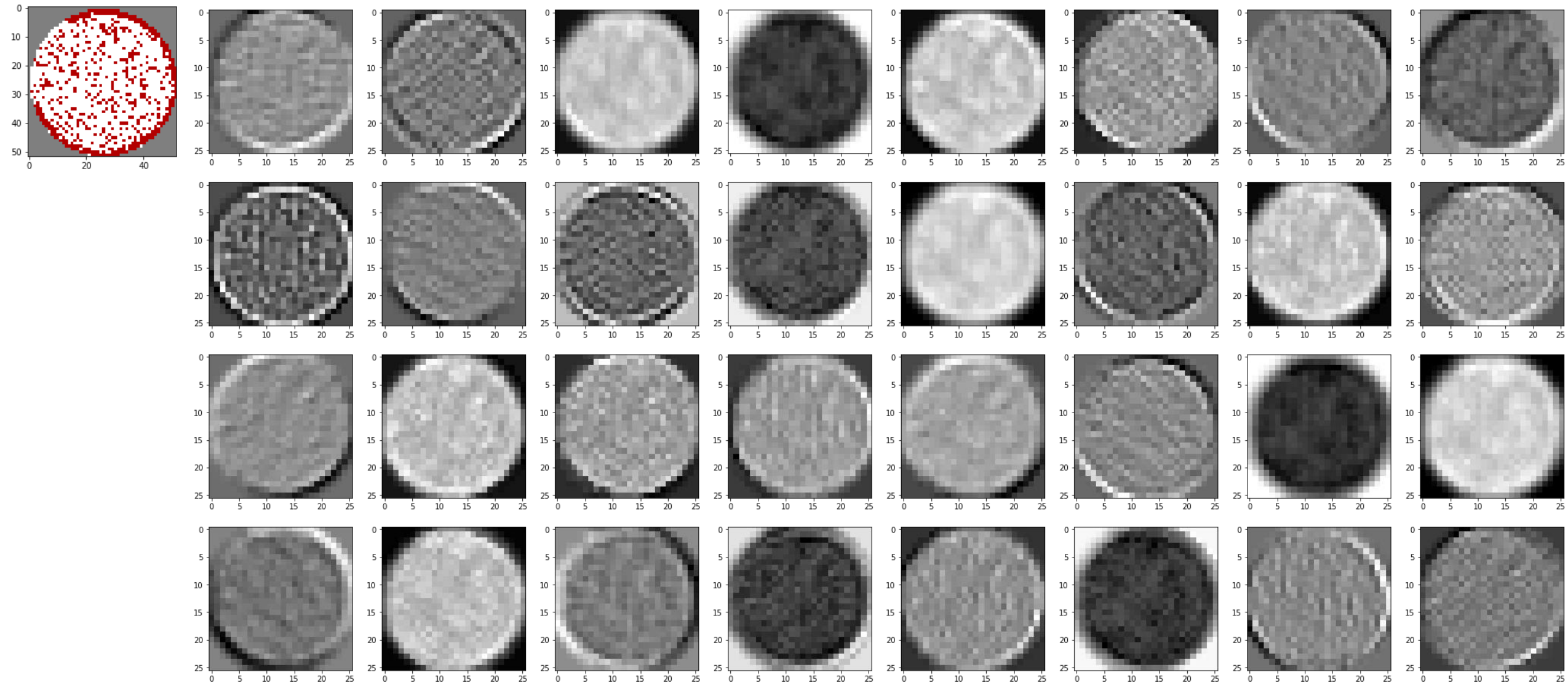


# Feature Maps from the 1<sup>st</sup> Con Layer: DONUT

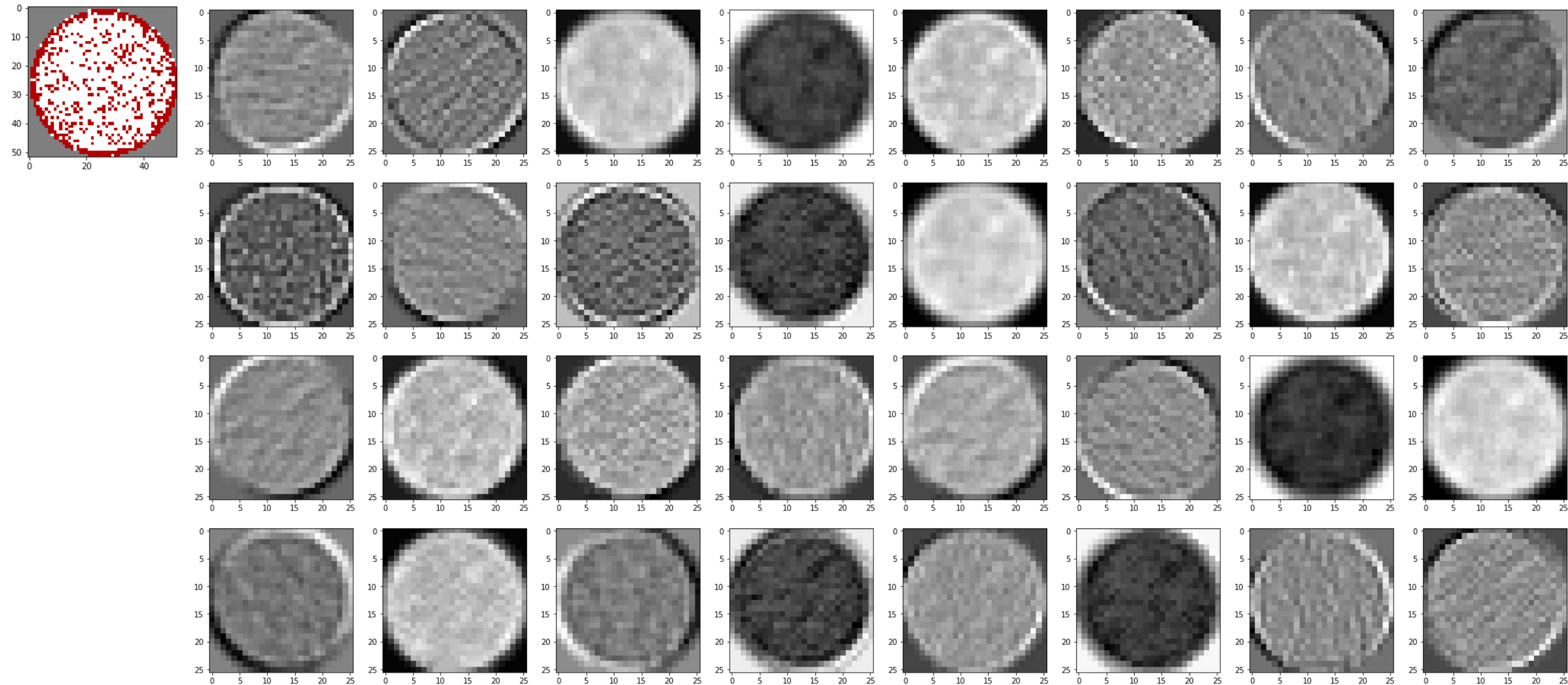




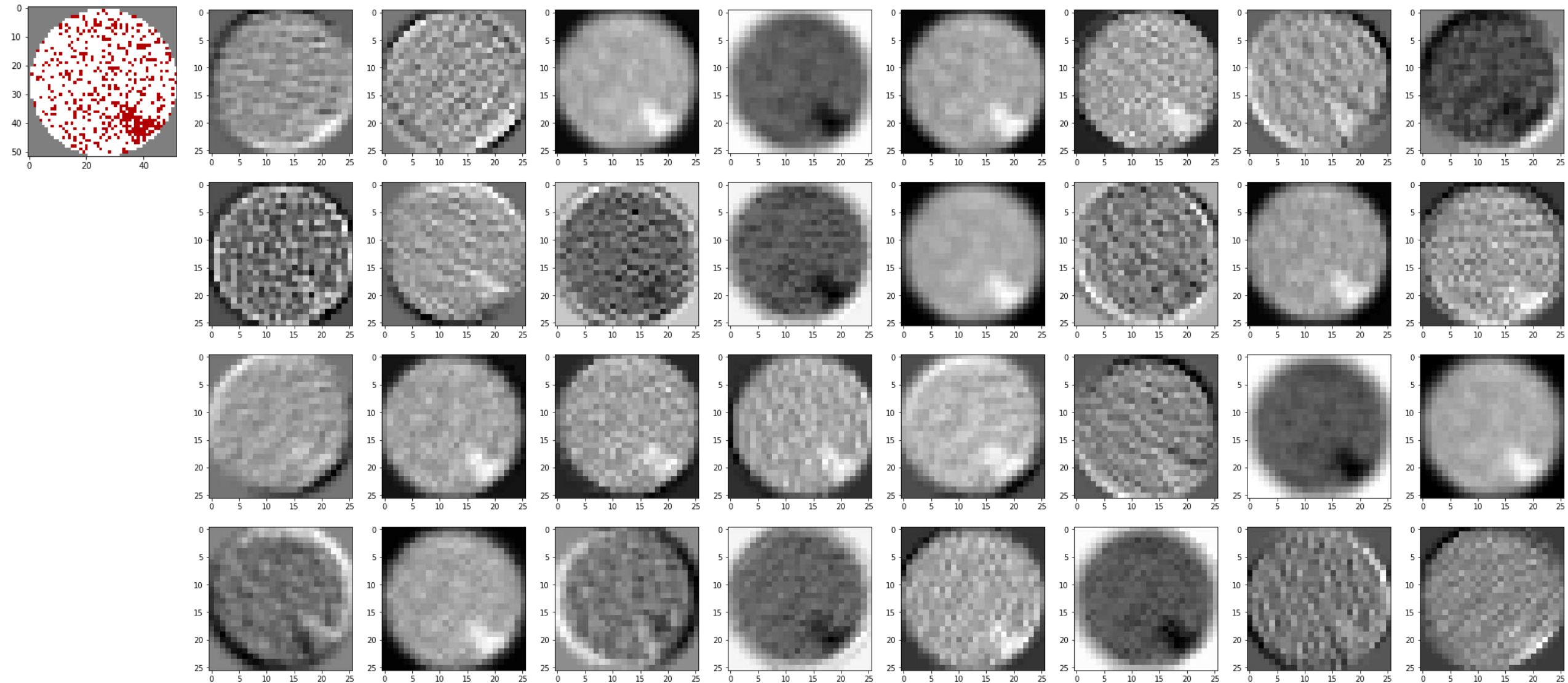
# Feature Maps from the 1<sup>st</sup> Con Layer: **EDGE-LOCAL**



# Feature Maps from the 1<sup>st</sup> Con Layer: **EDGE-RING**

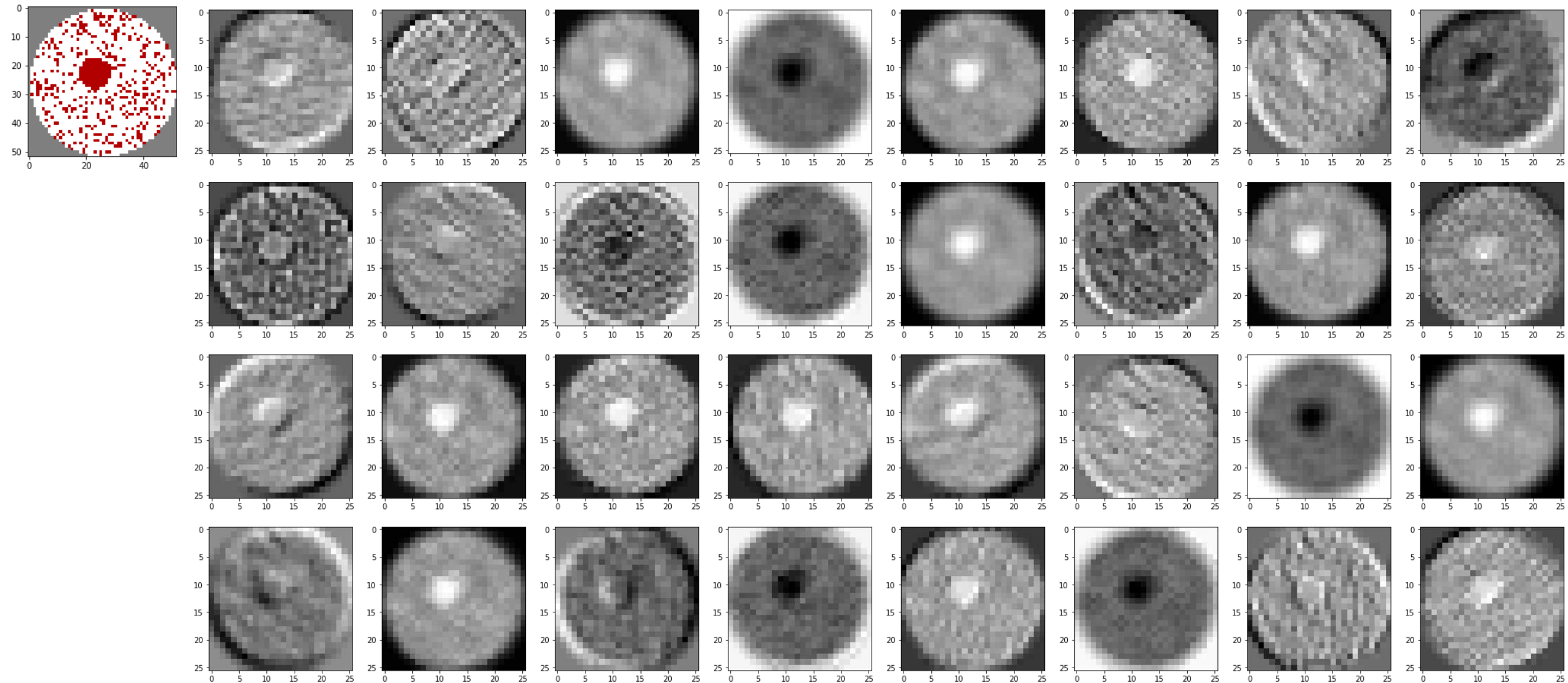


# Feature Maps from the 1<sup>st</sup> Con Layer: LOCAL

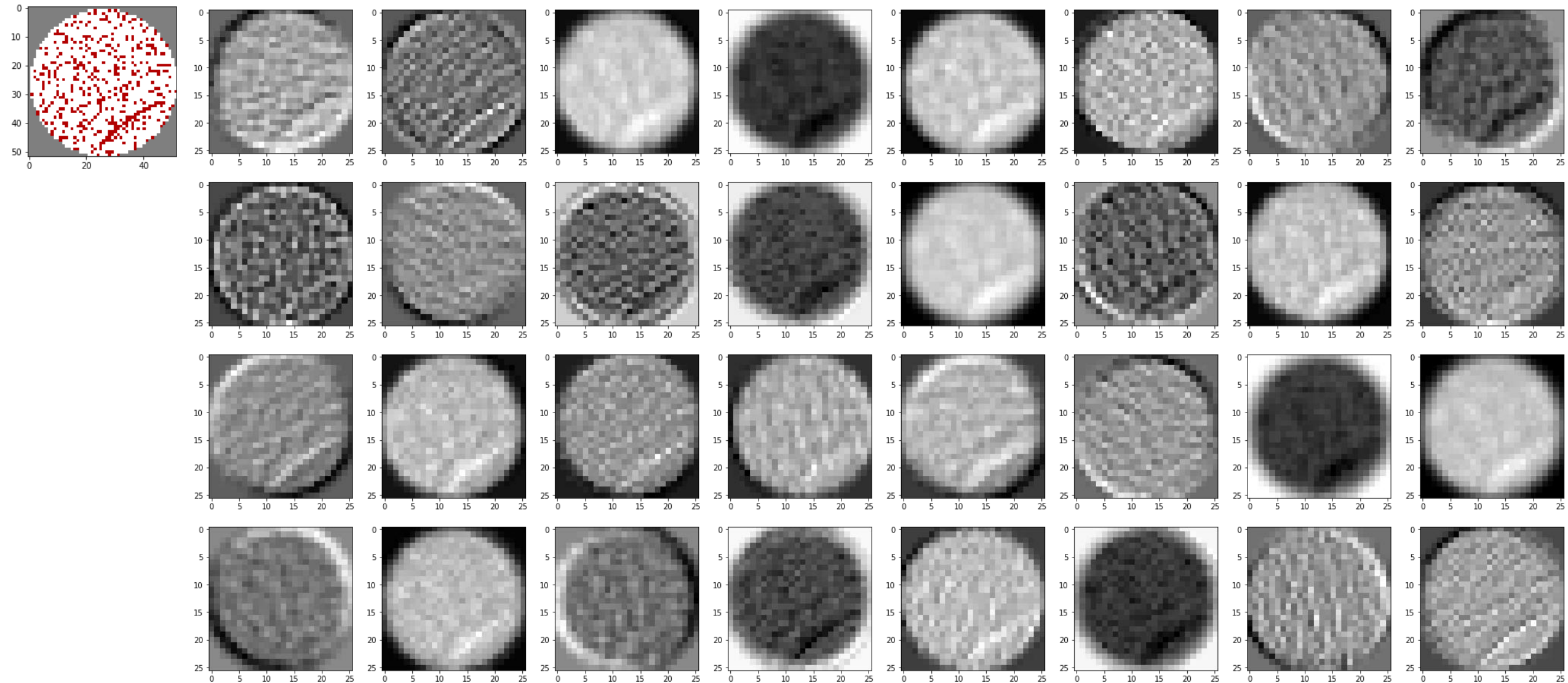




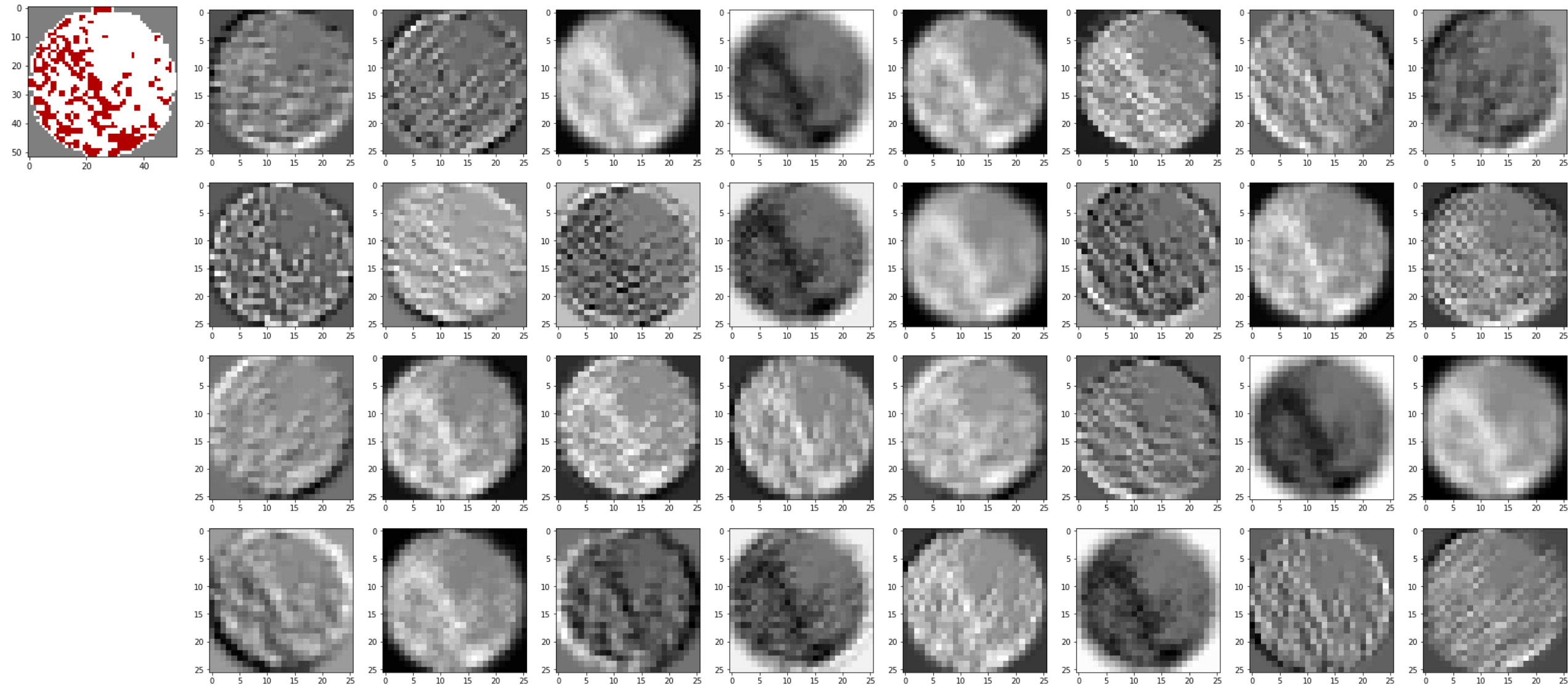
# Feature Maps from the 1<sup>st</sup> Con Layer: **CENTER**



# Feature Maps from the 1<sup>st</sup> Con Layer: **SCRATCH**



# Feature Maps from the 1<sup>st</sup> Con Layer: **RANDOM**





# Feature Maps from the 1<sup>st</sup> Con Layer: NEAR-FULL

