

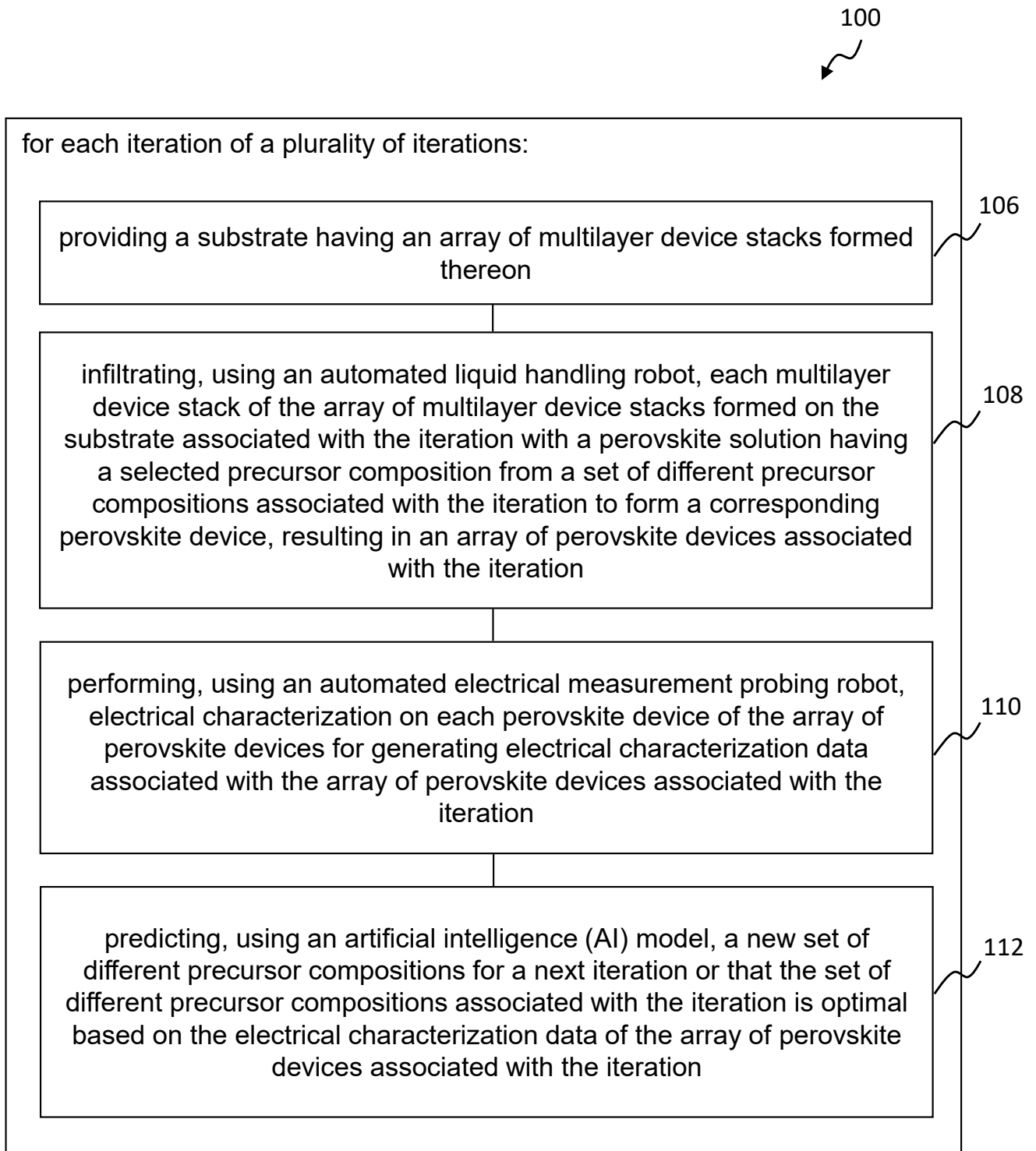


FIG. 1

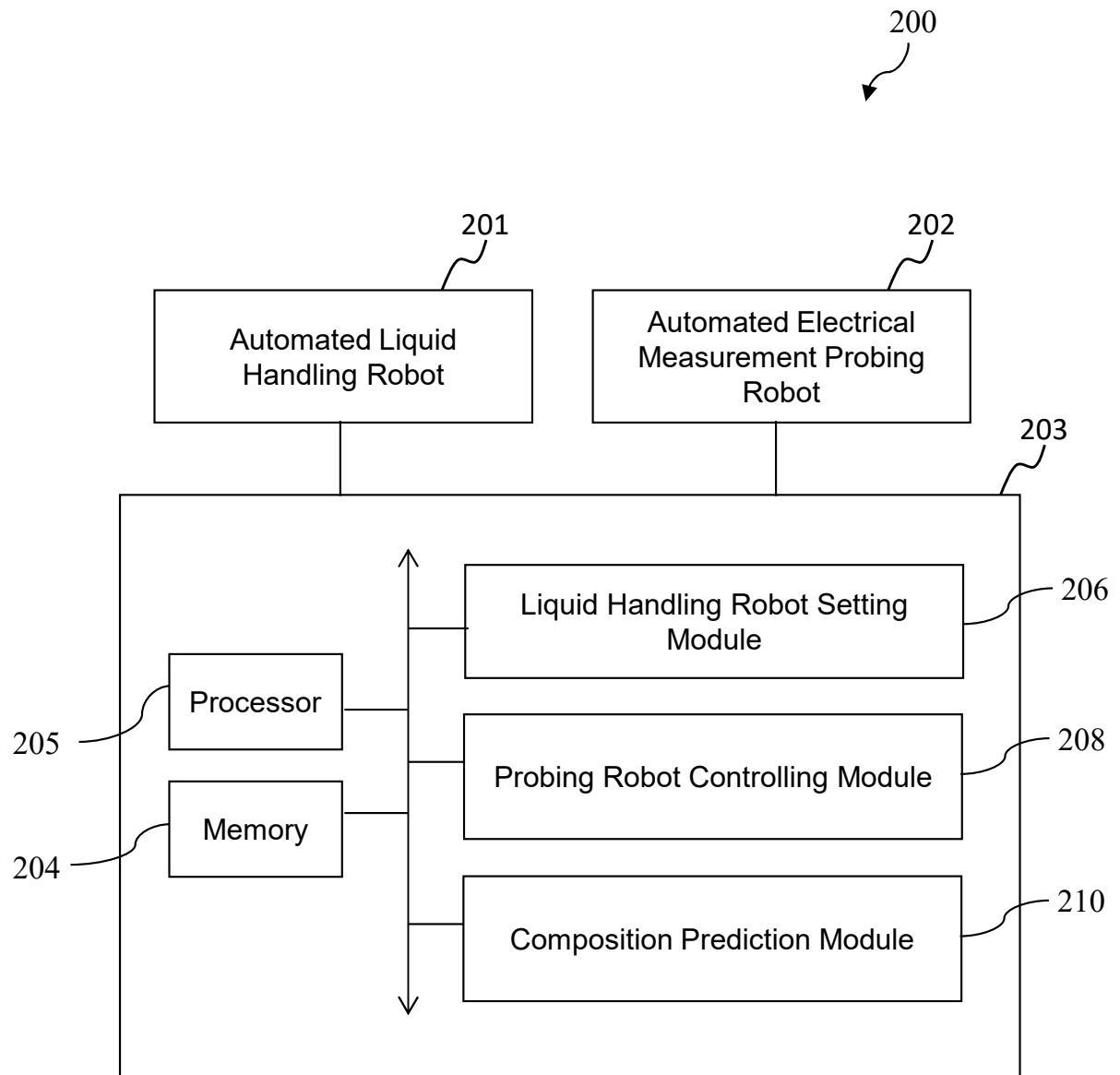
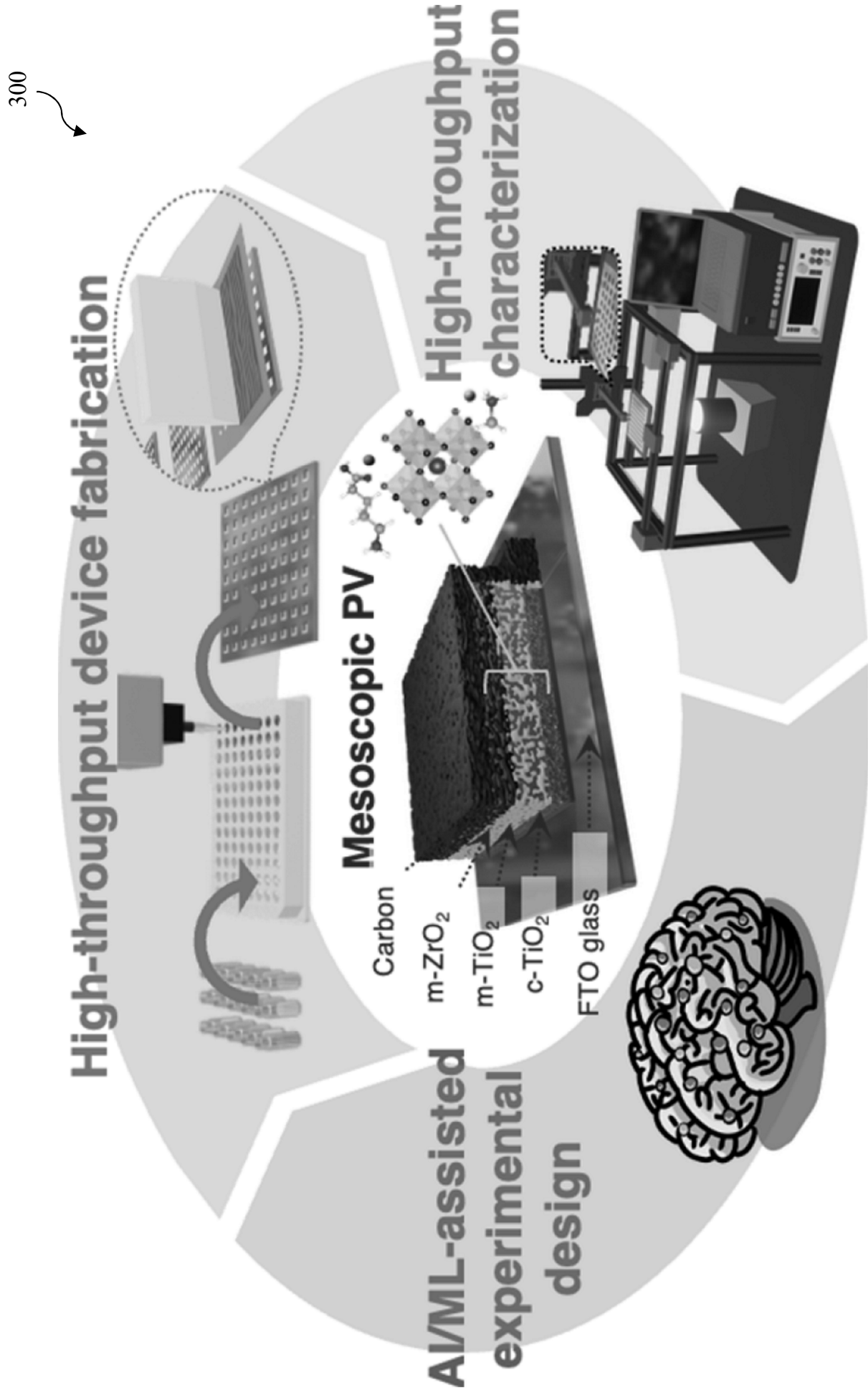


FIG. 2



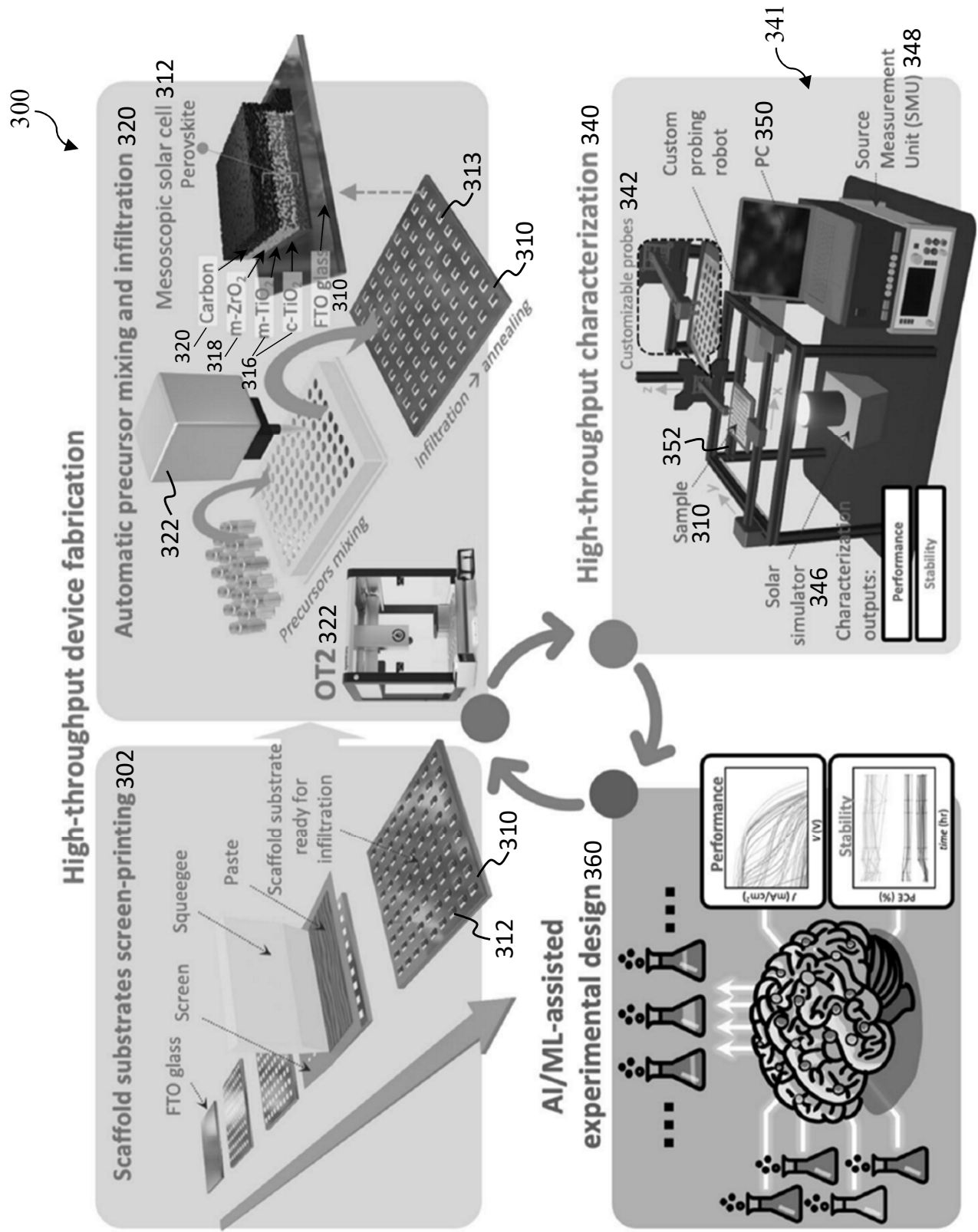


FIG. 4A

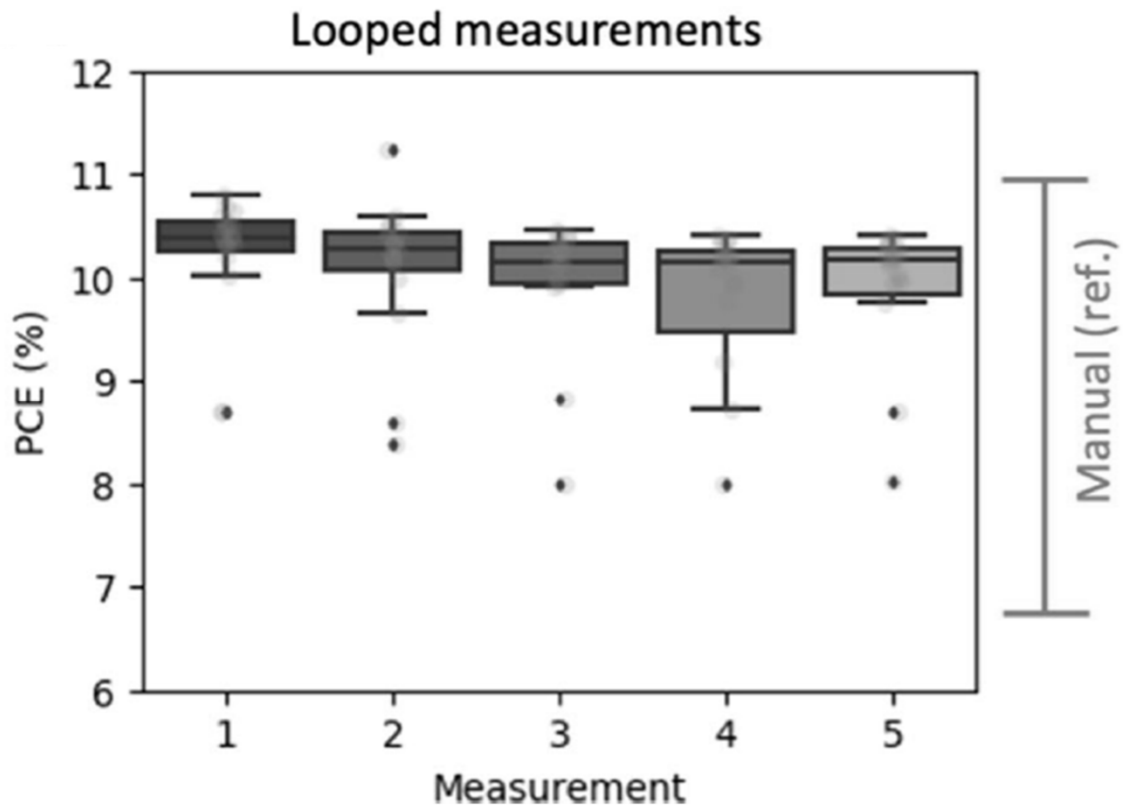


FIG. 4B

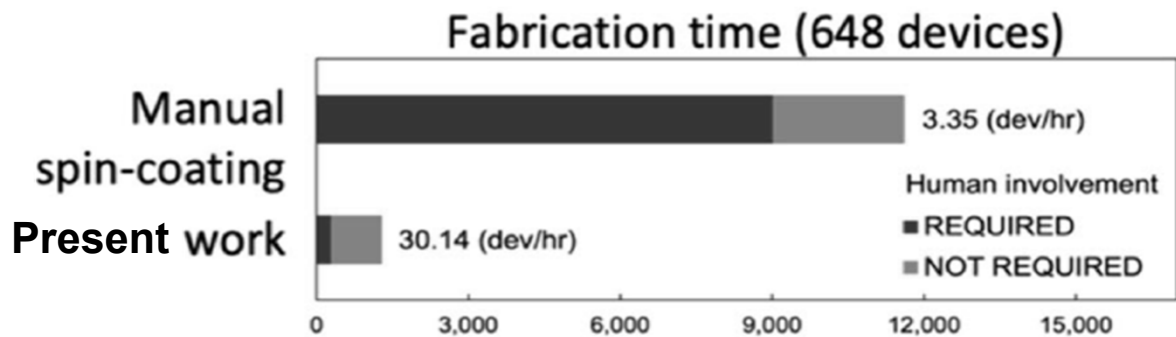


FIG. 4C

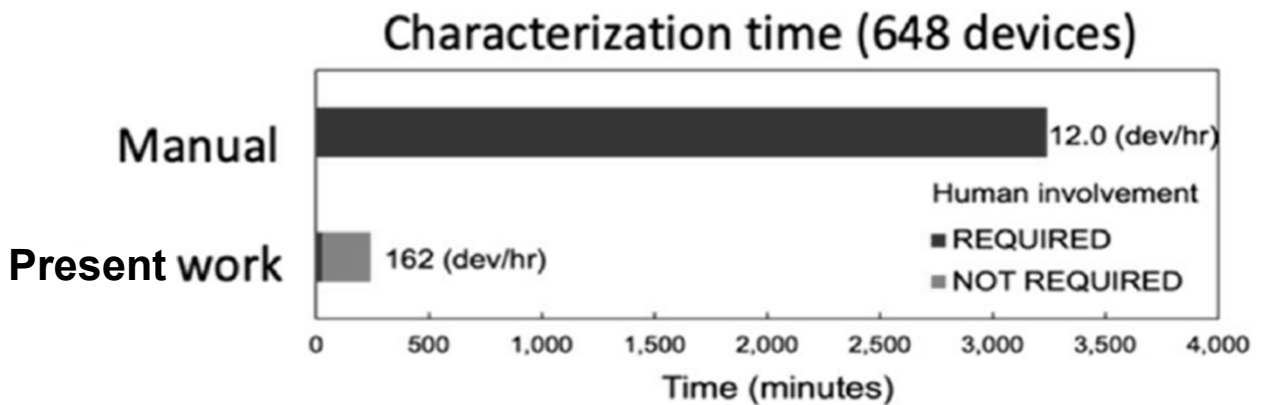


FIG. 4D

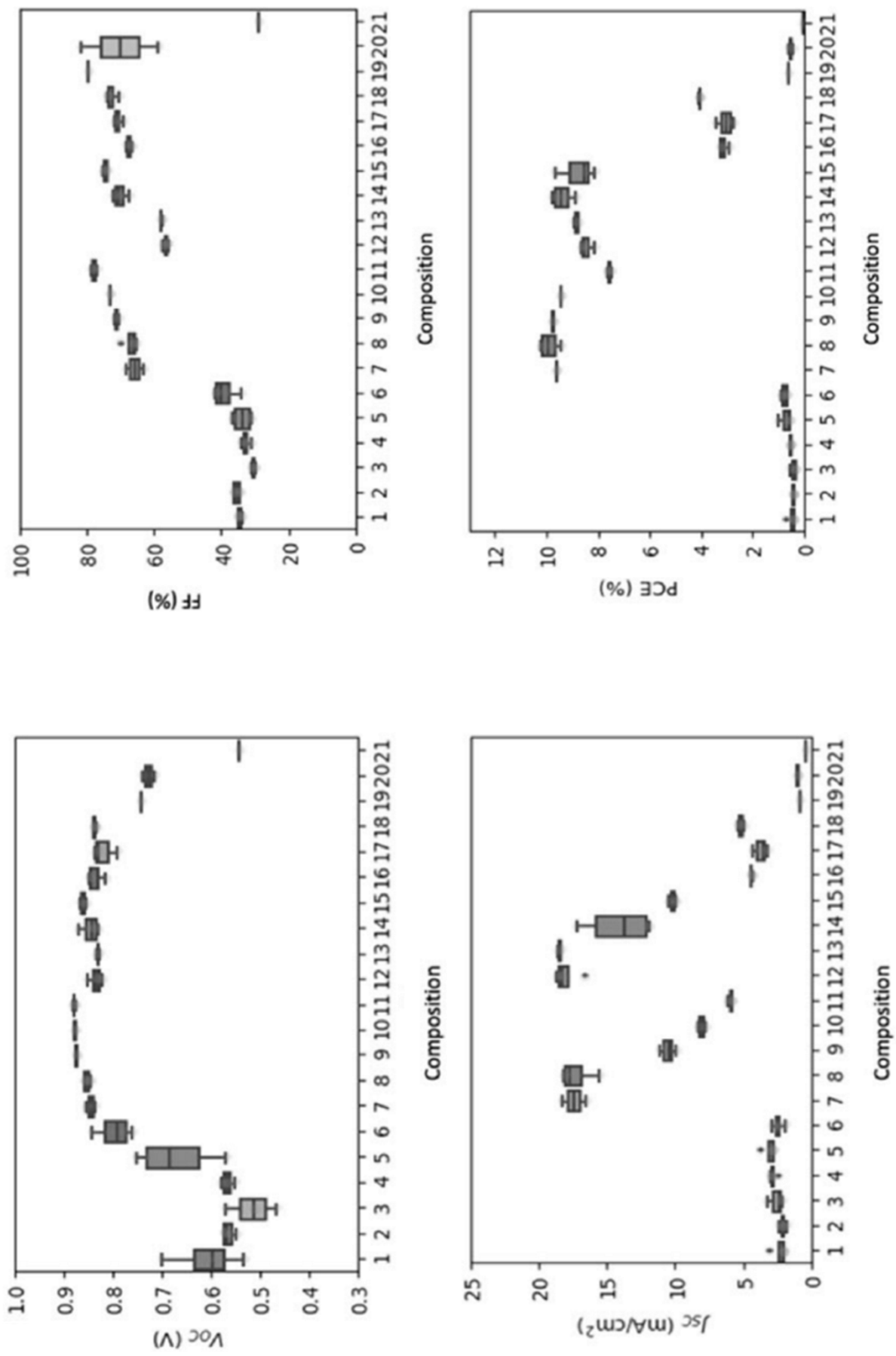


FIG. 5A

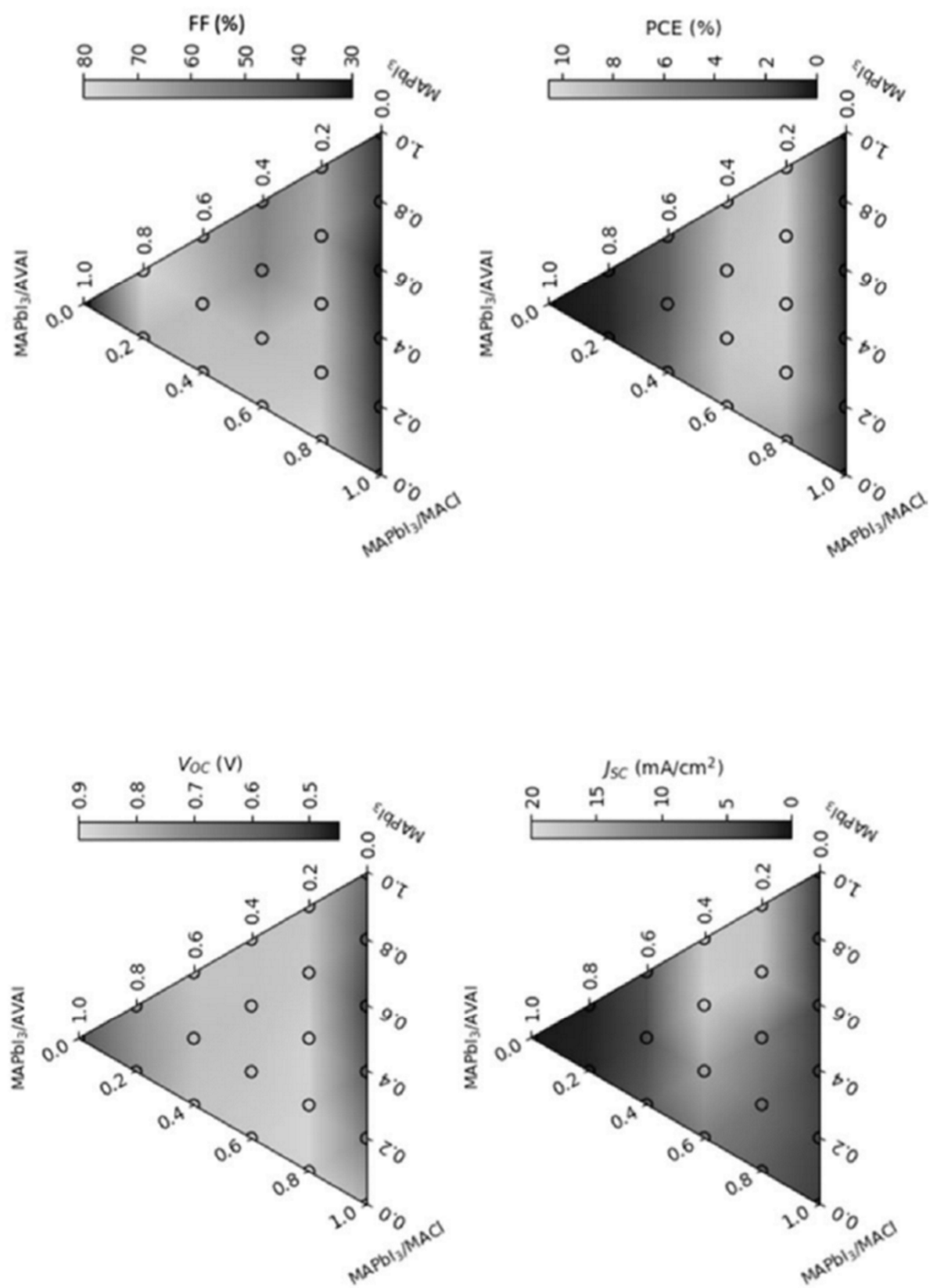


FIG. 5B

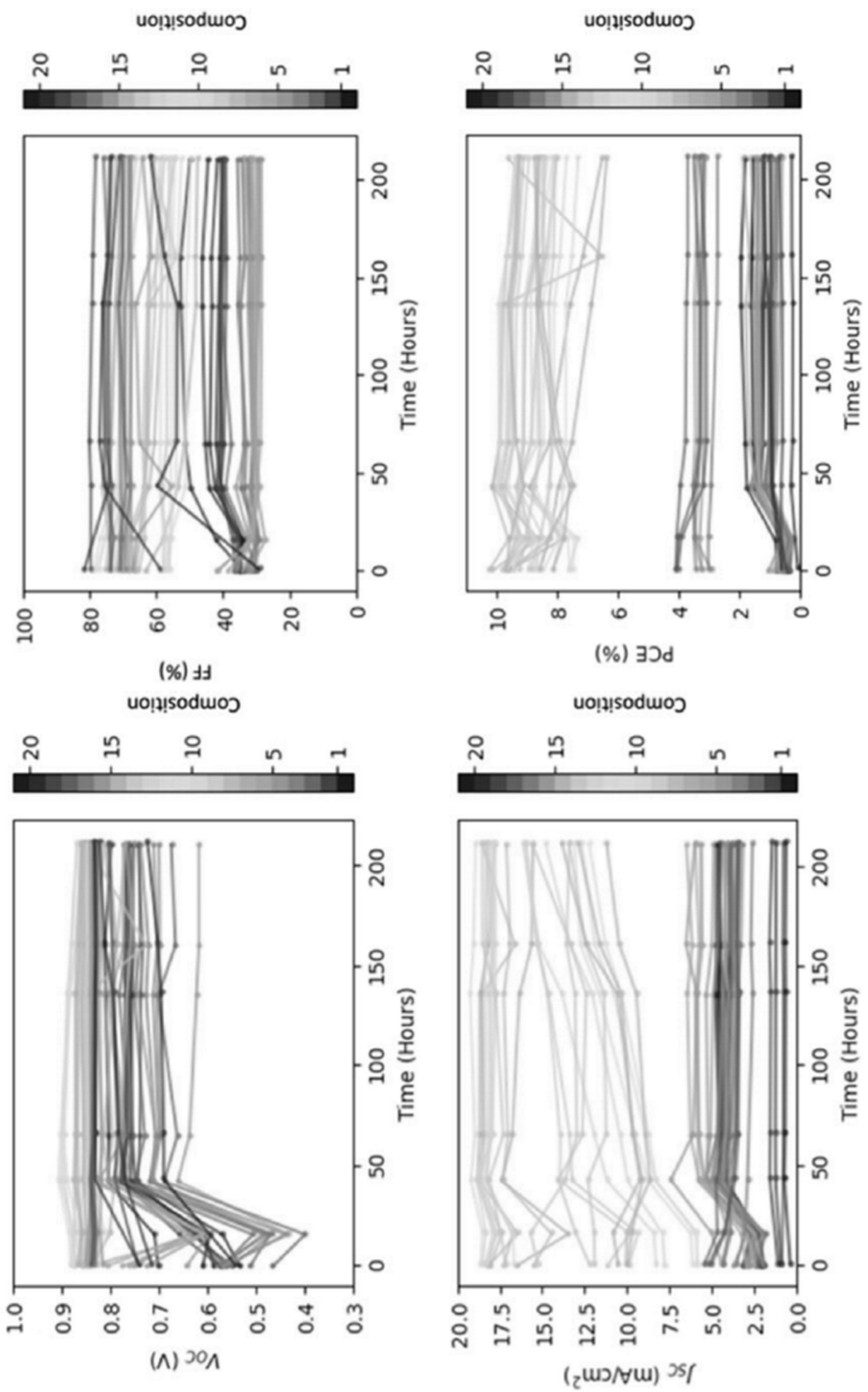


FIG. 5C

Table 1 : Precursor compositions for Batch 1 experiment

Composition	MAPbI ₃ /AVAL (% Vol)	MAPbI ₃ /MACl (% Vol)	MAPbI ₃ (% Vol)
1	0	0	100
2	0	20	80
3	0	40	60
4	0	60	40
5	0	80	20
6	0	100	0
7	20	0	80
8	20	20	60
9	20	40	40
10	20	60	20
11	20	80	0
12	40	0	60
13	40	20	40
14	40	40	20
15	40	60	0
16	60	0	40
17	60	20	20
18	60	40	0
19	80	0	20
20	80	20	0
21	100	0	0

FIG. 5D

GP Regressor (Batch 1 & Predicted Batch 2 candidates)

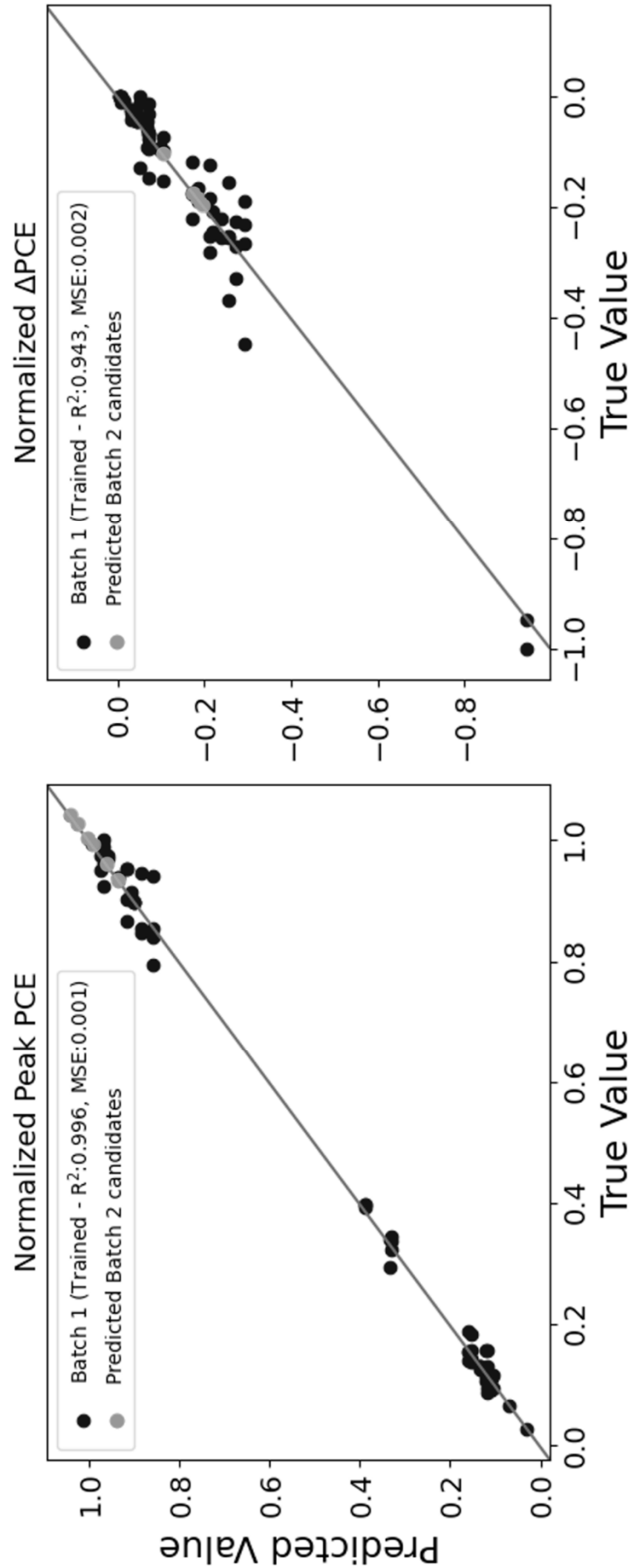


FIG. 6A

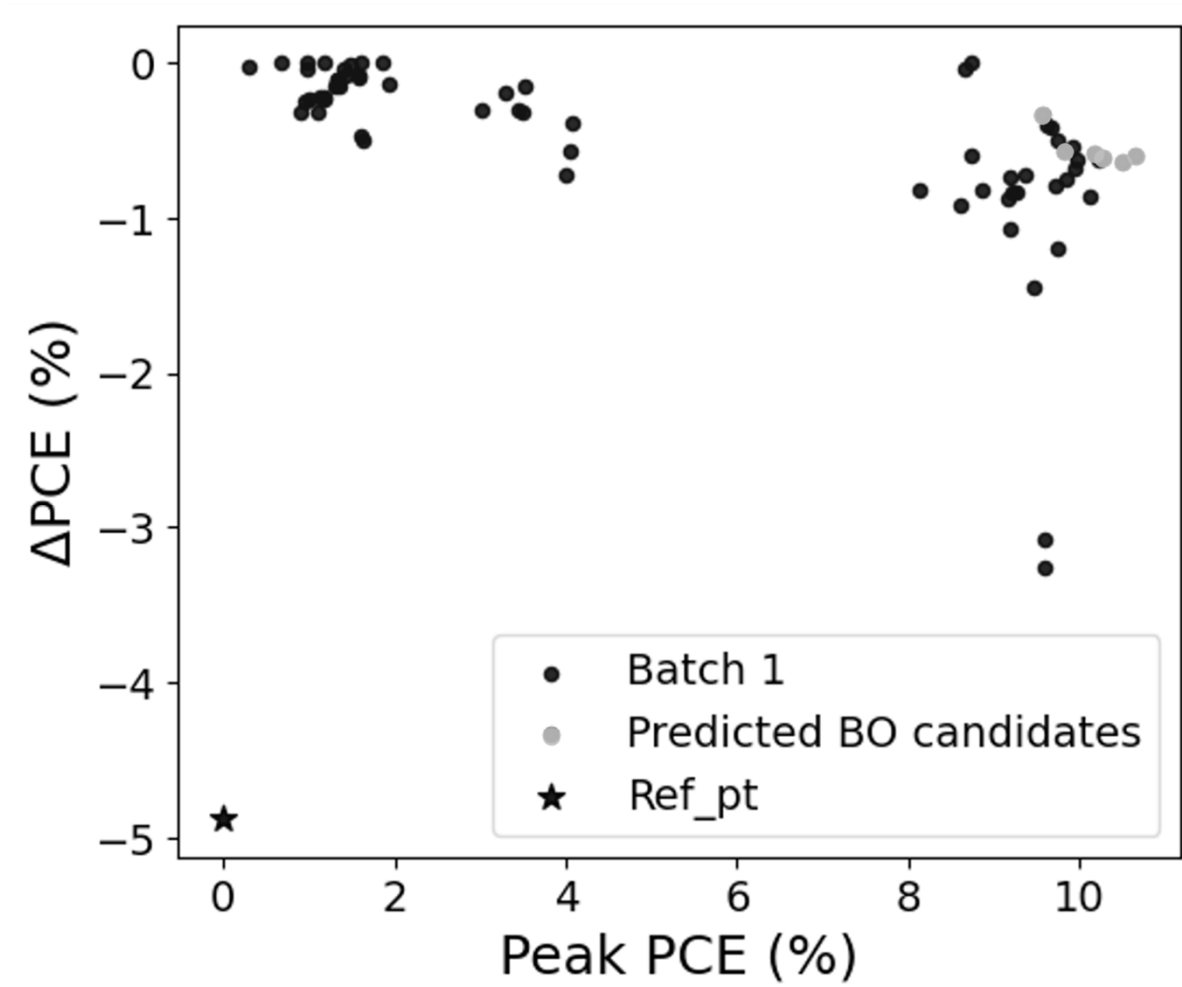


FIG. 6B

Table 2 : Batch 2 precursor composition candidates recommended by BO

Composition	MAPbI ₃ /AVAI (% Vol)	MAPbI ₃ /MACl (% Vol)	MAPbI ₃ (% Vol)
1	16.55	43.17	40.28
2	29.94	70.06	0
3	59.69	35.51	4.79
4	15.13	42.04	42.83
5	23.89	53.34	22.77
6	84.83	15.17	0
7 (control)	0	0	100

FIG. 6C

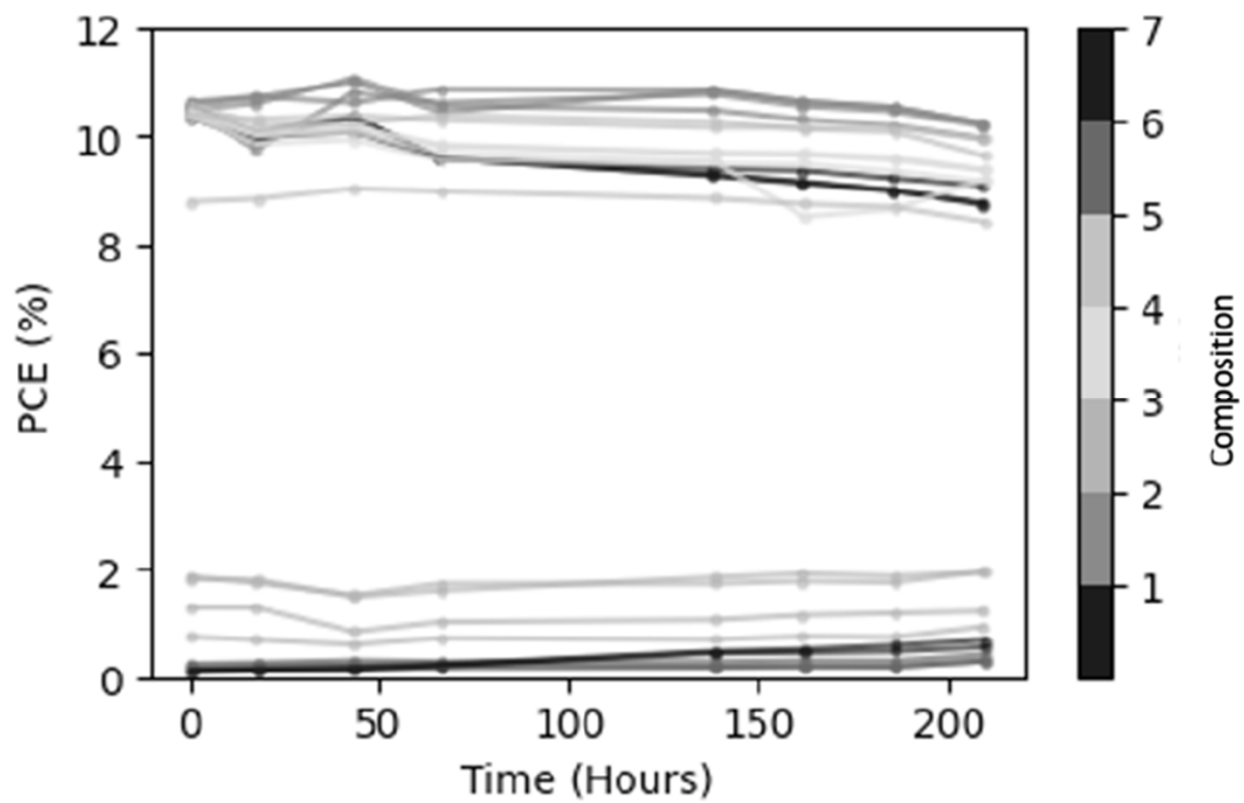


FIG. 6D

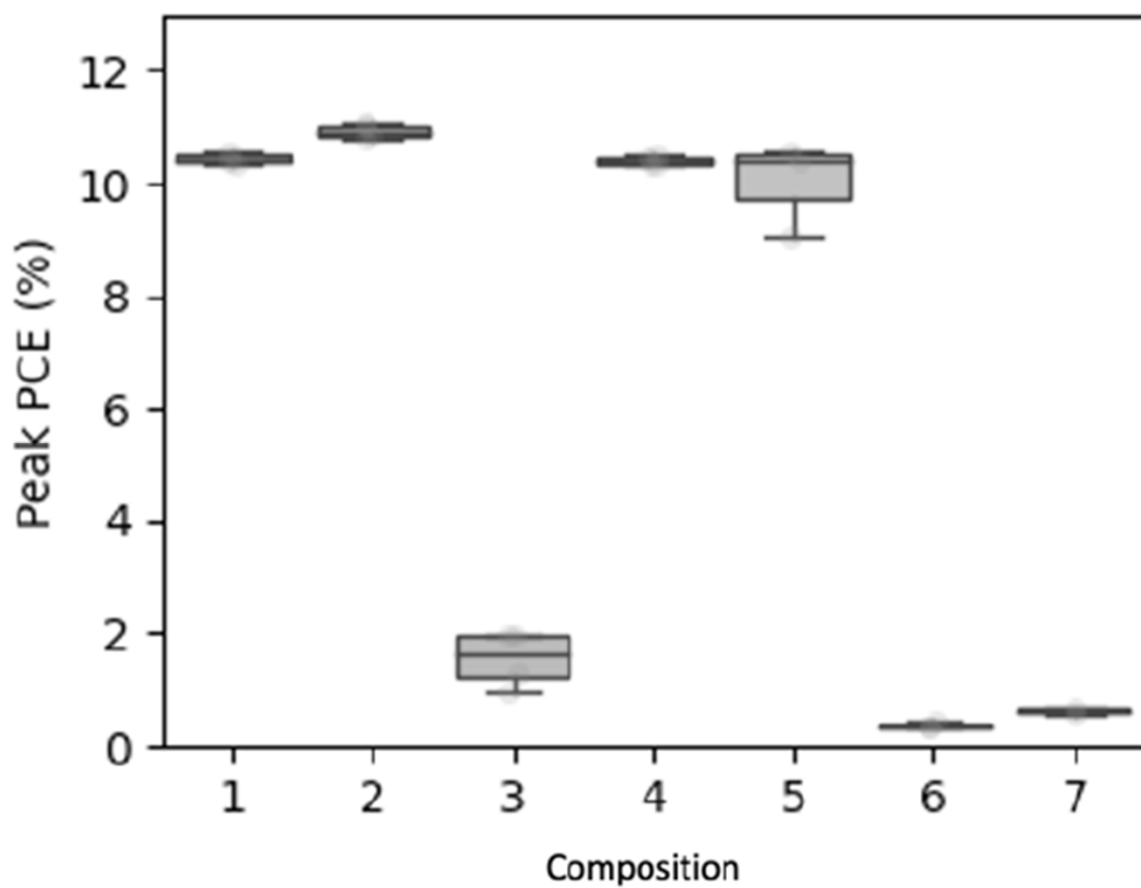


FIG. 6E

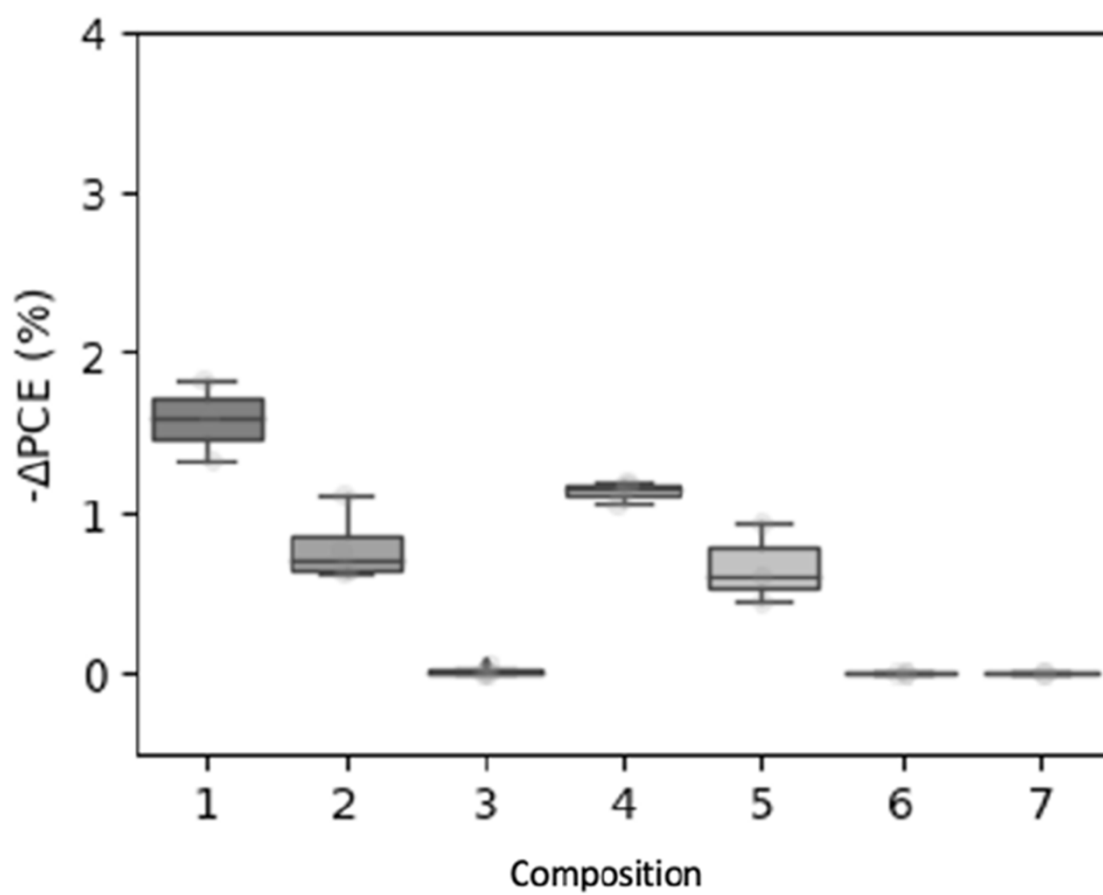


FIG. 6F

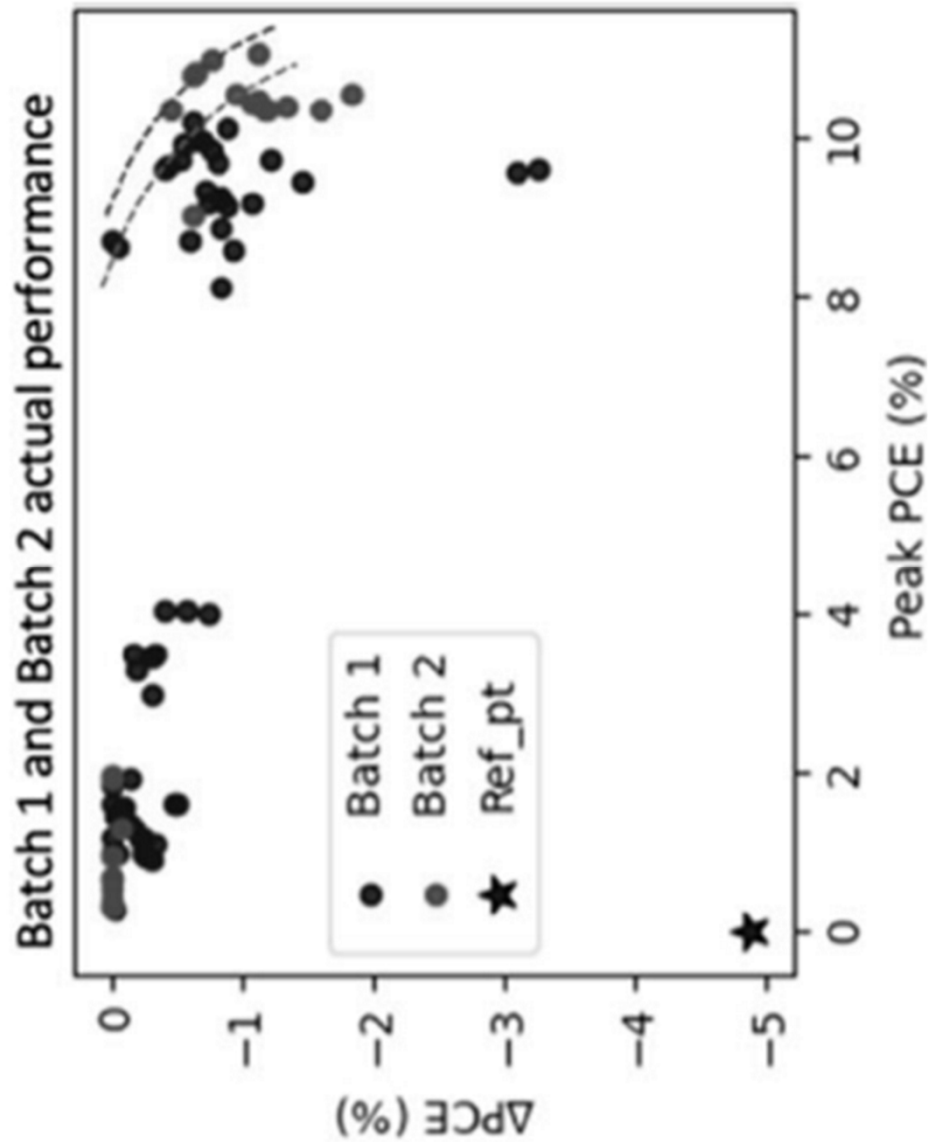


FIG. 6G

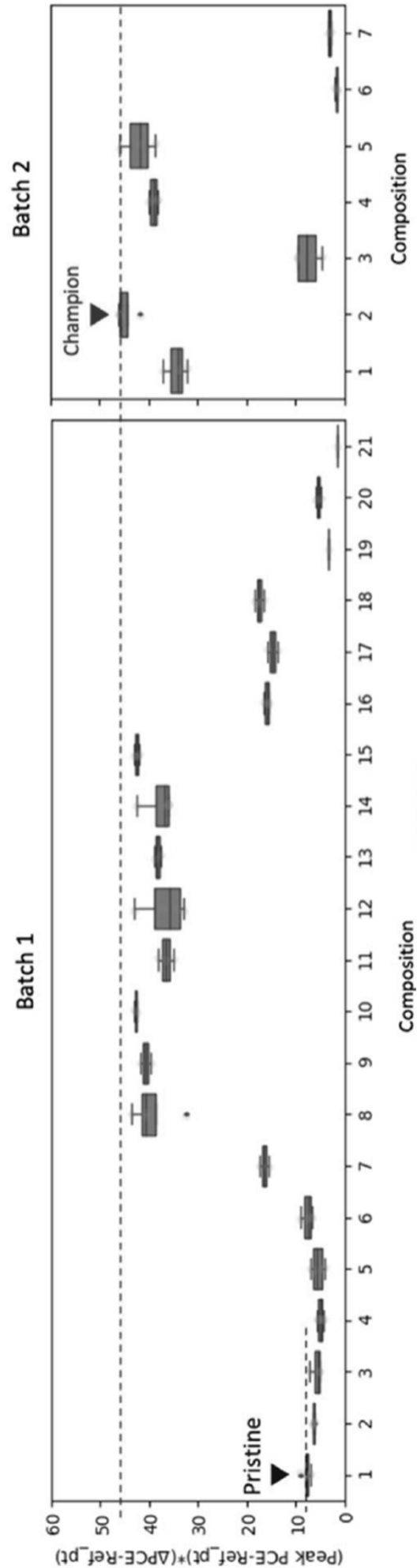


FIG. 6H

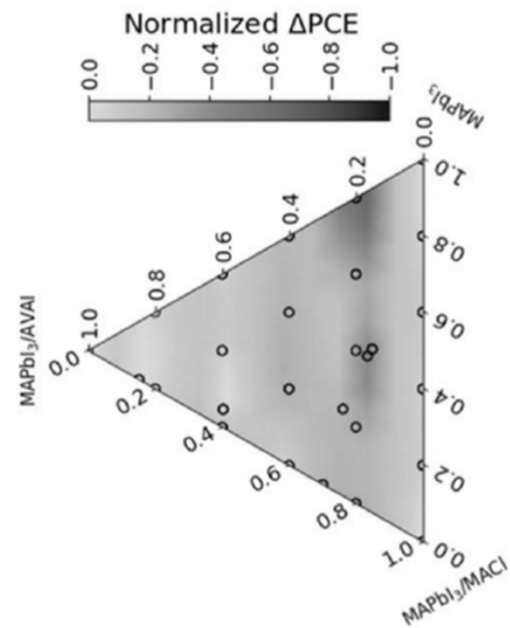


FIG. 6K

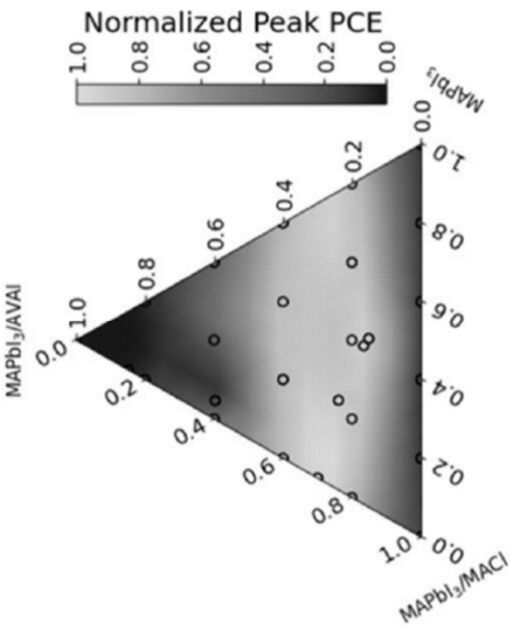


FIG. 6J

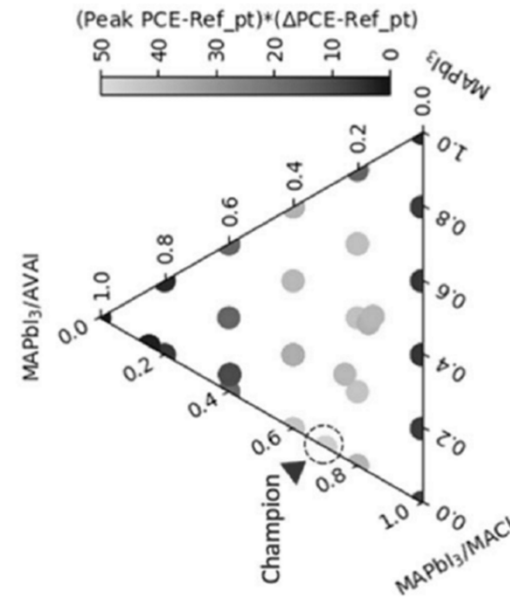


FIG. 6I

Trial 1

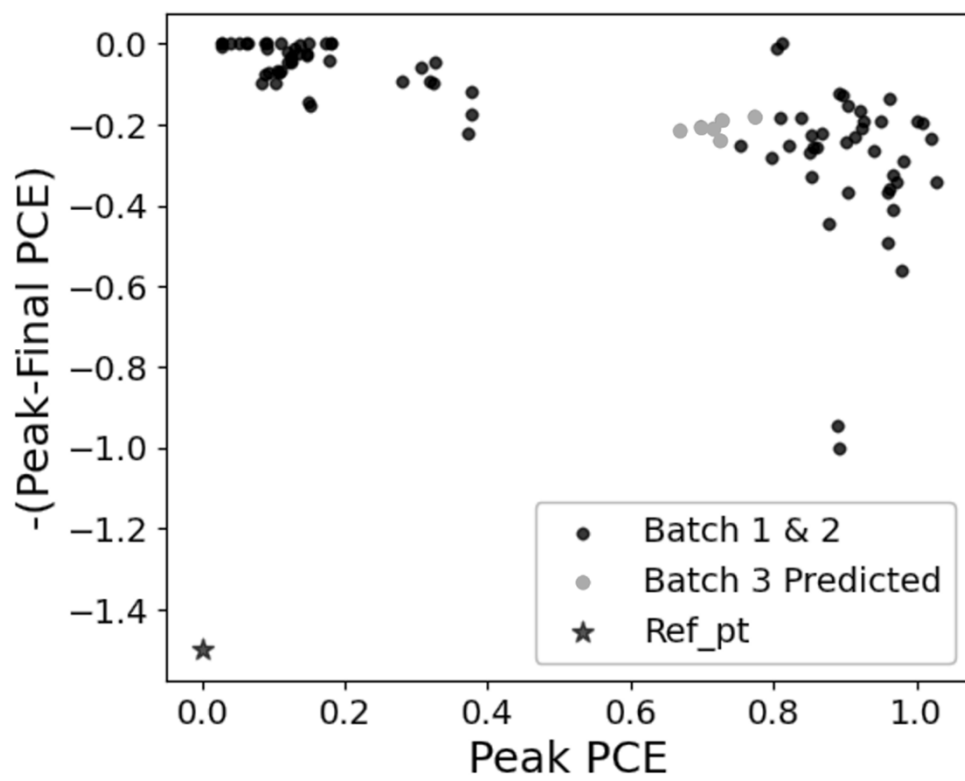


FIG. 6L

Trial 2

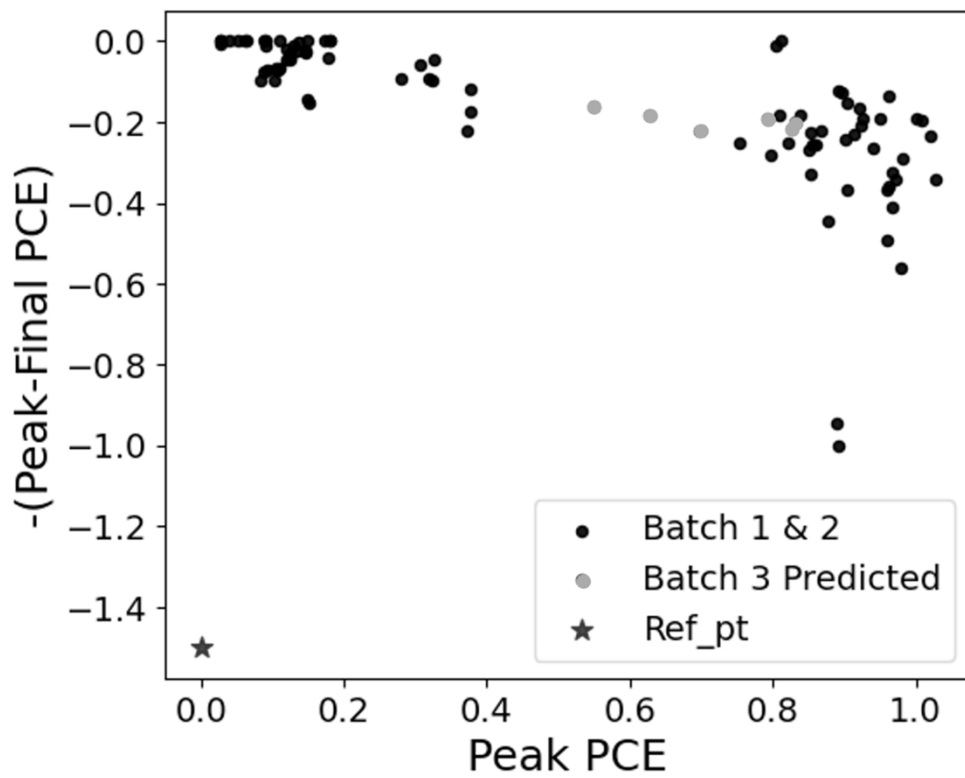


FIG. 6M

Trial 3

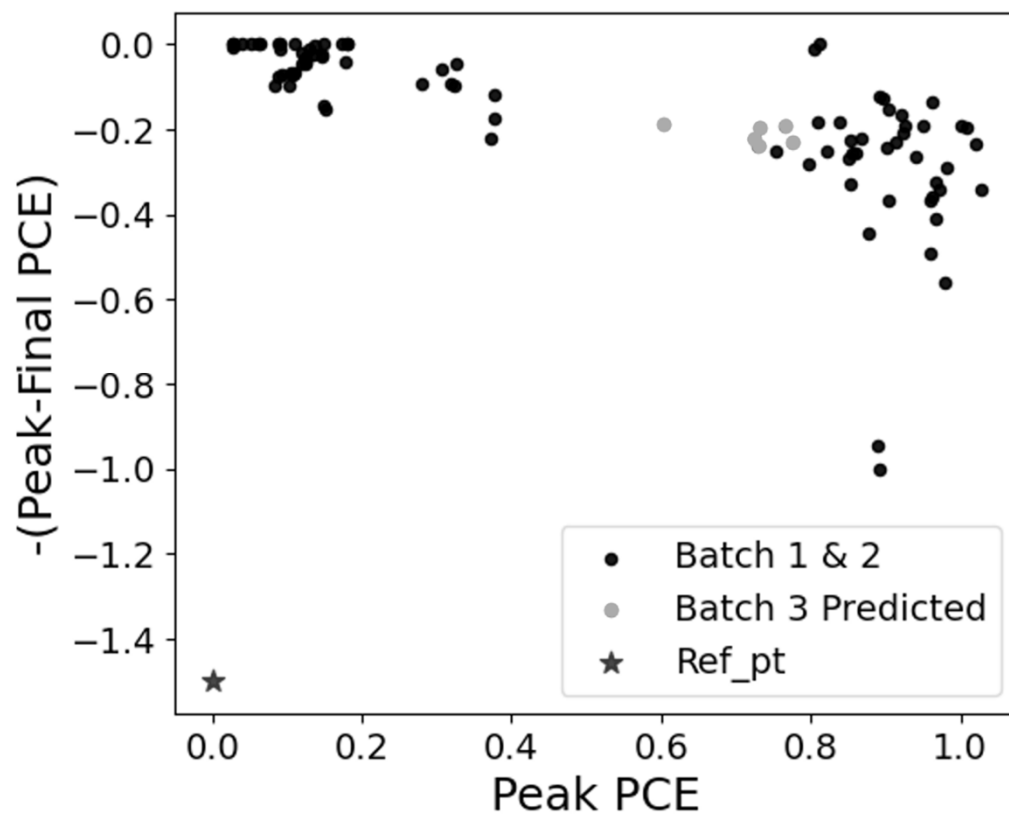


FIG. 6N

Trial 4

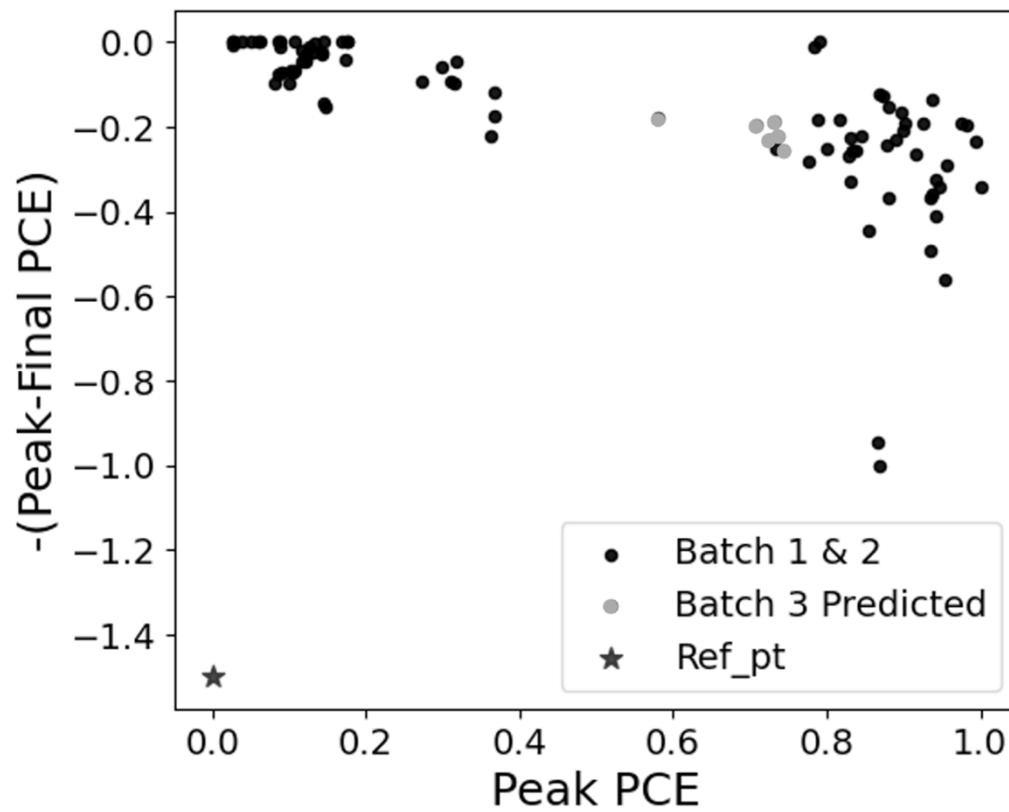


FIG. 6O

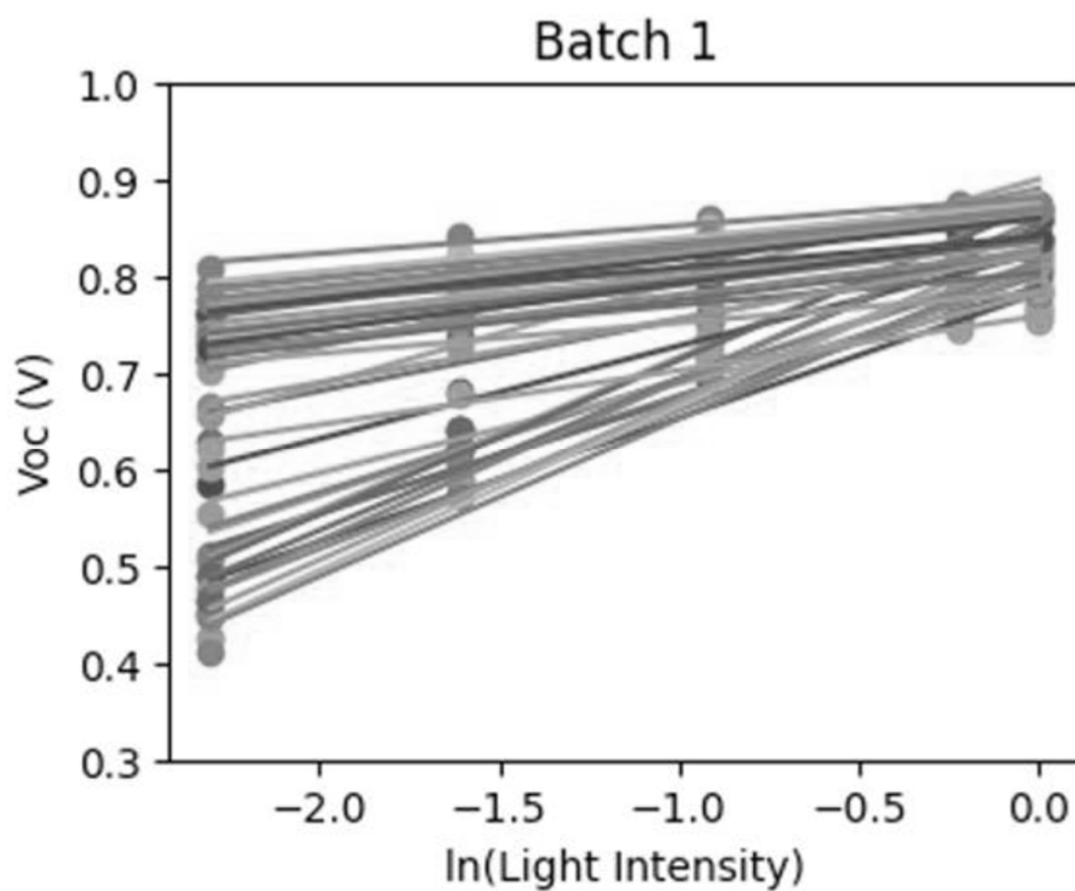


FIG. 7A

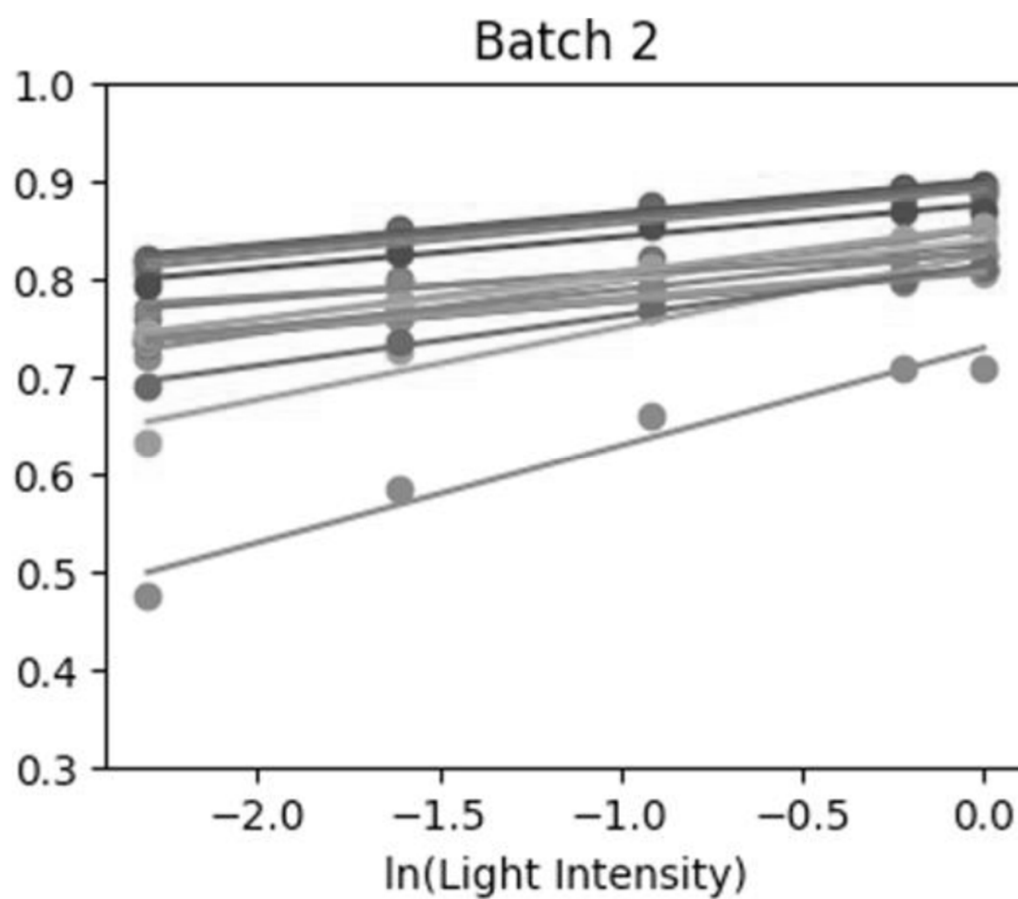


FIG. 7B

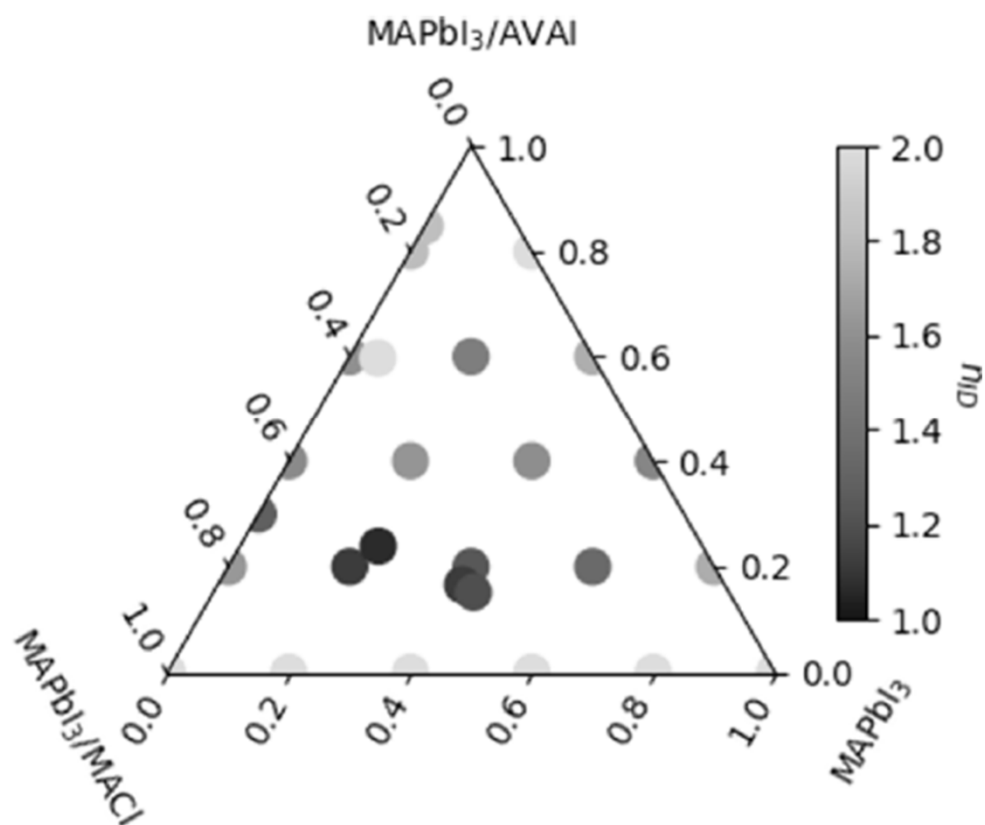


FIG. 8A

at 210h

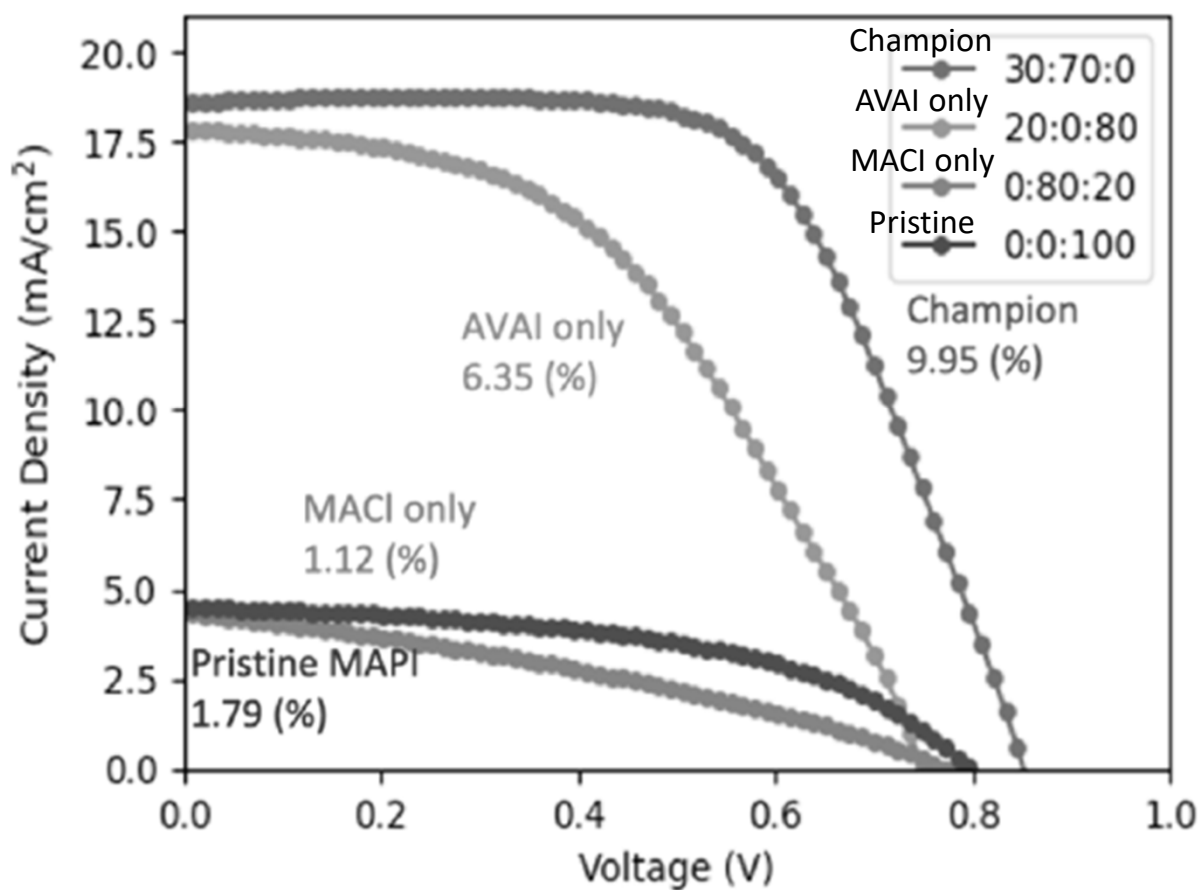


FIG. 8B

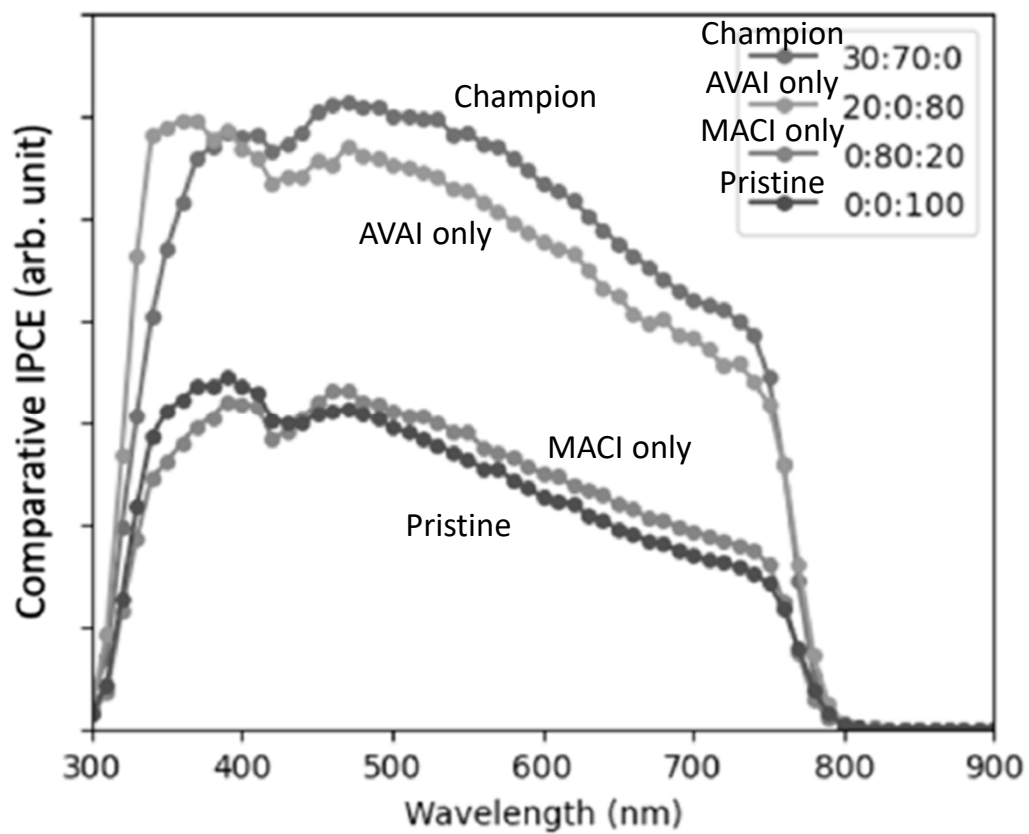


FIG. 8C

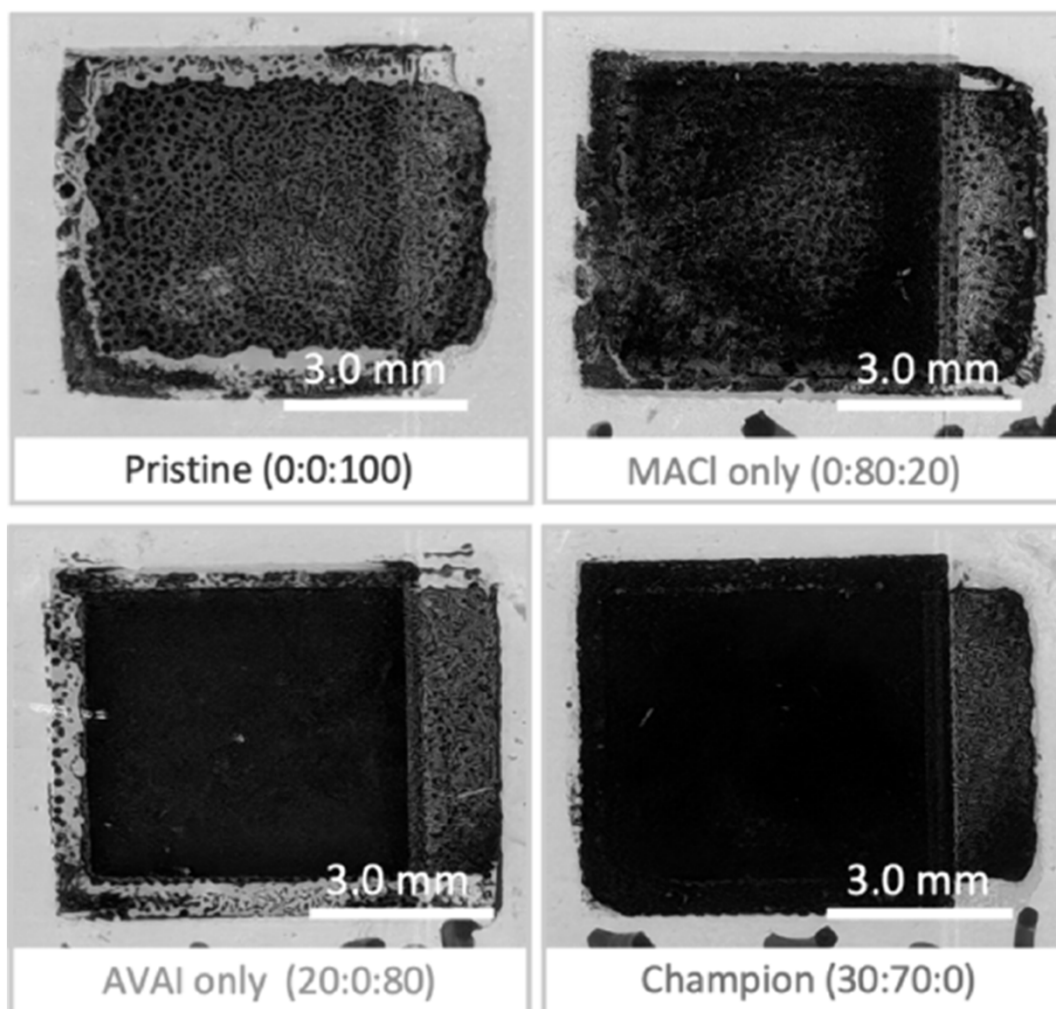


FIG. 8D

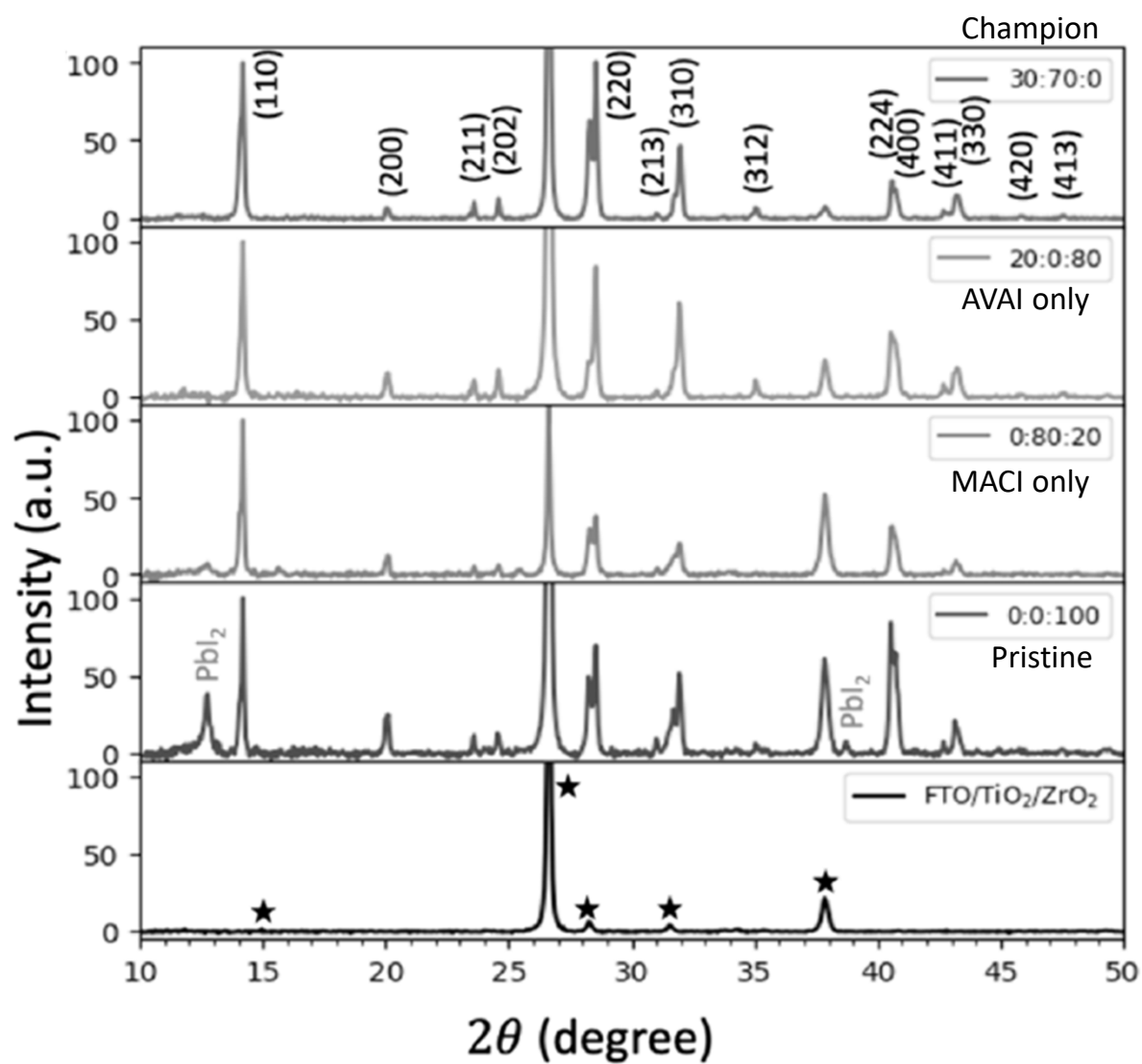


FIG. 8E

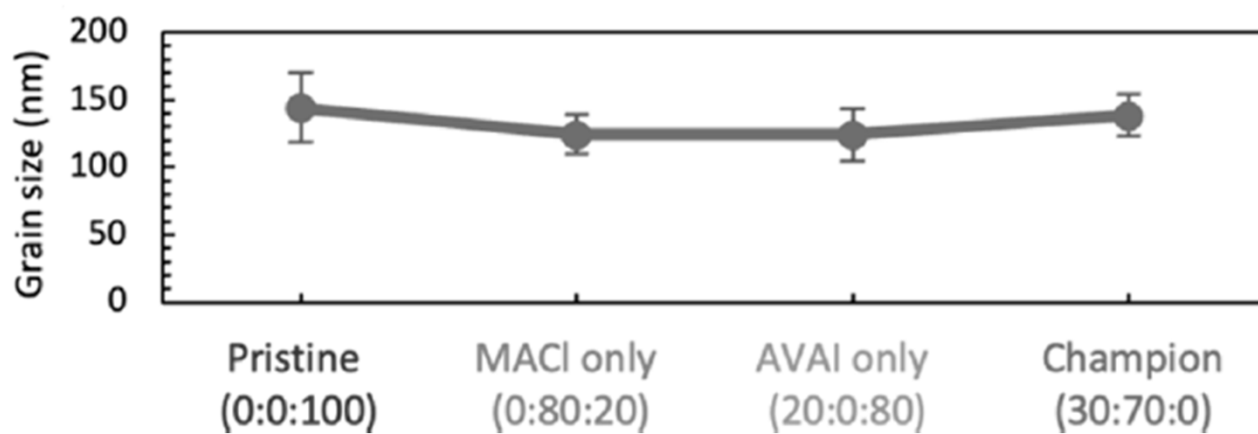


FIG. 8F

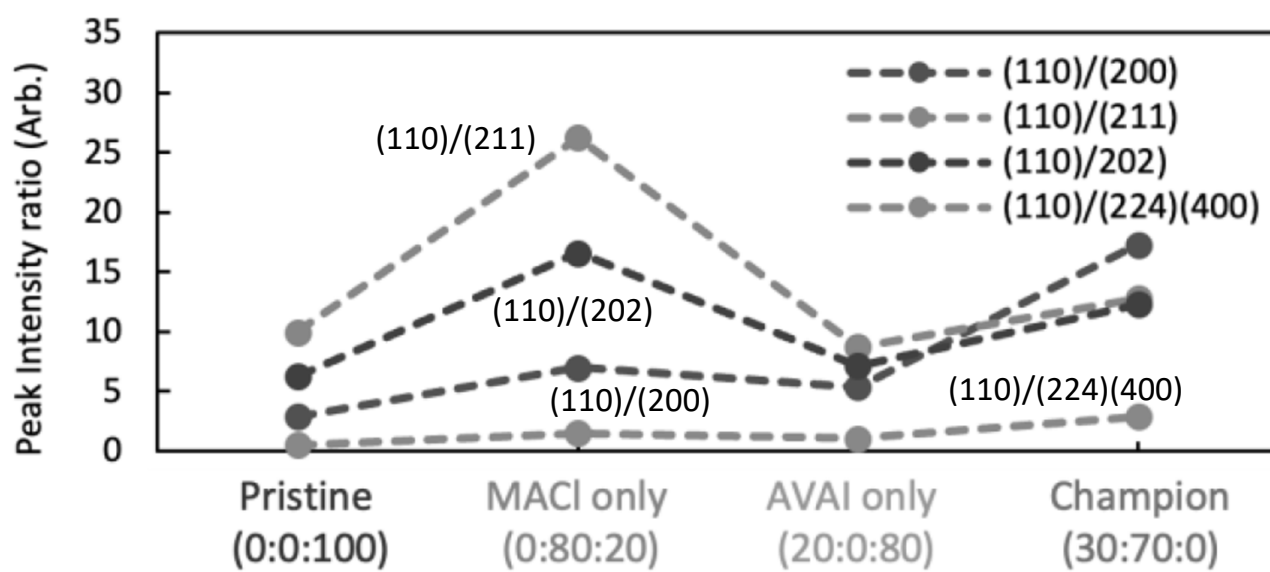


FIG. 9

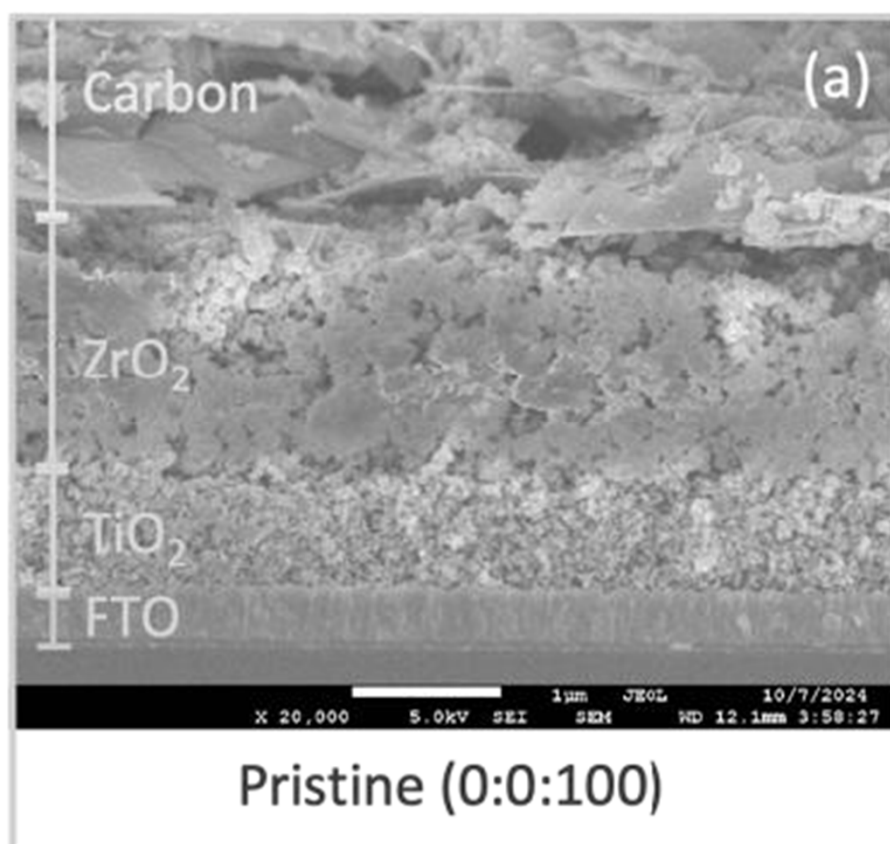


FIG. 10A

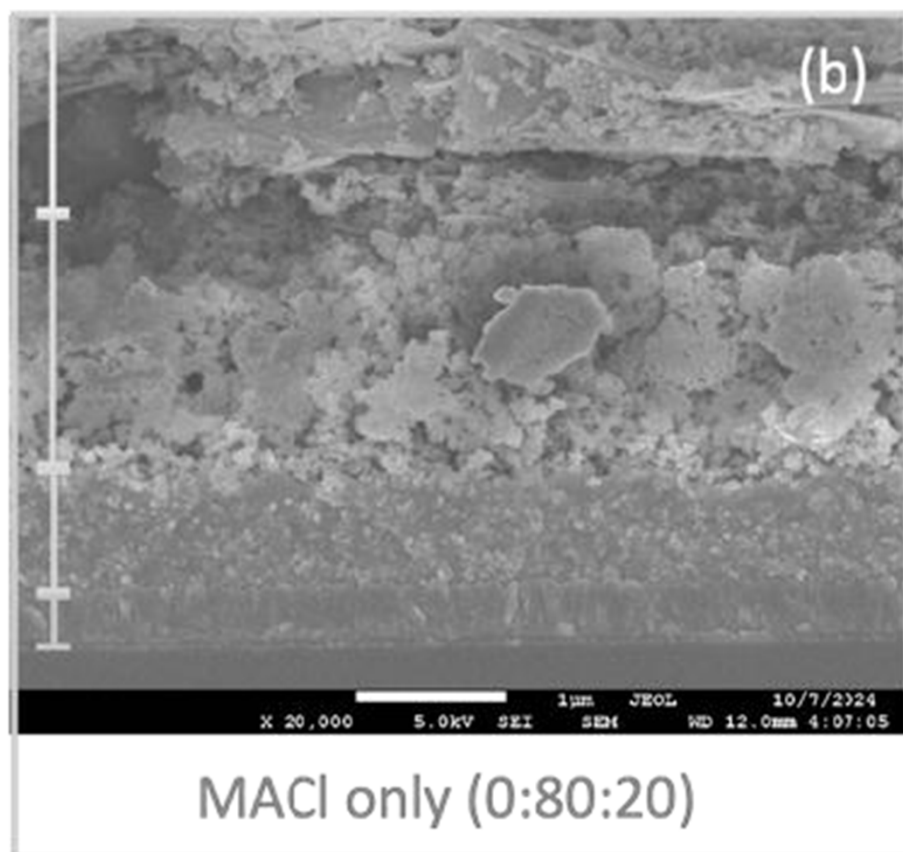


FIG. 10B

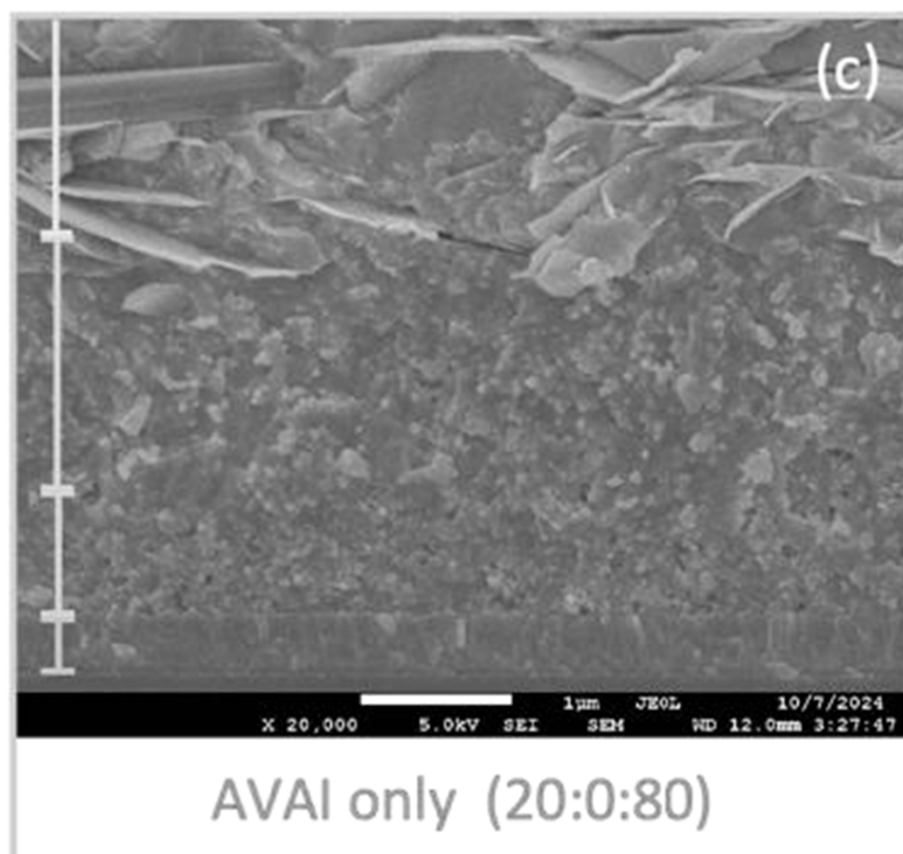


FIG. 10C

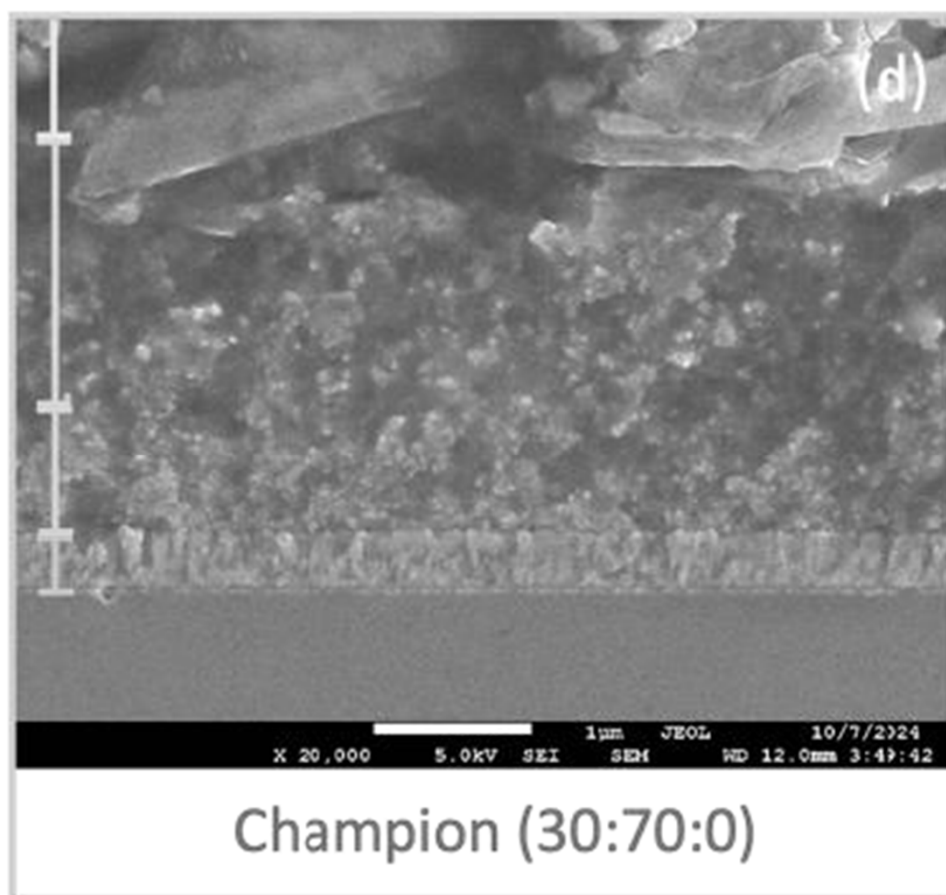


FIG. 10D

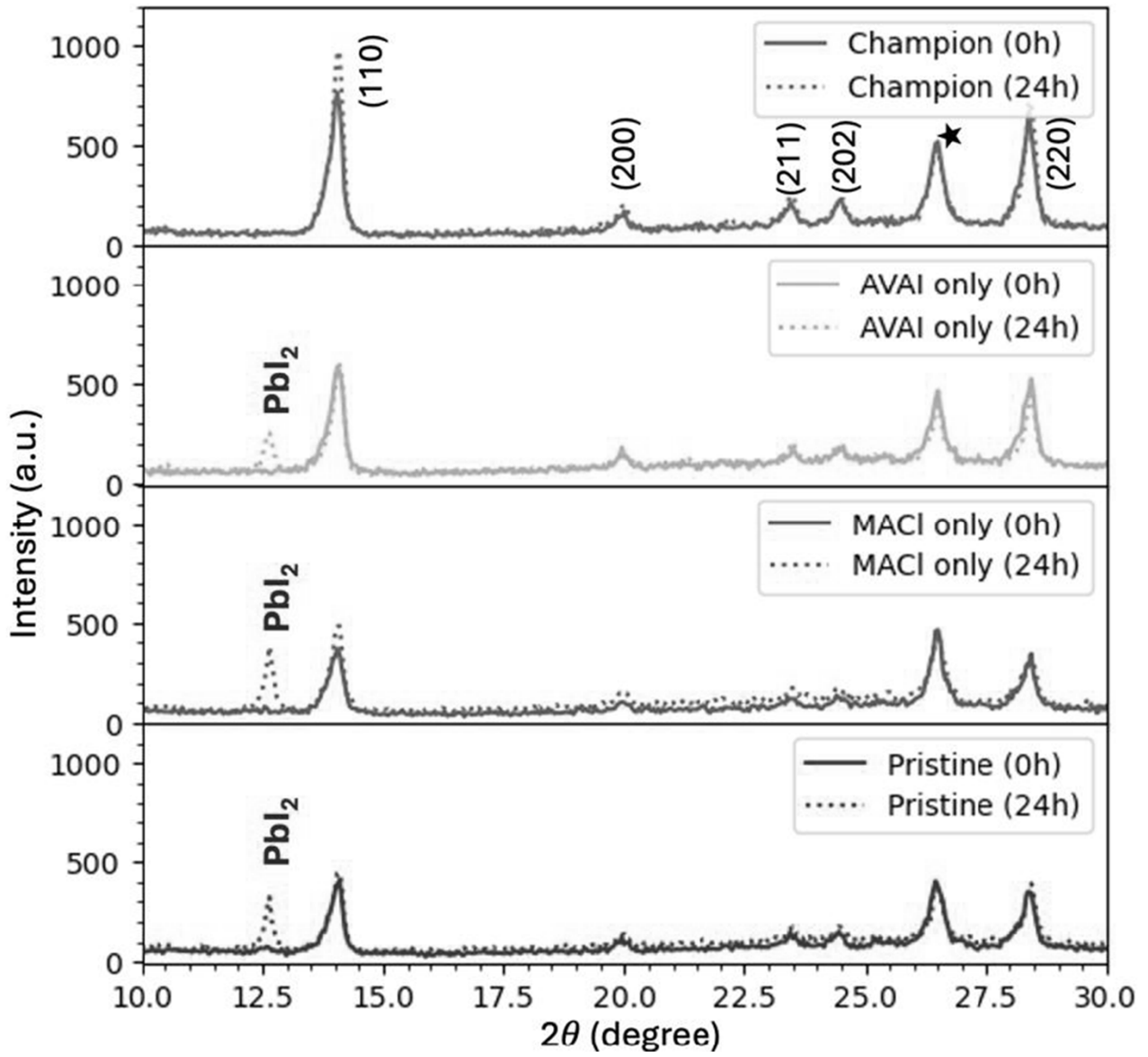


FIG. 11

Table 3: Screen parameters of different layers for mesoscopic device.

Screen	Mesh count	Mesh Anole	Emulsion thickness(μm)	Mesh tension(N)
c-TiO ₂	PY100	22.5 °	15	18 $\pm$ 2
m-TiO ₂	PW180	22.5 °	15	18 $\pm$ 2
ZrO ₂	PY120	22.5 °	15	18 $\pm$ 2
C	PW048	22.5 °	15	18 $\pm$ 2

FIG. 12

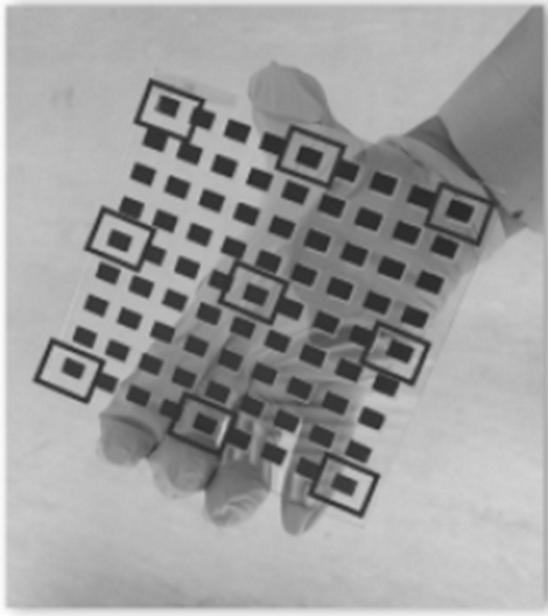


FIG. 13A

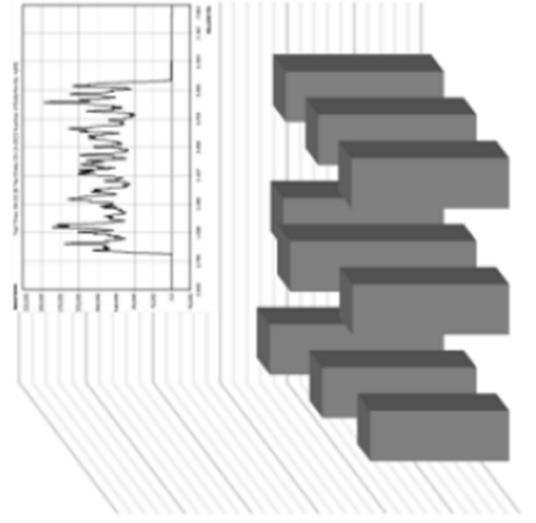
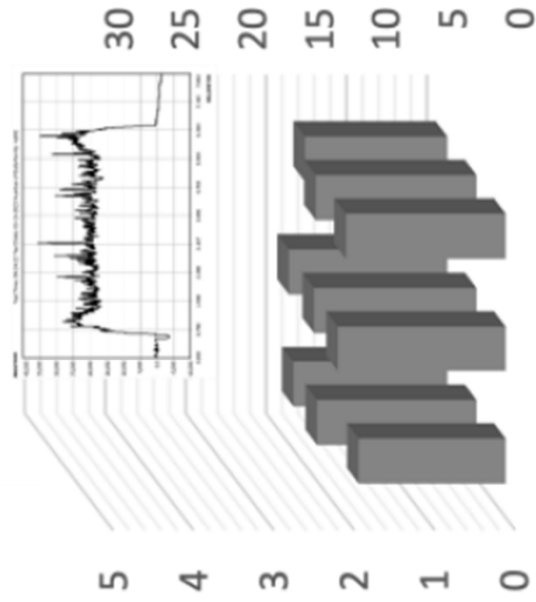
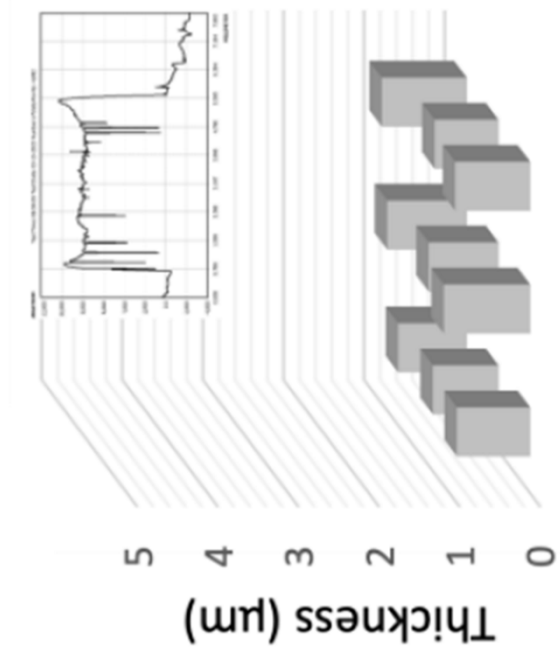


Table 4 : Thickness measurement result of m-TiO₂, ZrO₂, and Carbon layers

Layer	m-TiO ₂	ZrO ₂	Carbon
Thickness	0.92±0.12 μm	1.95±0.15 μm	12±1.5 μm
Roughness	0.15 μm	0.75 μm	12 μm

FIG. 13E

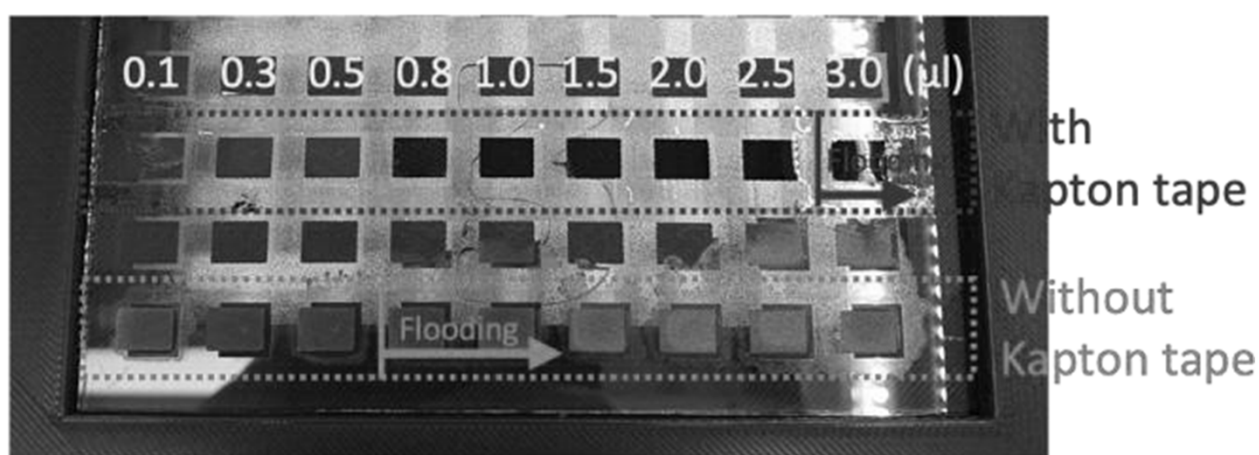


FIG. 14A

With Kapton tape

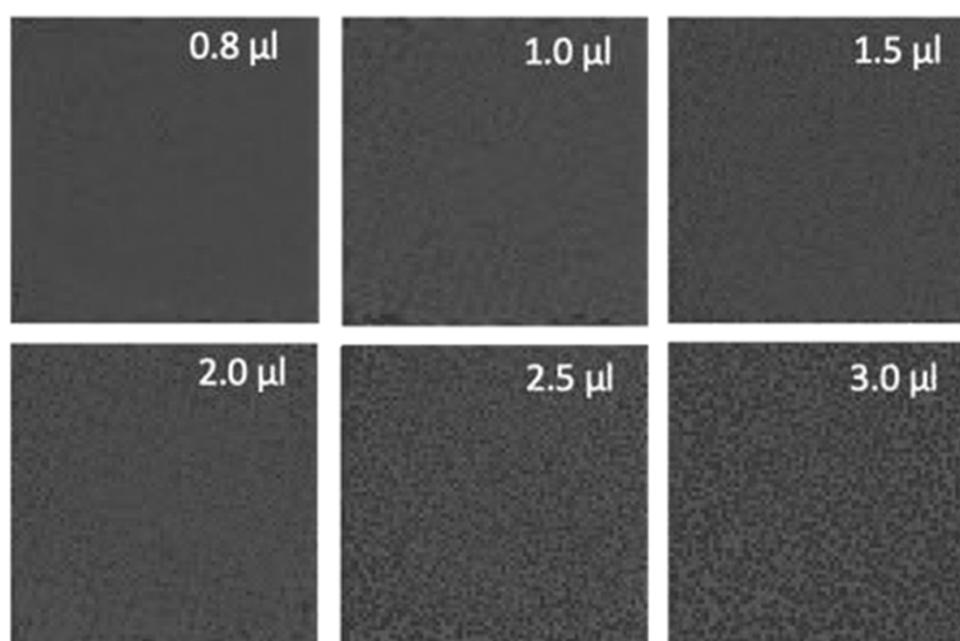


FIG. 14B

Without Kapton tape

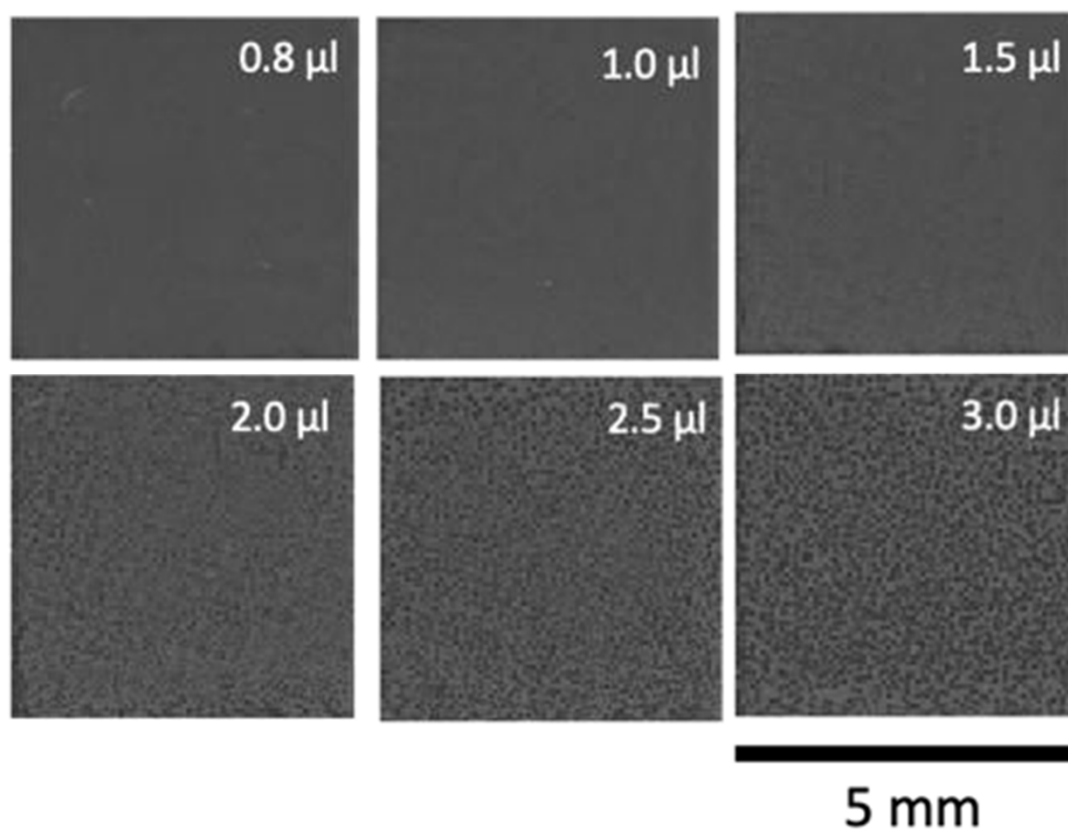


FIG. 14C

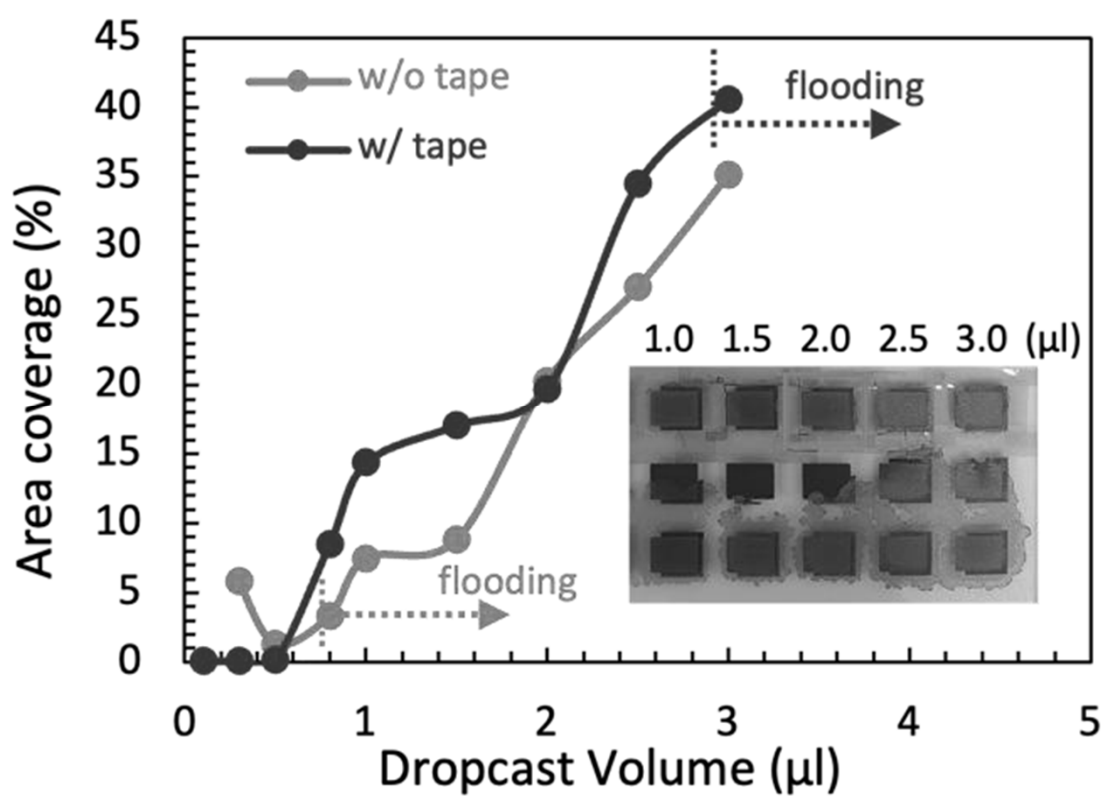


FIG. 14D

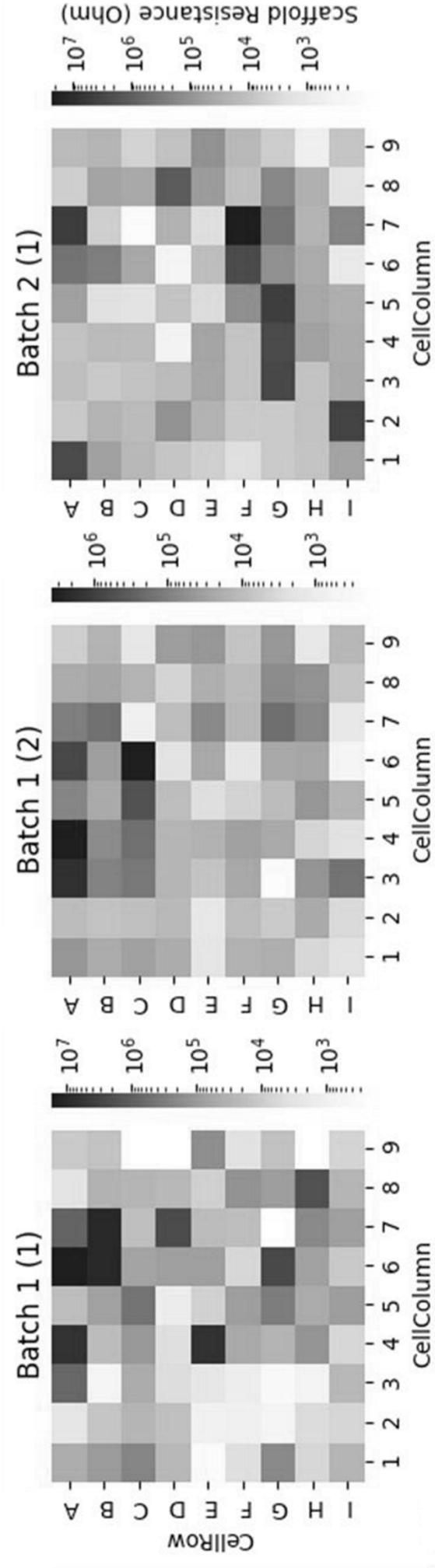


FIG. 15C

FIG. 15B

FIG. 15A

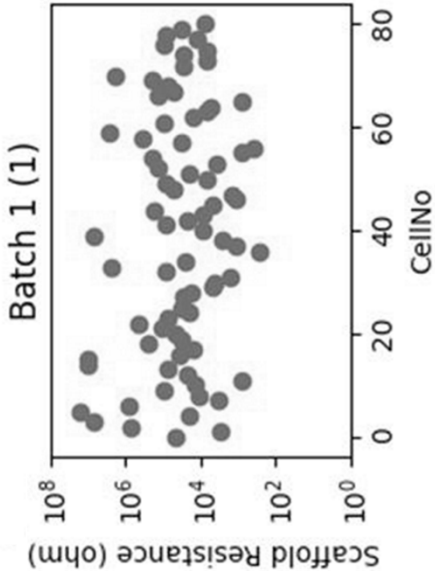


FIG. 15D

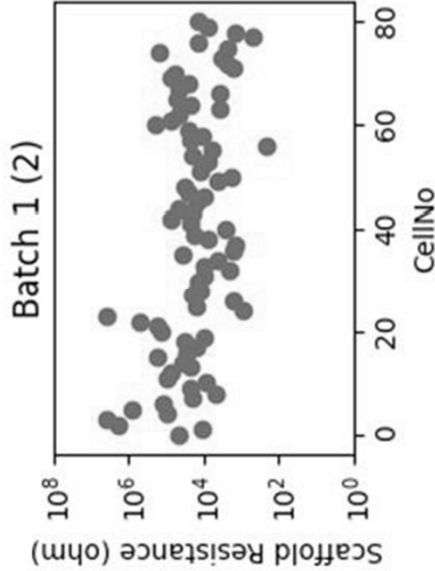


FIG. 15E

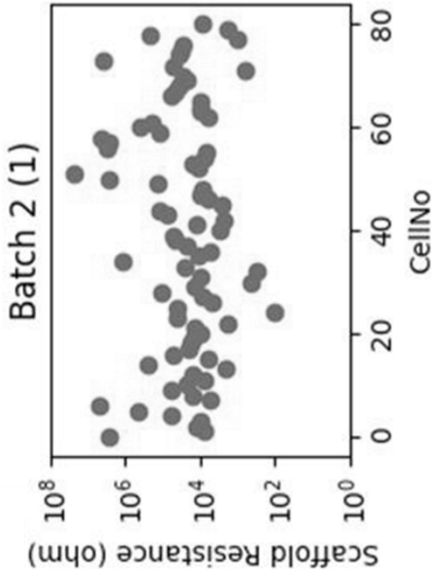


FIG. 15F

FIG. 16A

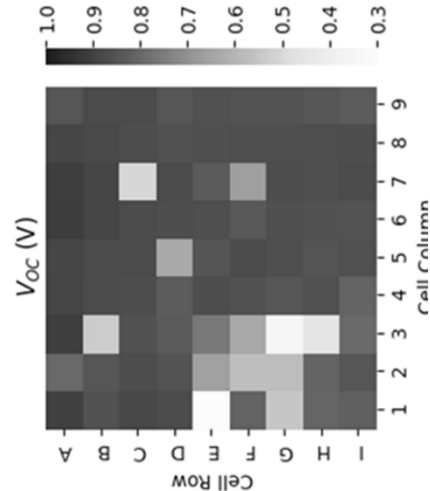


FIG. 16B

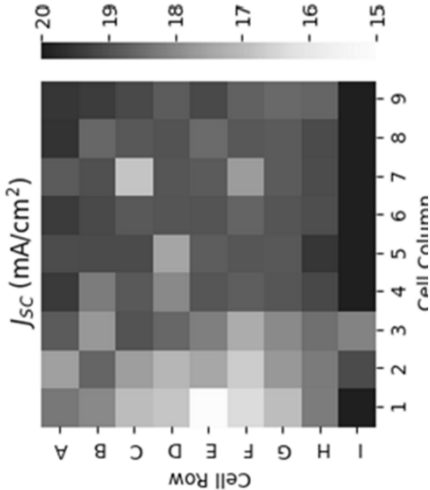


FIG. 16C

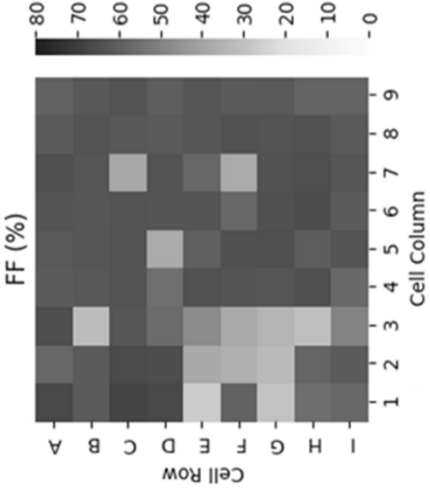


FIG. 16D

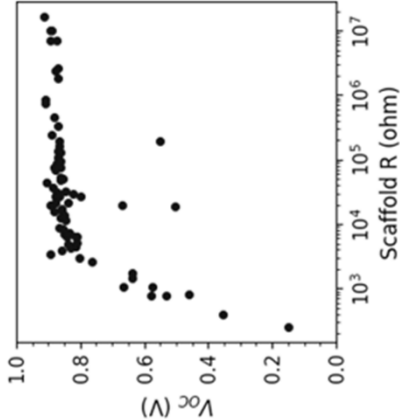
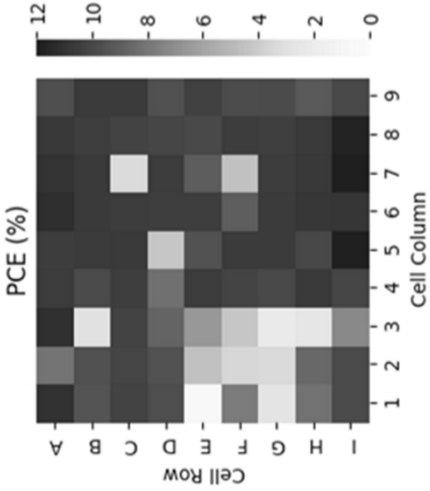


FIG. 16E

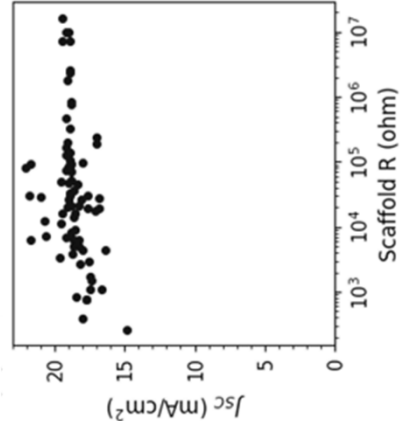


FIG. 16F

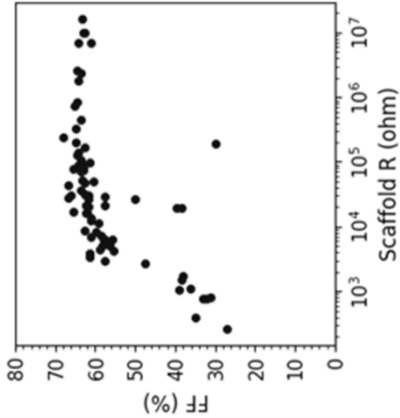


FIG. 16G

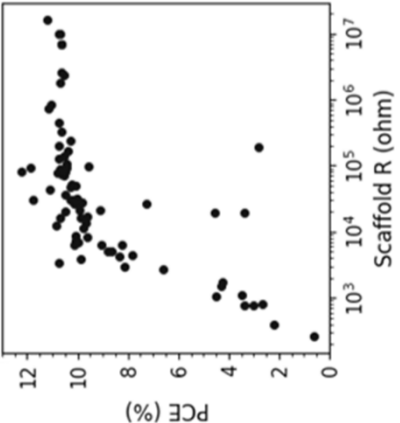


FIG. 16H

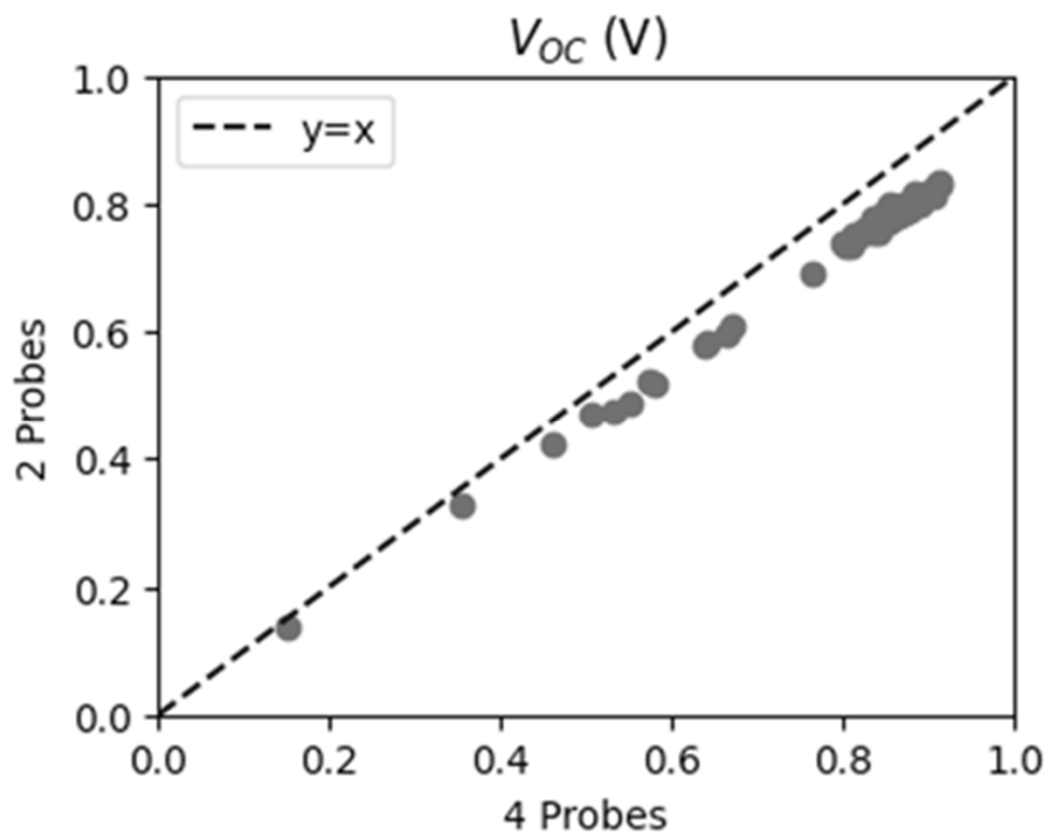


FIG. 17A

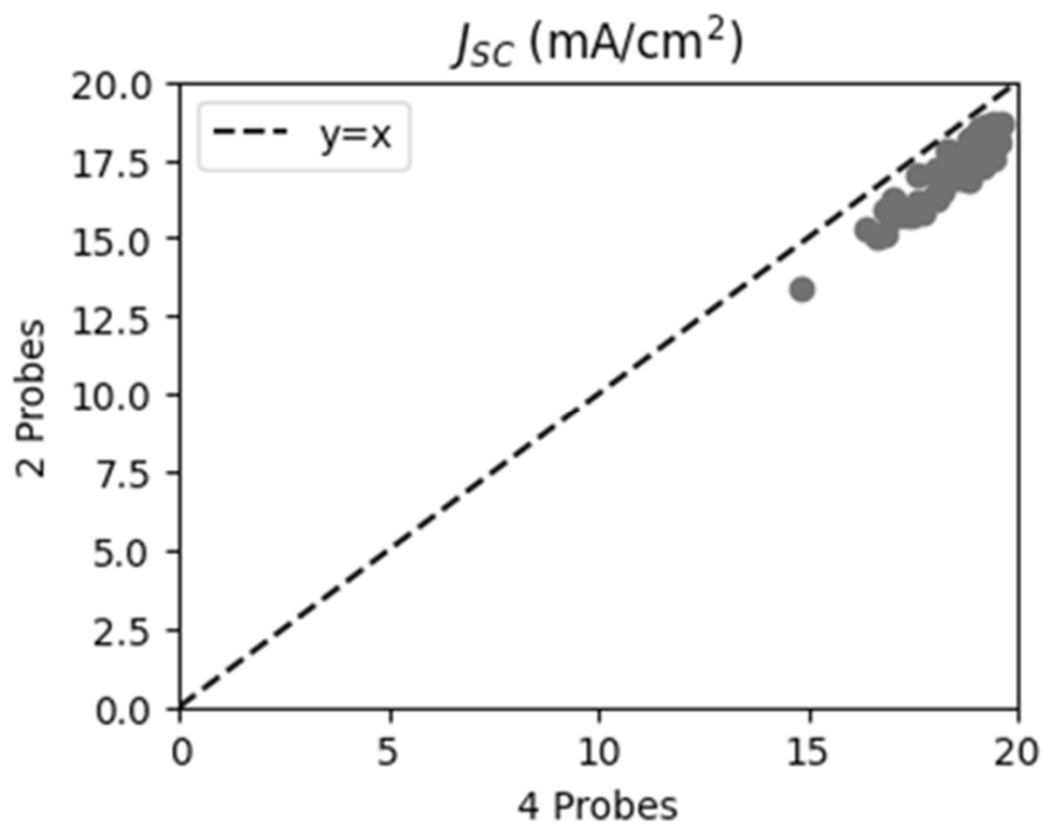


FIG. 17B

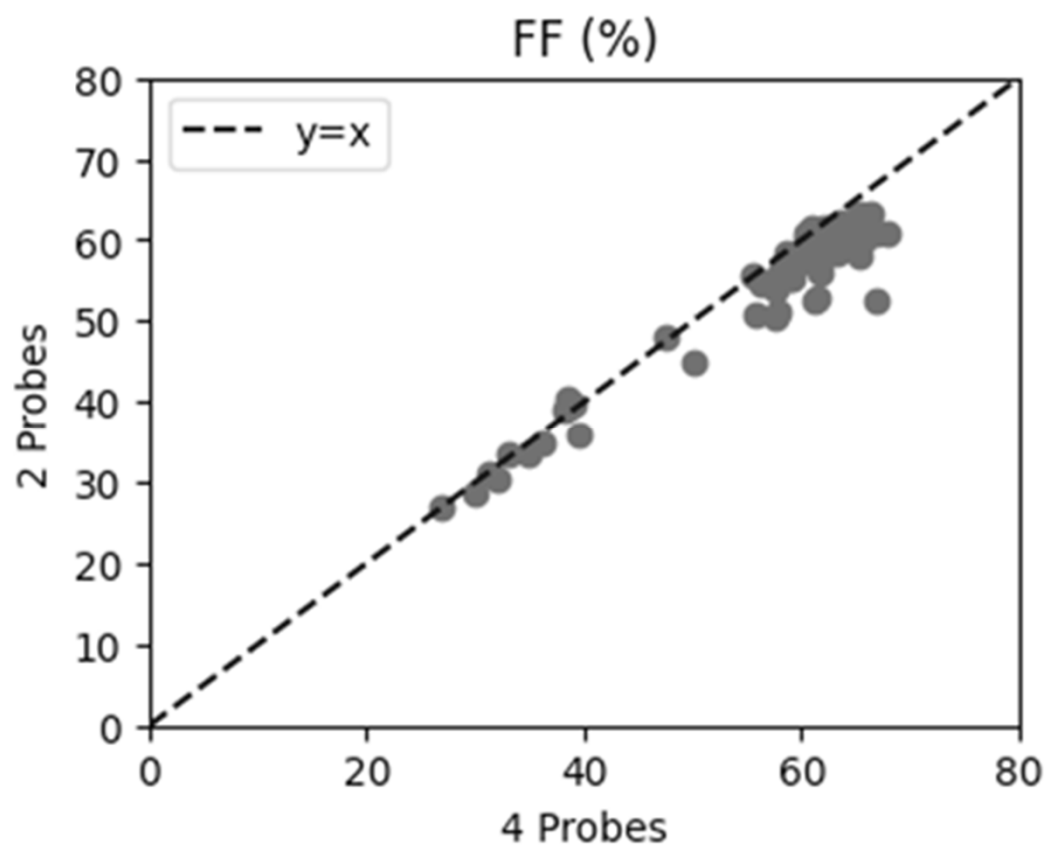


FIG. 17C

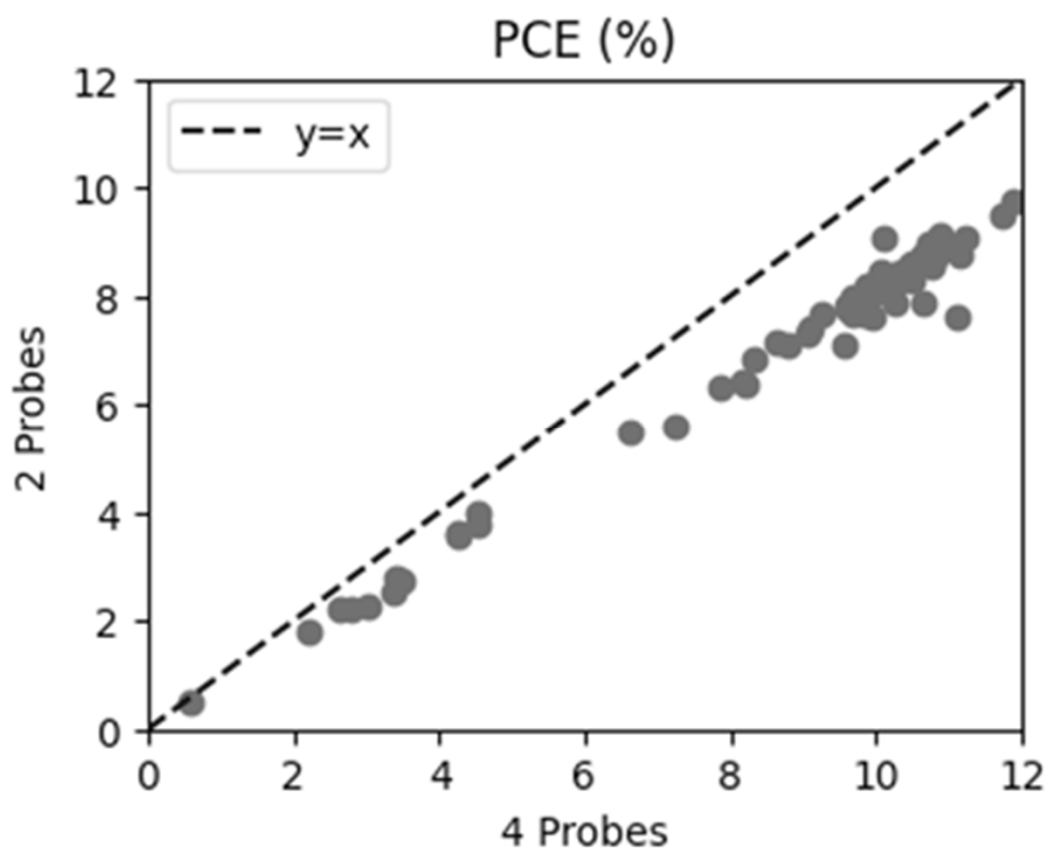


FIG. 17D

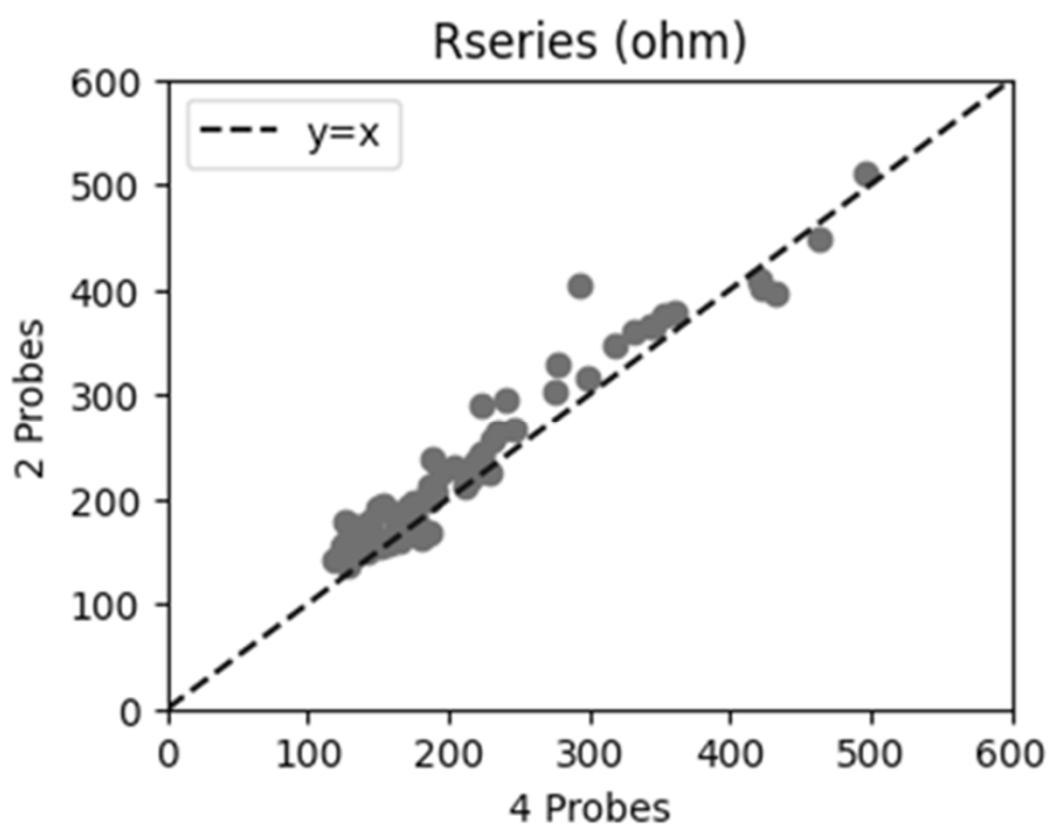


FIG. 17E

Table 5 : Data spread extracted from boxplot of solar cell parameters acquired by this platform and manual measurement from reference.

Range (box plot)	V_{oc} (V)	J_{sc} (mA/cm ²)	FF (%)	PCE (%)
This platform	0.04	0.6	4.8	0.9
Manual (ref)	0.13	3.9	17	4.1

FIG. 21

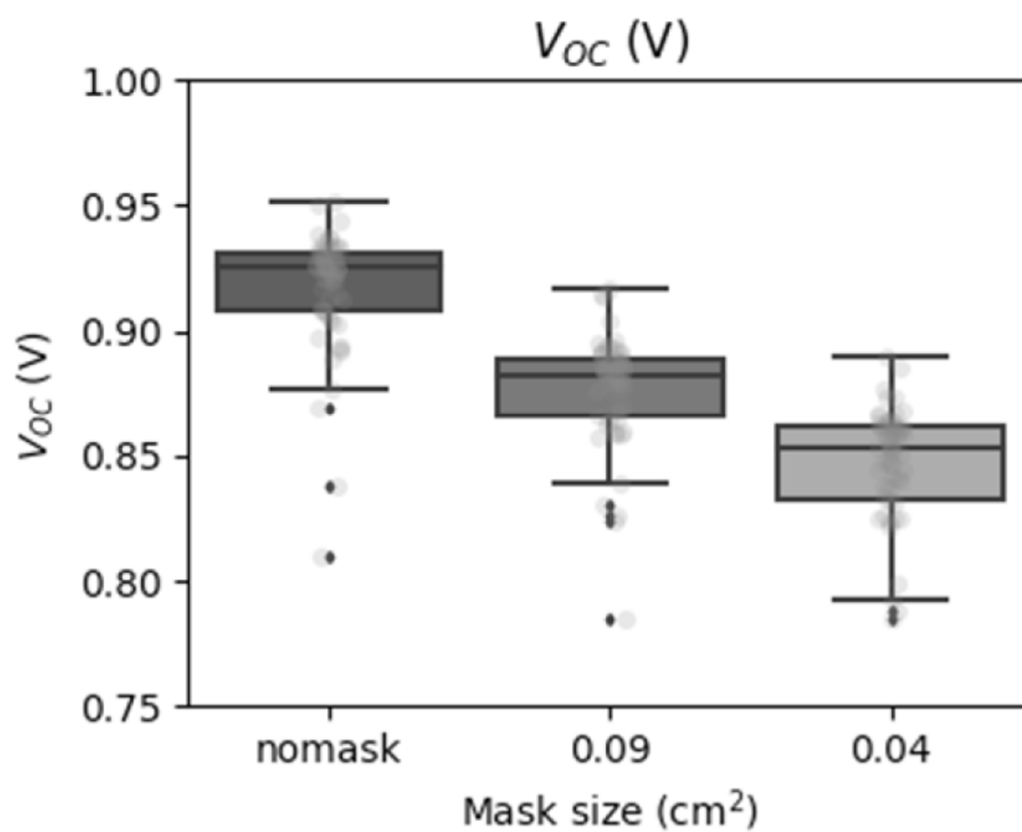


FIG. 18A

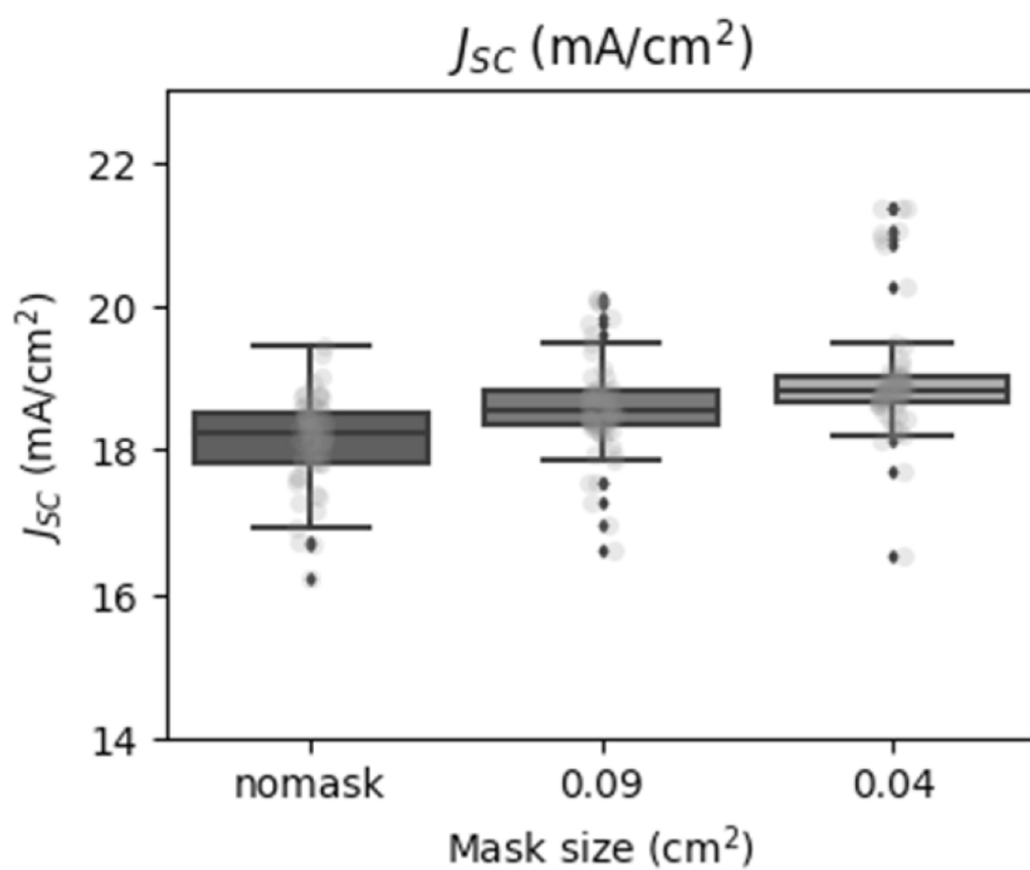


FIG. 18B

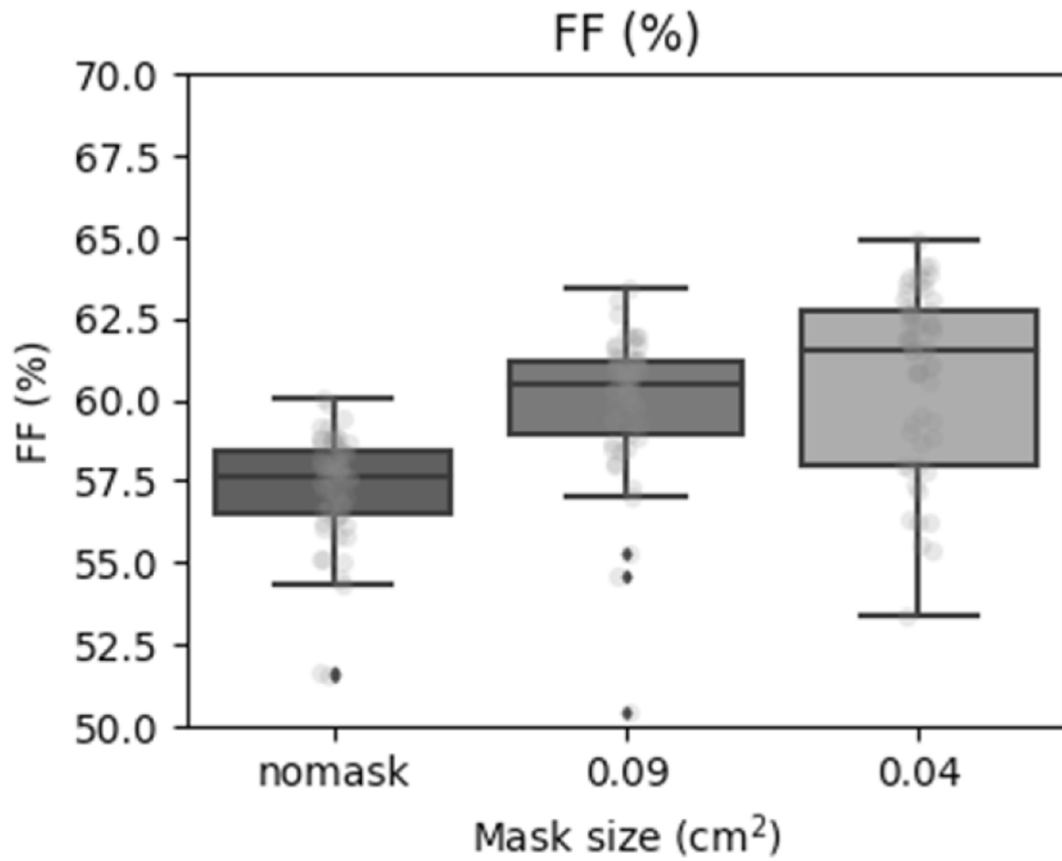


FIG. 18C

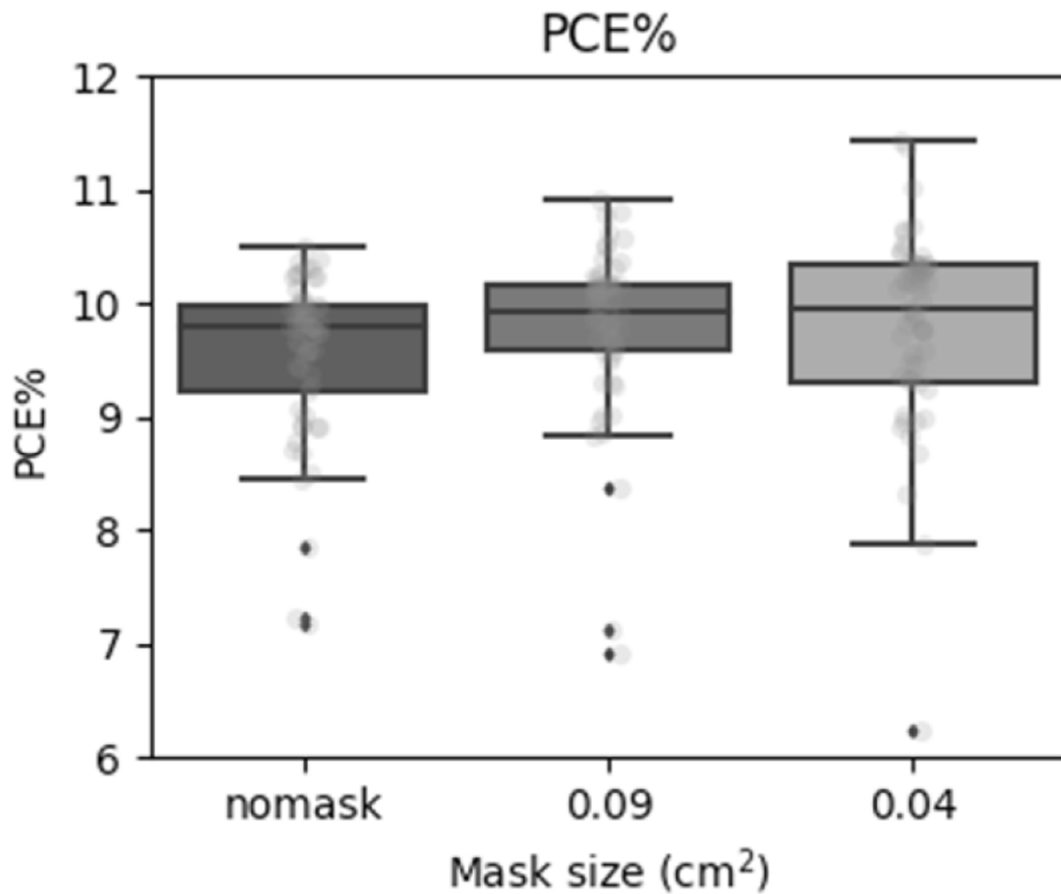


FIG. 18D

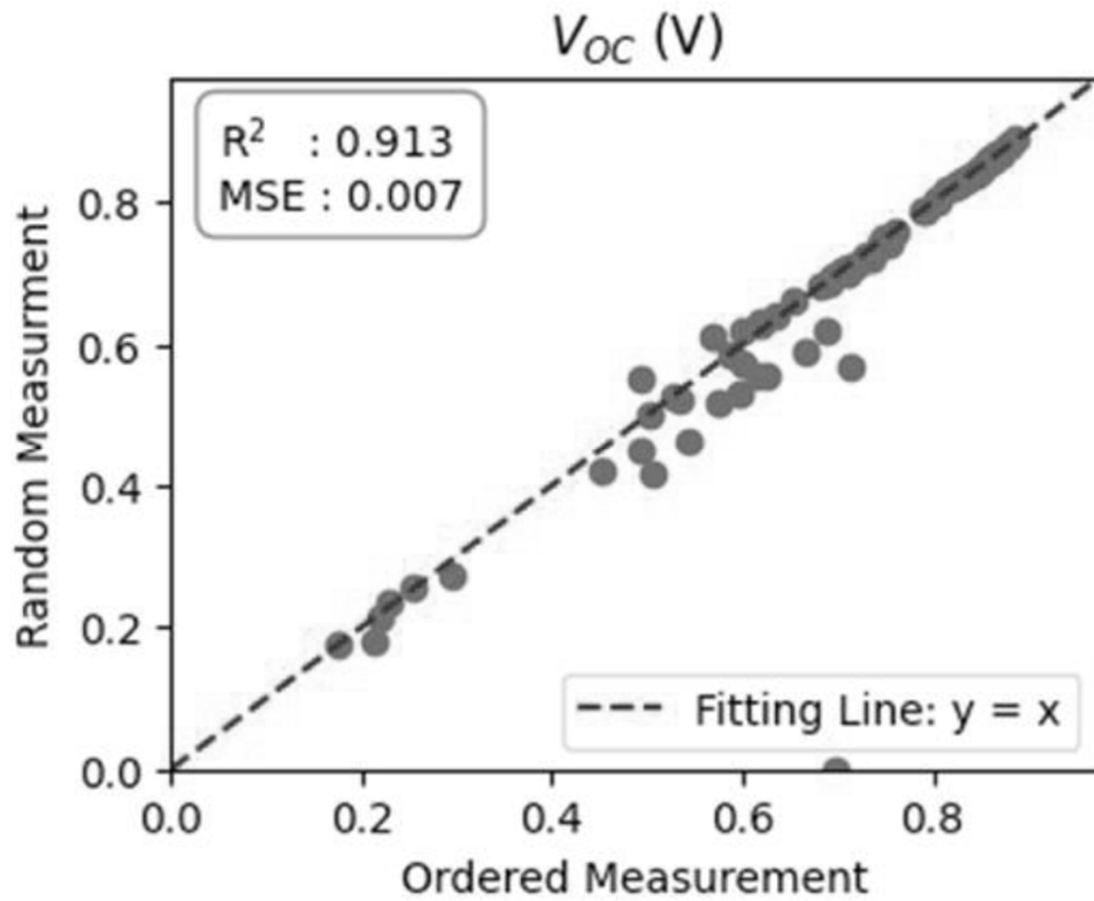


FIG. 19A

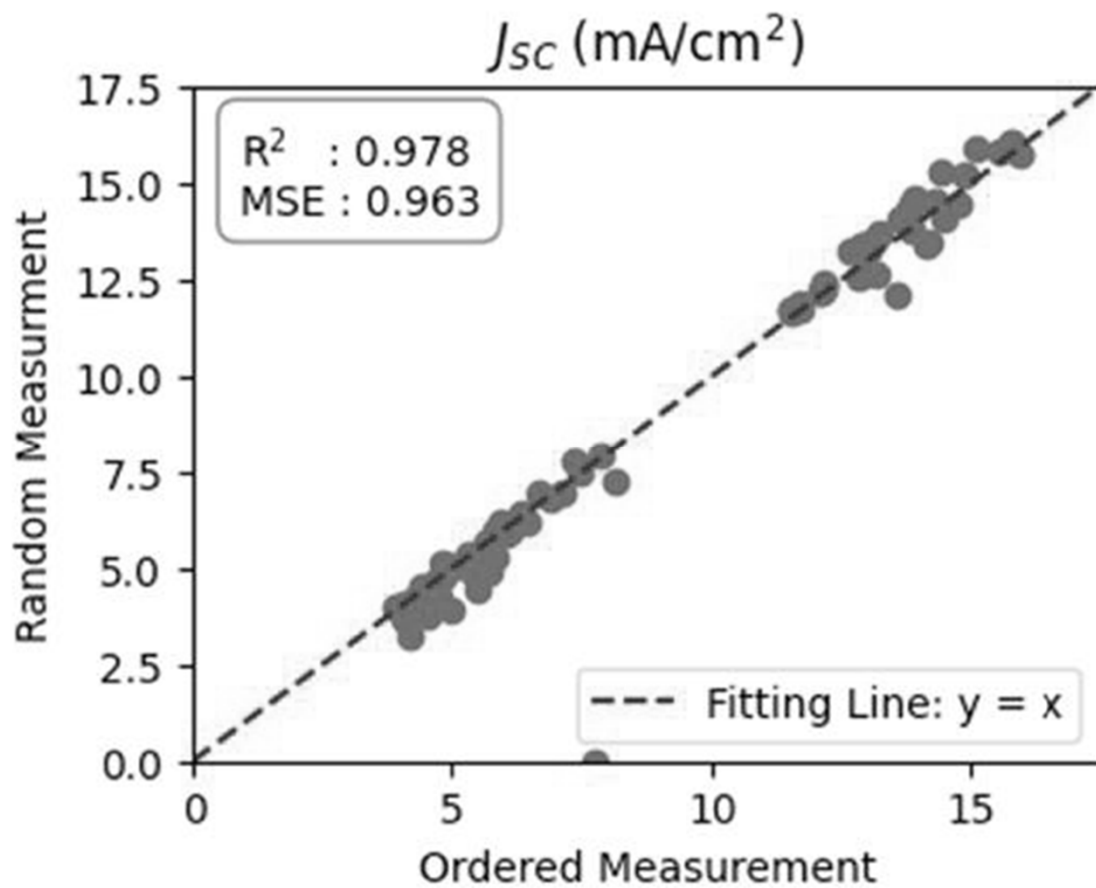


FIG. 19B

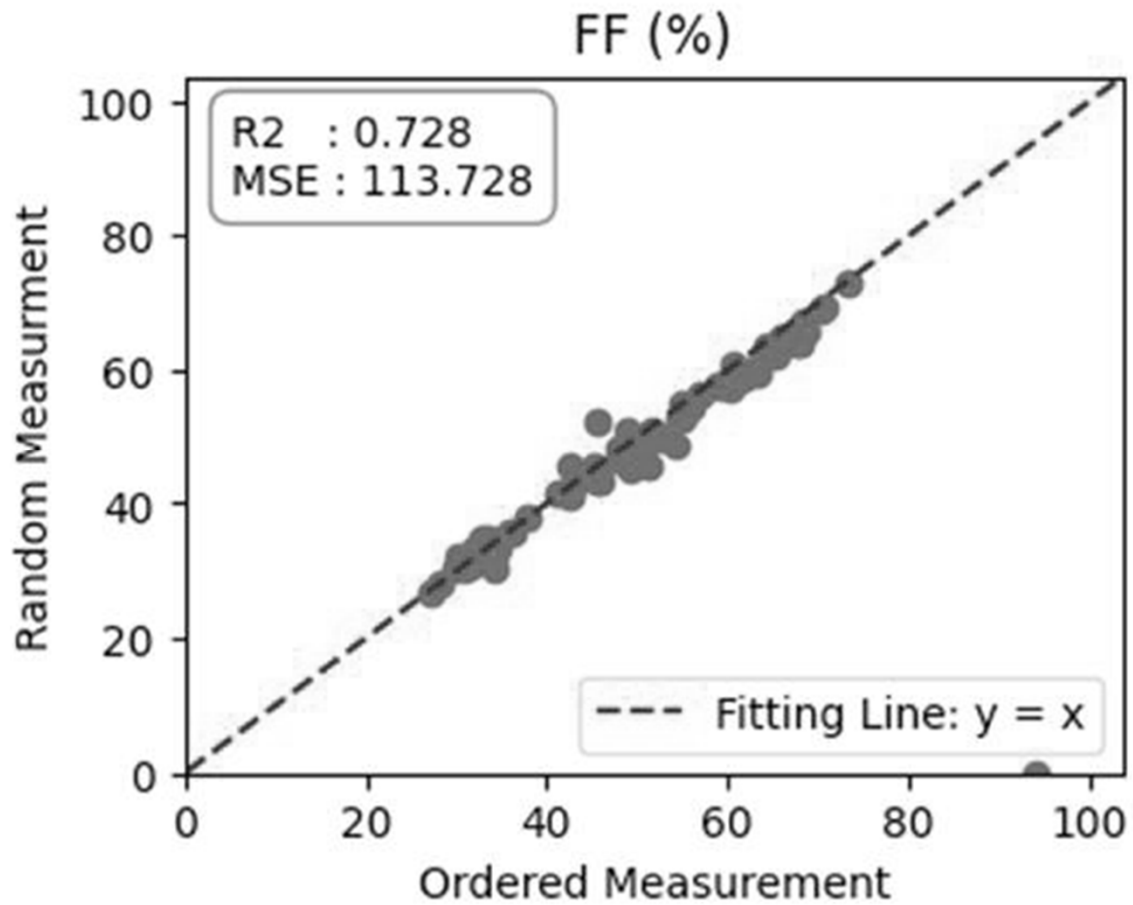


FIG. 19C

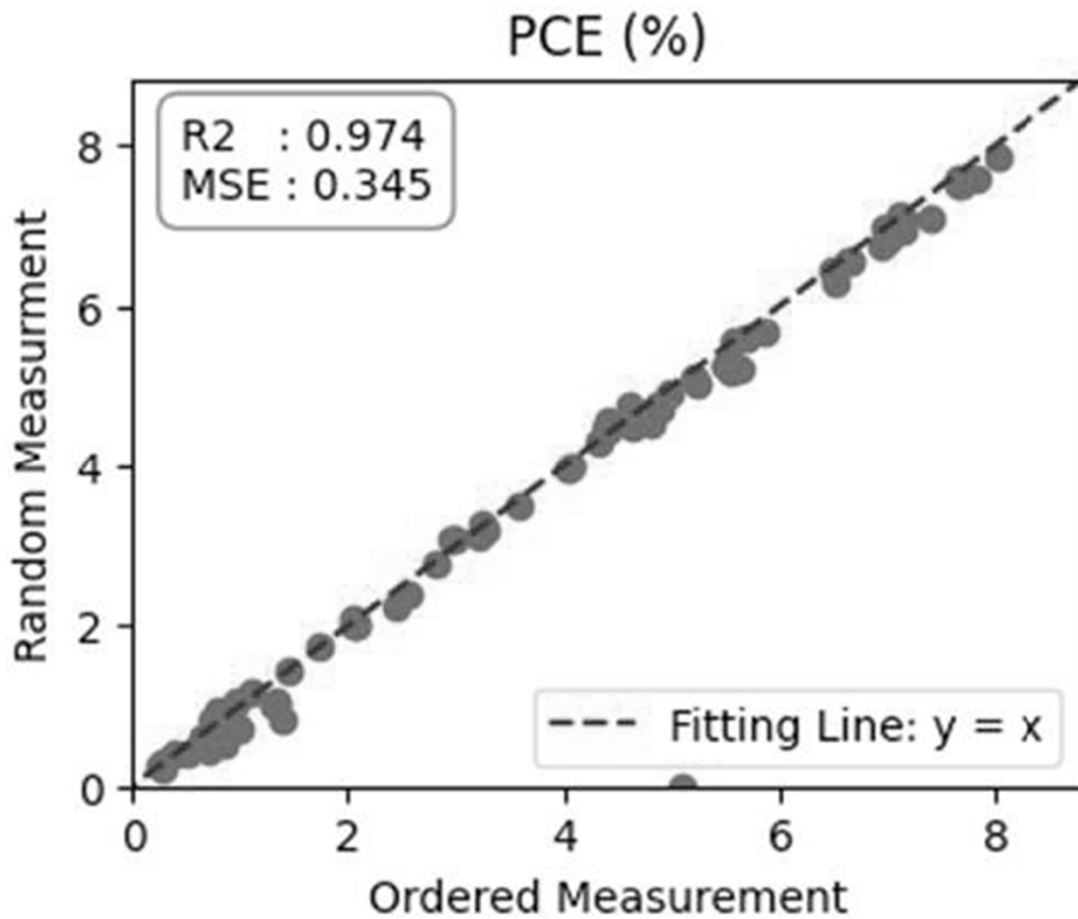


FIG. 19D

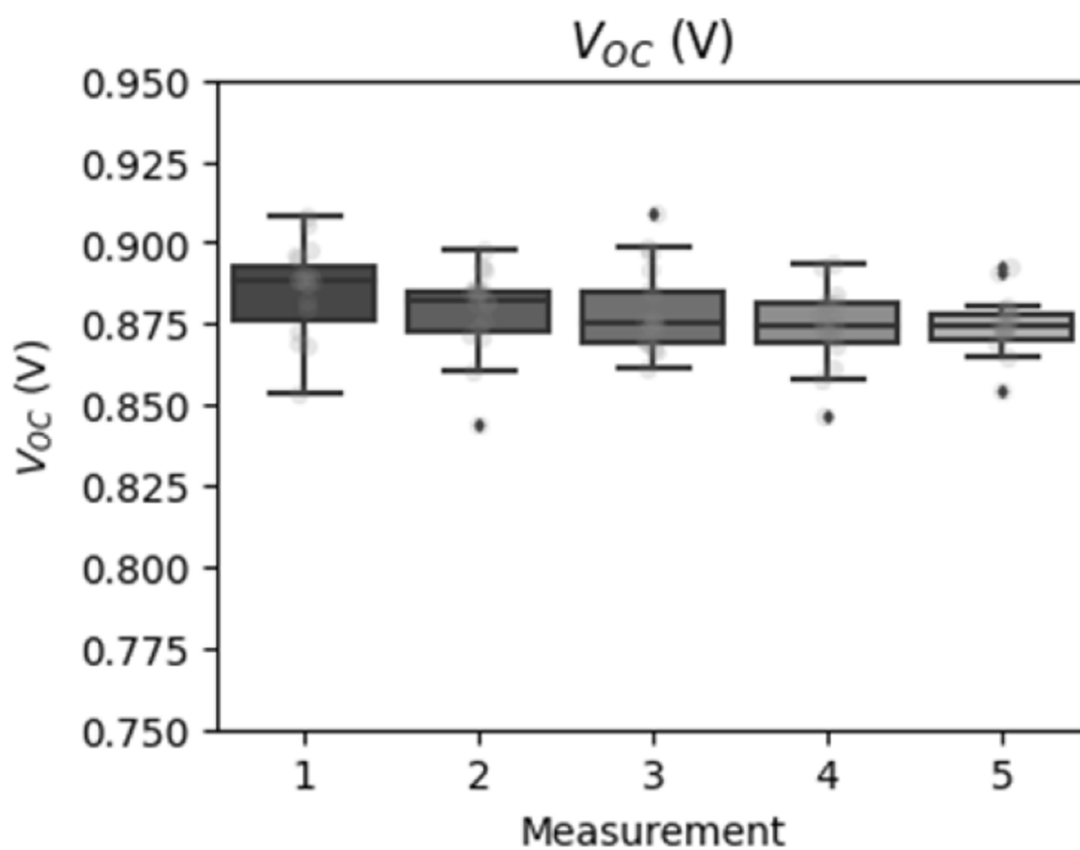


FIG. 20A

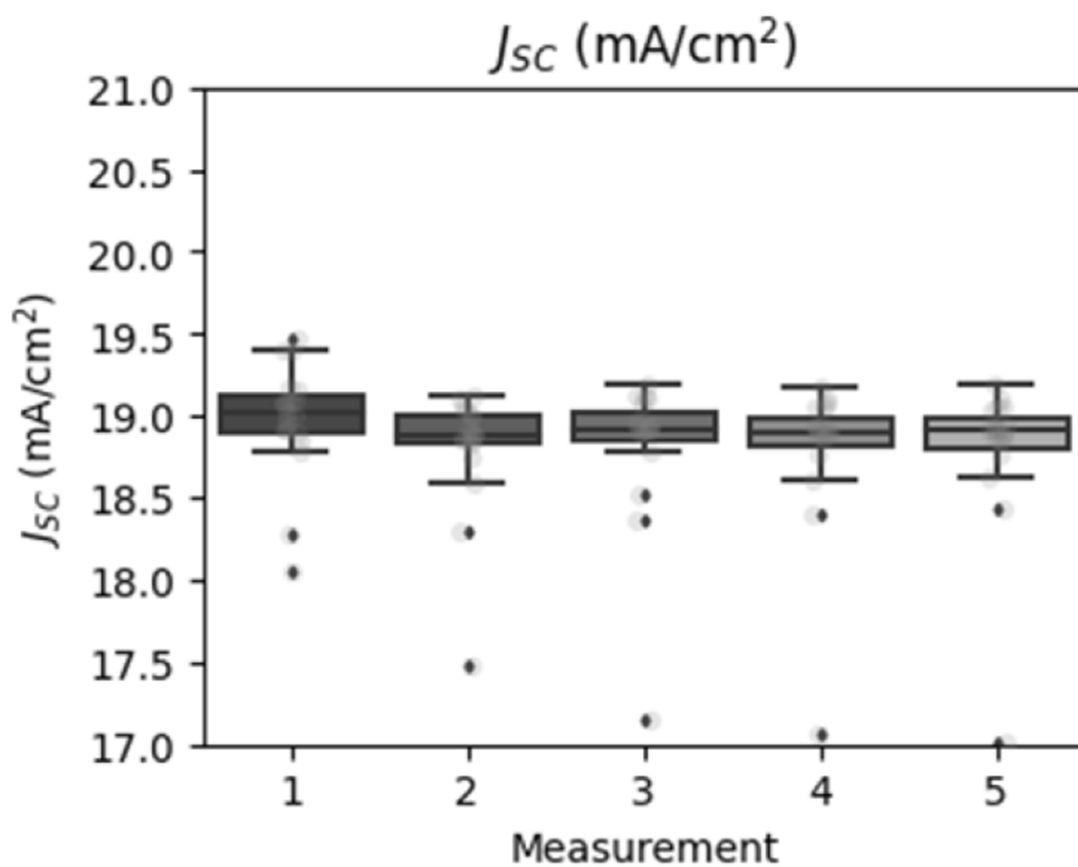


FIG. 20B

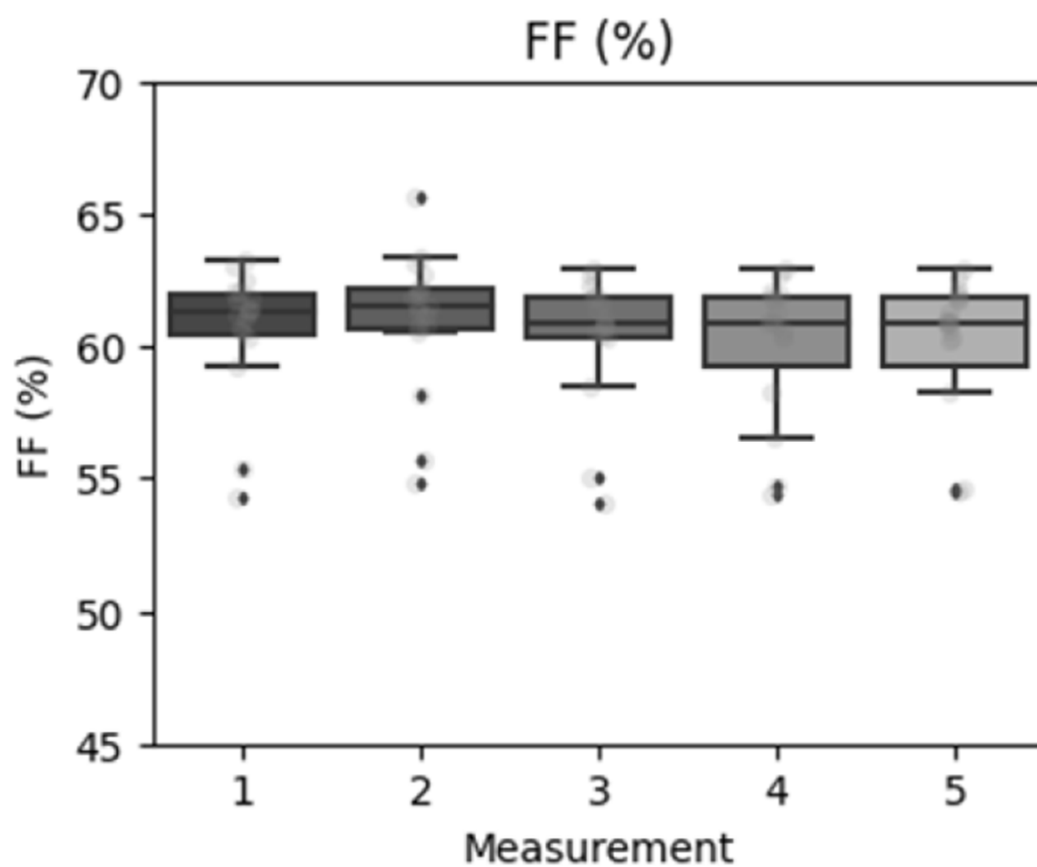


FIG. 20C

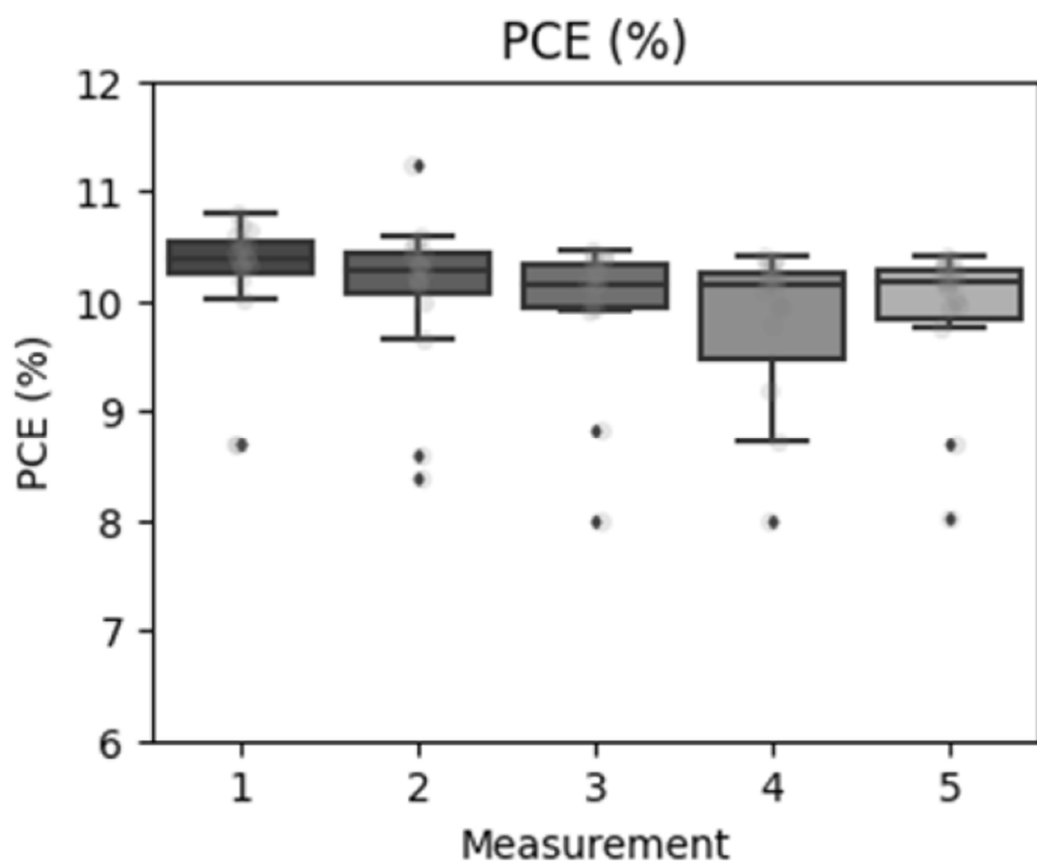


FIG. 20D

Table 6 : Device fabrication speed comparison between high-throughput device fabrication in this work and standard spin-coating procedure.

No	High-throughput device fabrication (This work)		Spin coating method	
	Process	Time (min)	Process	Time (min)
1	Substrate cleaning (8 substrate at once)	90	Substrate cleaning (648 cells at once)	90
2	Scaffold printing processes (4 layer scaffolds $\times$ 5 min $\times$ 8 substrate)	160	Spin coating processes of the electron transport layer, perovskite, hole transport layer. (3 layers $\times$ 3 min $\times$ 648)	5832
3	Annealing process and cool down (4 layer scaffold $\times$ 200 min)	800	Annealing process and cool down for each layers. Suppose 648 cells at once. (3 layers $\times$ 60 min)	180
4	Mixing and drop casting of 648 distinctive formula using robot. (8 substrates $\times$ 15 min)	120	Manual mixing of 648 distinctive formula (1 min $\times$ 648 formula)	648
5	Perovskite annealing. 8 substrate at once (120 min)	120	Electrode evaporation, 4 cells per evaporation (162 batch $\times$ 30 min)	4860
Total time (min)		1,290	Total time (min)	11,610
Fabrication speed (device/hour)		30.14	Fabrication speed (device/hour)	3.35

FIG. 22A

Table 7 : Device characterization speed comparison between developed high-throughput device characterization in this work and manual characterization.

No	High-throughput characterization (This work)		Manual characterization	
	Process	Time (min)	Process	Time (min)
1	Preparation includes installing a mask, putting sample on the sample holder, and adjusting position. (8 substrates $\times$ 3 min)	24	Preparation includes installing a mask, electrodes clipping, and adjusting position (648 cells $\times$ 3 min)	1944
2	Measurement: One button click, autonomous movement and reverse-forward sweep (8 substrates $\times$ 27 min)	216	Measurement: Manually inputting parameters, conducting reverse-forward sweep (648 cells $\times$ 1 min)	648
Total time (min)		240	Total time (min)	2592
Measurement speed (cells/hour)		162	Measurement speed (cells/hour)	15

FIG. 22B