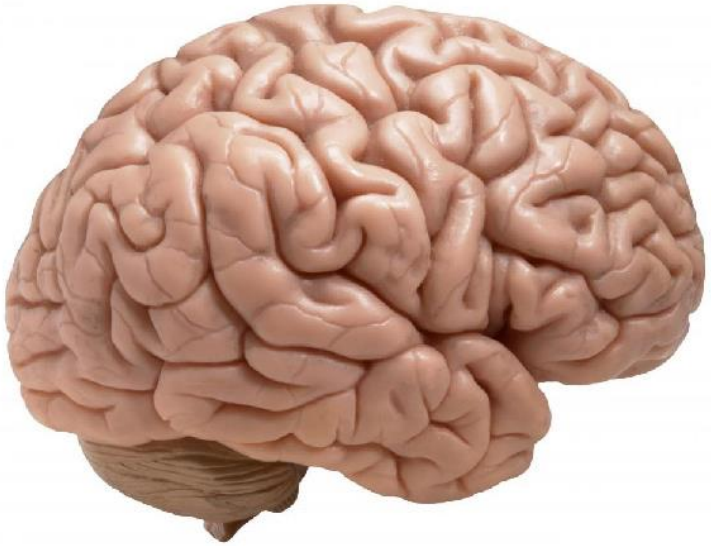
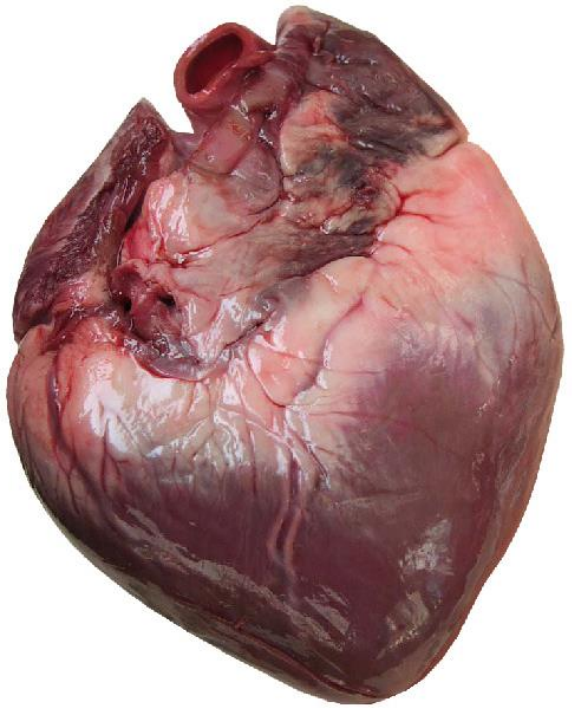
CMOS electronics probe inside biological cellular networks (1st generation device)

Donhee Ham, Harvard University

Electrogenic cellular networks



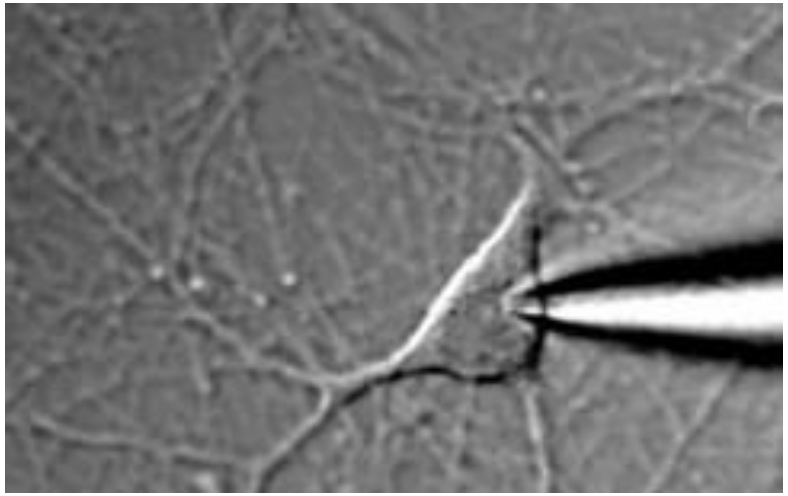


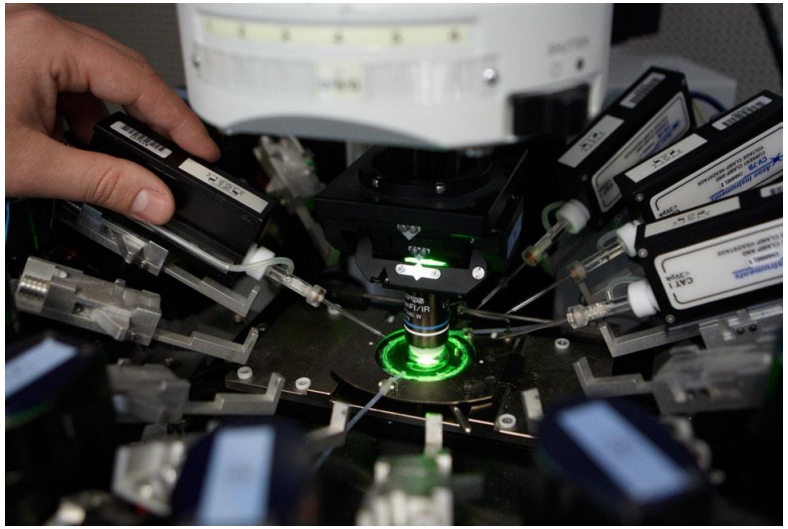
~10^{11} neurons
~10^{15} synapses

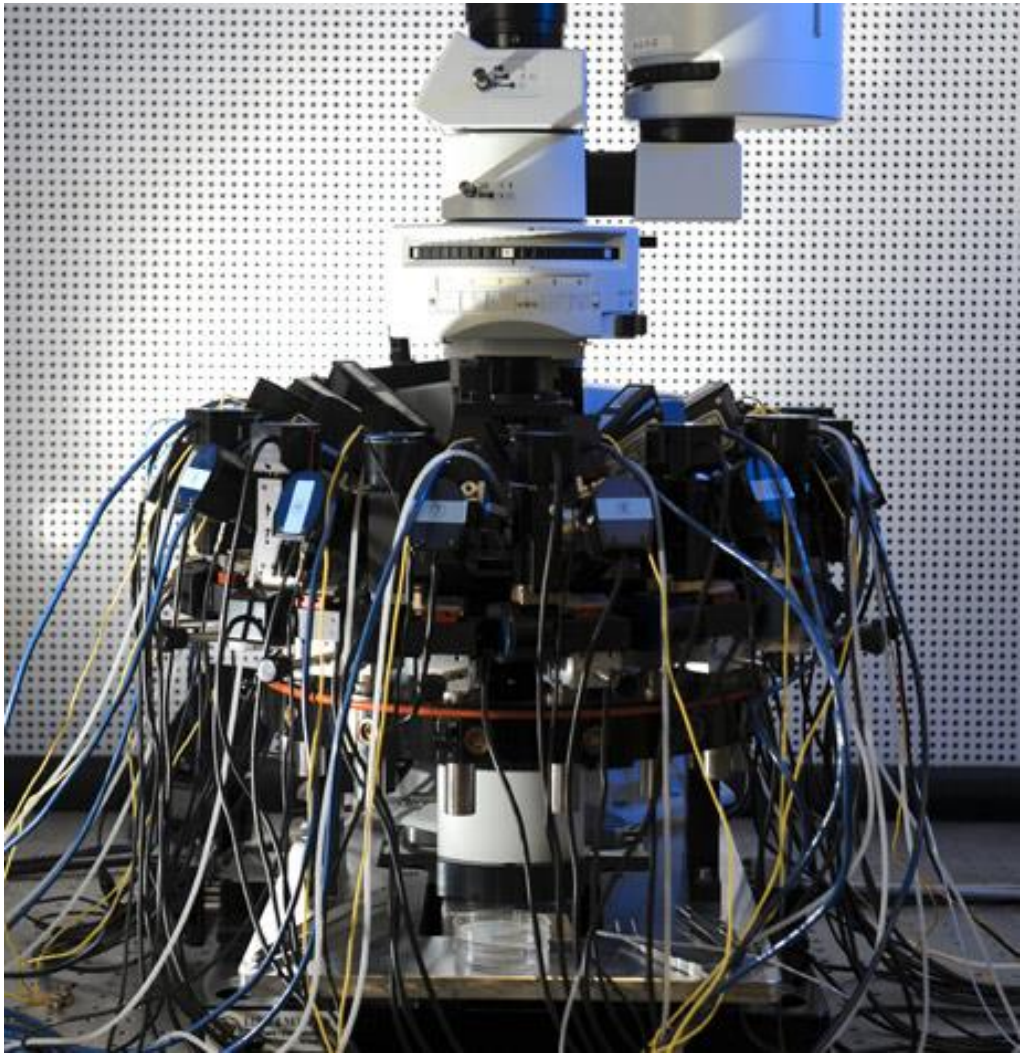
~10^{9} cardiomyocytes
~10^{10} cell-cell connections

Dichotomy —— intracellular vs. parallel

Patch pipette —— Intracellular, but not parallel

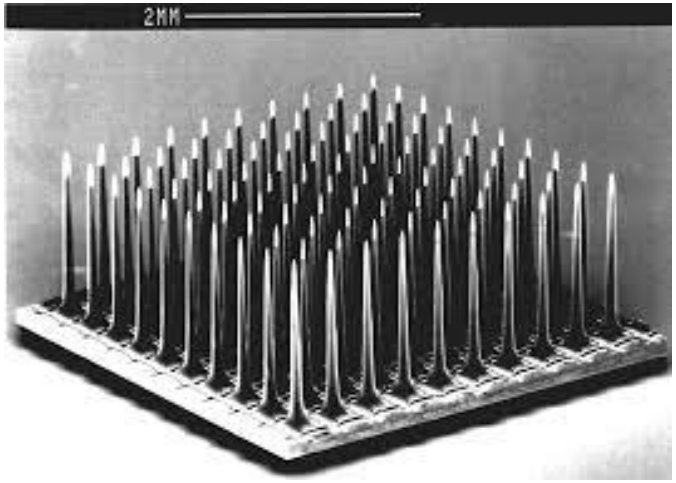


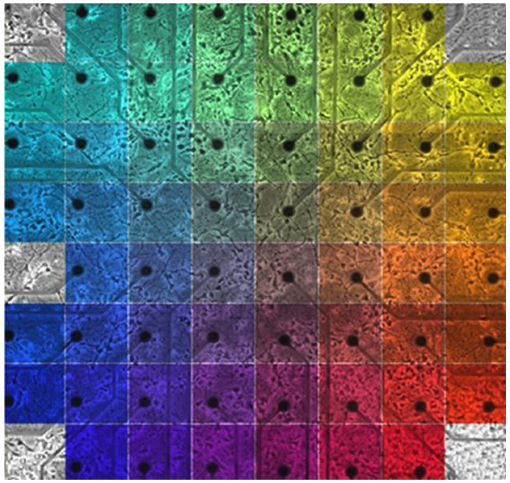


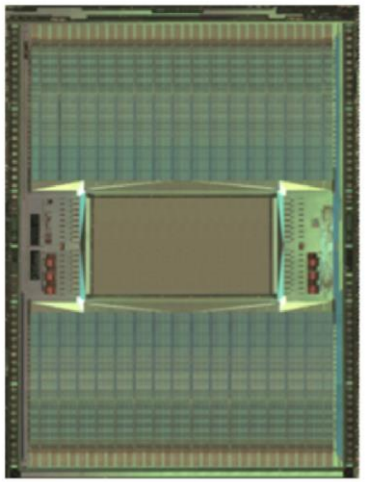


Dichotomy —— intracellular vs. parallel

Microelectrode array —— parallel, but not intracellular



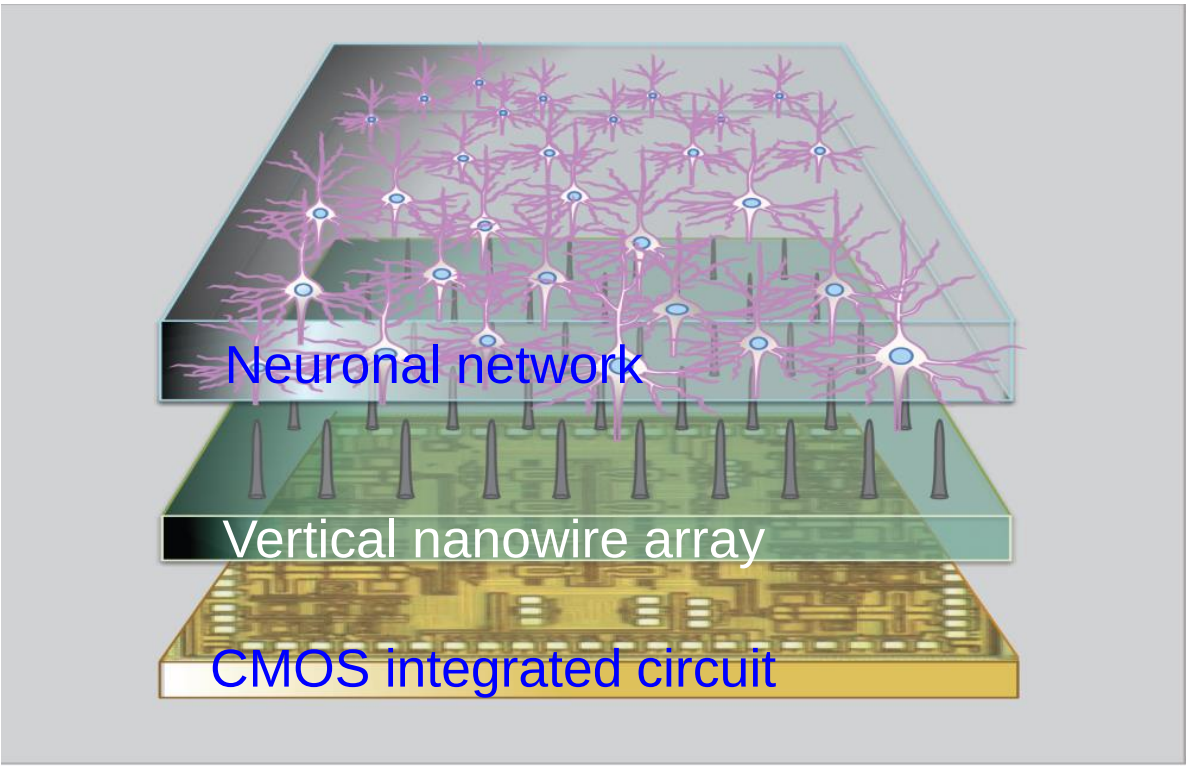


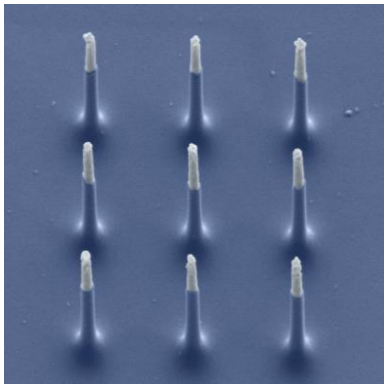


26,400 electrodes
1,024 channels

M. Ballini et al.,
IEEE JSSC (2014)

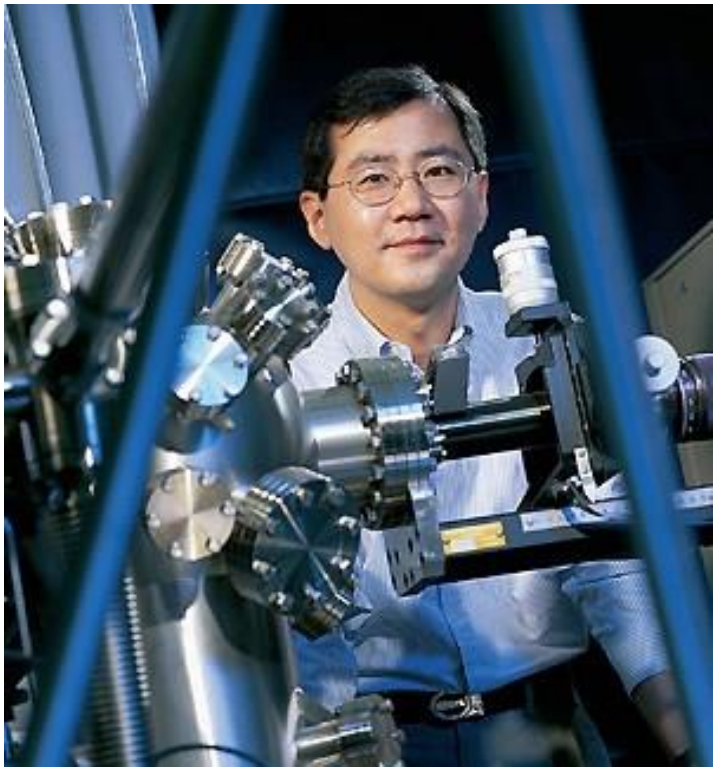
CMOS nanoelectrode array —— Intracellular + parallel





Vertical Nanowires

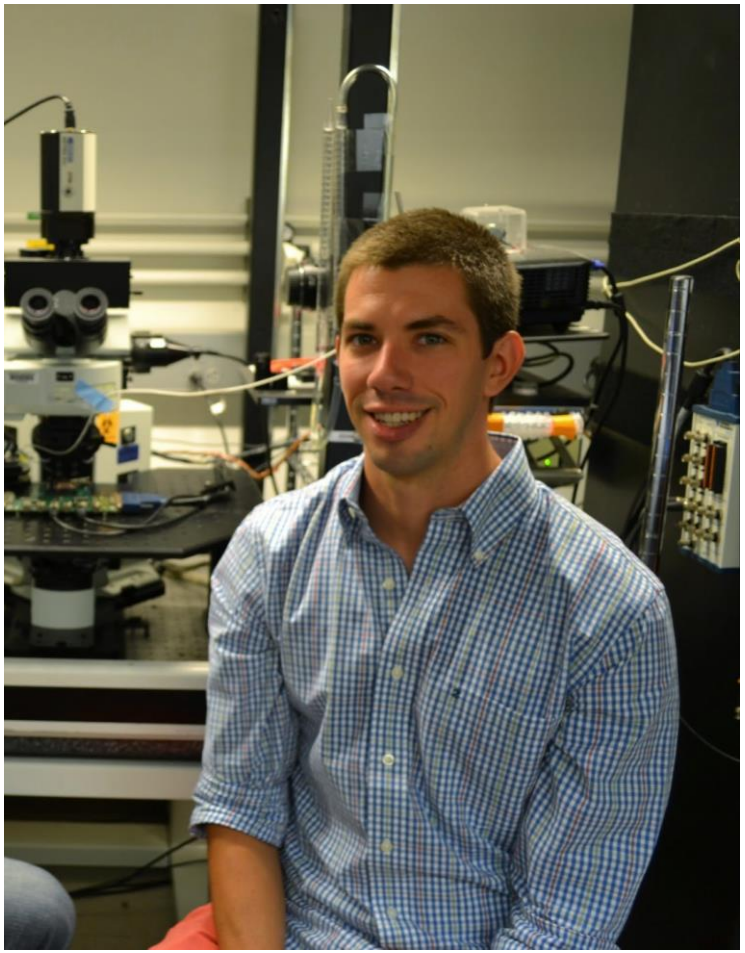
Park lab, *Nature Nano.* 7, 180 (2012).



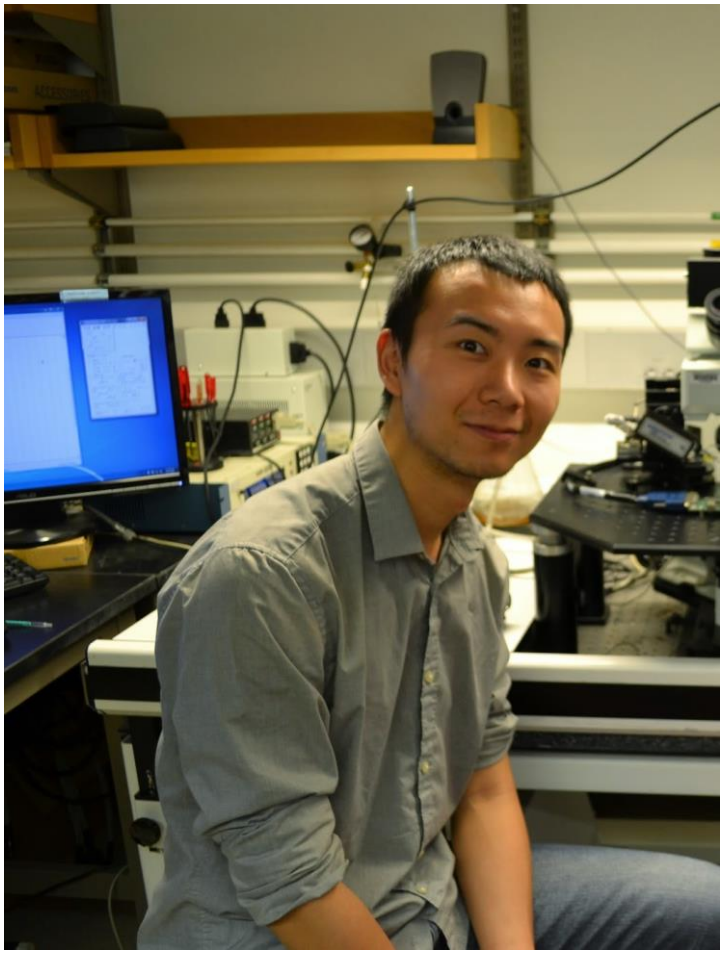
Prof. Hongkun Park
(Harvard Chemistry & Physics)

Nature Nanotechnology (2017)

CMOS nanoelectrode array —— Intracellular + parallel

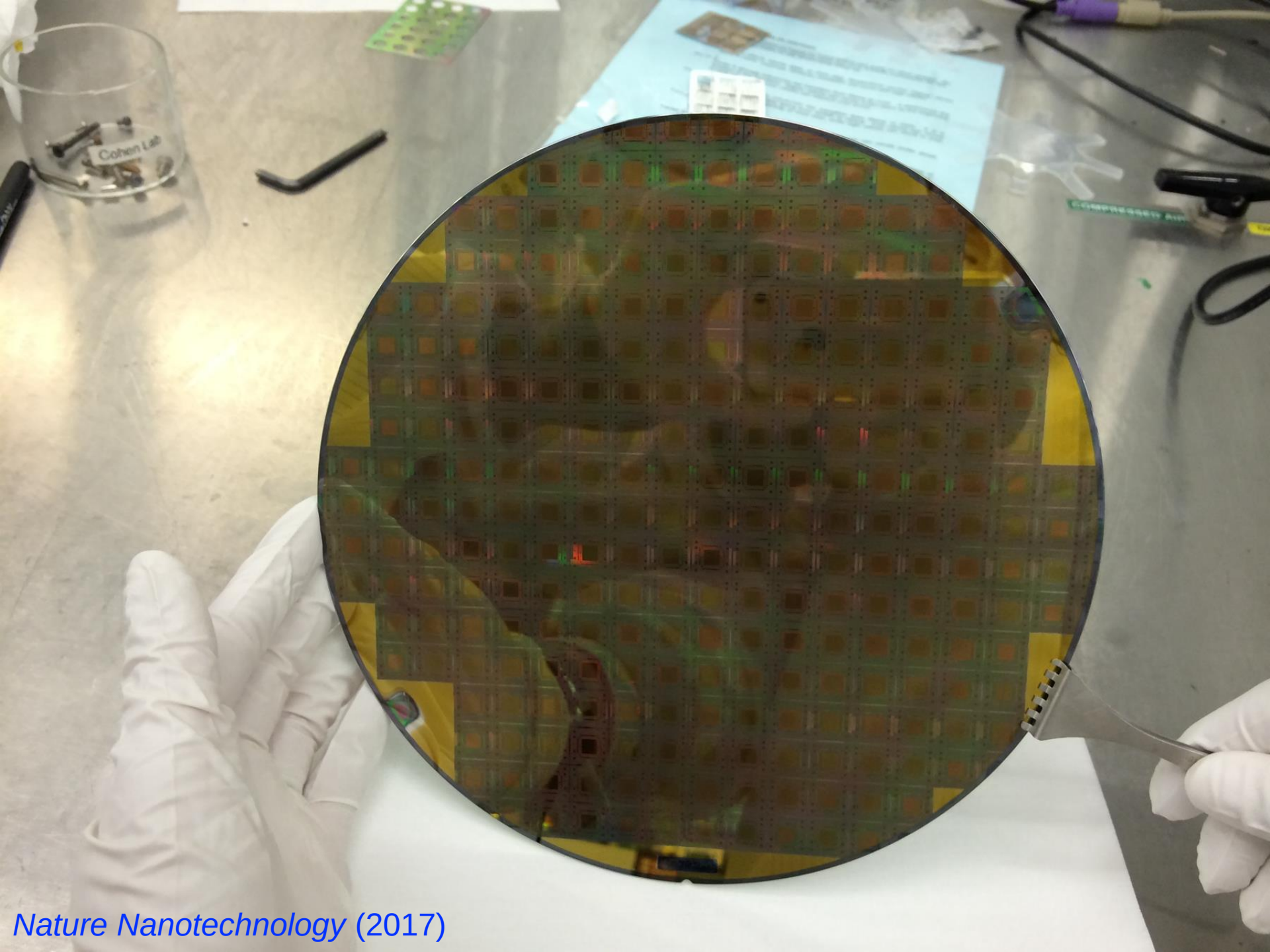


Jeffrey Abbott



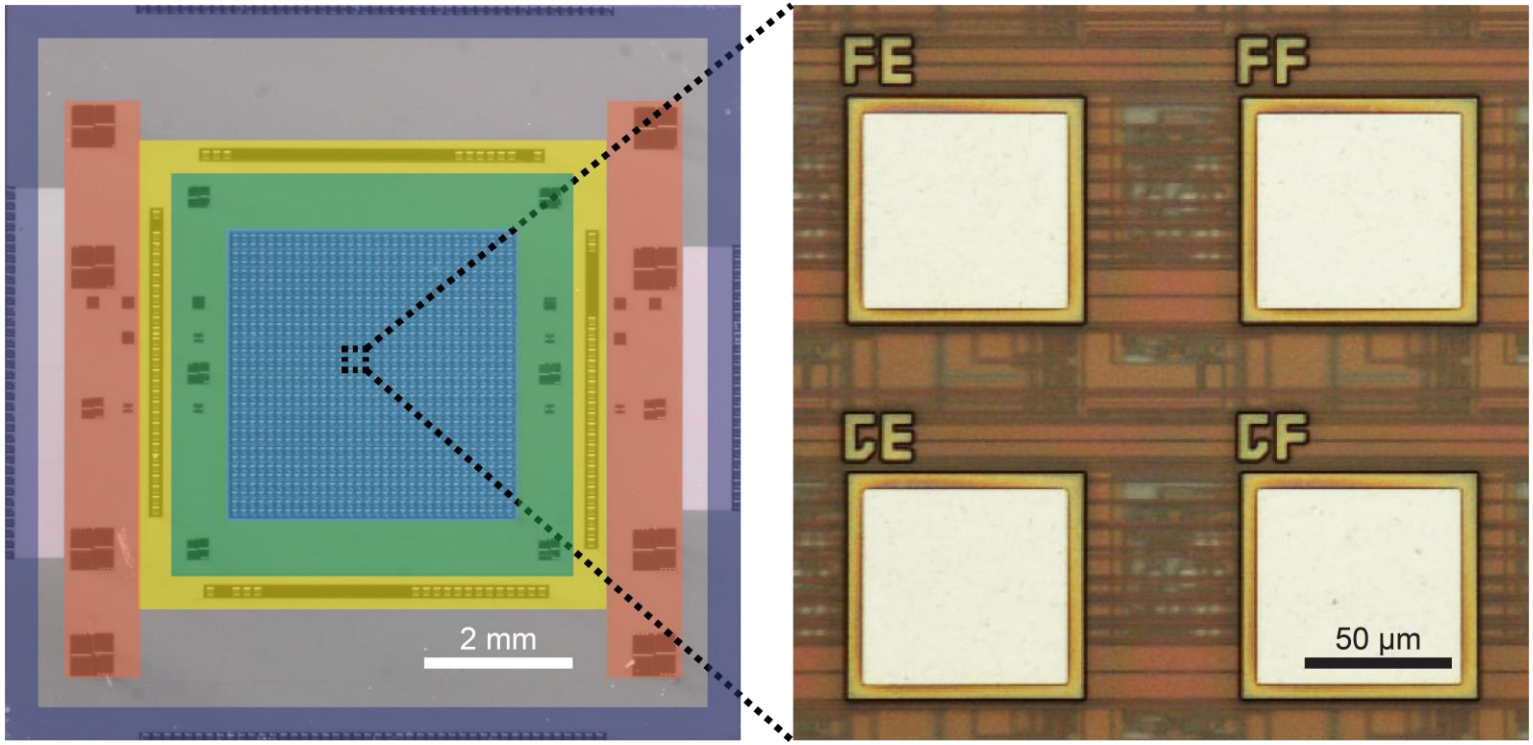
Tianyang Ye (Park lab)

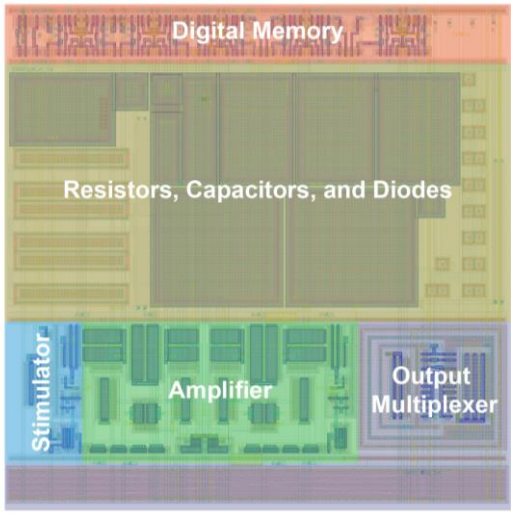
Nature Nanotechnology (2017)



Nature Nanotechnology (2017)

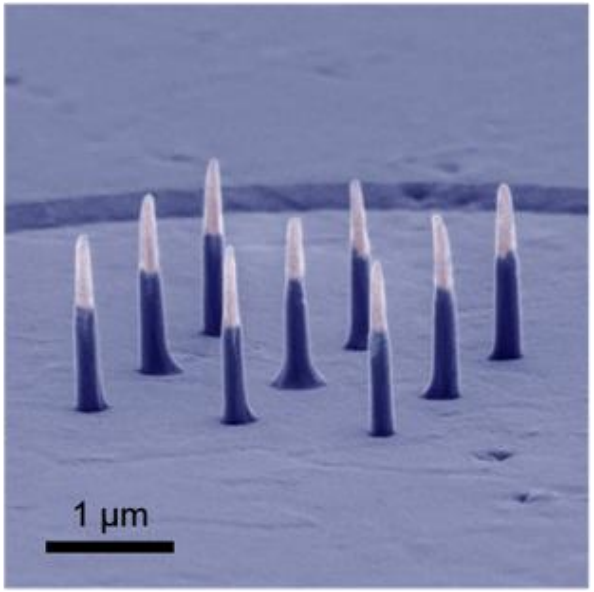
CMOS IC chip (1024 active site array)



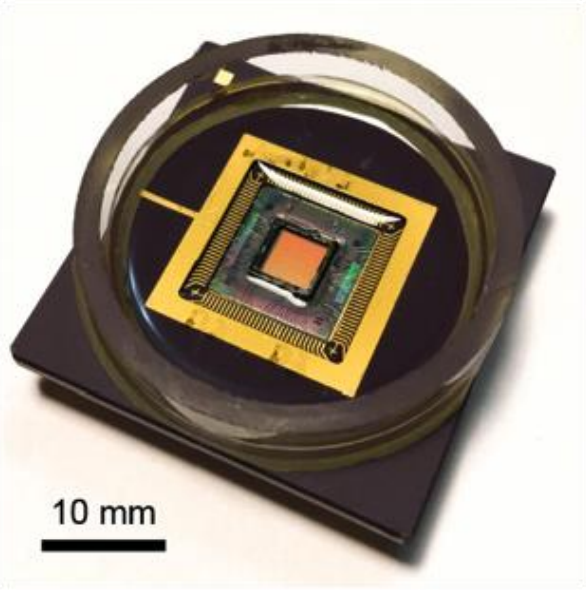


Nature Nanotechnology (2017)

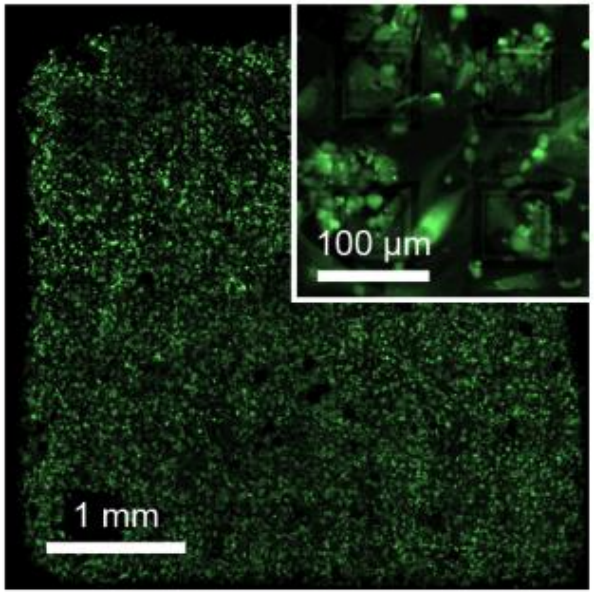
Vertical nanoelectrodes on the surface + packaging



9 nanoelectrodes
per pixel



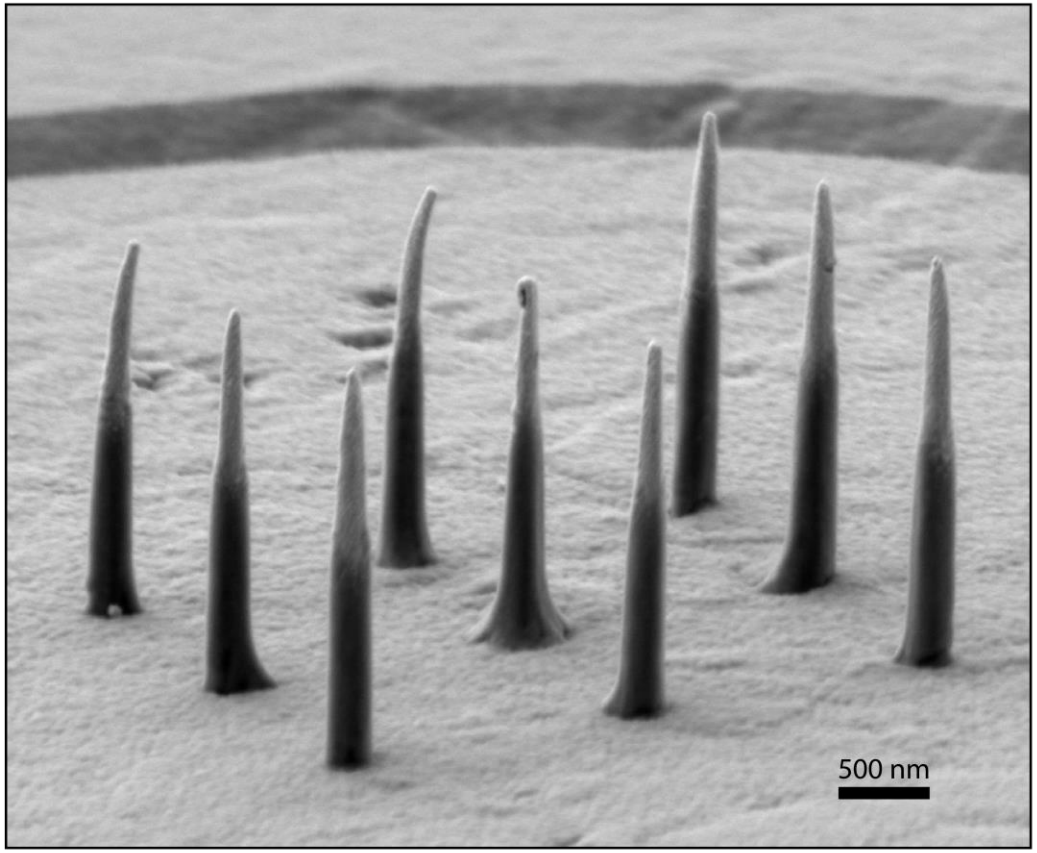
Packaged device

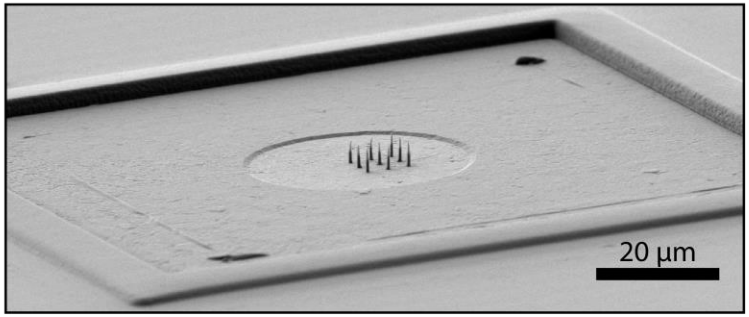


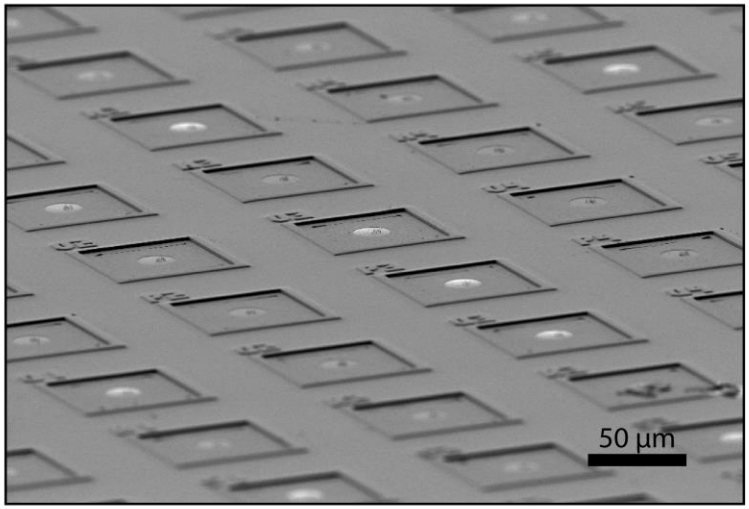
Cardiomyocyte tissue
in vitro cultured on top

Nature Nanotechnology (2017)

Vertical nanoelectrodes







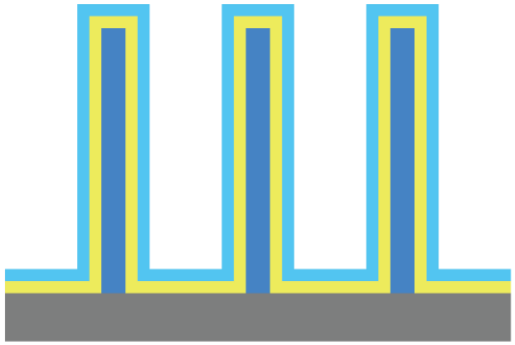
Nature Nanotechnology (2017)

Post fabrication steps

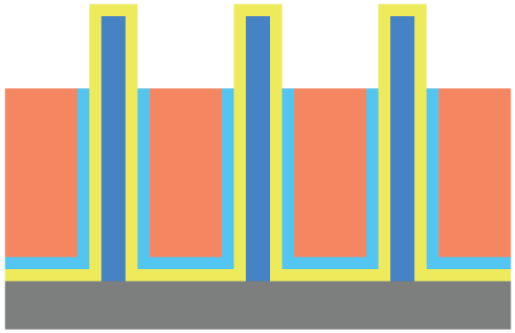
PECVD SiO_2 on Al pad

Stepper lithography and dry etch to form SiO_2 pillar

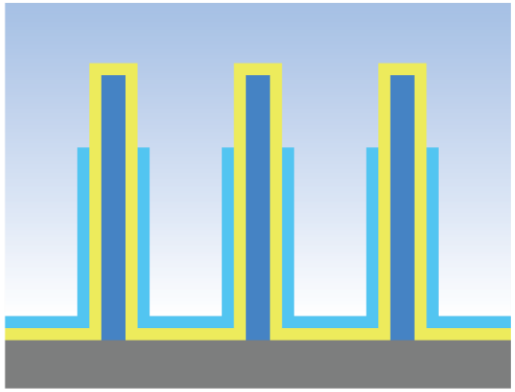
Wet etch pillar into SiO_2 wires



Sputter metal coating; insulate with ALD SiO_2



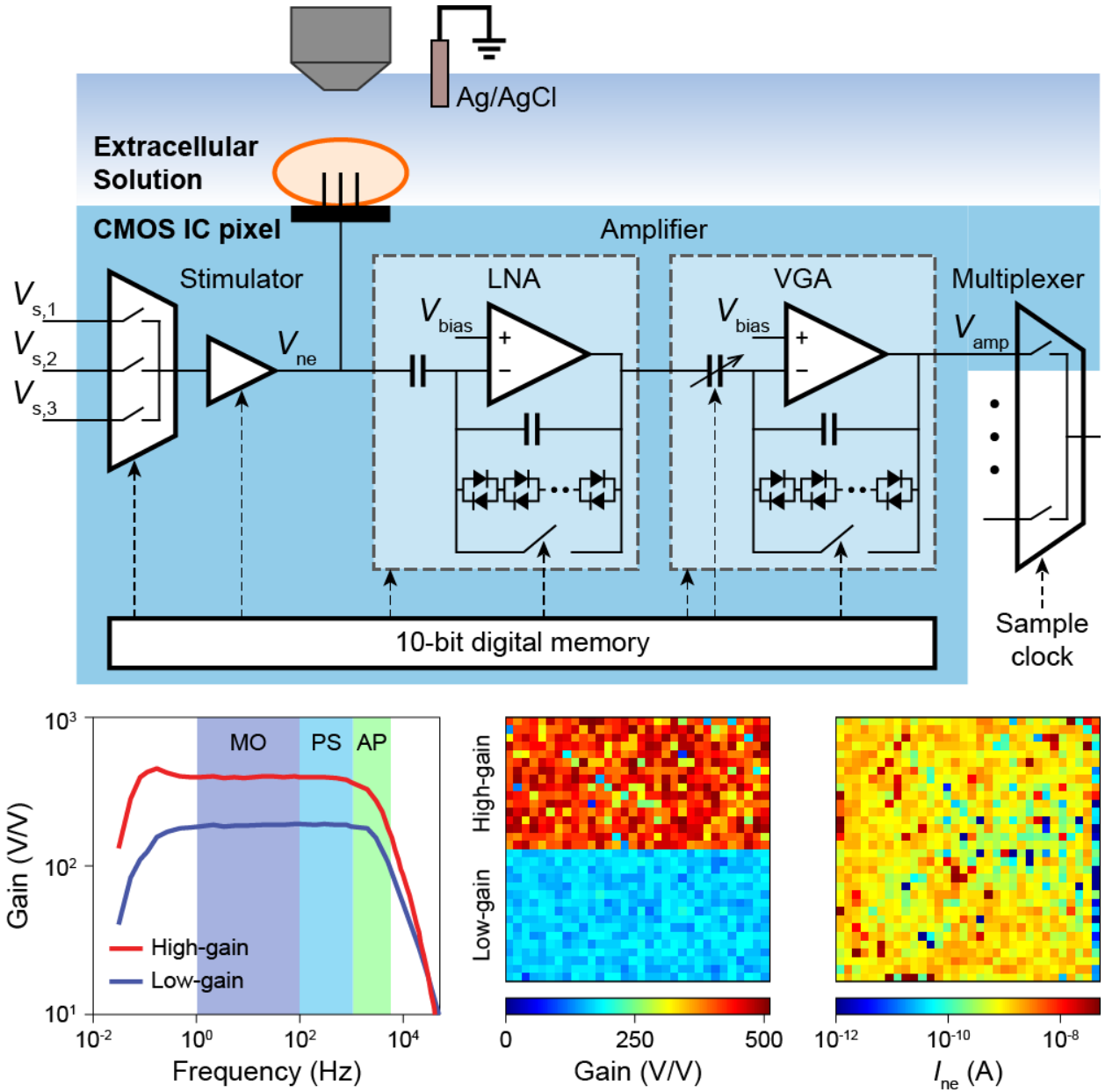
Spincoat resist; wet etch nanowire tip



Ready for cell experiment in solution

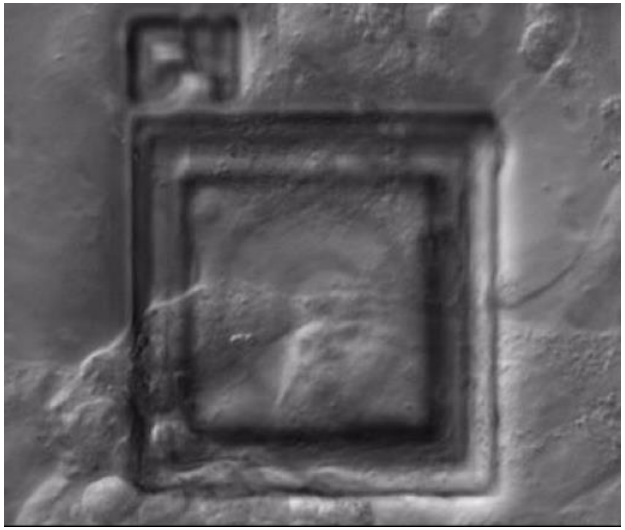
Nature Nanotechnology (2017)

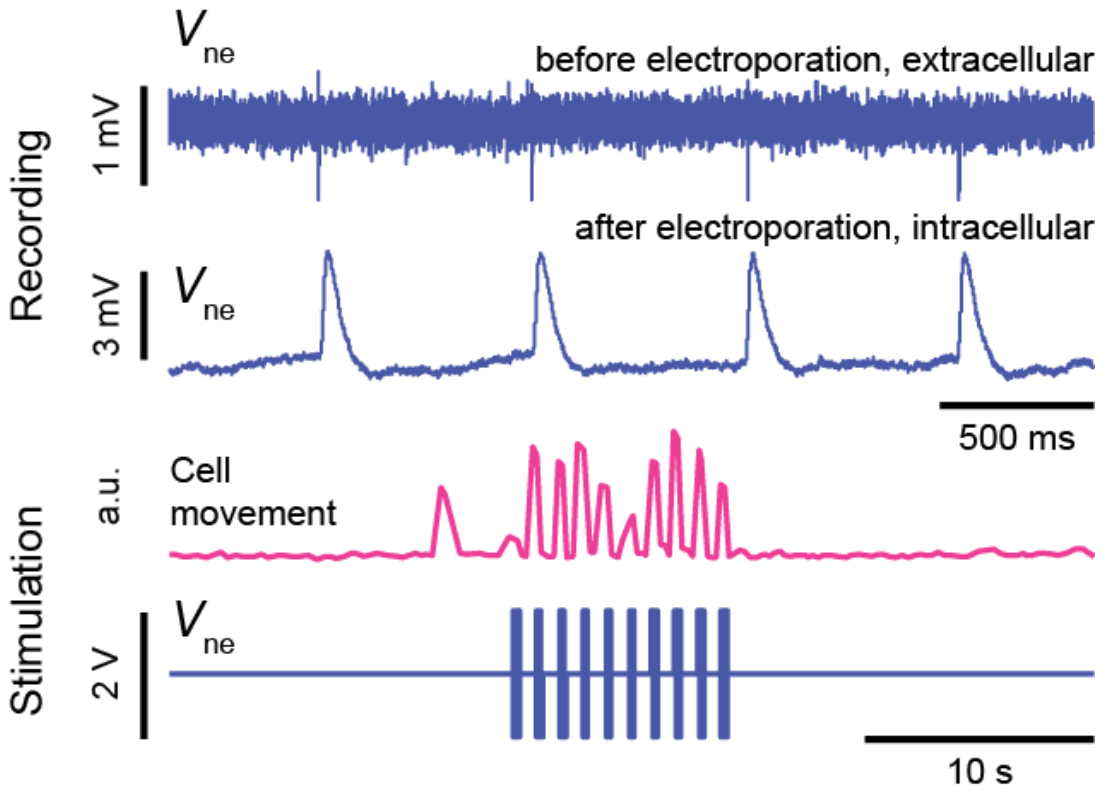
Pixel circuit & electrode characterization



Nature Nanotechnology (2017)

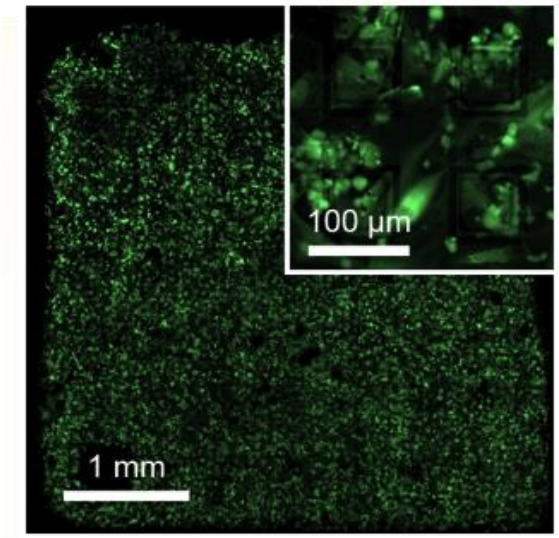
Single myocyte intracellular recording & stimulation

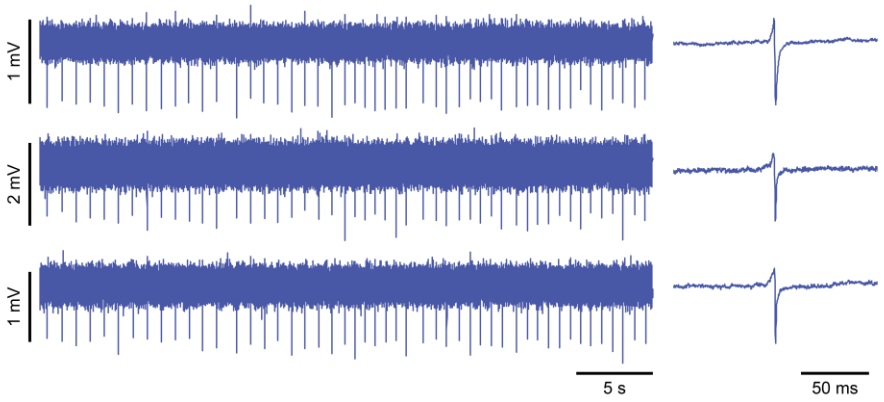




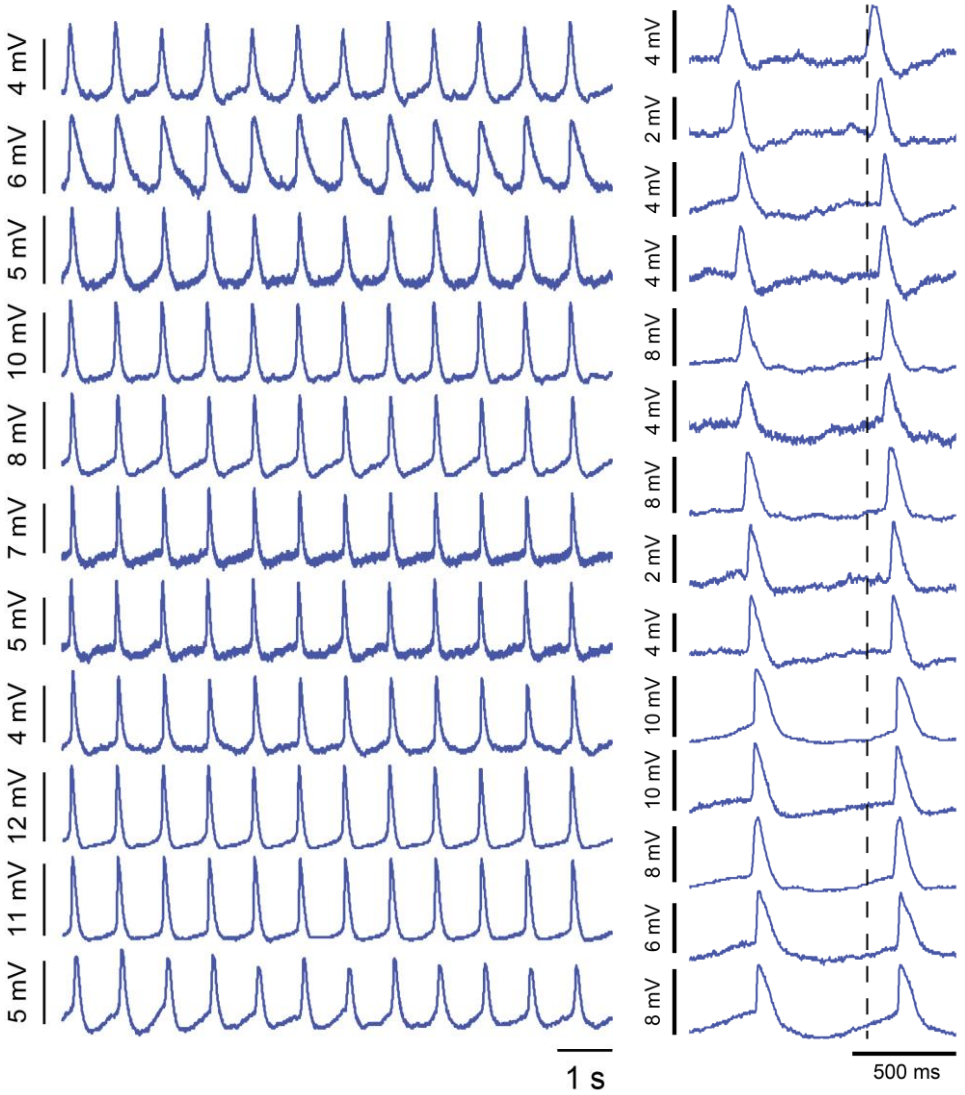
Nature Nanotechnology (2017)

Parallel + intracellular recording from 235 cardiomyocytes





Extracellular recording



Intracellular recording

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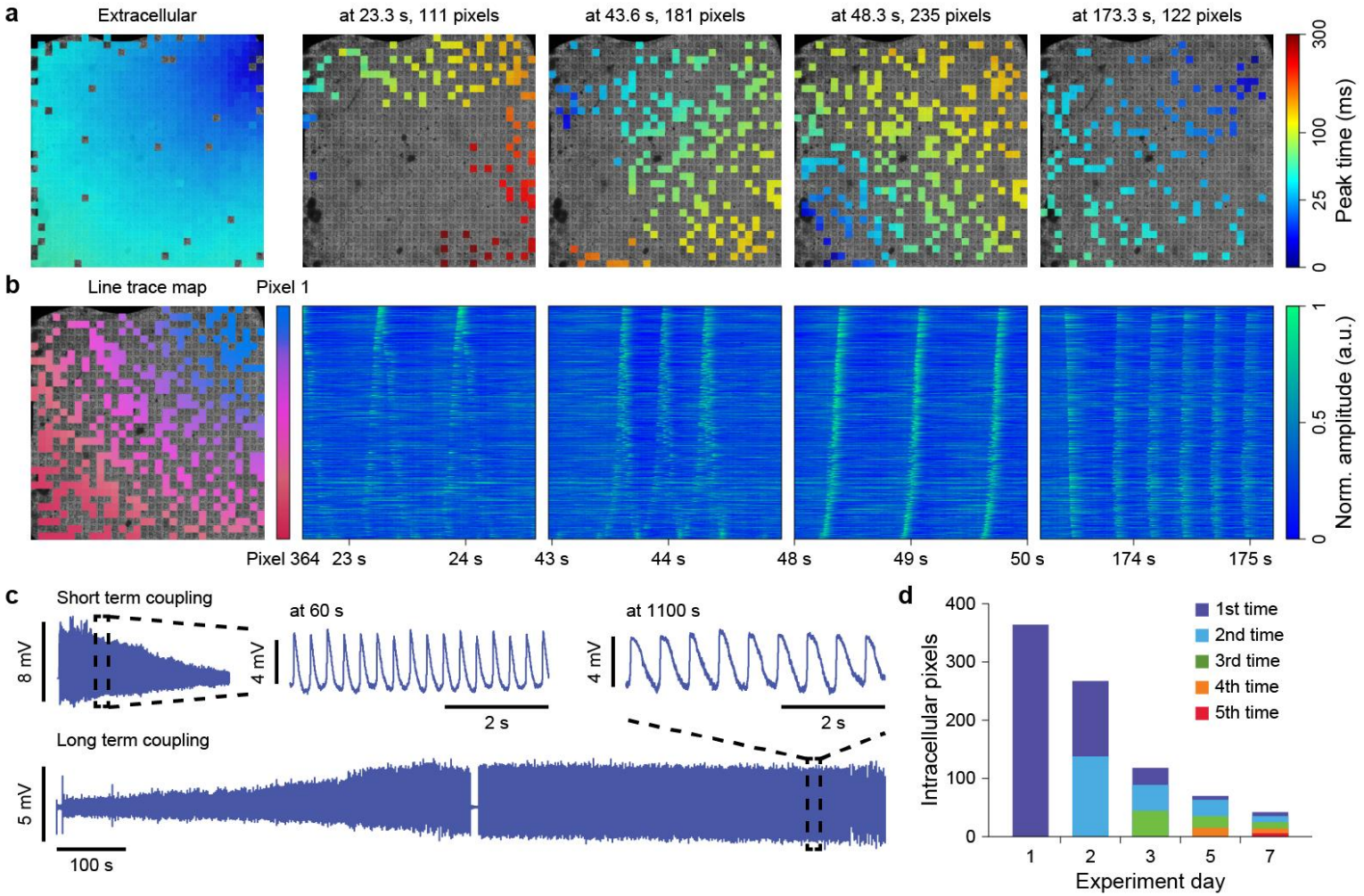
Parallel + intracellular recording from 235 cardiomyocytes



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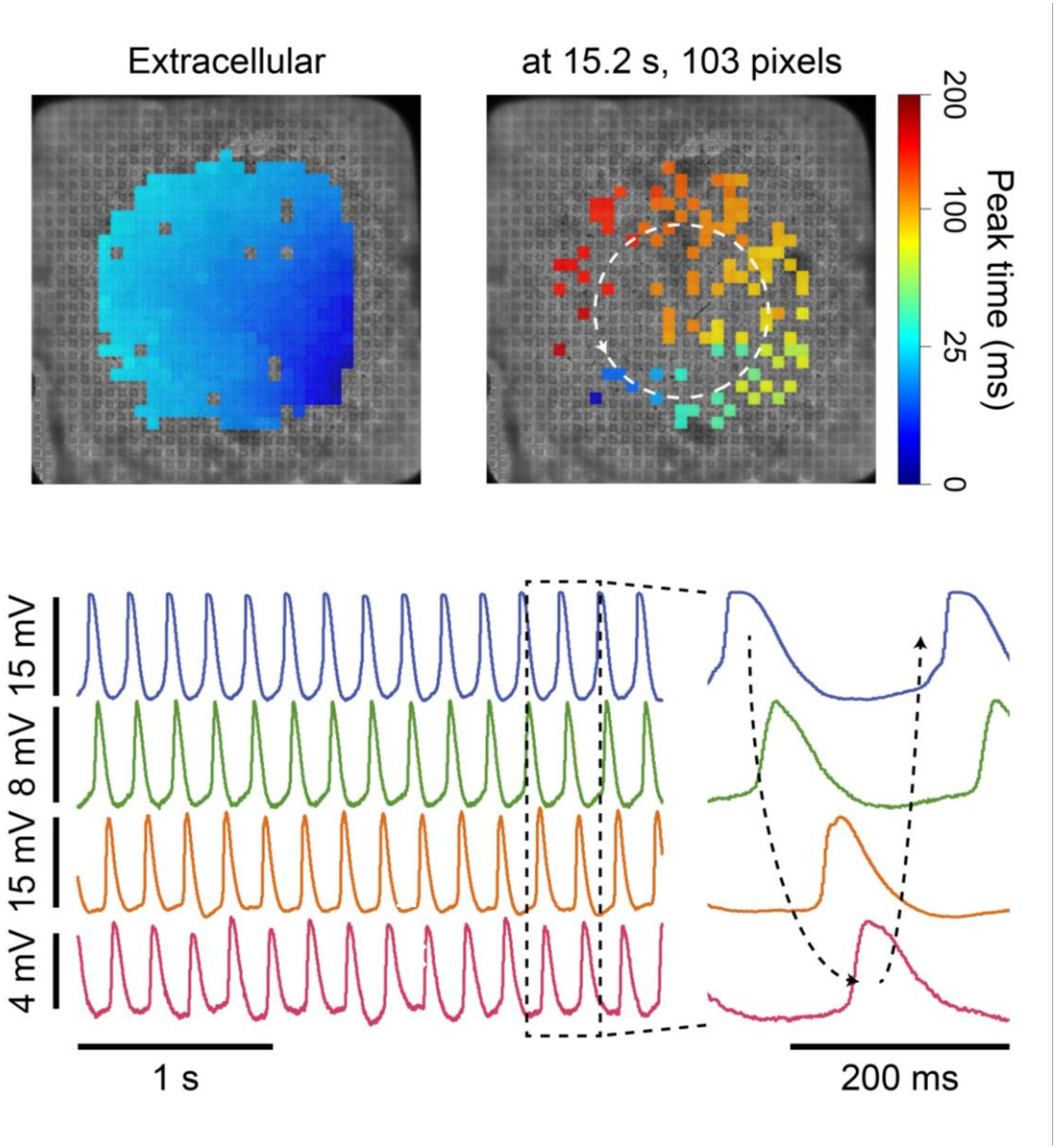
Parallel + intracellular recording – another example



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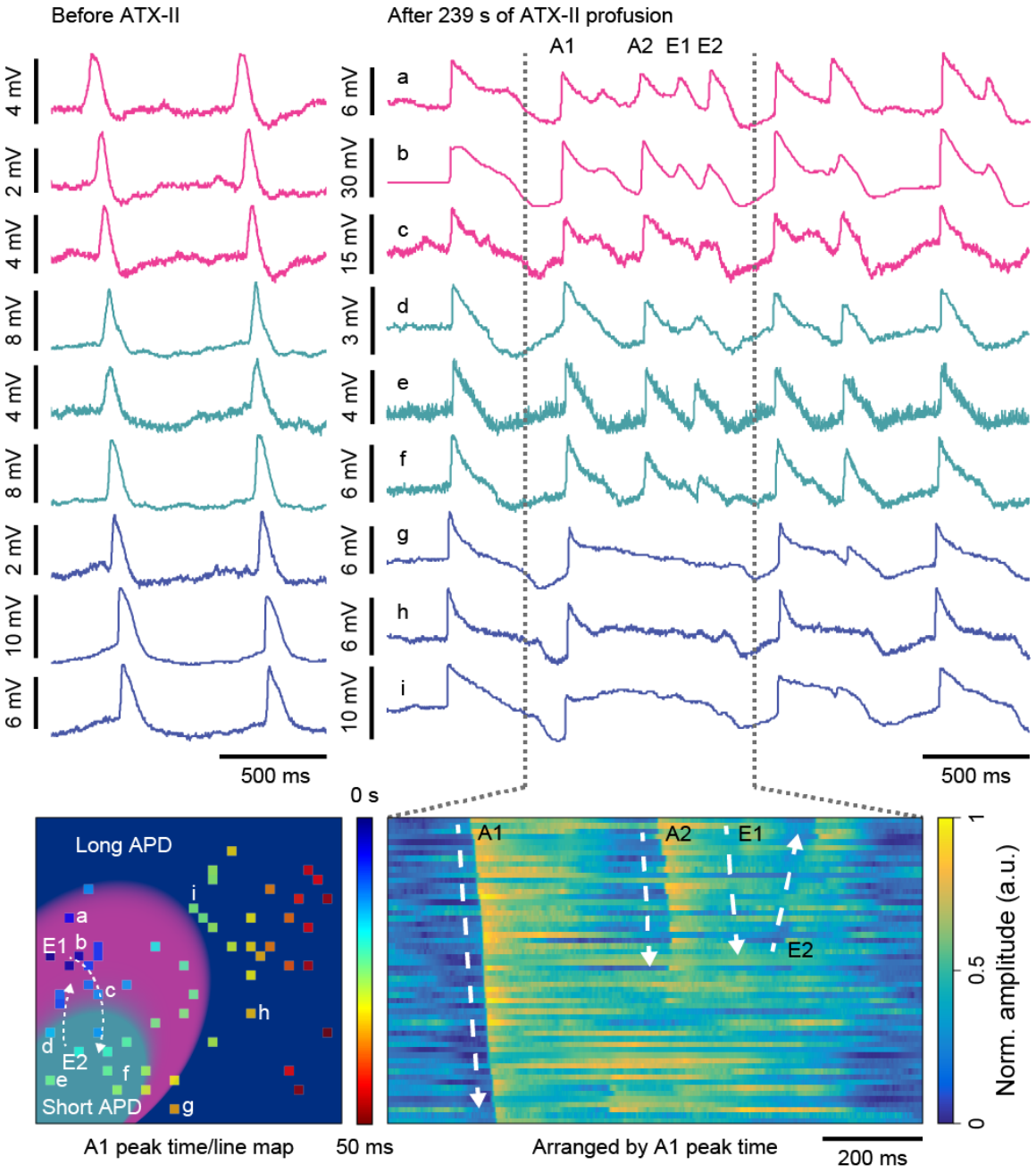
Drug-screening — Network-level intracellular investigation



Nature Nanotechnology (2017)

nature nanotechnology

ARTICLES

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CMOS nanoelectrode array for all-electrical intracellular electrophysiological imaging

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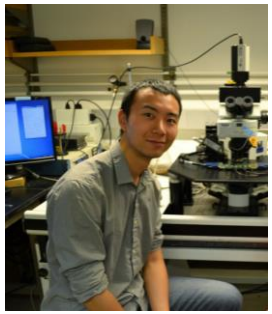
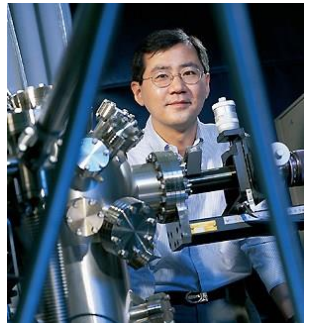
Jeffrey Abbott



Tianyang Ye (Park)

Ling Qin

Marsela Jorgolli (Park)



Prof. Hongkun Park

Catalyst Foundation