Biosensor Systems in Standard CMOS: Fact or Function?

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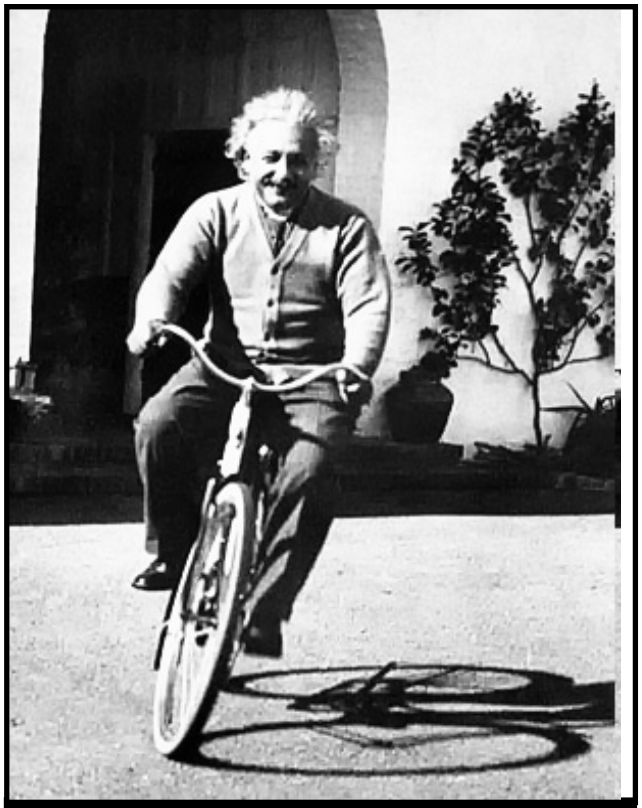
Why Biosensors? Why Genomics?



Albert Einstein (1879-1955)
Greatest Achievement: Theory of Relativity

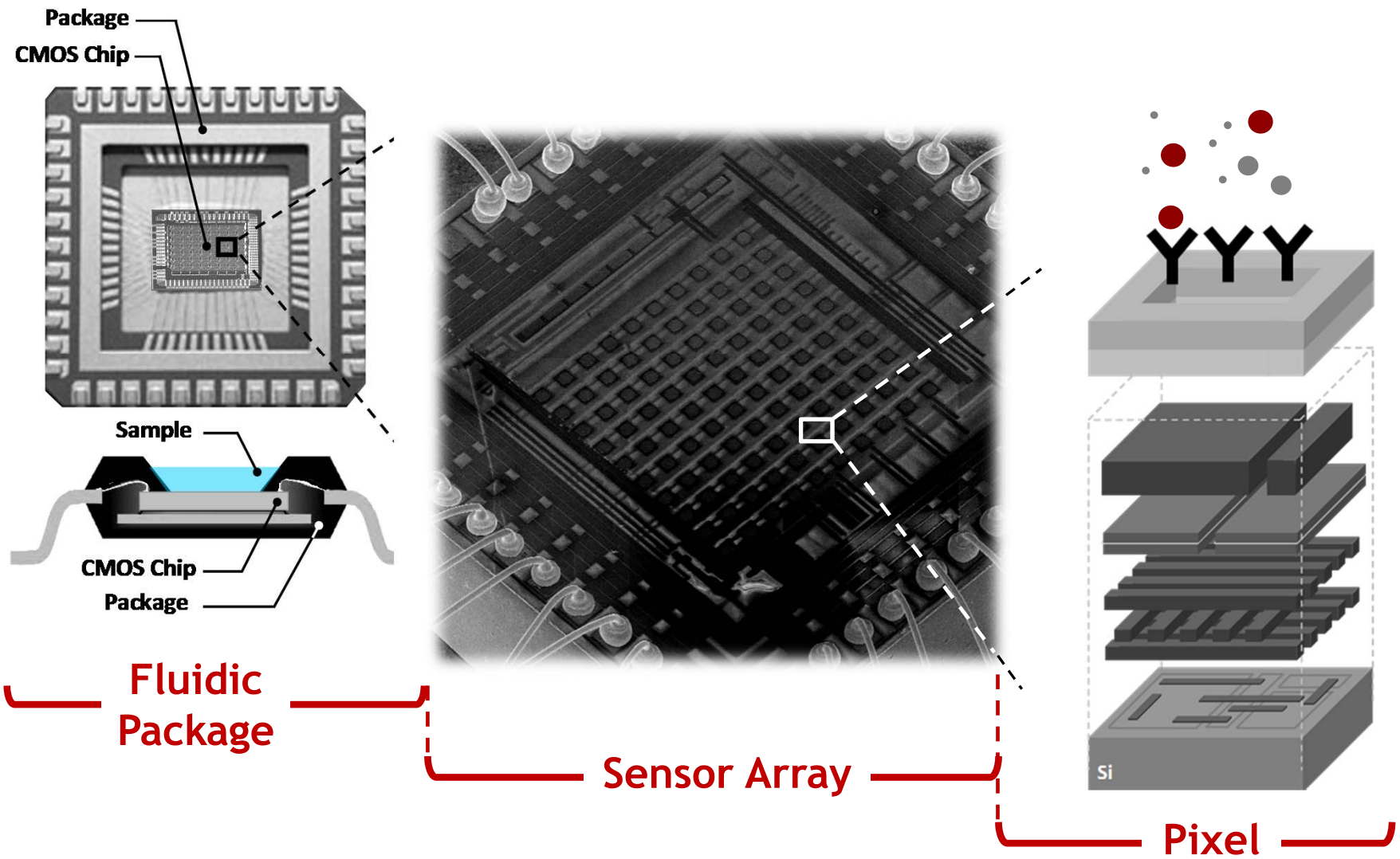
–

Bobo the Chimp (1995-Now)
Greatest Achievement: Shown Above

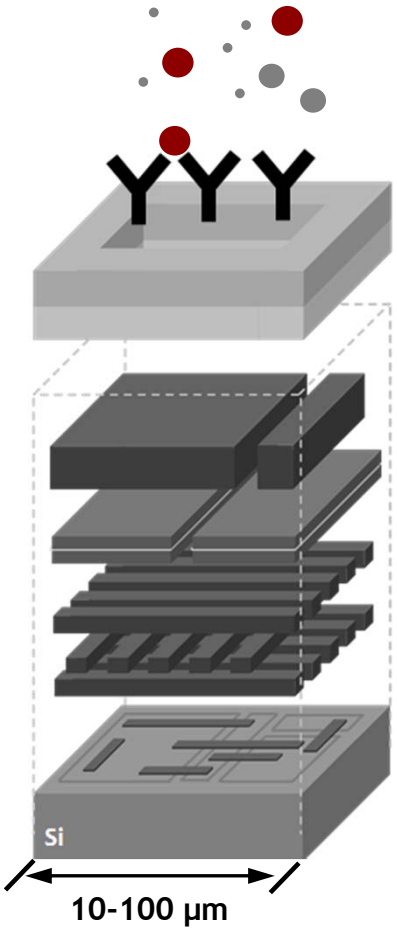
= 1.5% DNA Difference

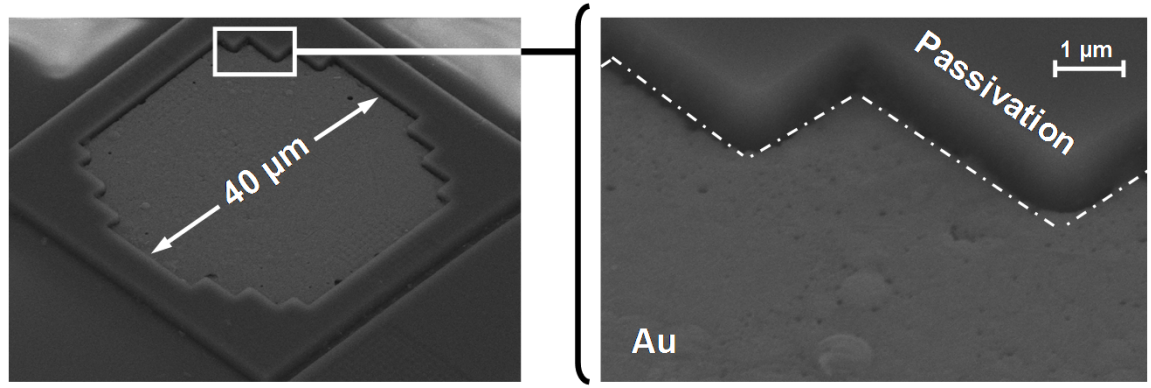
Small details in the DNA can make a huge difference!

CMOS-Integrated Biosensors

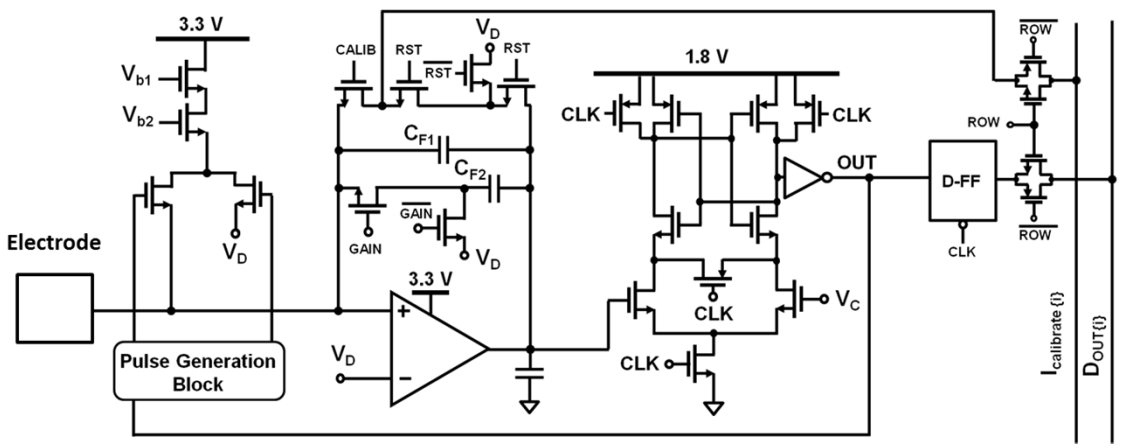


CMOS-Integrated Biosensors





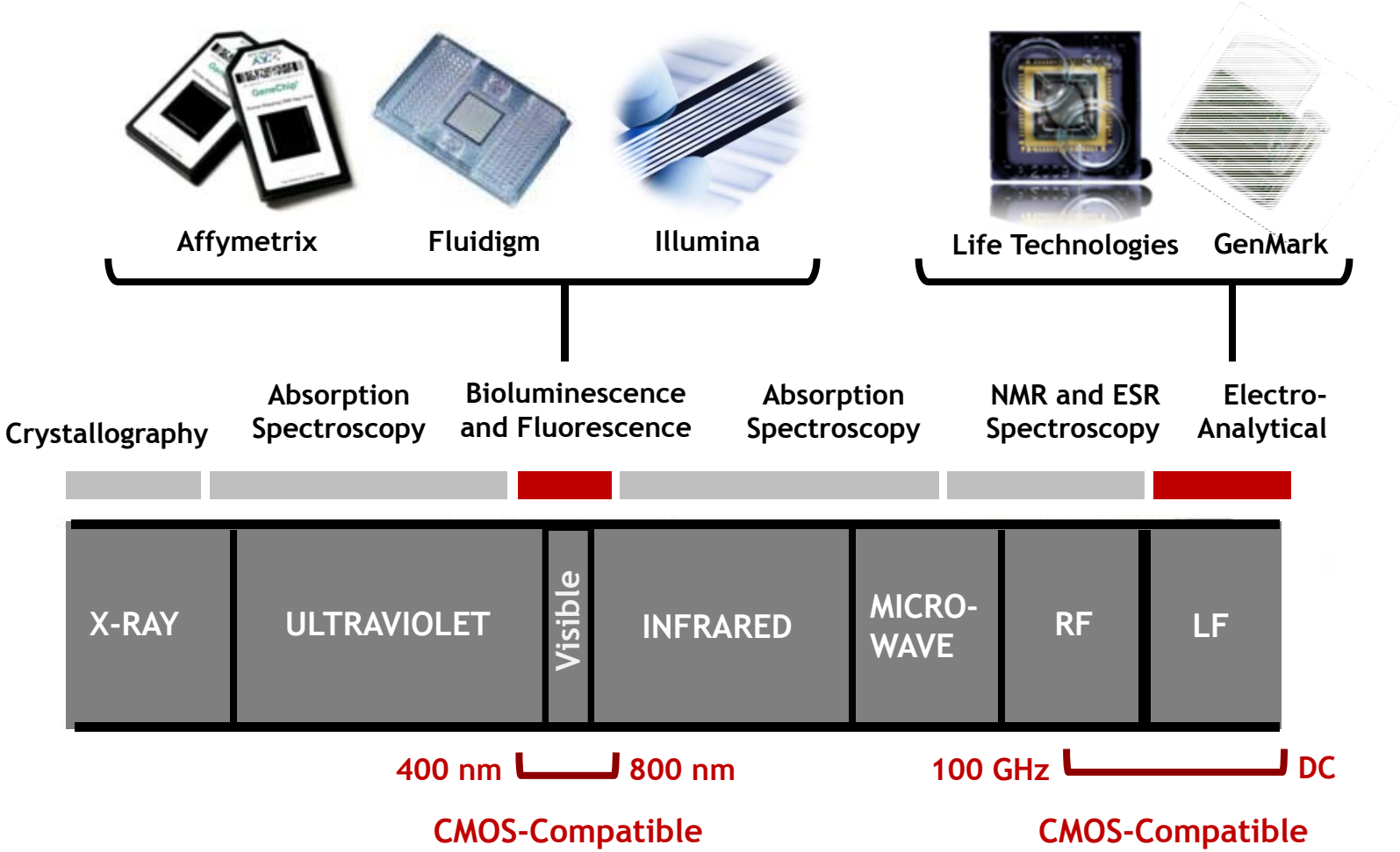
CMOS-Compatible Transducer



CMOS Integrated Sensor

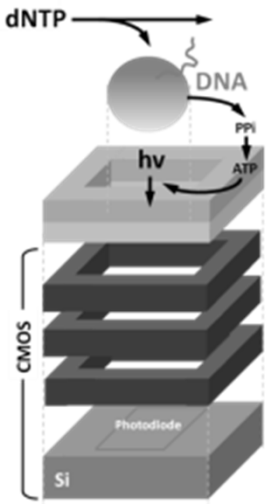
CMOS Biosensing Capabilities

> 95% of molecular detection systems rely on visible-range optical or LF electrical transducers

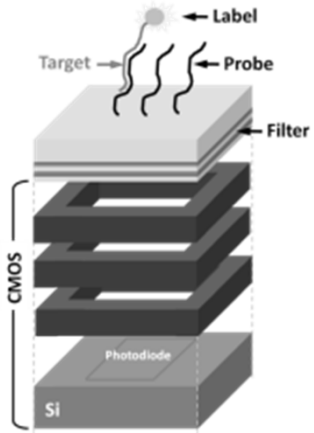


CMOS Biochip Examples

Optical

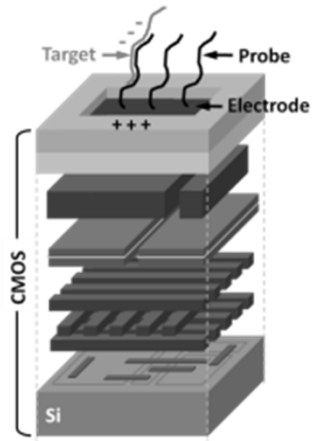


Fluorescence

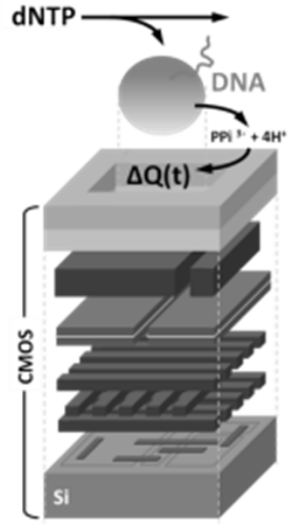


Impedance

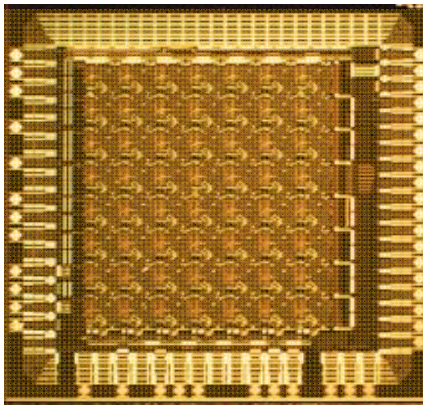
Electro-Analyticalc



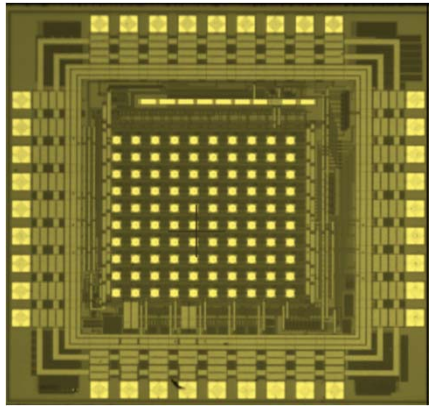
Bioluminescence



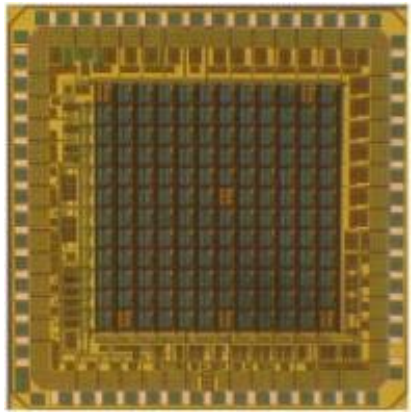
pH



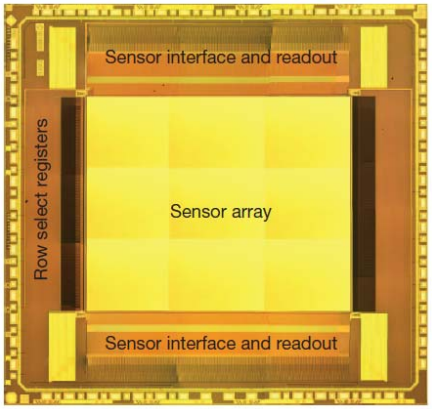
ISSCC 2009



ISSCC 2010

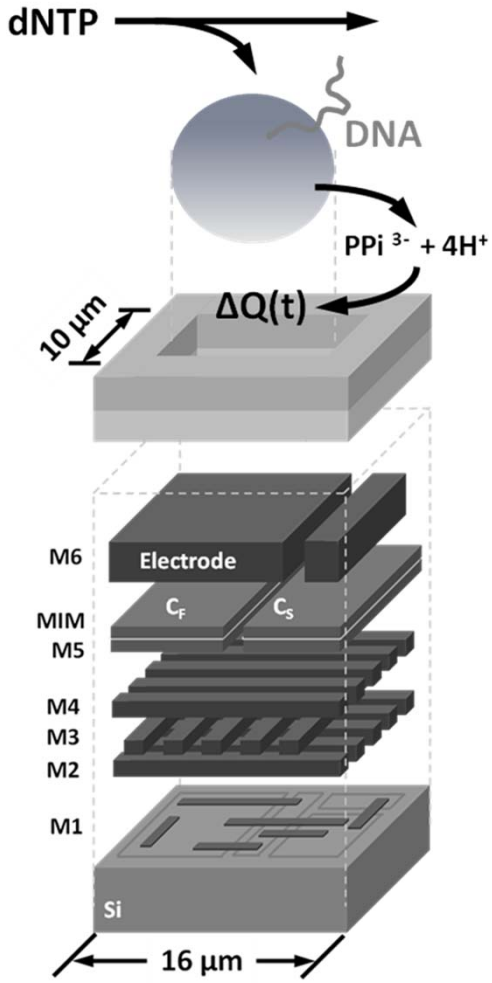


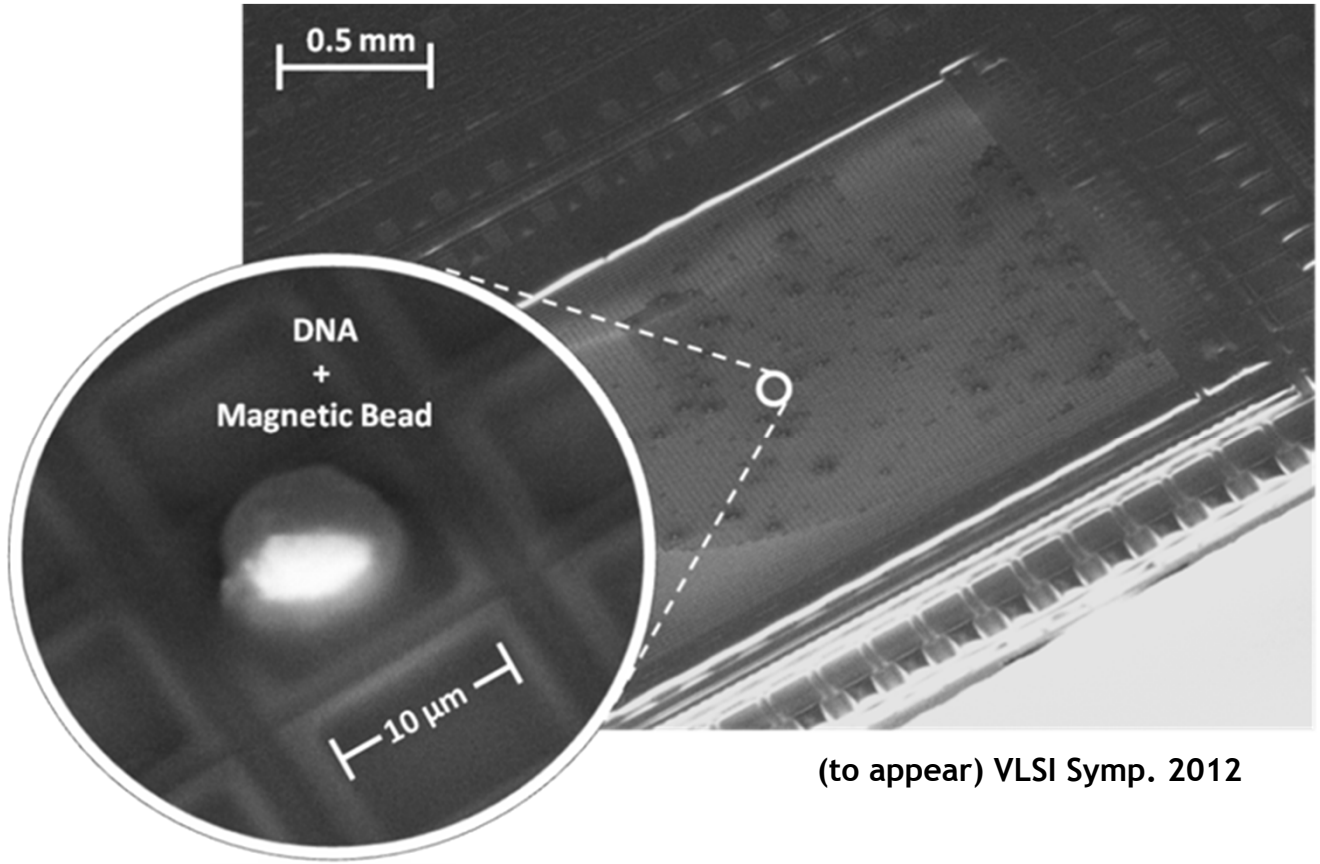
VLSI 2011



Nature 2011

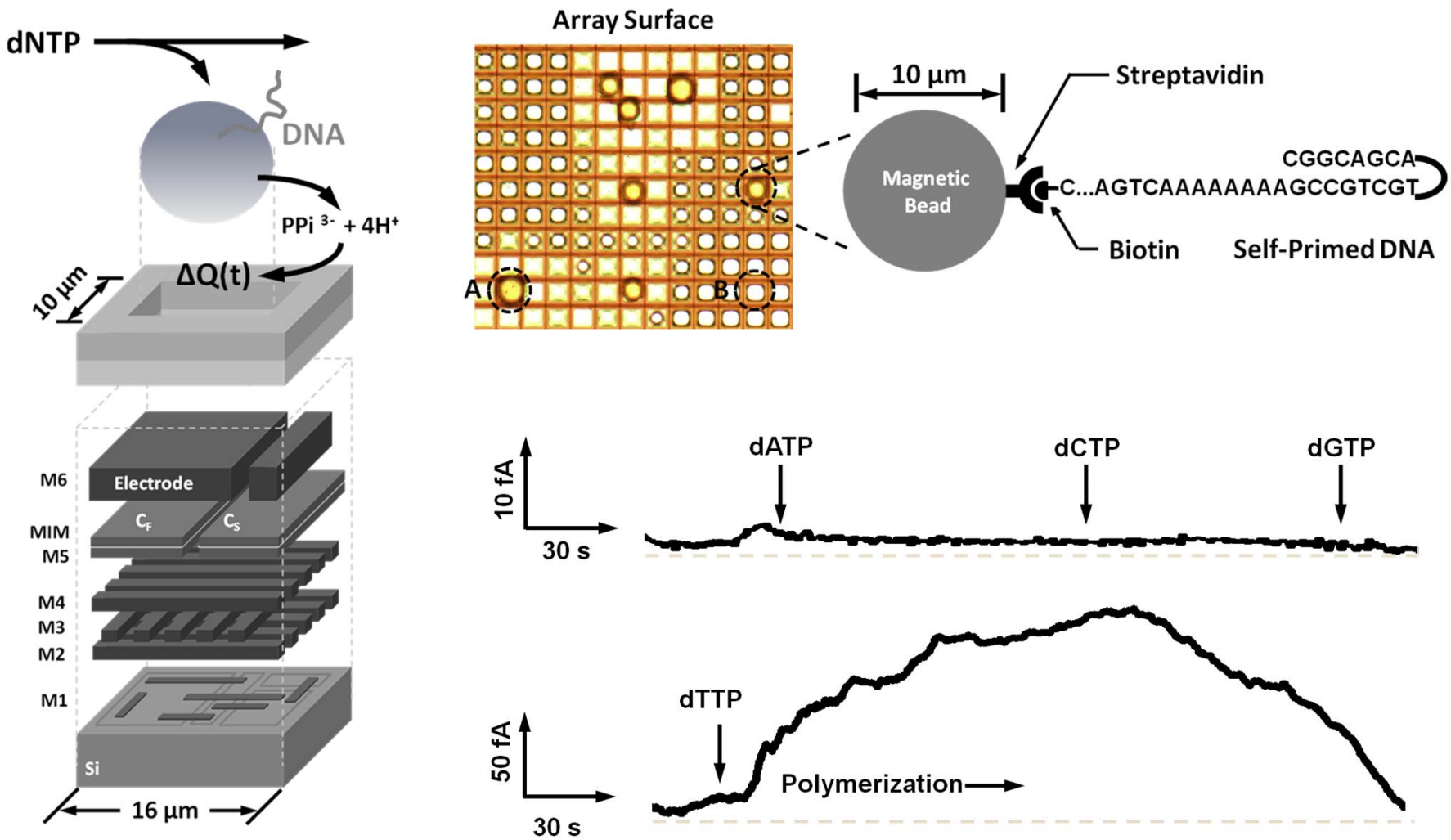
Example: Sequencing CMOS Biochip





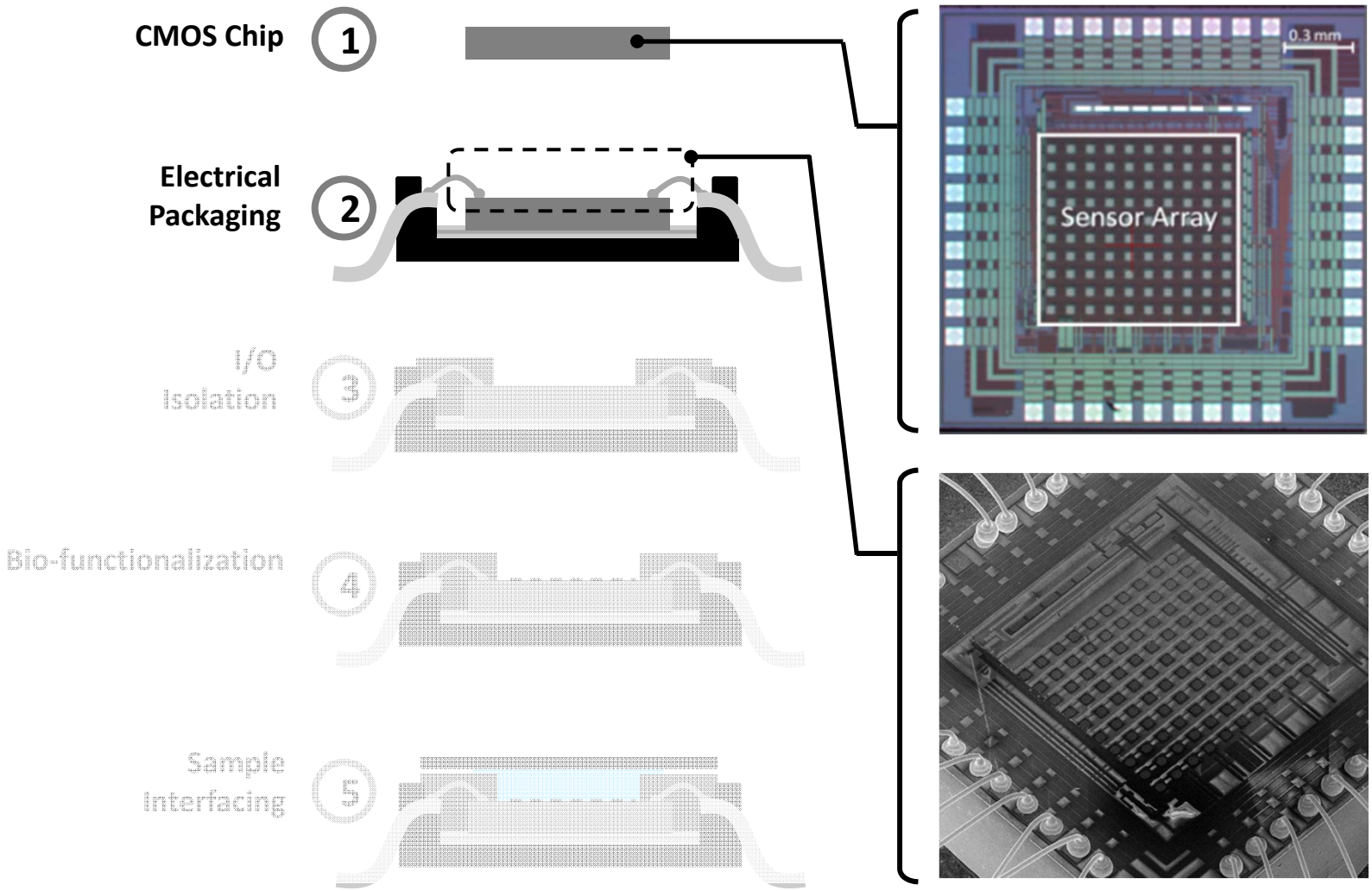
(to appear) VLSI Symp. 2012

Example: Sequencing CMOS Biochip



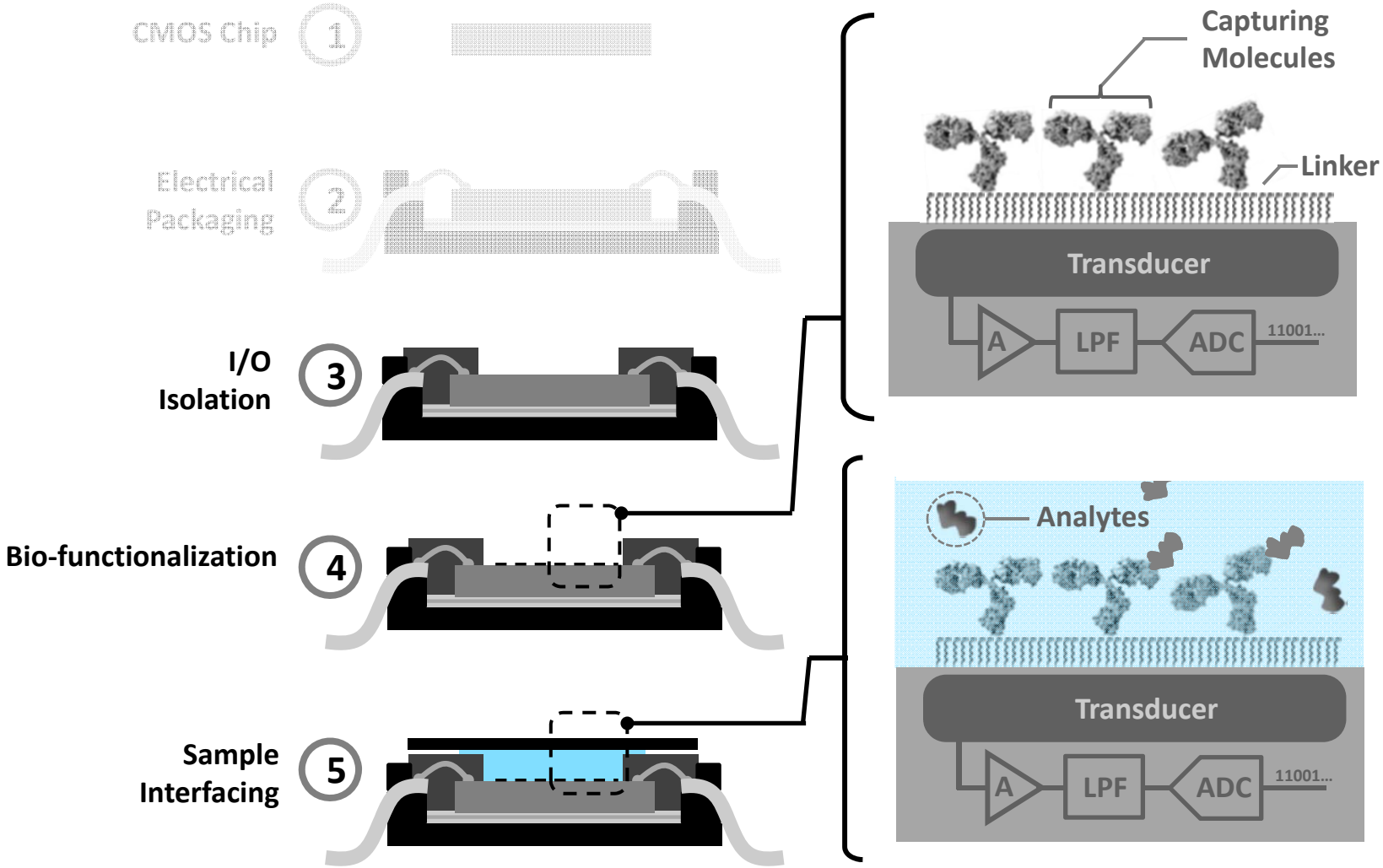
Fabrication/Assembly (1)

Additional Steps are required to create a disposable biochip



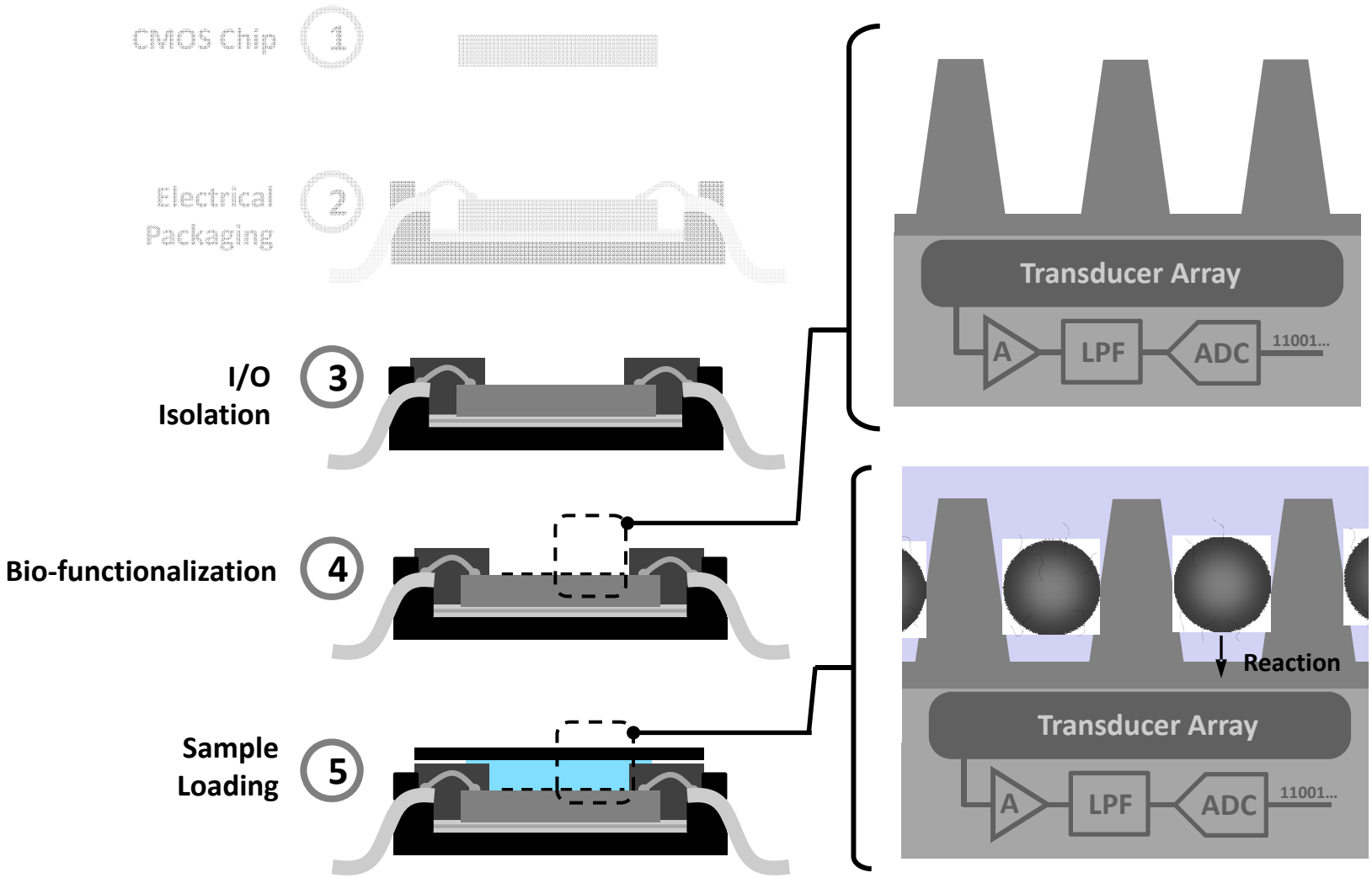
Chip Fabrication/Assembly (2)

Example: Affinity-based biosensors



Chip Fabrication/Assembly (3)

Example: Random bead arrays



Huge Application Space

Application	Pixel	Typical Array Size	IC Design	Post-CMOS Processing	Bio-functionalization
DNA Microarrays	Fluorescence	10^4	Photo-Detection	Optical Filter	DNA Attachment
qPCR	Fluorescence	10^2	Photo-Detection	Optical Filter	DNA Attachment
Digital PCR	Fluorescence	10^5	Photo-Detection	Optical Filter	-
Label-Free Microarrays	Amperometric	10^4	Active Electrode	Electrode	DNA Attachment
Electrical-qPCR	Amperometric	10^2	Active Electrode	Electrode	DNA Attachment
Sequencing (Roche/454)	Bioluminescence	10^6	Photo-Detection	Micro-well	-
Sequencing (Illumina)	Fluorescence	10^8	Photo-Detection	Optical Filter	DNA Attachment
Sequencing (Ion)	pH Detection	10^7	ISFET	Micro-well	-
Sequencing (InSilixa)	Charge Detection	10^7	Active Electrode	Micro-well	-