

PROBING THE INTERACTIONS AT THE NANO-SCALE USING NANO-OPTO-MECHATRONICS INSTRUMENTATION (NOMI)

Hamed Sadeghian, PhD, MBA
Scientific leader NOMI, Principal Scientist

[1]TNO, Delft, The Netherlands

TNO innovation for life

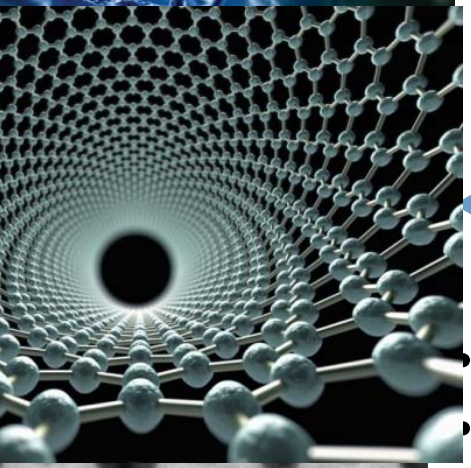
NOMI

TNO innovatio for life

PLICATIONS

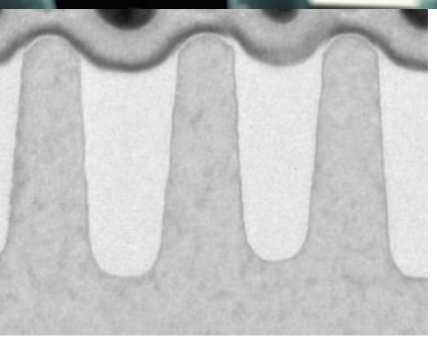


- Bio-medical research
- Ultra early diagnosis
- Bio-chem detection (security)



10^{-9} 10^{9}

- Nanotransistors
- Quatum device
- Memory
- nano-enabled products





Sp

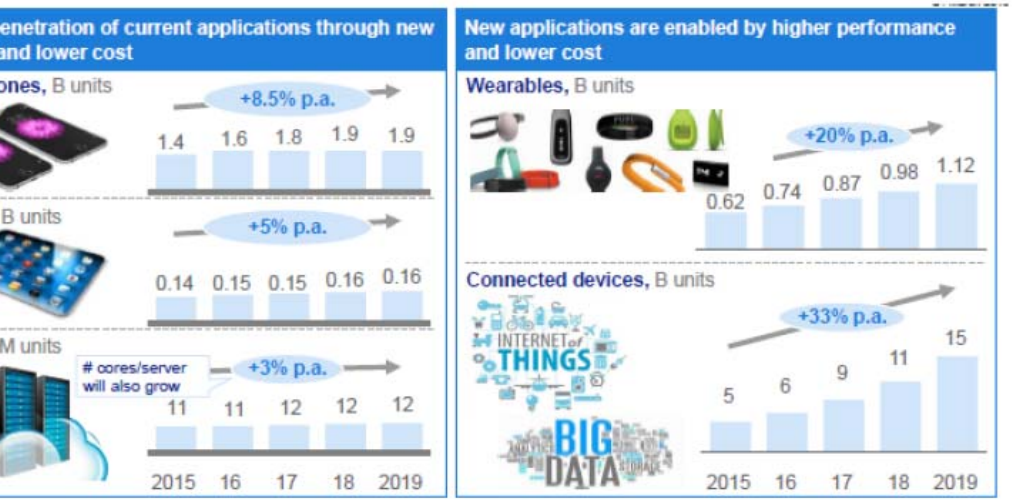


Gravitational wave dete

NOMI

TNO innovatic for life

ANOELECTRONICS (SEMICONDUCTOR) APPLICATION





8.4 billion connected device 2017, by 2020:40 bi

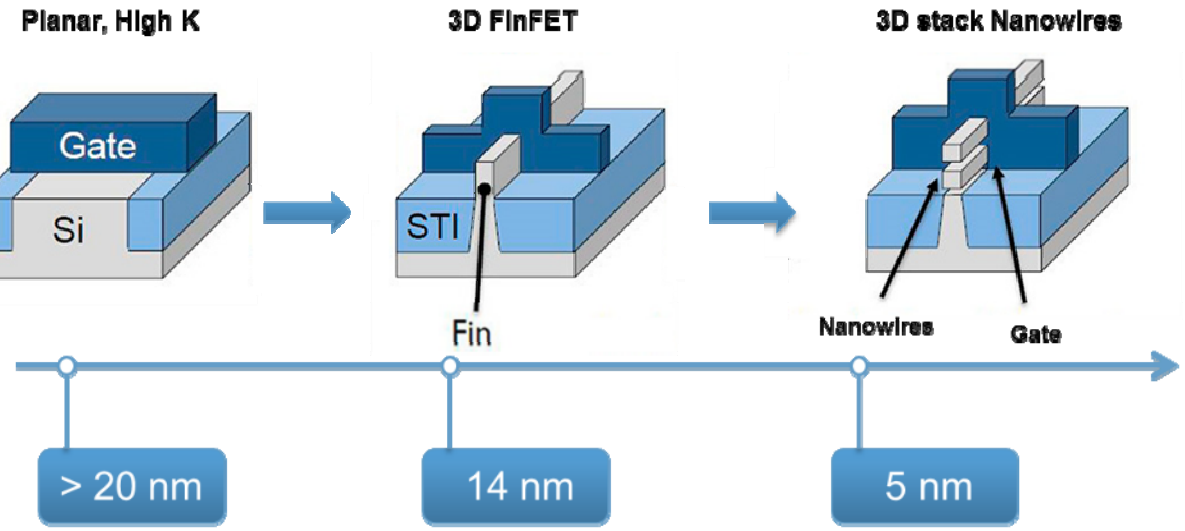
arket drivers for Moore's law, source: Gartner 2016.

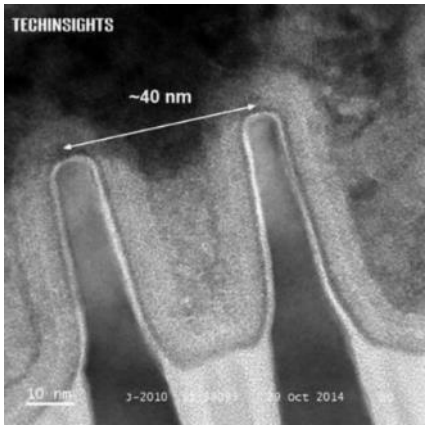


NOMI

TNO innovatic for life

OORE'S LAW &CHALLENGES OF NANOMETROLOGY

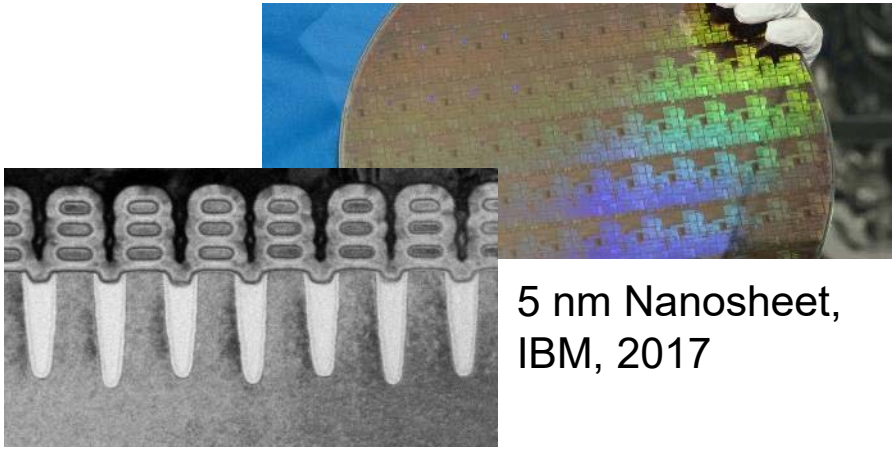




10 nm FinFET,
Intel, 2014

1) How to accurately fabricate them?

2) How to accurately measure?



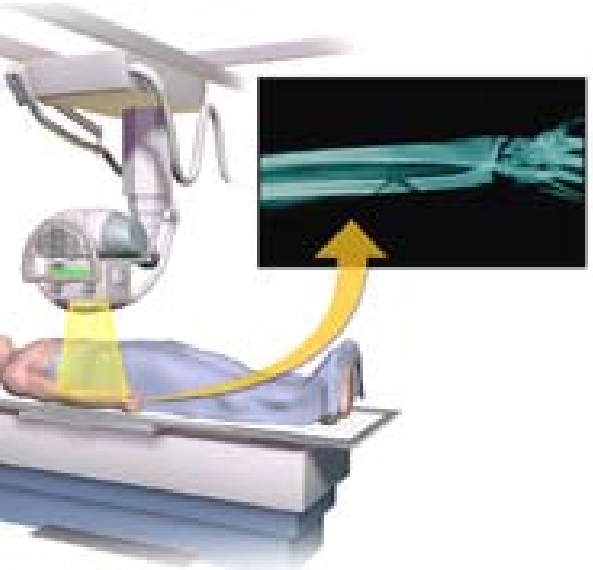
5 nm Nanosheet,
IBM, 2017

OOL-DRIVEN REVOLUTION

he effect of concept-driven revolution is to explain old things in new ways. The effect of tool-

iven revolution is to discover new things that have to be explained."

eeman Dyson



X-ray

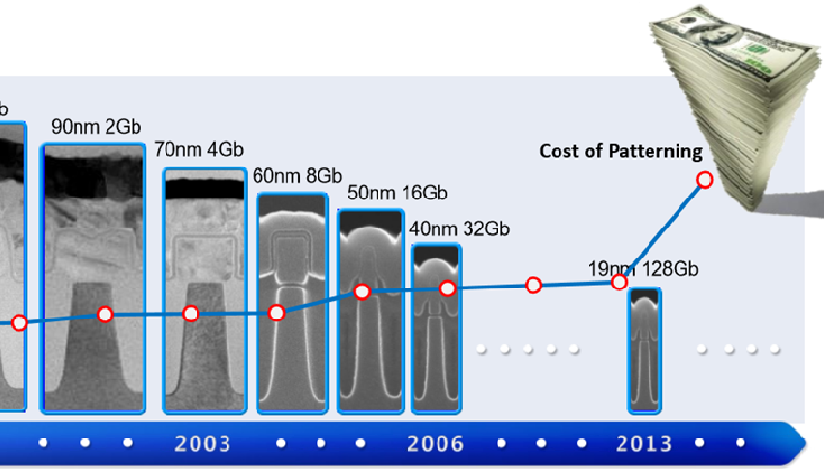


MRI

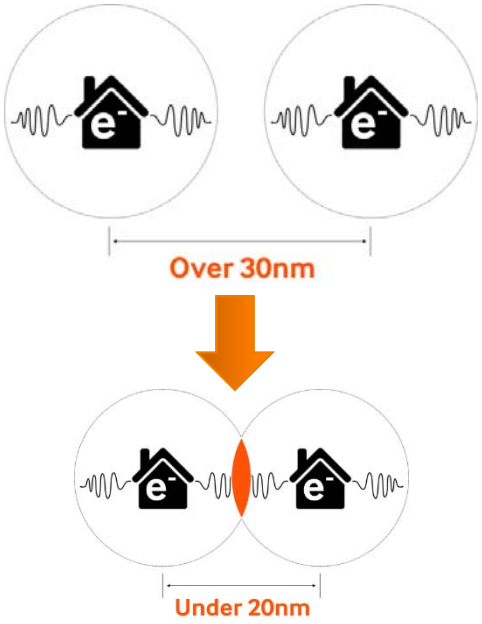


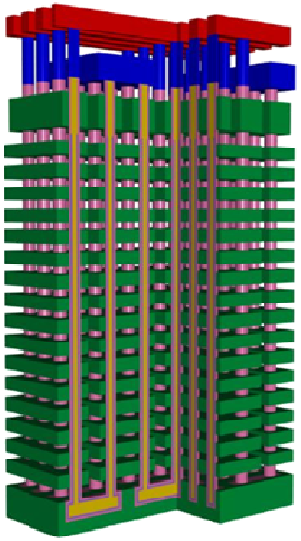
AFM

PARADIGM SHIFT



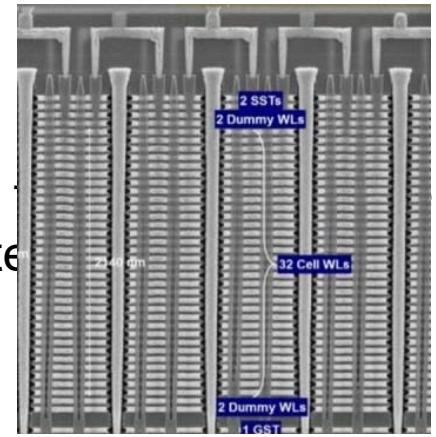
Planar (2D) NAND





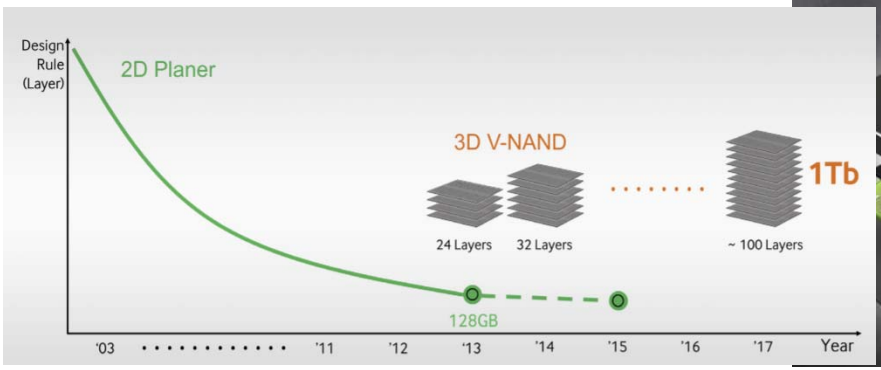
Vertical (3D) NAN

“Noisy Neighbor” Syndrome



ell
atte

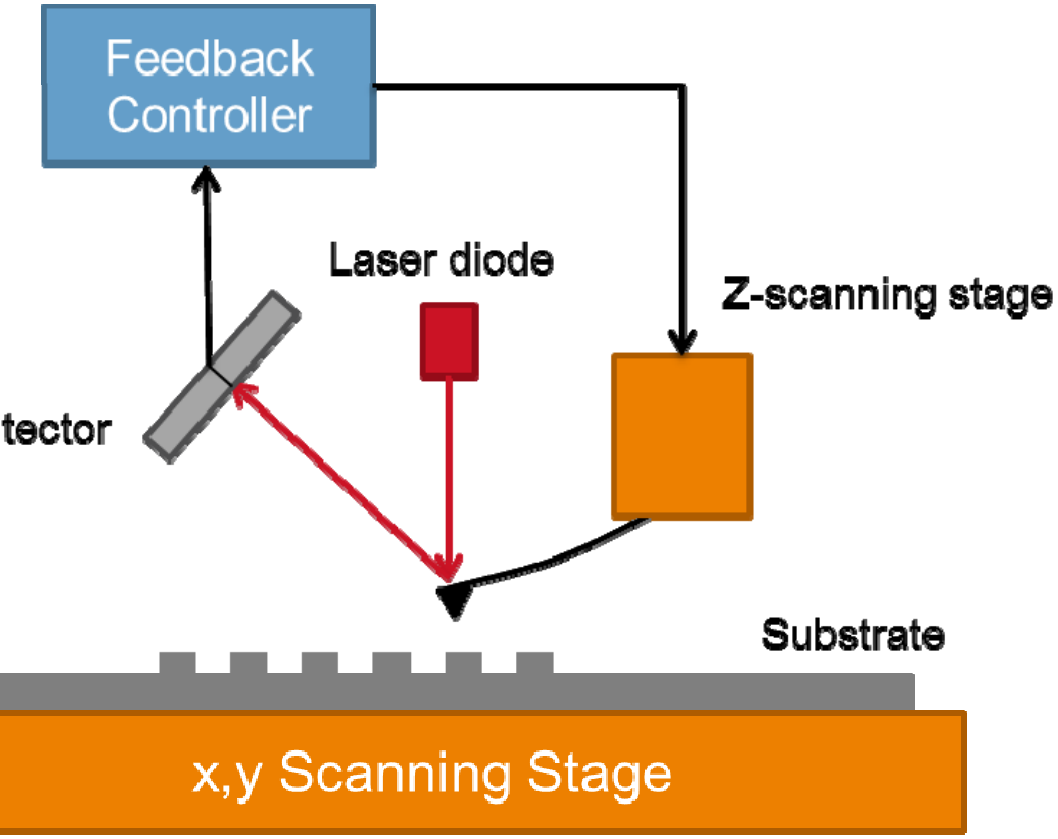
under 20nm
32 layers

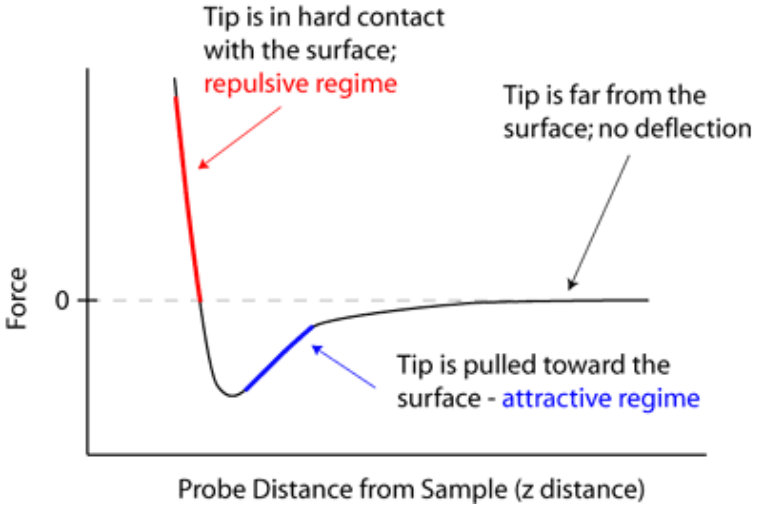


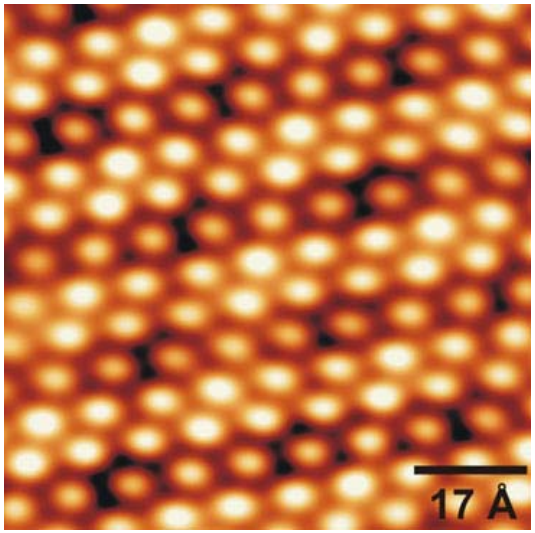


Source: Jung, Samsung, Au

OTENTIAL SOLUTION

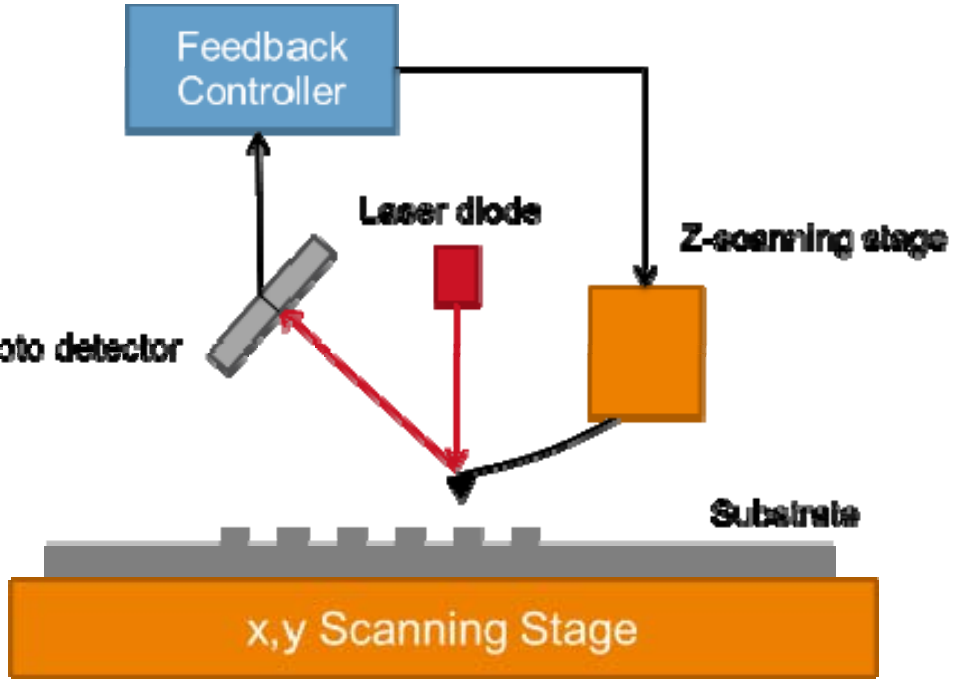


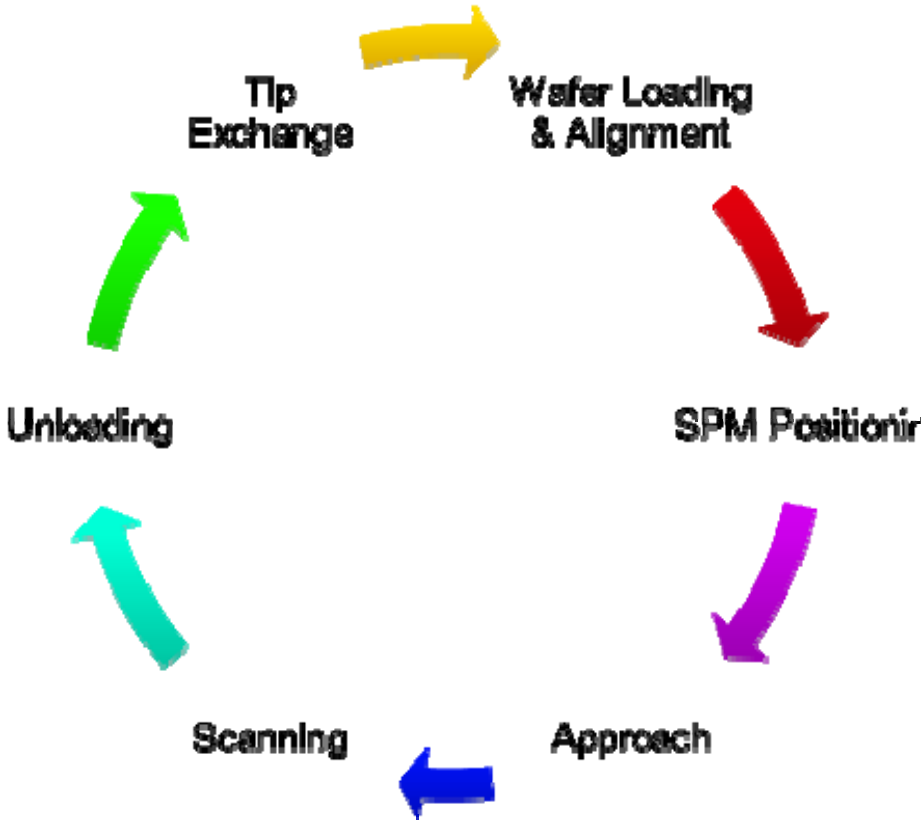




Topography measurement with Atomic resolution

SPM AS A POTENTIAL SOLUTION





Throughput (time to data) is extremely l

LAB ON AN INSTRUMENT

An instrument that can do:

High Throughput: measure many parameters at high speed

- Surface 3D topography
- Thermal, mechanical and electrical properties

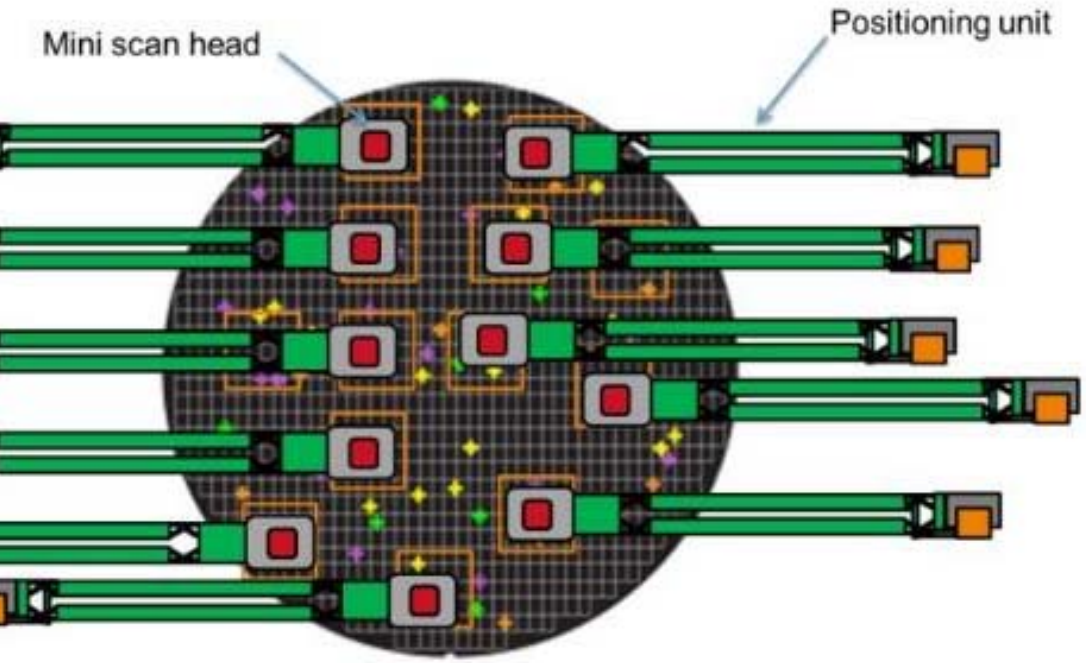
Nanfabrication, preferably in 3D

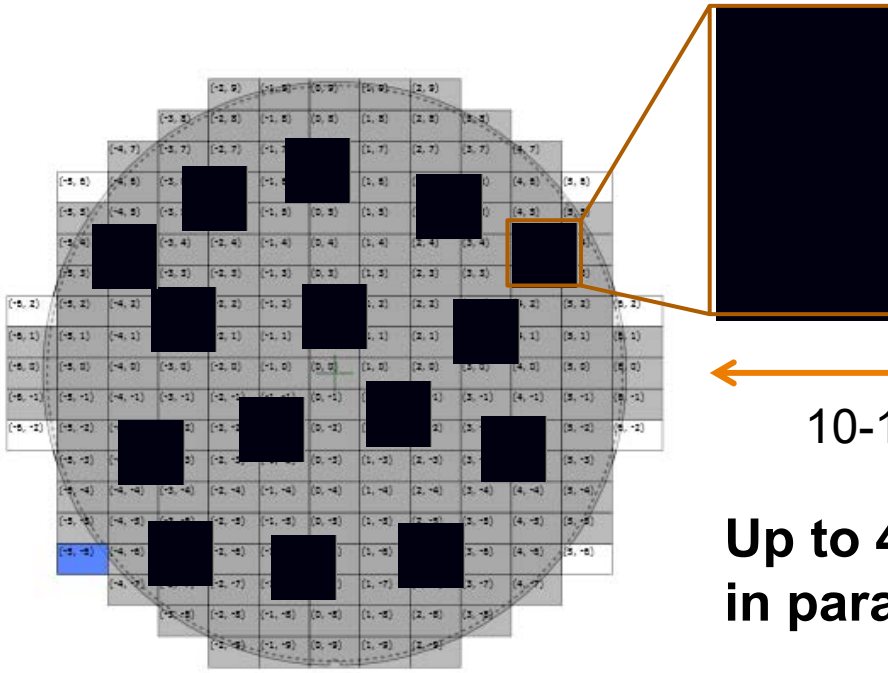
Non-destructive subsurface Imaging

NOMI

TNO innovatic for life

IGH THROUGHPUT PARALLEL SPM

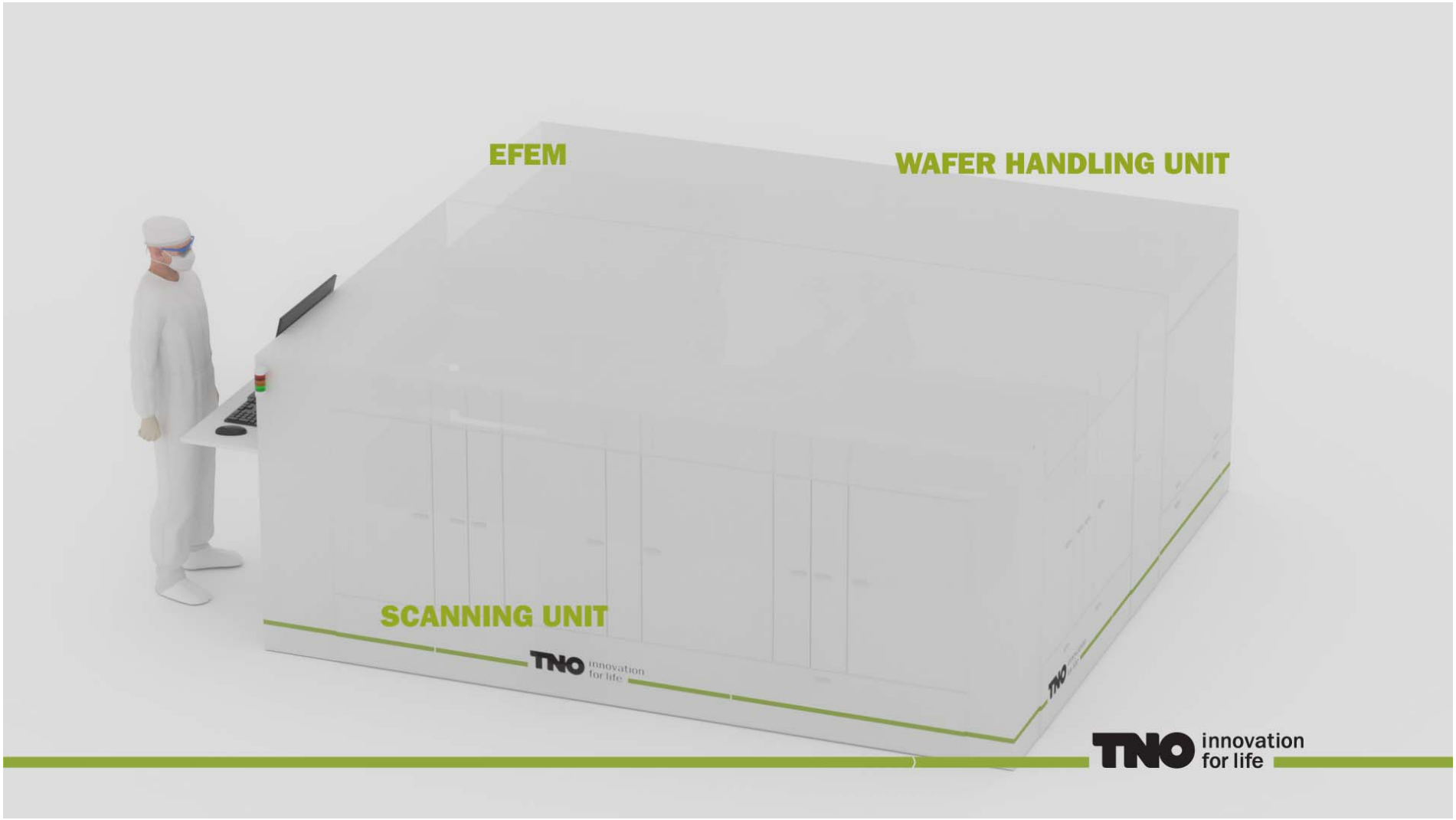




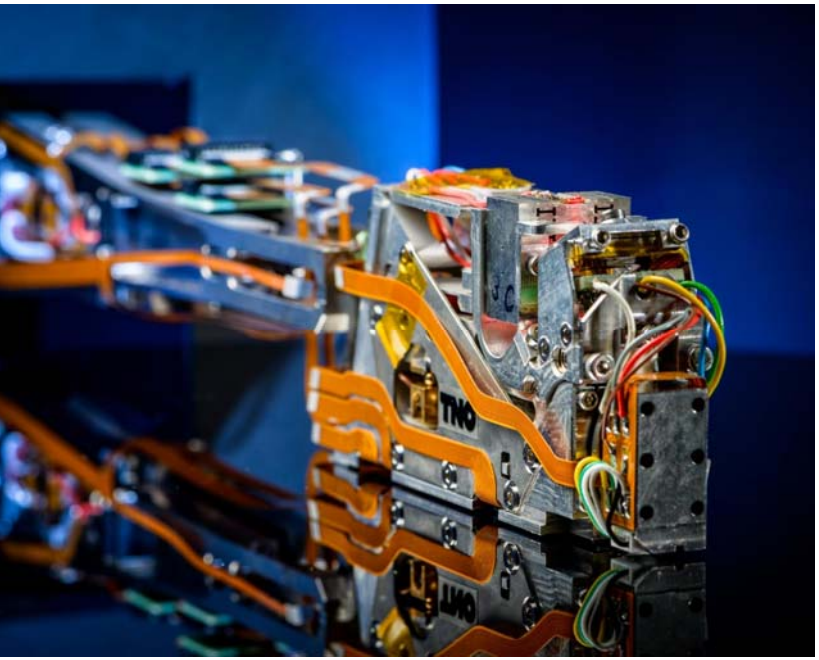
10-1

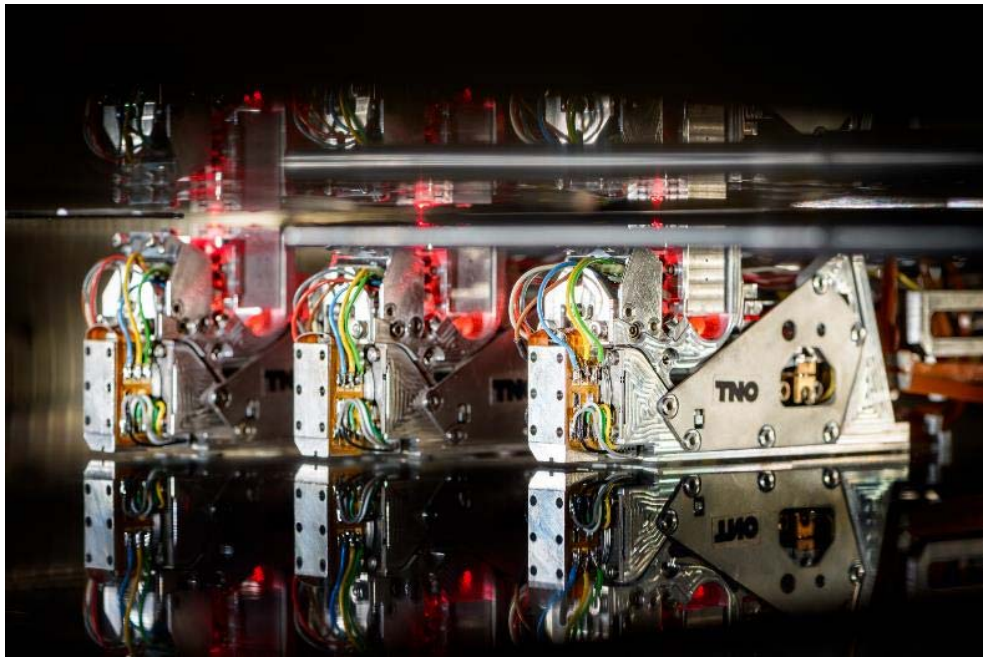
Up to 4
in para

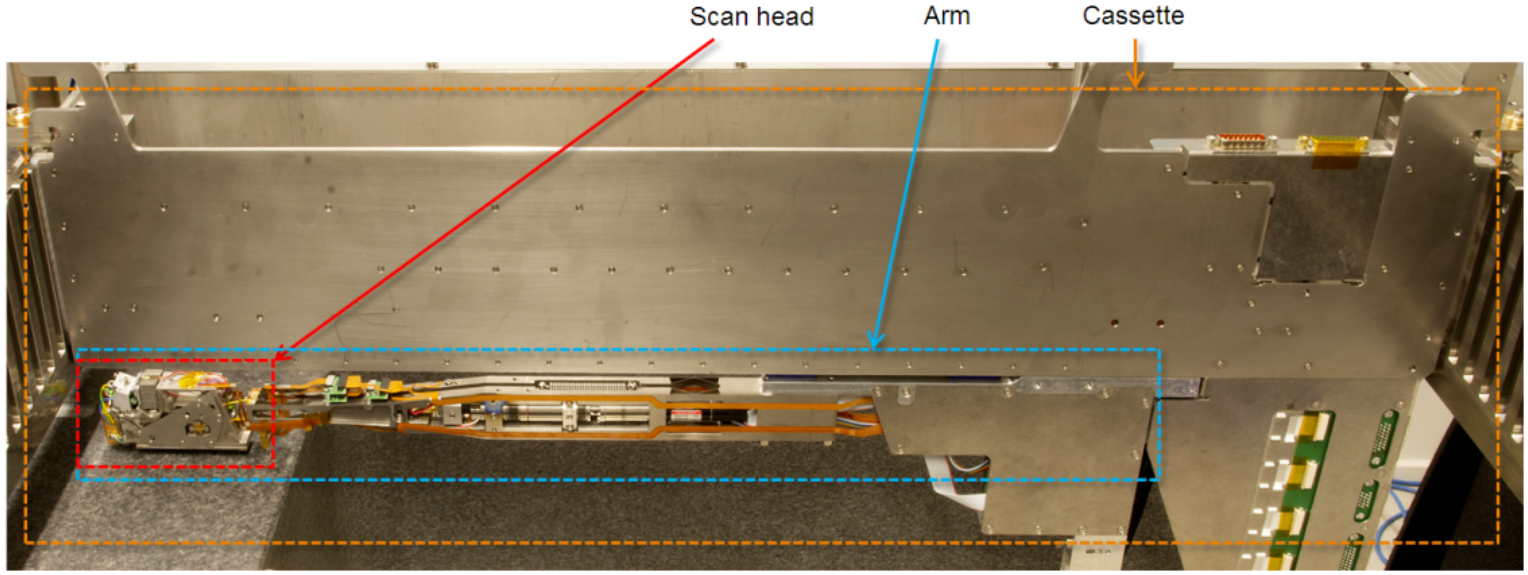
Sadeghian, et al., Development of a detachable high speed miniature scanning probe microscope for large area
bstrates inspection, Rev. Sci. Instrum. 86, 113706 (2015).



H. Sadeghian, et al., High-Throughput Atomic Force Microscopes Operating in Parallel, Review of Scientific Instruments 88, 033703 (2017).

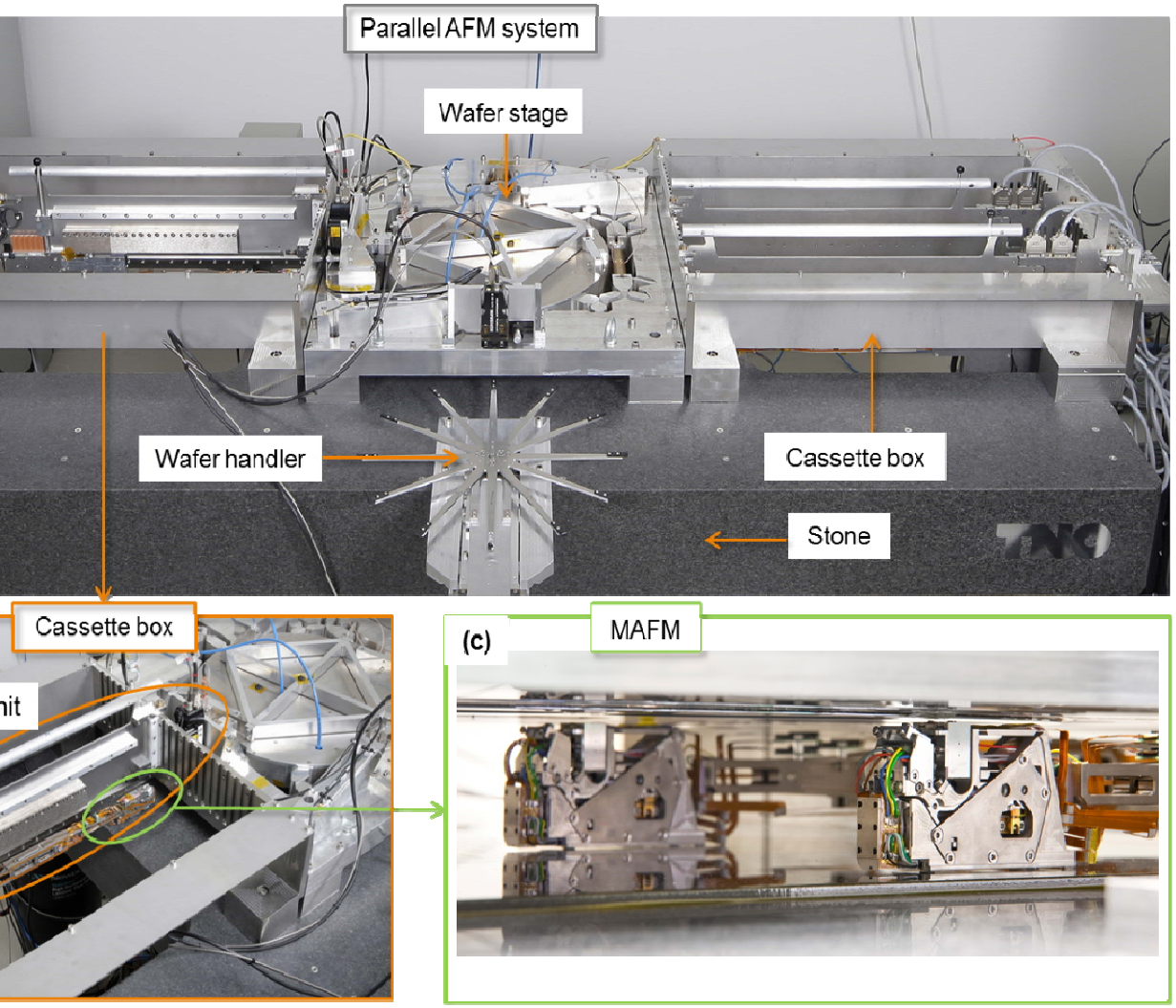

TNO


TNO

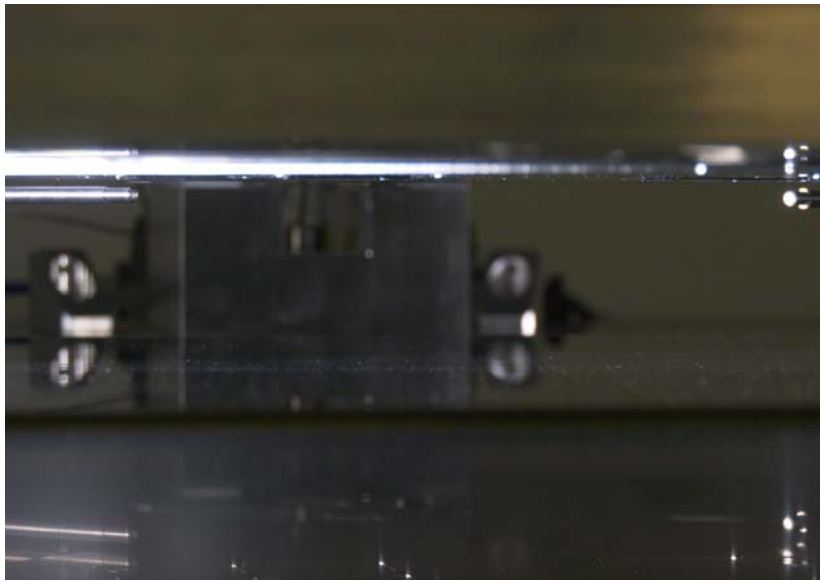

Scan head
Arm
Cassette

NOMI

TNO innovatic for life



Demonstrator of parallel Scanning F Microscopes

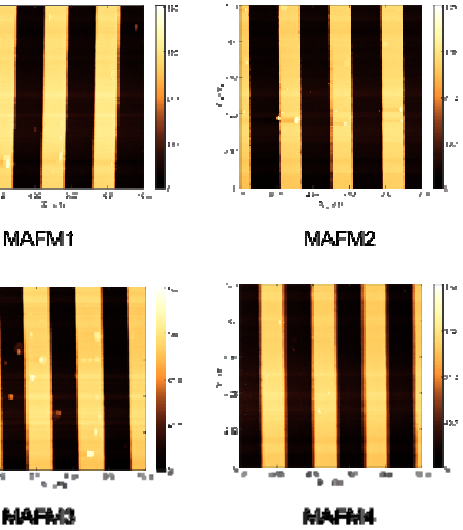


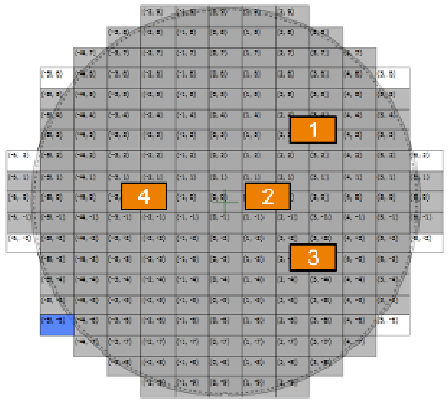
H. Sadeghian, et al., High-Throughput Atomic Force Microscopes Operating in Parallel, Review of Scientific Instruments 88, 033703 (2017).

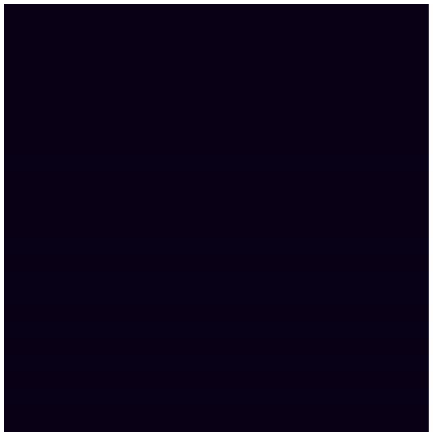
NOMI

TNO innovatic for life

MAGING PERFORMANCE



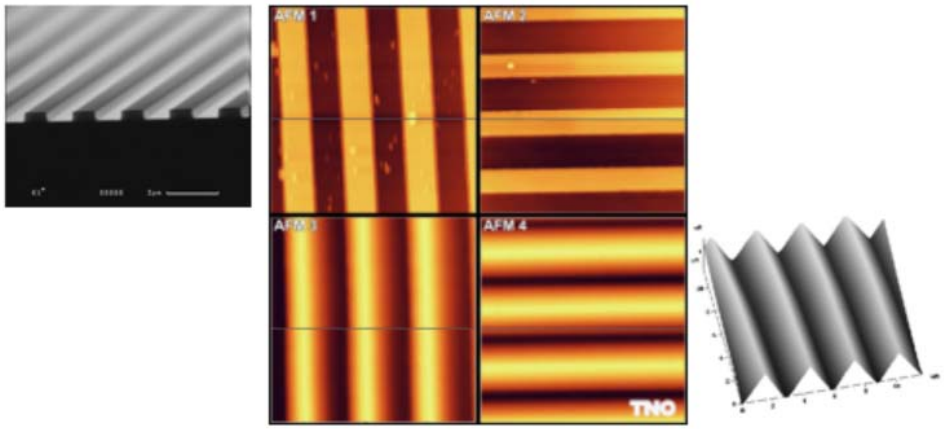




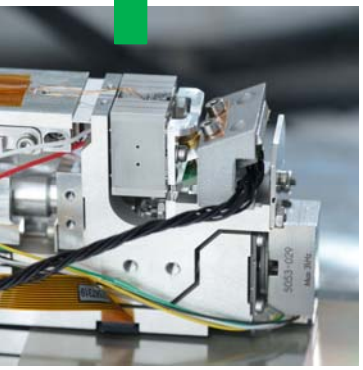
EUV mask, 5µm, 20 Hz



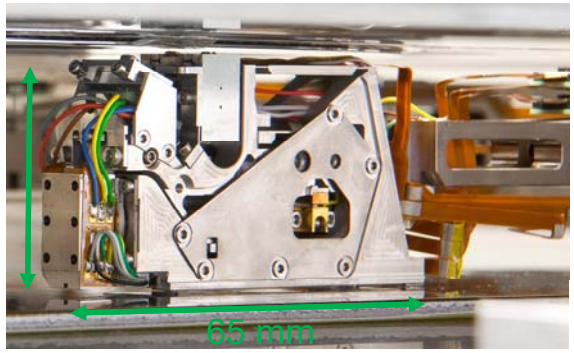
5µm, 40 Hz



NI AFM NEXT GENERATIONS

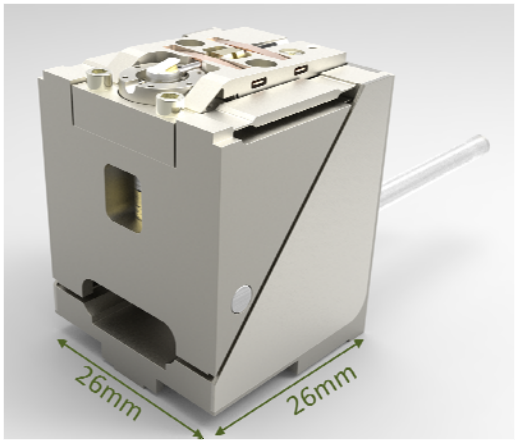


st Gen.



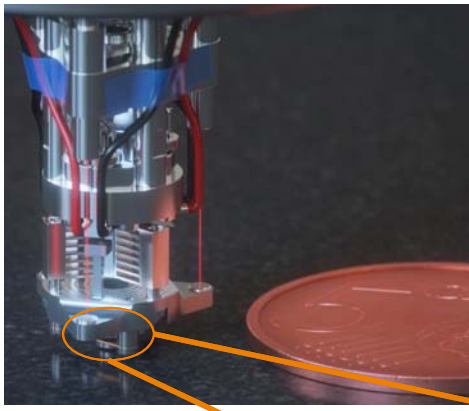
2nd Gen.

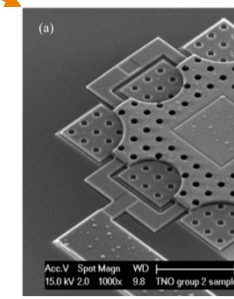
- Mechanical resonance > 50 kHz
- Readout resolution < 20 fm/sqrt(Hz)
- Detachable from positioning arm



3rd Gen.

- Mechanical resonance > 80 kHz
- Readout resolution < 120 fm/sqrt(Hz)
- Arm-less

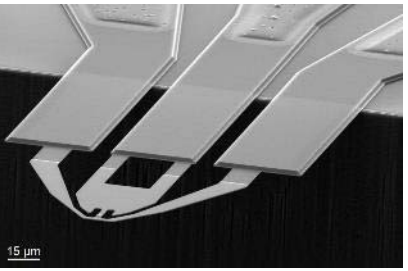


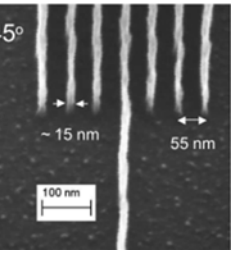


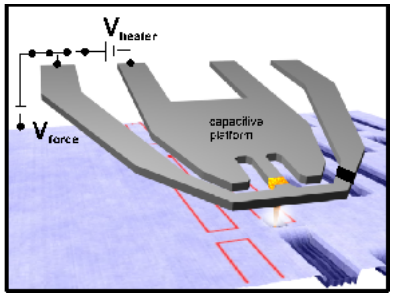
4th Gen.

- Mechanical resonance
- Readout resolution < 1 fm/sqrt(Hz)
- Arm-less
- MEMS scanner

ANOFABRICATION

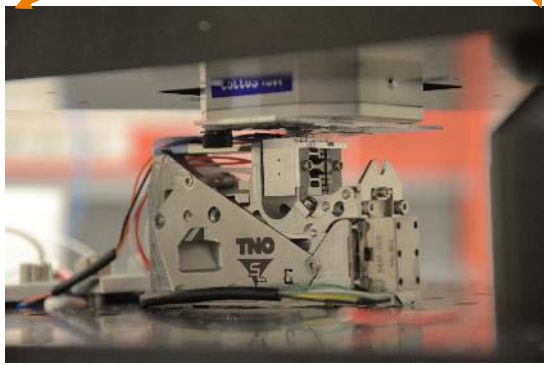




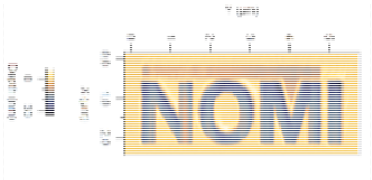


Scanning thermal nanolithography, IBM/SwissLitho



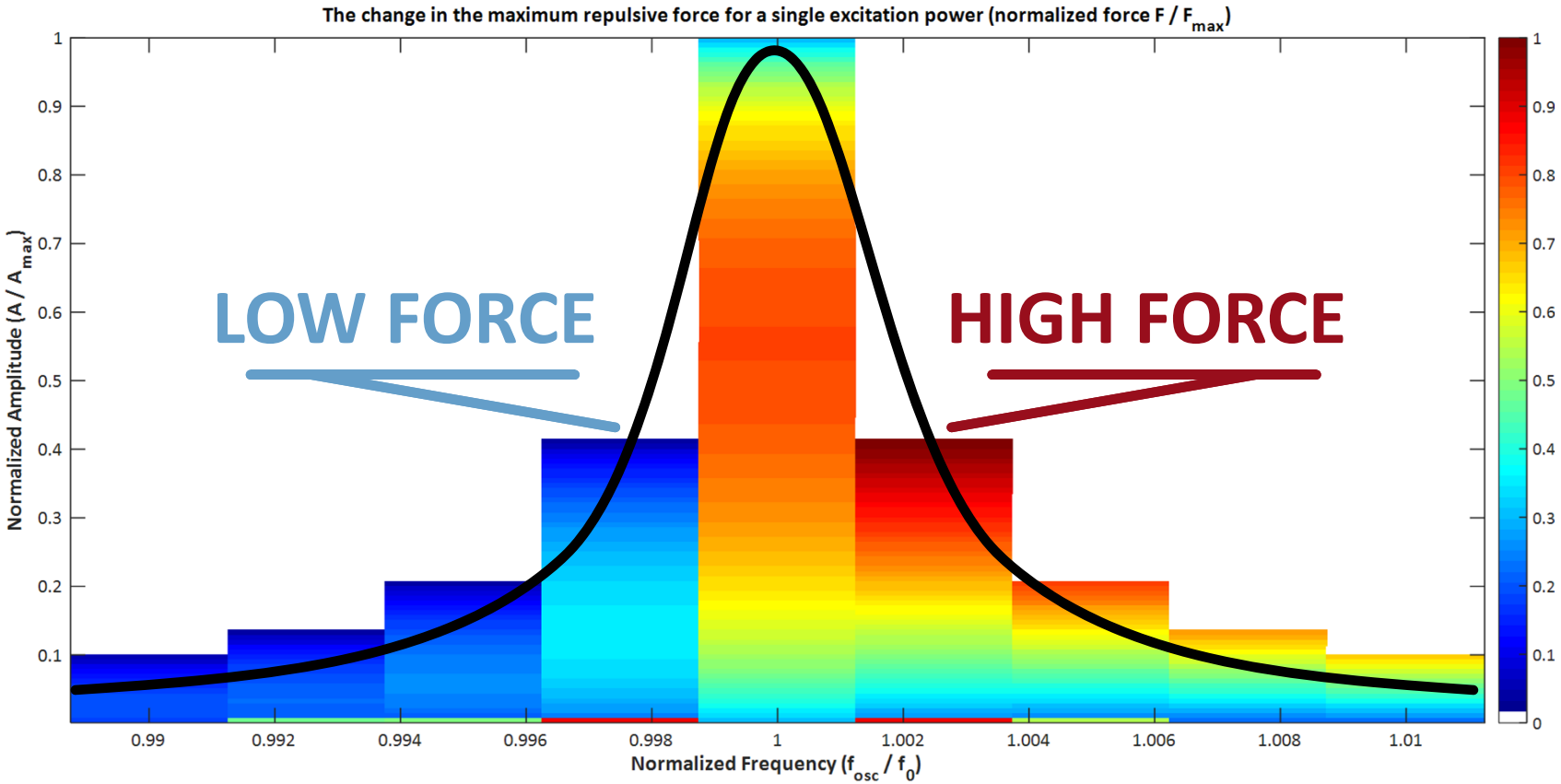


TNO / SwissLitho test setup





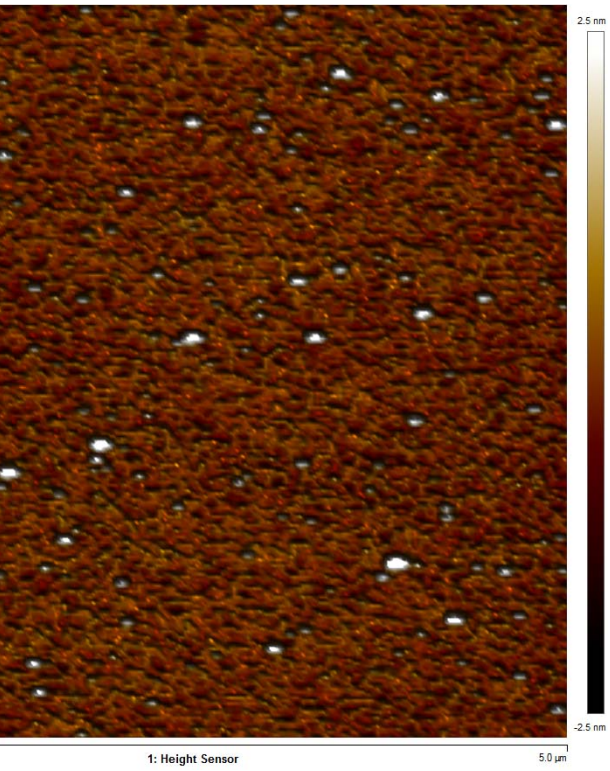
APPING THE PEAK REPULSIVE FORCE AT THE NAN CALE

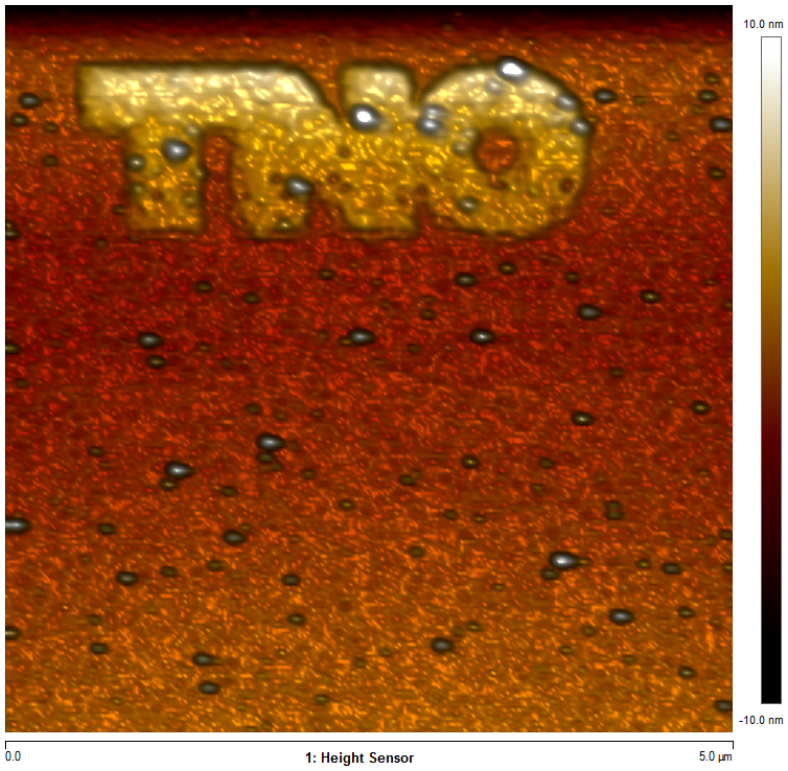


NOMI

TNO innovatic for life

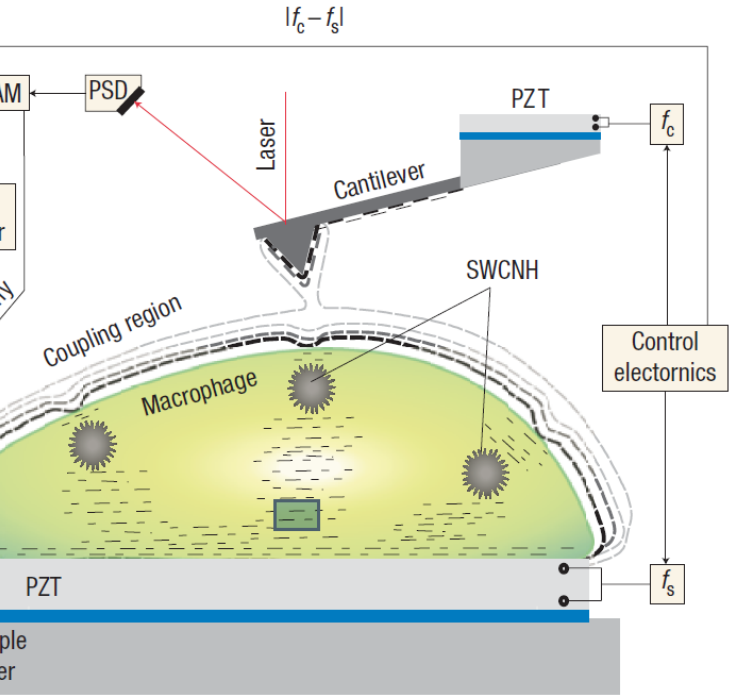
EAD AND WRITE AT THE SAME TIME





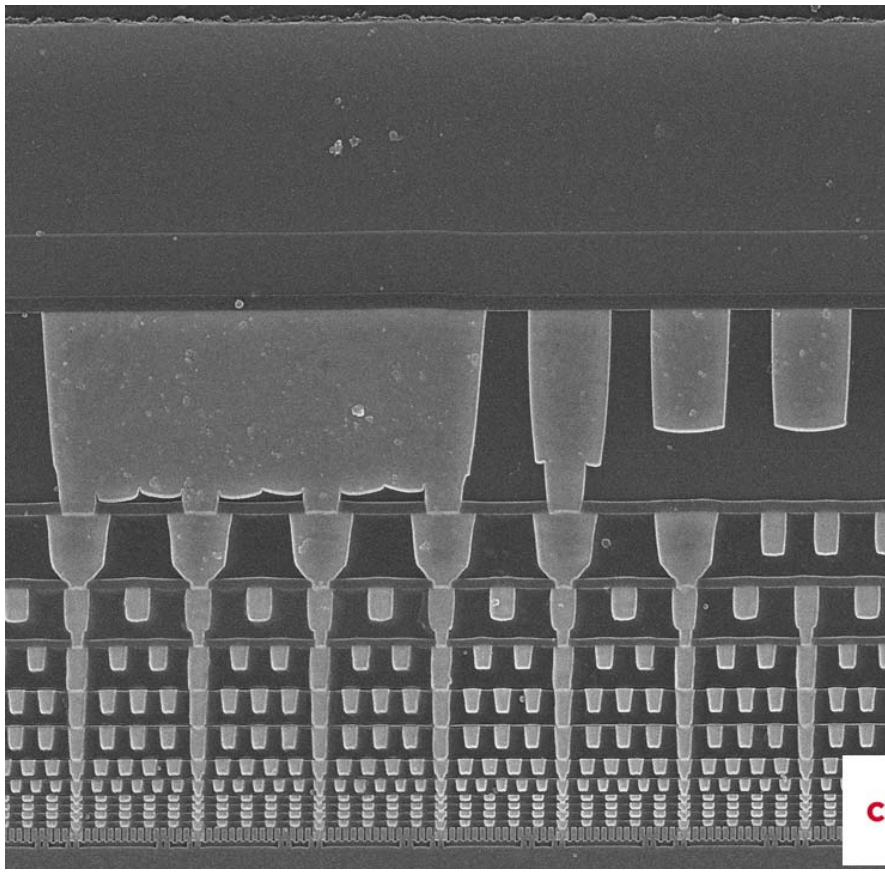


OW TO IMAGE INSIDE MATERIALS WITH NM ESOLUTION?



Inside a cell

Opaque layers



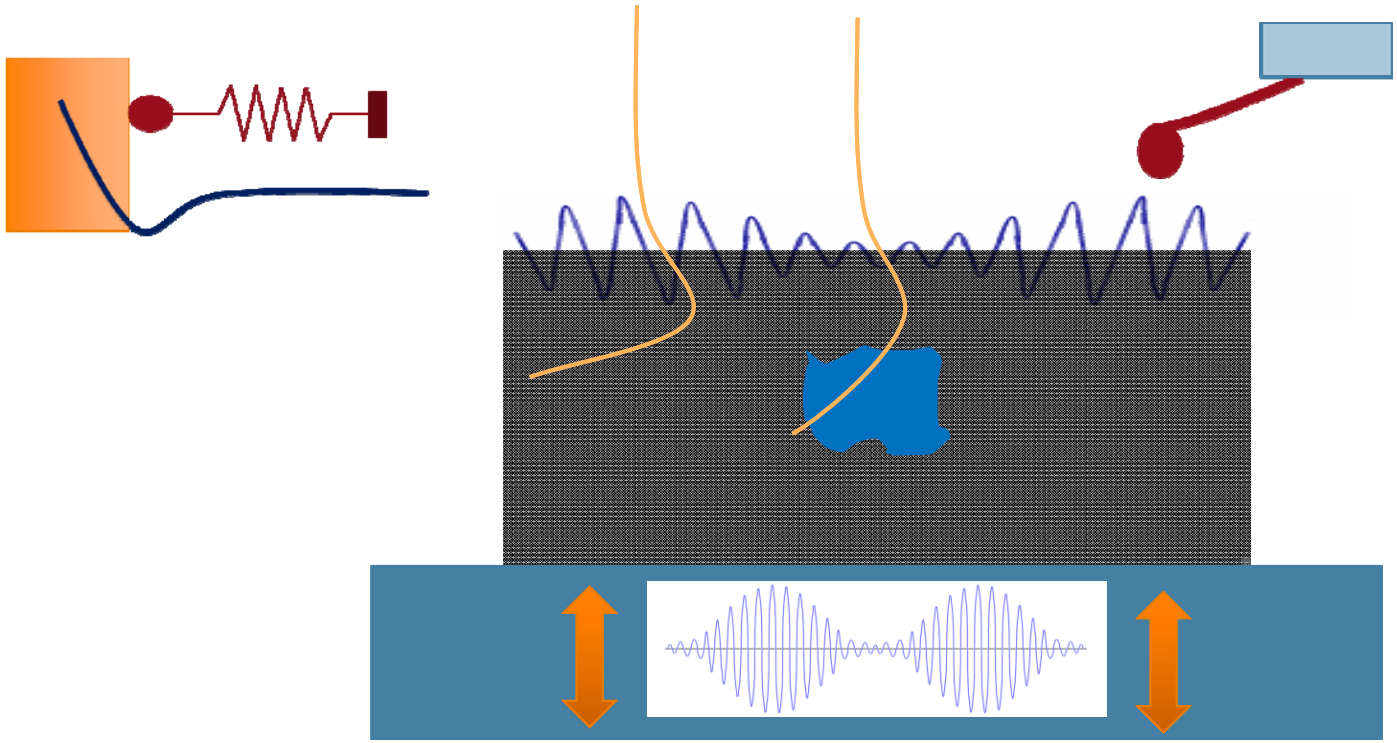
Smallest feature size ~ 14 nm

Inside a nanoelectronics

NOMI

TNO innovatic for life

TERROGATE BELOW THE SURFACE



MHz 100 MHz > 1 GHz

Elasticity

Elasticity and wave scatte

s *et al.,* Ultramicroscopy, under review Piras et al., Journal of Physics D: Applied Physics 50 (23

NOMI

TNO innovatic for life

HROUGH LAYERS IMAGING

gid structures in soft matrix

Multilayers

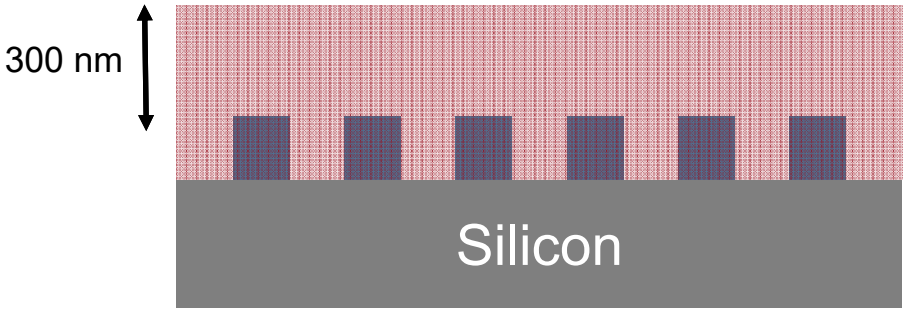
id structures in rigid matrix

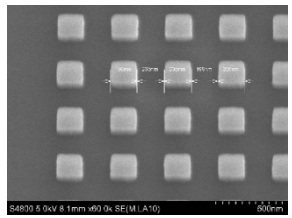
Depth of imaging

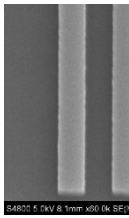
D, LER, LWR

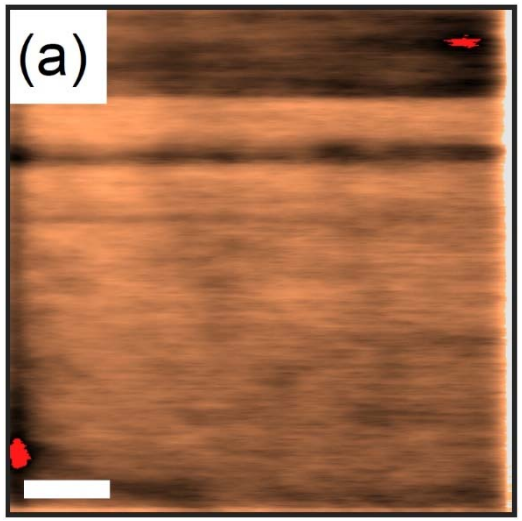
visible defects

ocation/pitch

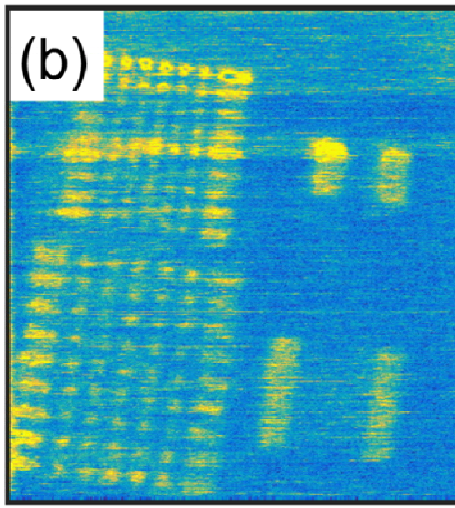








Surface imaging



Through layers imag

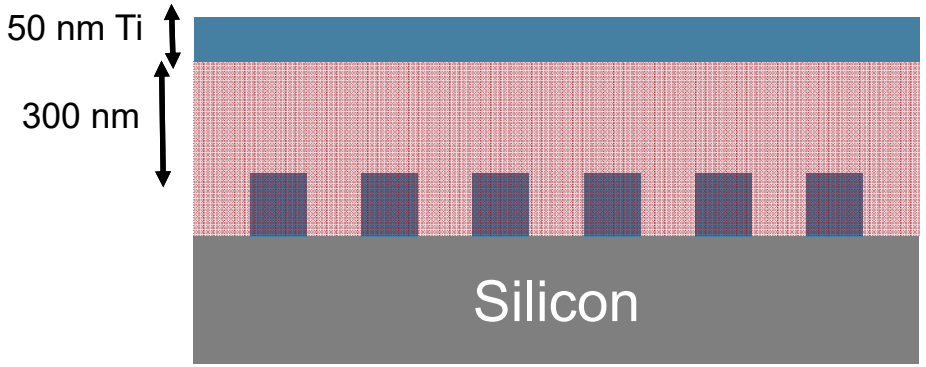
t al., Journal of Physics D: Applied Physics 50 (23), 235601

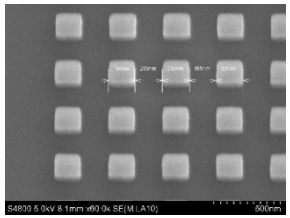
NOMI

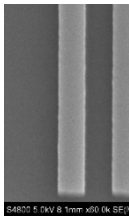
TNO innovatic for life

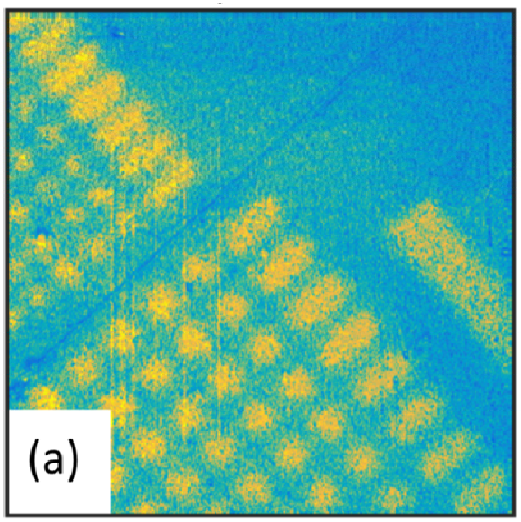
HROUGH LAYERS IMAGING

- igid structures in soft matrix
- Multilayers
- id structures in rigid matrix
- Depth of imaging

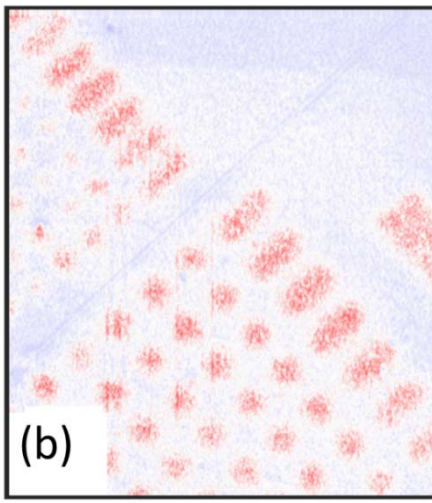








Amplitude



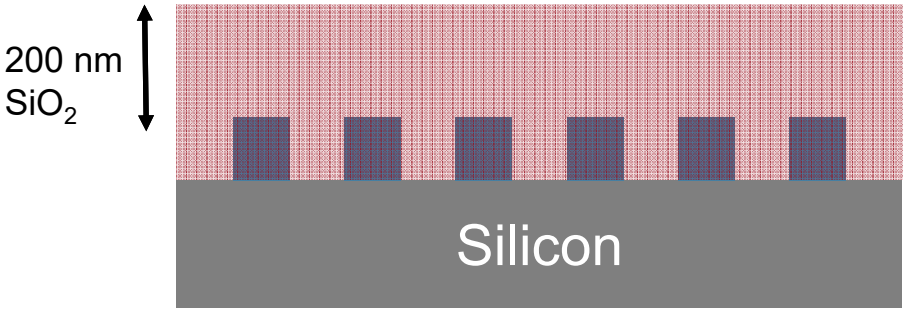
Phase

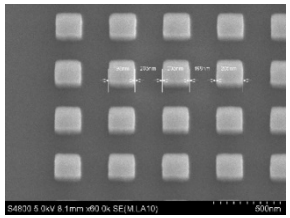
NOMI

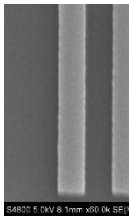
TNO innovatic for life

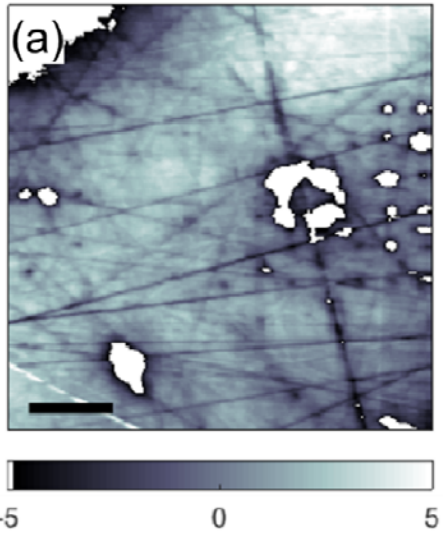
HROUGH LAYERS IMAGING

- igid structures in soft matrix
- Multilayers
- id structures in rigid matrix
- Depth of imaging

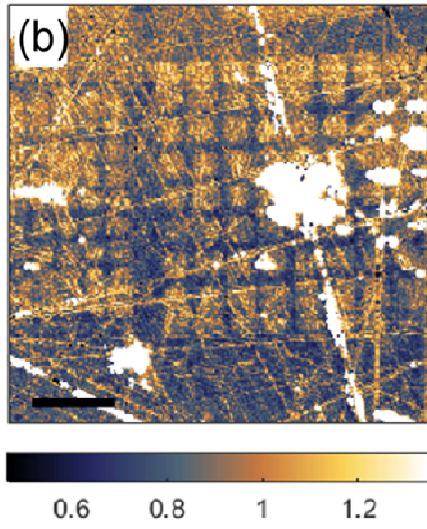








Surface imaging



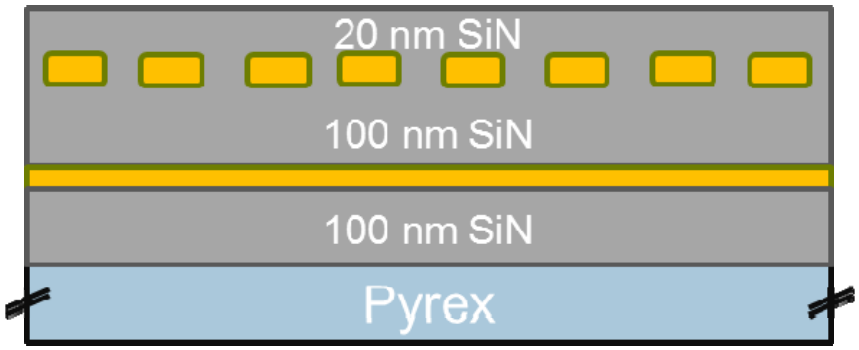
Through layers imag

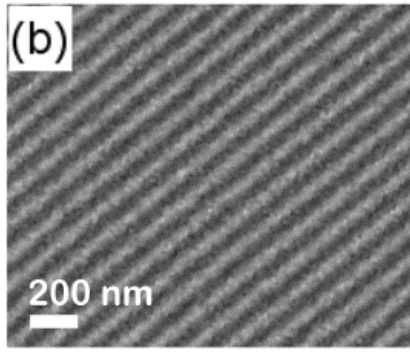
NOMI

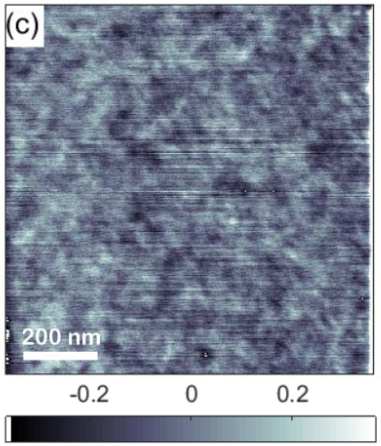
TNO innovatic for life

HROUGH LAYERS IMAGING

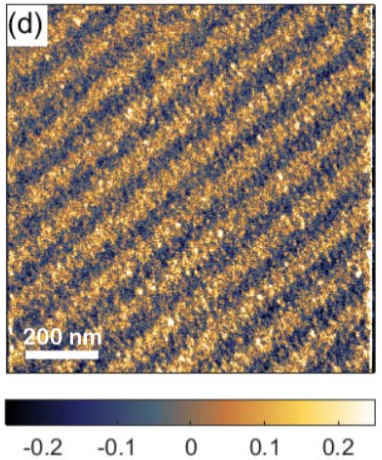
- gid structures in soft matrix
- Multilayers
- id structures in rigid matrix
- Depth of imaging



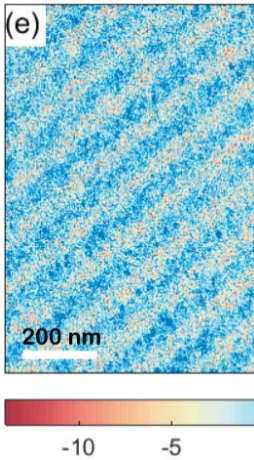




Surface topography



Amplitude (mV)



Phase (deg

abrication:
of A. Storm, H. van der Berg, R. Schmits

NOMI

TNO innovatic for life

CKNOWLEDGEMENT

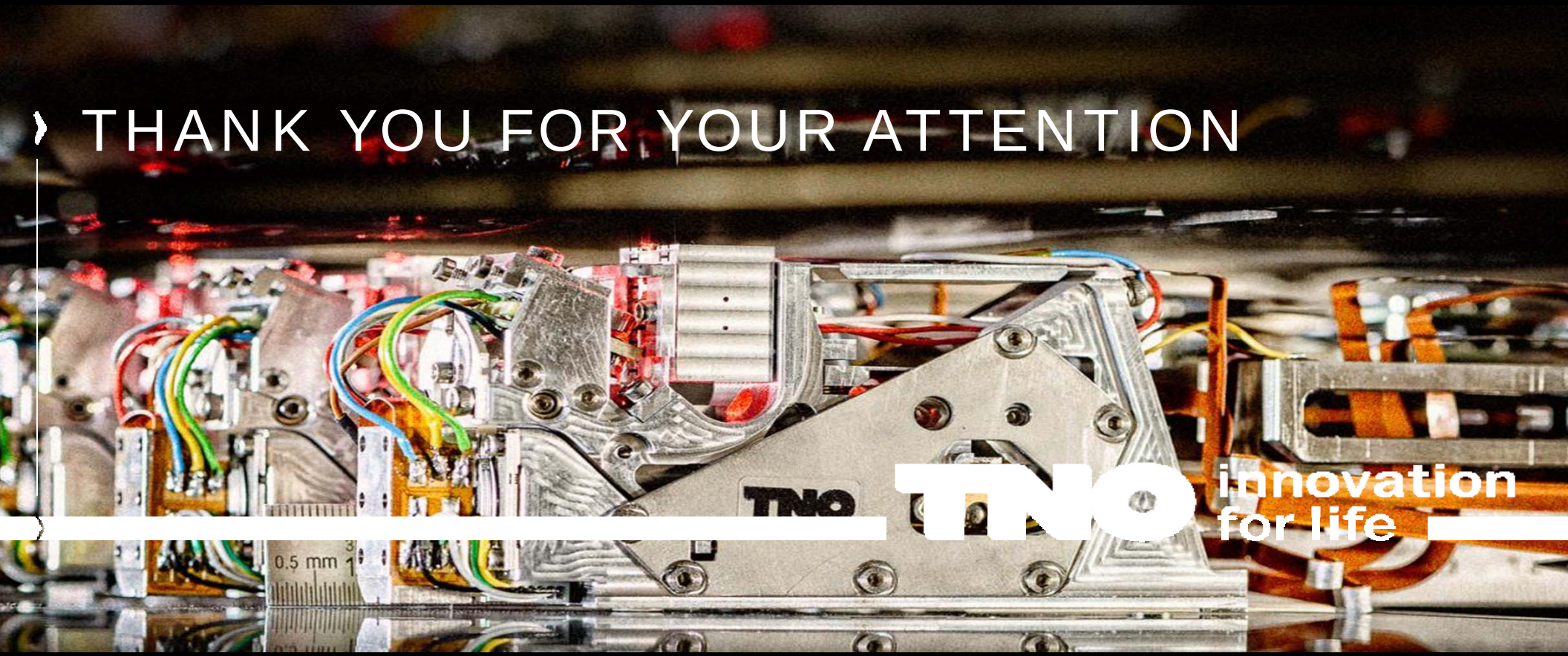


NOMI team

NOMI is expanding! Several research scientist positions available.

Early Research Program 3D Nanomanufacturing (tno.nl/3dnano)

THANK YOU FOR YOUR ATTENTION



TNO innovation for life