Park Atomic Force Microscopy

AFM Probe Selection Guide

How to choose an AFM probe

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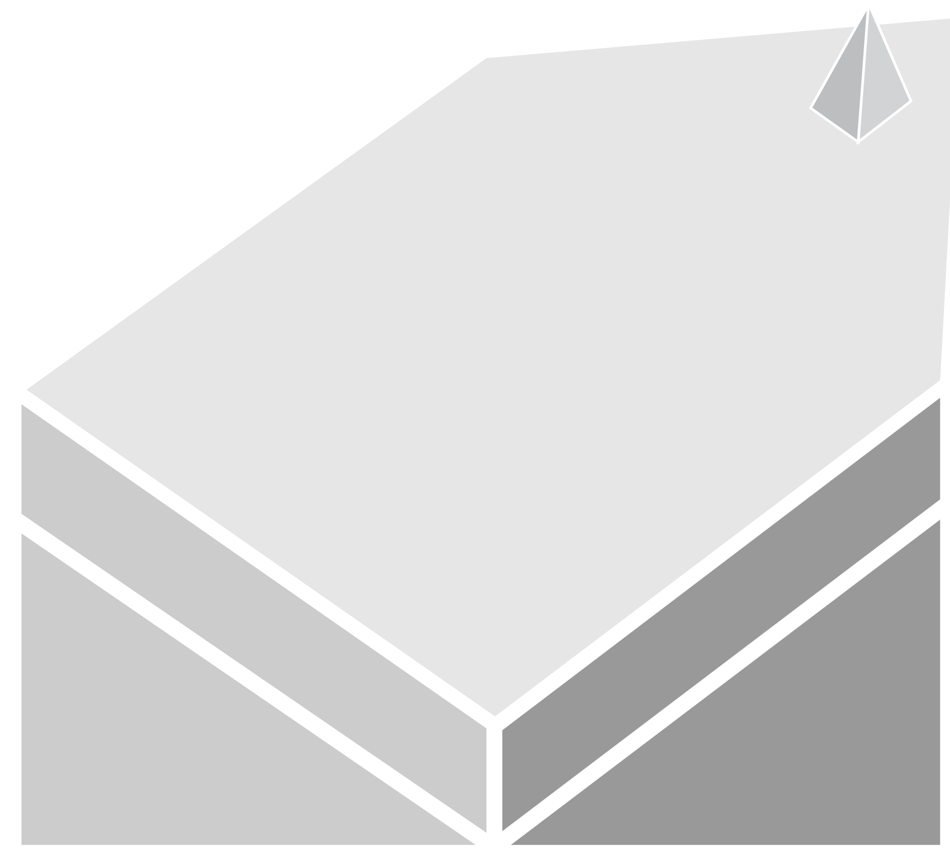

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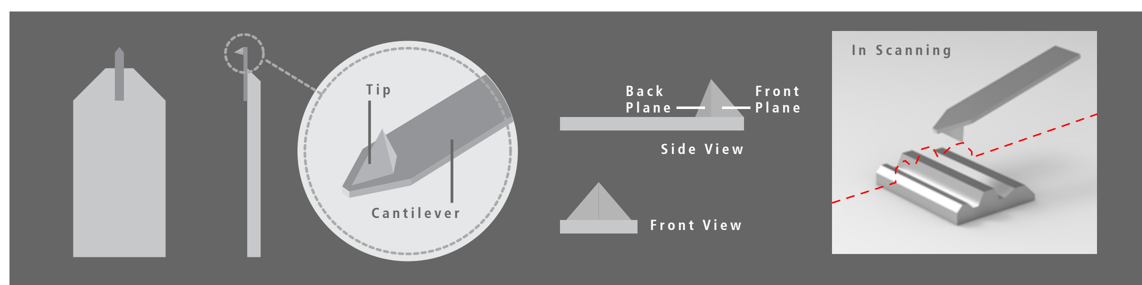
PART I
AFM IMAGING MODES

PART I
AFM IMAGING MODES

INTRODUCTION

Proper selection of a probe for an atomic force microscope (AFM) is important to obtain good quality sample surface images. In general, an AFM probe consists of a silicon chip, a cantilever (Si or Si_3N_4) hanging from the chip, and a tip (Si or Si_3N_4) attaching at the end of the cantilever (Figure 1). AFM probes come in a variety of materials, shapes (geometry), stiffnesses (spring constants), resonance frequencies and Q-factors. Probe selection depends on the material and application.

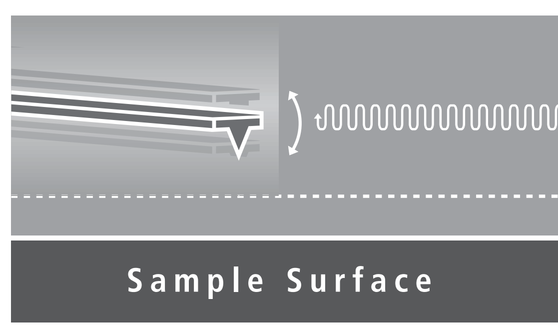
The probe variations come mainly from the variations of cantilever types. Typically, the backside of an AFM cantilever has a metallic coating such as gold or aluminum to increase reflectivity. Depending on the properties of a cantilever, it can be classified as a non-contact or a contact mode cantilever. For example, a cantilever with high spring constant (>20 N/m) and resonance frequency (>200 kHz) is suitable for the non-contact mode, whereas a cantilever with low spring constant (<10 N/m) and low resonance frequency (<200 kHz) is good for the contact mode. Therefore, you must first consider the type of cantilever to choose when selecting an AFM probe.



[Figure 1] Views of a typical AFM probe including close up of tip.

		Non-contact Mode	Tapping Mode	Contact Mode
In Air	Recommended	AC160TS[1]	AC160TS	PPP-CONTSCR[4]
	Alternative Recommendation	PPP-NCHR[2]	PPP-NCHR	NSC36 / Al BS[5] PPP-FMR[6]
In Liquid	Recommended	BL-AC40TS[3]	BL-AC40TS	BL-AC40TS
	Alternative Recommendation	NSC36 / Al BS	NSC36 / Al BS	PPP-CONTSCR

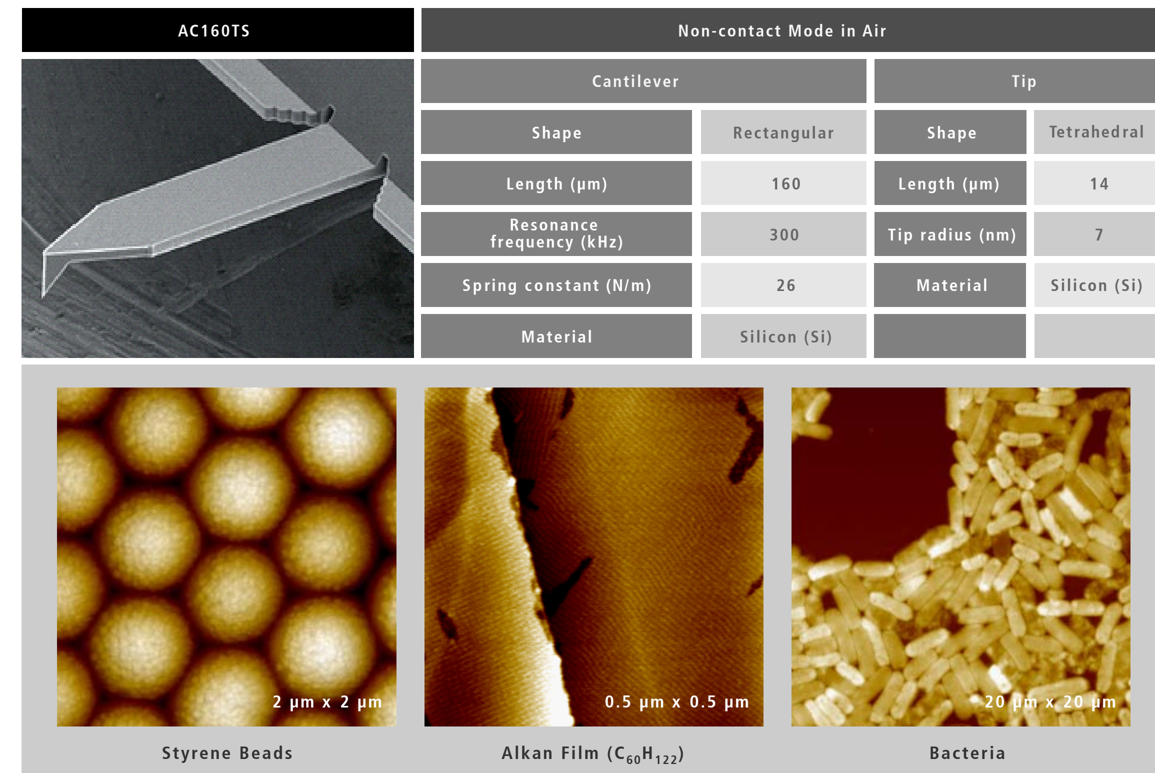
[Table 1] Recommended AFM probes by imaging modes.



NON-CONTACT MODE

For non-contact mode, we recommend that you use a probe with a higher resonance frequency (~300 kHz) and higher spring constant (~20 N/m). The reason is that when scanning in non-contact mode under ambient conditions, the tip often traps moisture, creating a contaminated layer on the sample. This happens more often when using a cantilever with a low spring constant.

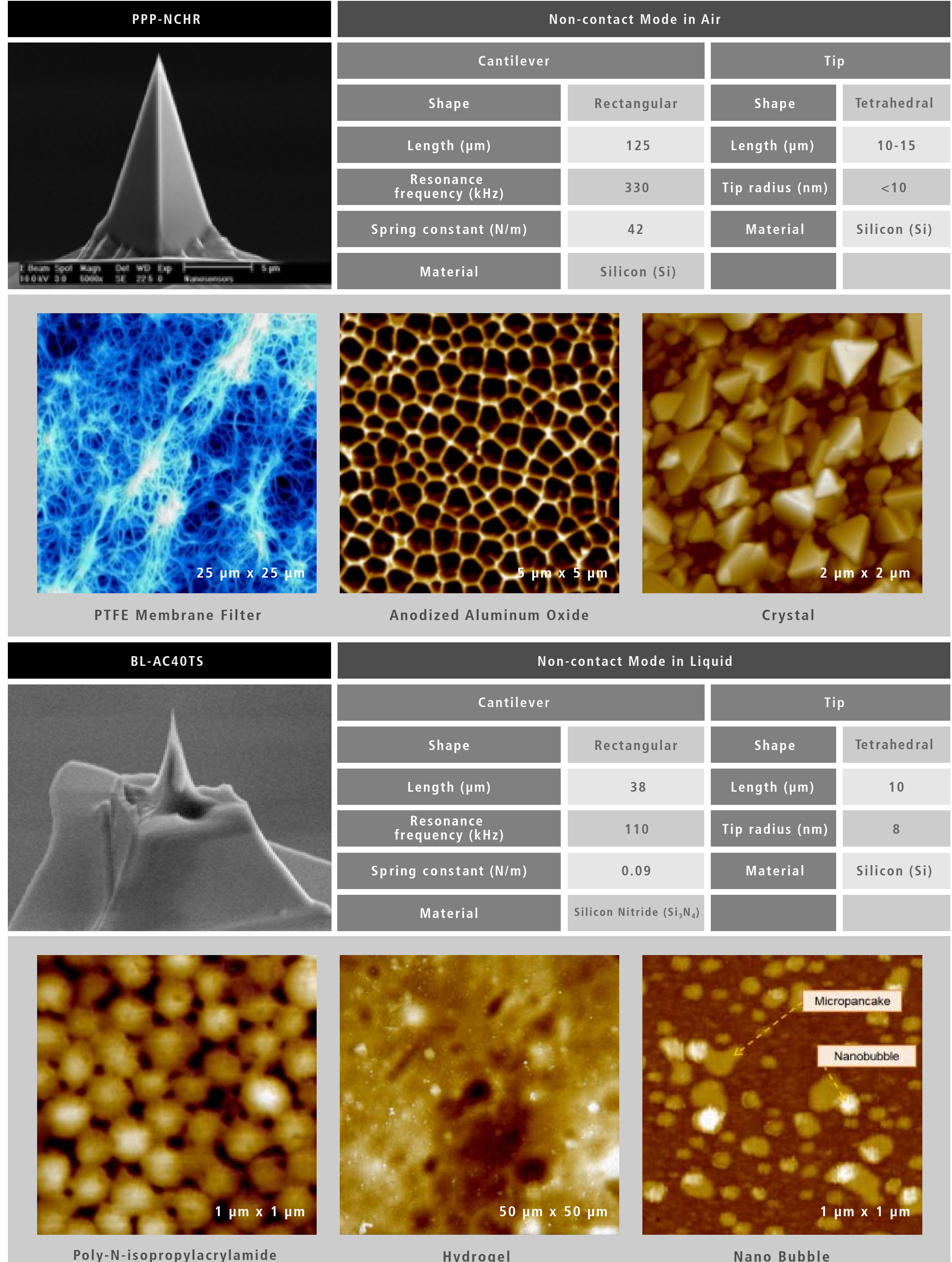
AFM probe for Non-contact mode	• High resonance frequency (>200 kHz) • High spring constant (>20 N/m)



AC160TS	Non-contact Mode in Air			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	160	Length (µm)	14
	Resonance frequency (kHz)	300	Tip radius (nm)	7
	Spring constant (N/m)	26	Material	Silicon (Si)
	Material	Silicon (Si)		

Styrene Beads | Alkan Film ($C_{60}H_{122}$) | Bacteria

PART I
AFM IMAGING MODES



PPP-NCHR	Non-contact Mode in Air			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	125	Length (µm)	10-15
	Resonance frequency (kHz)	330	Tip radius (nm)	<10
	Spring constant (N/m)	42	Material	Silicon (Si)
	Material	Silicon (Si)		

25 µm x 25 µm — PTFE Membrane Filter

5 µm x 5 µm — Anodized Aluminum Oxide

2 µm x 2 µm — Crystal

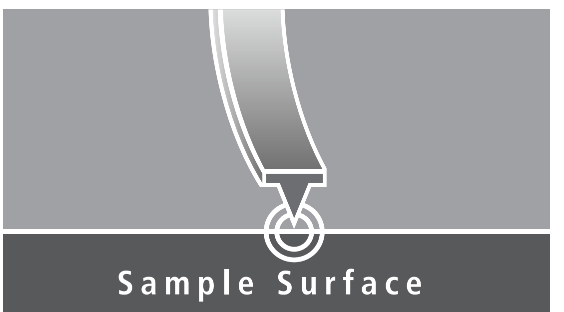
BL-AC40TS	Non-contact Mode in Liquid			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	38	Length (µm)	10
	Resonance frequency (kHz)	110	Tip radius (nm)	8
	Spring constant (N/m)	0.09	Material	Silicon (Si)
	Material	Silicon Nitride (Si_3N_4)		

1 µm x 1 µm — Poly-N-isopropylacrylamide

50 µm x 50 µm — Hydrogel

1 µm x 1 µm — Nano Bubble

CONTACT MODE



For contact mode, a soft cantilever with low spring constant (~ 1 N/m) is required to determine the small force between the sample surface and the tip. A hard or stiff cantilever will cause the tip to exert high forces to the surface, which can damage the AFM tip, the sample surface, or both.

AFM probe for Contact mode	• Low resonance frequency (<200 kHz) • Low spring constant (<10 N/m)

PPP-CONTSCR	Contact Mode in Air			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	225	Length (µm)	10
	Resonance frequency (kHz)	25	Tip radius (nm)	<10
	Spring constant (N/m)	0.2	Material	Silicon (Si)
	Material	Silicon (Si)		

20 µm x 20 µm — Graphene on Cu

3 µm x 3 µm — $BiFeO_3$

1 µm x 1 µm — ITO Glass

PART I

AFM IMAGING MODES

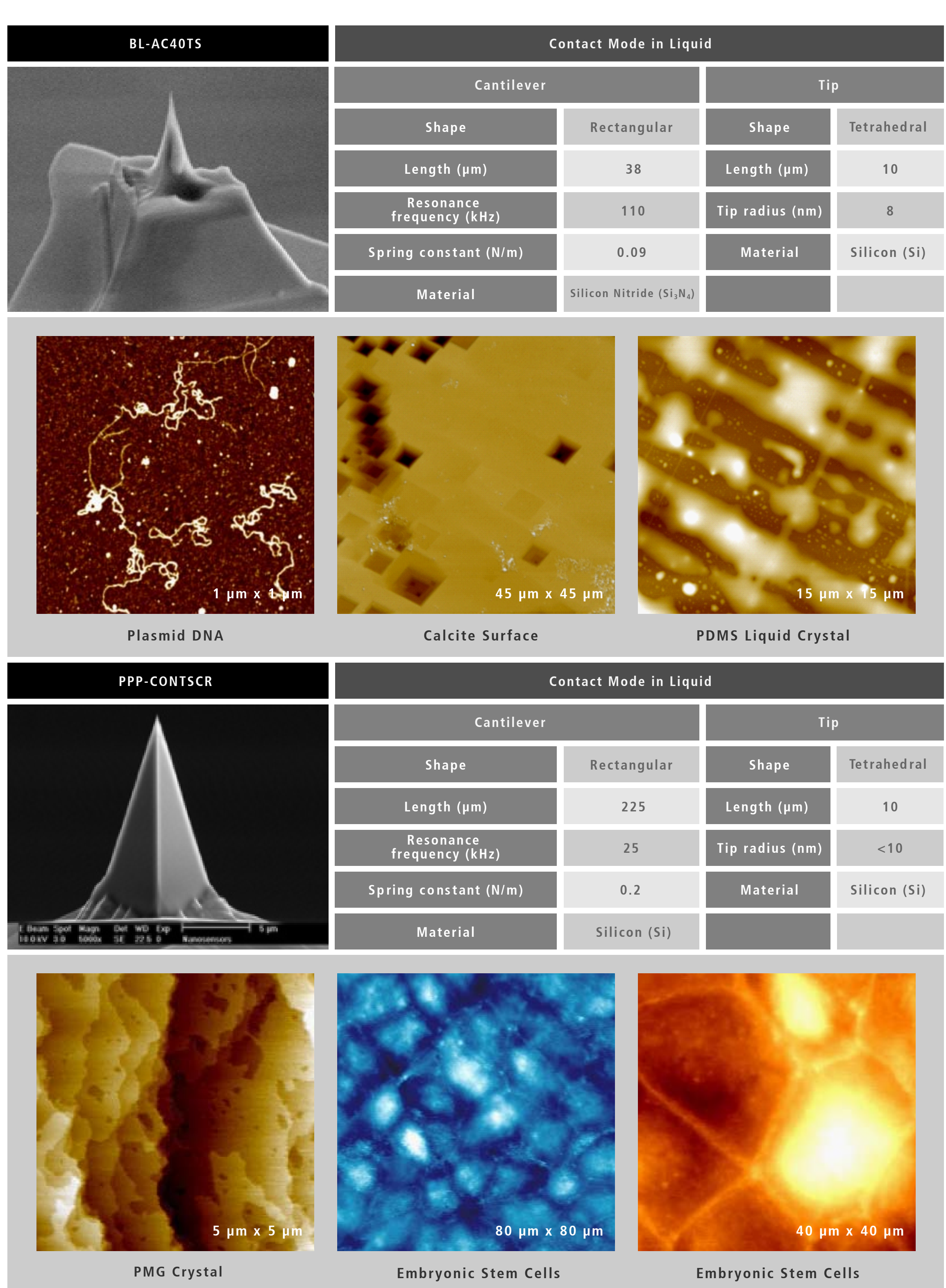
NSC36 / Al BS	Contact Mode in Air			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Material	Silicon (Si)	Length (µm)	12-18
			Tip radius (nm)	8
			Material	Silicon (Si)

Cantilever Type	Resonance frequency (kHz)	Spring constant (N/m)	Length (µm)
A	90	1	110
B	130	2	90
C	65	0.6	130

45 µm x 45 µm
CNT Film

10 µm x 10 µm
Floppy

30 µm x 30 µm
SIC Device



BL-AC40TS	Contact Mode in Liquid			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	38	Length (µm)	10
	Resonance frequency (kHz)	110	Tip radius (nm)	8
	Spring constant (N/m)	0.09	Material	Silicon (Si)
	Material	Silicon Nitride (Si_3N_4)		

1 µm x 1 µm
Plasmid DNA

45 µm x 45 µm
Calcite Surface

15 µm x 15 µm
PDMS Liquid Crystal

PPP-CONTSCR	Contact Mode in Liquid			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	225	Length (µm)	10
	Resonance frequency (kHz)	25	Tip radius (nm)	<10
	Spring constant (N/m)	0.2	Material	Silicon (Si)
	Material	Silicon (Si)		

5 µm x 5 µm
PMG Crystal

80 µm x 80 µm
Embryonic Stem Cells

40 µm x 40 µm
Embryonic Stem Cells

PART II
ADVANCED AFM MODES

PART II
ADVANCED AFM MODES

ADVANCED AFM MODES

Besides the surface imaging mode, the AFM can measure many other surface properties, such as the electrical, nanomechanical, magnetic and thermal properties. For these surface property measurements, there are additional experimental parameters; however, utilizing a functionalized or metallic coated AFM probe is one of the most important factors to obtain appropriate results.

In this section, we list the recommended AFM probes for each of the AFM surface property measurement modes. The AFM probes are categorized by metallic coating, probe geometry and mechanical properties.

	Options	Recommended	Alternative Recommendation
Electrical	EFM / KPFM	NSC36 / Cr-Au[7]	PPP-NCSTAu[8]
	PFM / SCM	PPP-EFM[9]	ElectriMulti75-G[10]
	C-AFM / PCM	PPP-CONTSCPt[11]	CDT-CONTR[12]
	SSRM	IMEC[13]	CDT-NCHR[14]
Nano-Mechanical	F/d / PinPoint / FMM	NSC36 / Al BS	PPP-FMR
	Lithography	DT-NCHR[15] (Scratching)	
		ElectriMulti75-G (Oxidation)	
Magnetic	MFM	PPP-MFMR[16]	NSC18 / Co-Cr / Al BS[17]
Thermal	SThM	NanoThermal[18]	

[Table 2] Recommended AFM probes for other modes.

ELECTRICAL PROPERTIES

The electrical properties of a sample surface can be measured using the advanced mode with a conductive AFM cantilever. In order to measure electrical properties properly, the characteristics of the AFM probe such as tip shape/radius, cantilever geometry and coating materials has to be considered.

While characteristics of the probe differ little from the imaging mode to mode, the metallic coating materials should be taken into account. This is due to the electrical interaction between the AFM tip and the sample. In general, there are several tip choices to measure electrical properties; these include gold (Au), platinum-iridium alloy (Pt-Ir), and conductive diamond. All of these metallic materials can be coated at the cantilever and tip to make the probe conductive. These metallic materials have different mechanical conductivity and stability; therefore, probe choice is a function of the sample type and the AFM mode used.

NSC36 / Cr-Au	Electrical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
			Length (μm)	12-18
			Tip radius (nm)	<35
			Material	Silicon (Si)
	Material	Cr-Au coating		

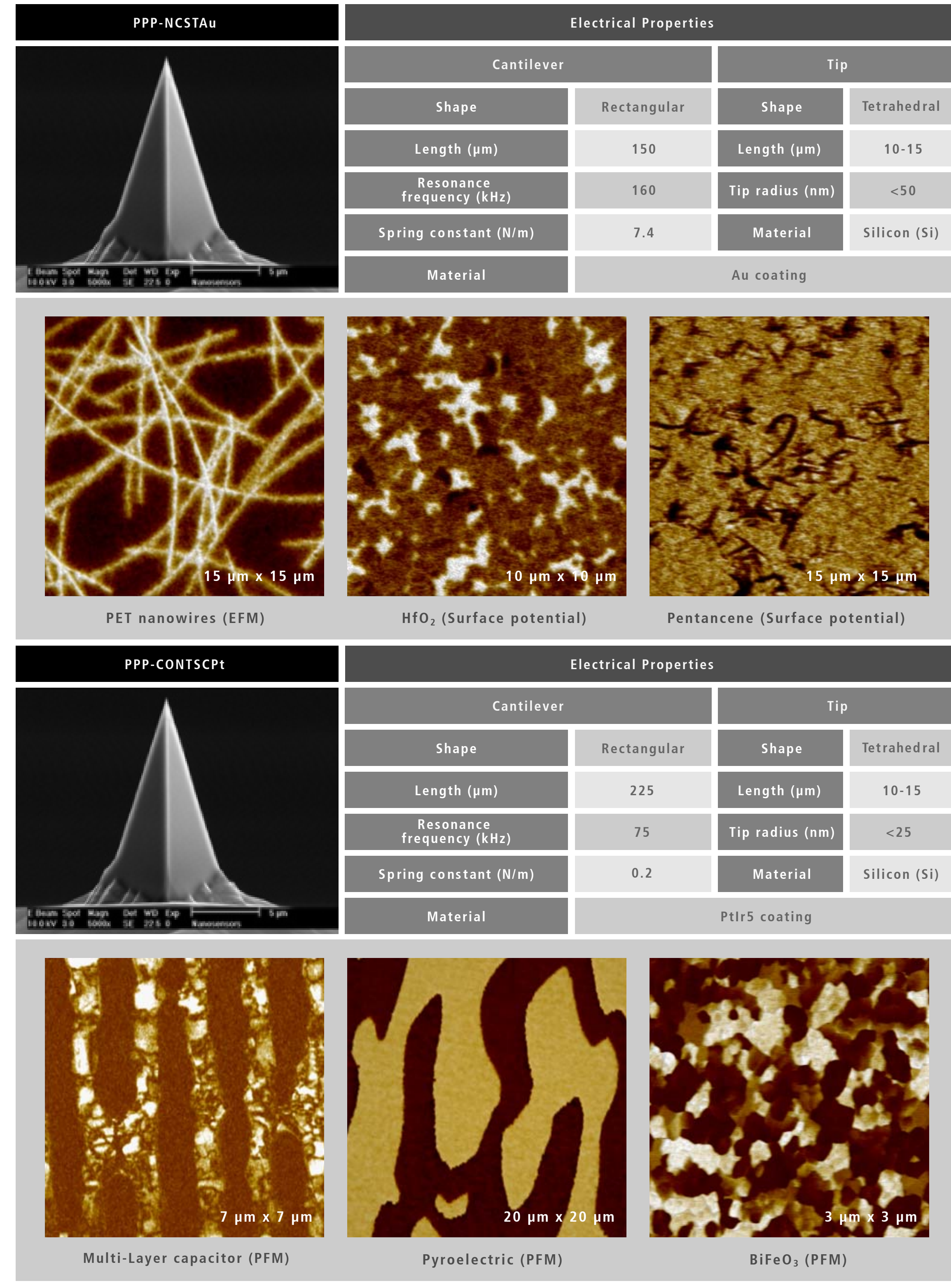
Cantilever Type	Resonance frequency (kHz)	Spring constant (N/m)	Length (μm)
A	90	1	110
B	130	2	90
C	65	0.6	130

30 μm x 30 μm — MoS_2 (Surface potential)

10 μm x 10 μm — Metallo-DNA (EFM)

10 μm x 10 μm — PMN-PT Crystal (EFM)

PART II
ADVANCED AFM MODES



PPP-NCSTAu	Electrical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	150	Length (µm)	10-15
	Resonance frequency (kHz)	160	Tip radius (nm)	<50
	Spring constant (N/m)	7.4	Material	Silicon (Si)
	Material	Au coating		

15 µm x 15 µm — PET nanowires (EFM)

10 µm x 10 µm — HfO_2 (Surface potential)

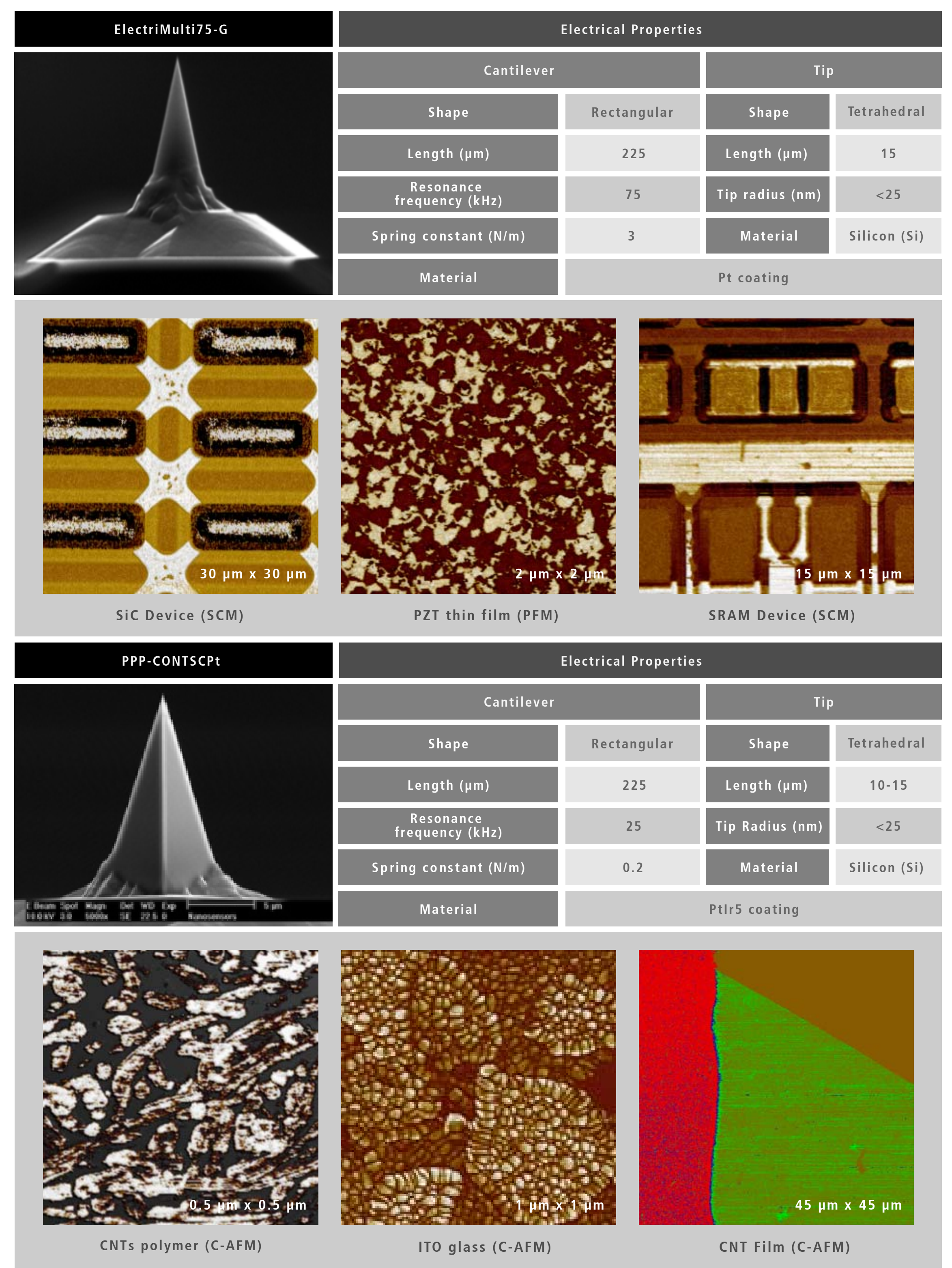
15 µm x 15 µm — Pentancene (Surface potential)

PPP-CONTSCPt	Electrical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	225	Length (µm)	10-15
	Resonance frequency (kHz)	75	Tip radius (nm)	<25
	Spring constant (N/m)	0.2	Material	Silicon (Si)
	Material	PtIr5 coating		

7 µm x 7 µm — Multi-Layer capacitor (PFM)

20 µm x 20 µm — Pyroelectric (PFM)

3 µm x 3 µm — $BiFeO_3$ (PFM)



ElectriMulti75-G	Electrical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	225	Length (µm)	15
	Resonance frequency (kHz)	75	Tip radius (nm)	<25
	Spring constant (N/m)	3	Material	Silicon (Si)
	Material	Pt coating		

30 µm x 30 µm — SiC Device (SCM)

2 µm x 2 µm — PZT thin film (PFM)

15 µm x 15 µm — SRAM Device (SCM)

PPP-CONTSCPt	Electrical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	225	Length (µm)	10-15
	Resonance frequency (kHz)	25	Tip Radius (nm)	<25
	Spring constant (N/m)	0.2	Material	Silicon (Si)
	Material	PtIr5 coating		

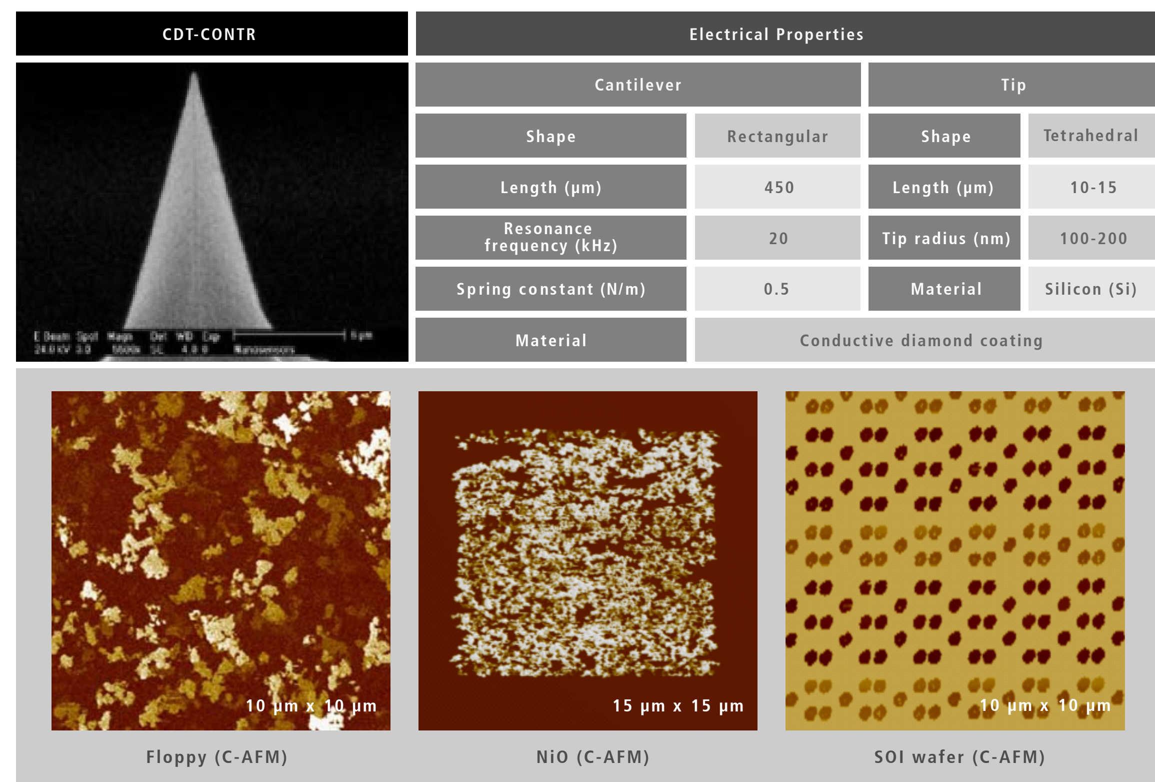
0.5 µm x 0.5 µm — CNTs polymer (C-AFM)

1 µm x 1 µm — ITO glass (C-AFM)

45 µm x 45 µm — CNT Film (C-AFM)

PART II

ADVANCED AFM MODES

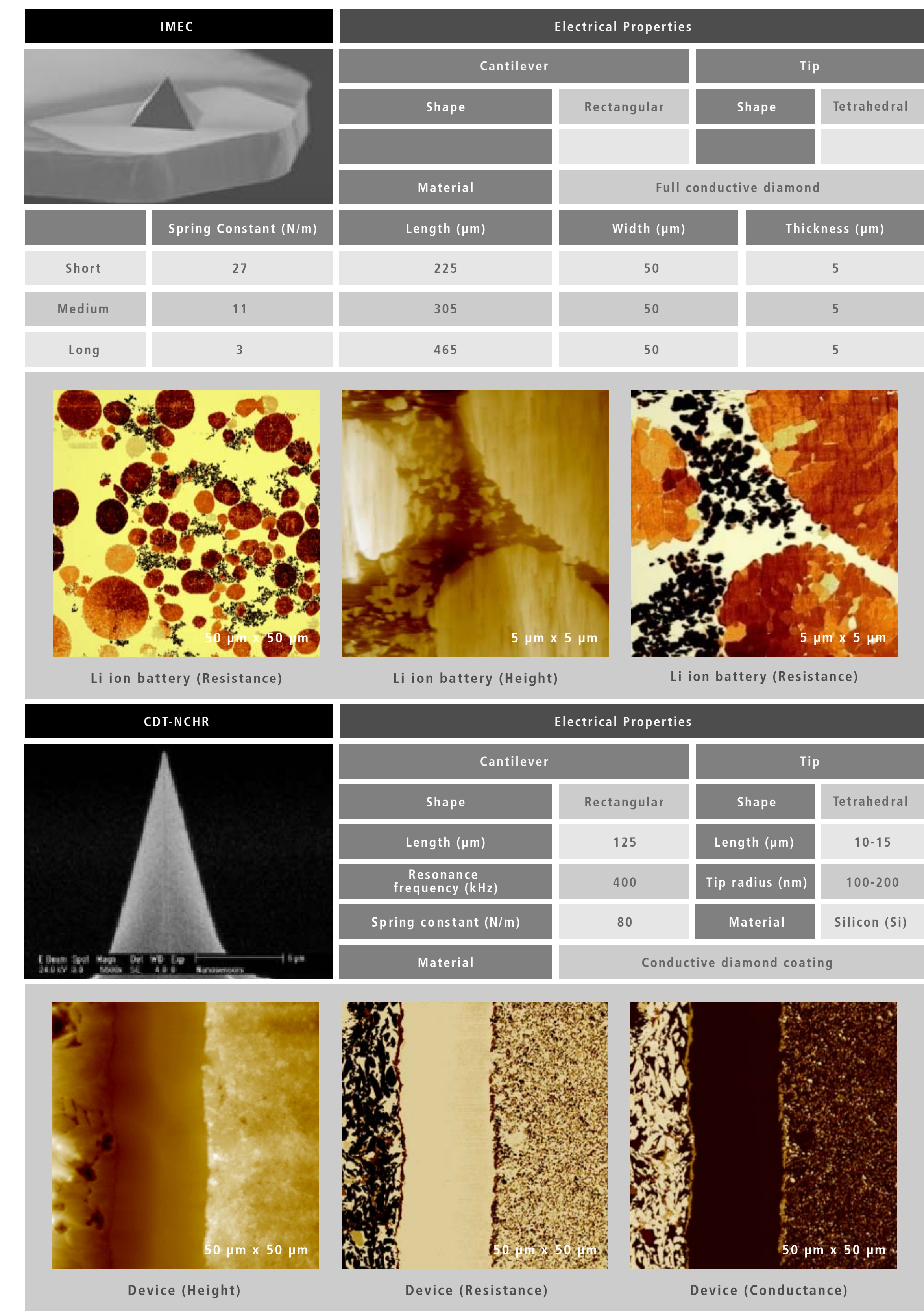


CDT-CONTR	Electrical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	450	Length (µm)	10-15
	Resonance frequency (kHz)	20	Tip radius (nm)	100-200
	Spring constant (N/m)	0.5	Material	Silicon (Si)
	Material	Conductive diamond coating		

Floppy (C-AFM)

NiO (C-AFM)

SOI wafer (C-AFM)



IMEC	Electrical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Material	Full conductive diamond		

	Spring Constant (N/m)	Length (µm)	Width (µm)	Thickness (µm)
Short	27	225	50	5
Medium	11	305	50	5
Long	3	465	50	5

Li ion battery (Resistance)

Li ion battery (Height)

Li ion battery (Resistance)

CDT-NCHR	Electrical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	125	Length (µm)	10-15
	Resonance frequency (kHz)	400	Tip radius (nm)	100-200
	Spring constant (N/m)	80	Material	Silicon (Si)
	Material	Conductive diamond coating		

Device (Height)

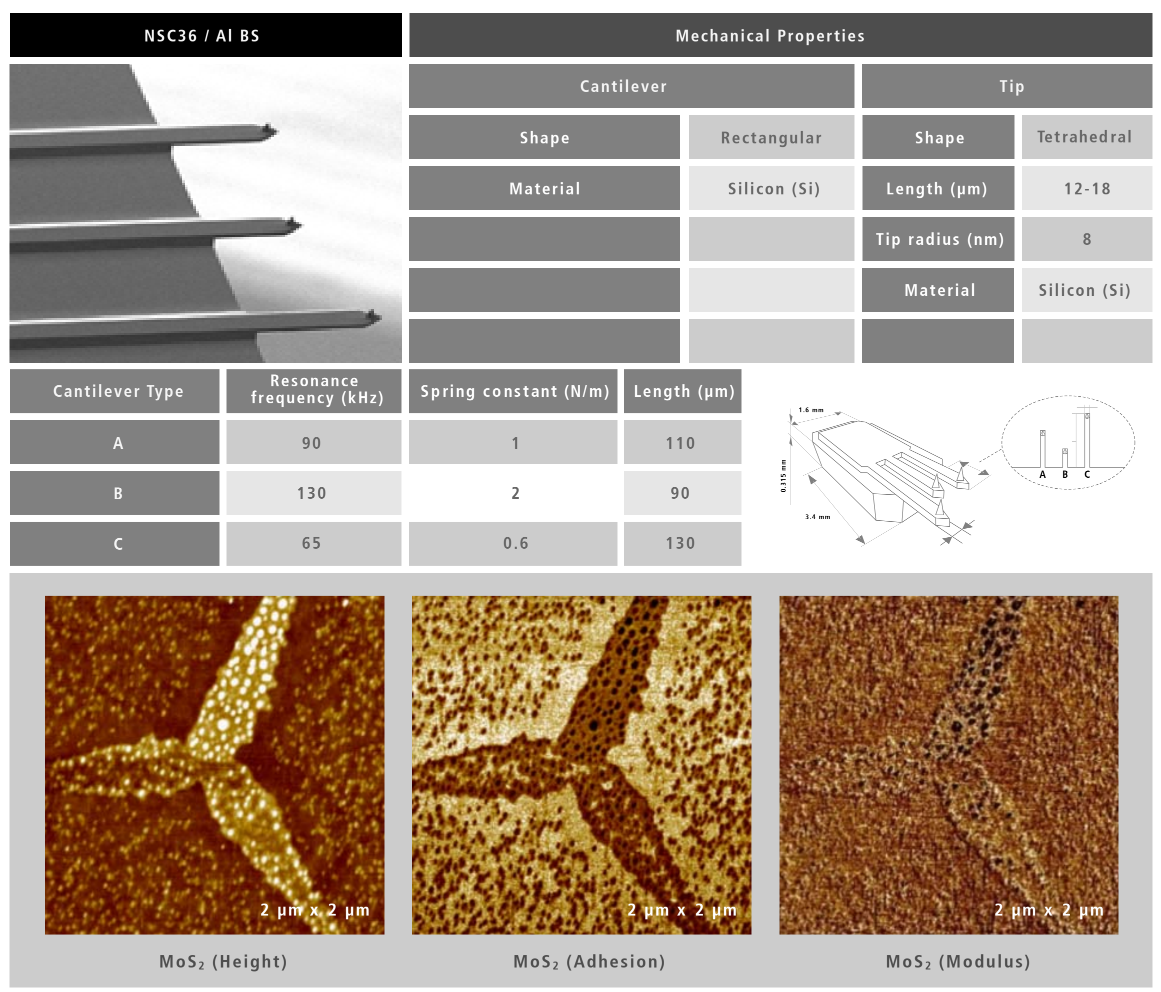
Device (Resistance)

Device (Conductance)

NANOMECHANICAL PROPERTIES

To measure nanomechanical properties, metallic coated tips are not necessary except in special cases (molecular recognition or single molecule force spectroscopy). Generally, a contact mode AFM probe (low frequency, low spring constant) is used for force measurements, bbut it has been found out that the proper AFM probe needs to be chosen depending on the mechanical properties of sample (While soft cantilever is suitable for soft materials, stiff cantilever is applicable for hard materials).

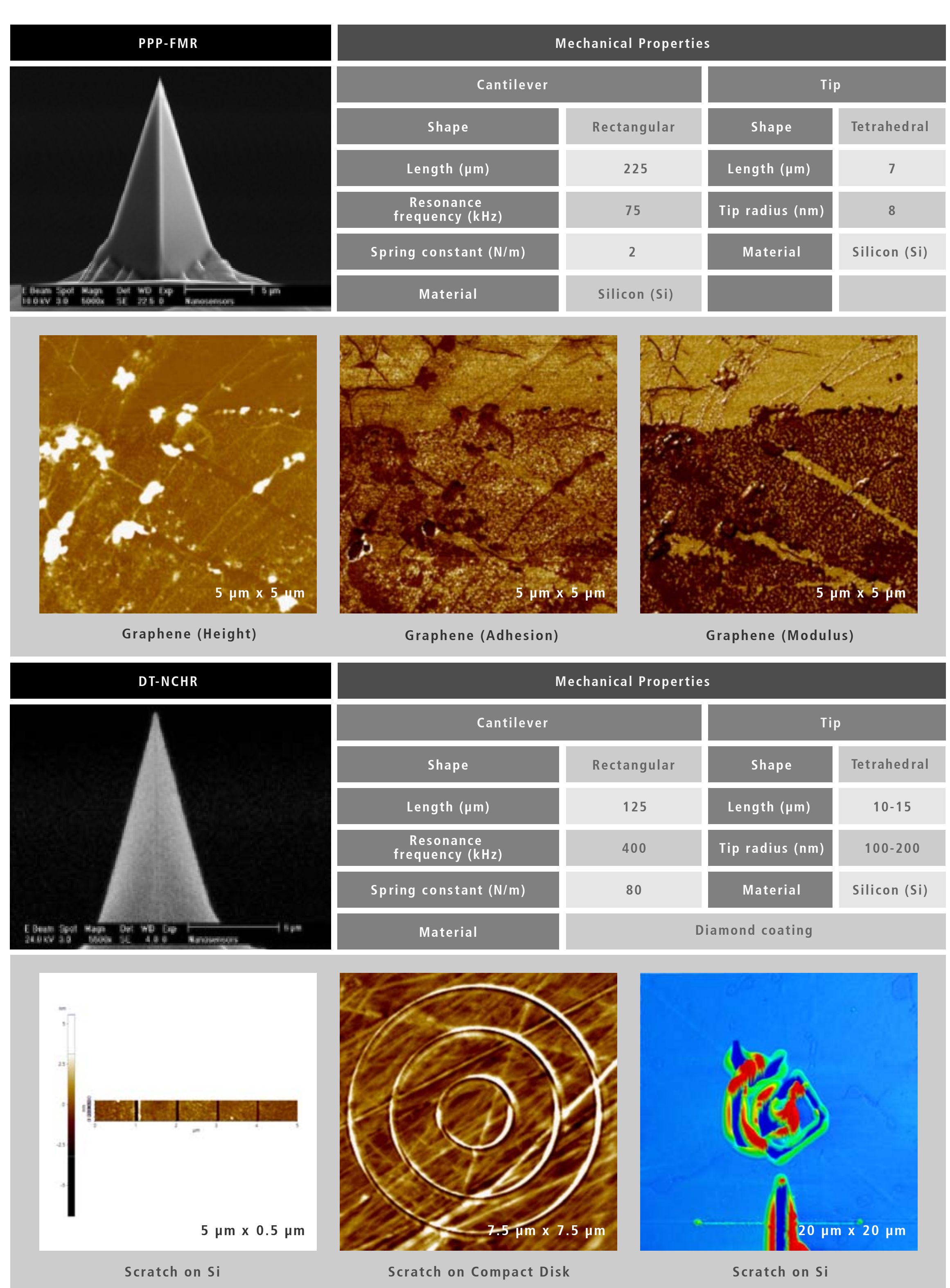
AFM probe for nanomechanical property measurement	• Soft sample: Soft probe (relatively) • Hard sample: Hard probe (relatively) • Avoid extremely sharp tip



NSC36 / Al BS	Mechanical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Material	Silicon (Si)	Length (µm)	12-18
			Tip radius (nm)	8
			Material	Silicon (Si)

Cantilever Type	Resonance frequency (kHz)	Spring constant (N/m)	Length (µm)
A	90	1	110
B	130	2	90
C	65	0.6	130

MoS_2 (Height) MoS_2 (Adhesion) MoS_2 (Modulus)

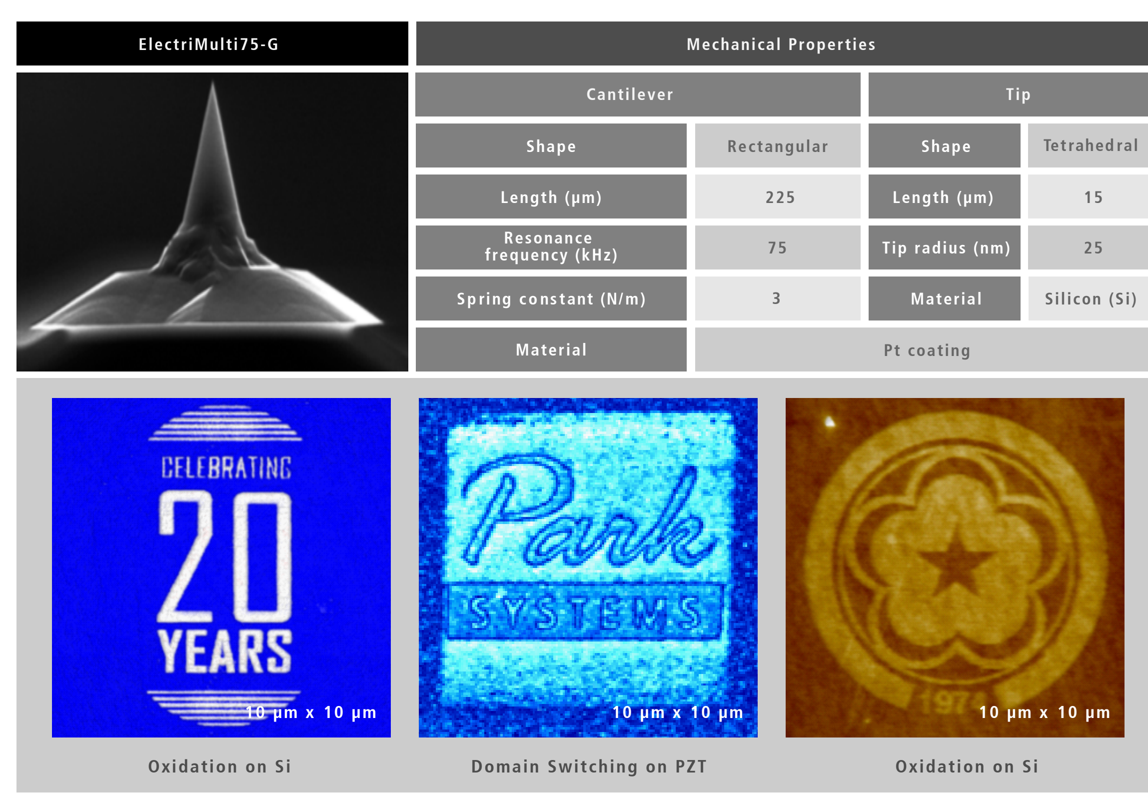


PPP-FMR	Mechanical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	225	Length (µm)	7
	Resonance frequency (kHz)	75	Tip radius (nm)	8
	Spring constant (N/m)	2	Material	Silicon (Si)
	Material	Silicon (Si)		

Graphene (Height) Graphene (Adhesion) Graphene (Modulus)

DT-NCHR	Mechanical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	125	Length (µm)	10-15
	Resonance frequency (kHz)	400	Tip radius (nm)	100-200
	Spring constant (N/m)	80	Material	Silicon (Si)
	Material	Diamond coating		

Scratch on Si Scratch on Compact Disk Scratch on Si



ElectriMulti75-G	Mechanical Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (μm)	225	Length (μm)	15
	Resonance frequency (kHz)	75	Tip radius (nm)	25
	Spring constant (N/m)	3	Material	Silicon (Si)
	Material	Pt coating		

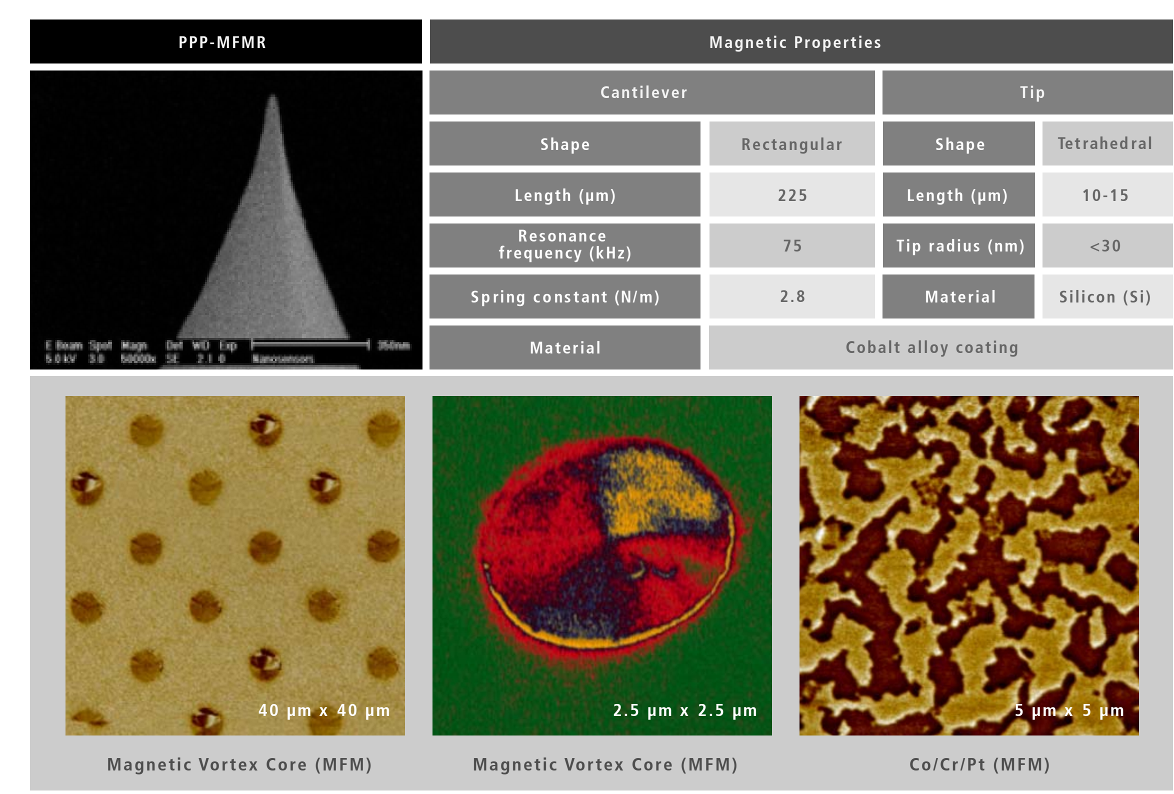
Oxidation on Si

Domain Switching on PZT

Oxidation on Si

MAGNETIC PROPERTIES

Magnetic properties of a sample surface can be imaged using magnetic force microscopy (MFM), one of the surface property measurement modes of AFM. In this mode, the interaction force occurs between the magnetic tip and the sample. For MFM, the probe is coated with magnetic material to image the spatial variation of magnetic forces on the sample surface.



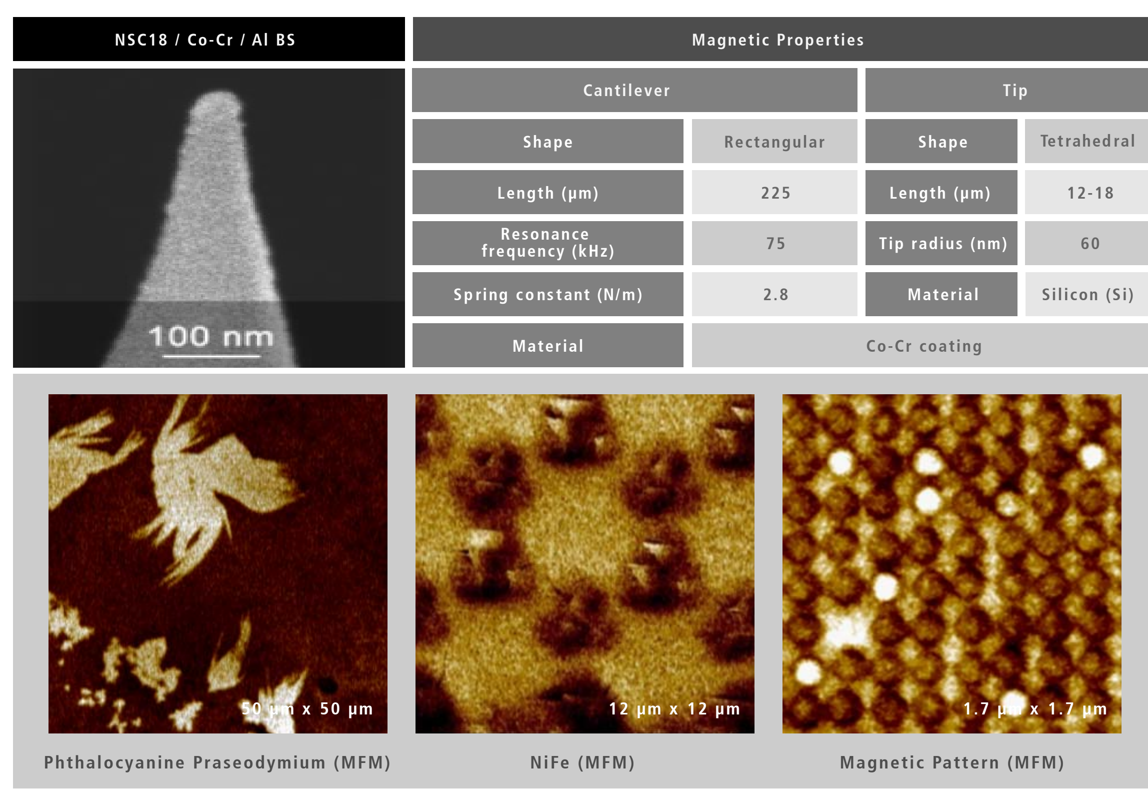
PPP-MFMR	Magnetic Properties			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (μm)	225	Length (μm)	10-15
	Resonance frequency (kHz)	75	Tip radius (nm)	<30
	Spring constant (N/m)	2.8	Material	Silicon (Si)
	Material	Cobalt alloy coating		

Magnetic Vortex Core (MFM)

Magnetic Vortex Core (MFM)

Co/Cr/Pt (MFM)

PART II
ADVANCED AFM MODES



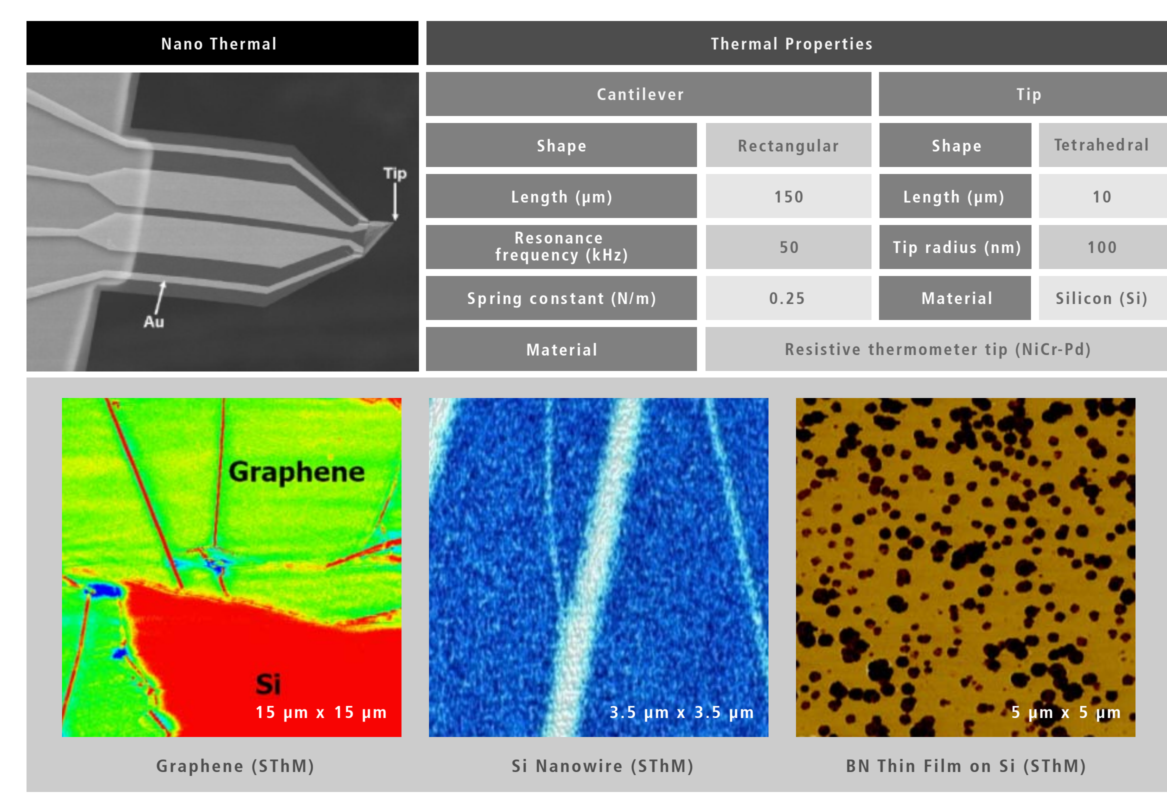
NSC18 / Co-Cr / Al BS

Magnetic Properties			
Cantilever		Tip	
Shape	Rectangular	Shape	Tetrahedral
Length (µm)	225	Length (µm)	12-18
Resonance frequency (kHz)	75	Tip radius (nm)	60
Spring constant (N/m)	2.8	Material	Silicon (Si)
Material	Co-Cr coating		

Phthalocyanine Praseodymium (MFM) | NiFe (MFM) | Magnetic Pattern (MFM)

THERMAL PROPERTIES

Scanning Thermal Microscopy (SThM) mode was developed to measure thermal properties of the sample surface at nanoscale level. The SThM uses nanofabricated thermal probes with resistive elements to achieve unprecedently high spatial, thermal resolution and sensitivity with unique signal detection method.



Nano Thermal

Thermal Properties			
Cantilever		Tip	
Shape	Rectangular	Shape	Tetrahedral
Length (µm)	150	Length (µm)	10
Resonance frequency (kHz)	50	Tip radius (nm)	100
Spring constant (N/m)	0.25	Material	Silicon (Si)
Material	Resistive thermometer tip (NiCr-Pd)		

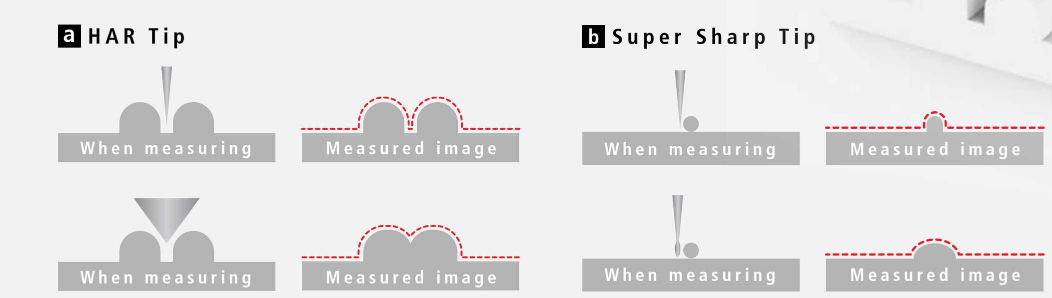
Graphene (SThM) | Si Nanowire (SThM) | BN Thin Film on Si (SThM)

PART III
SPECIAL PURPOSE PROBES

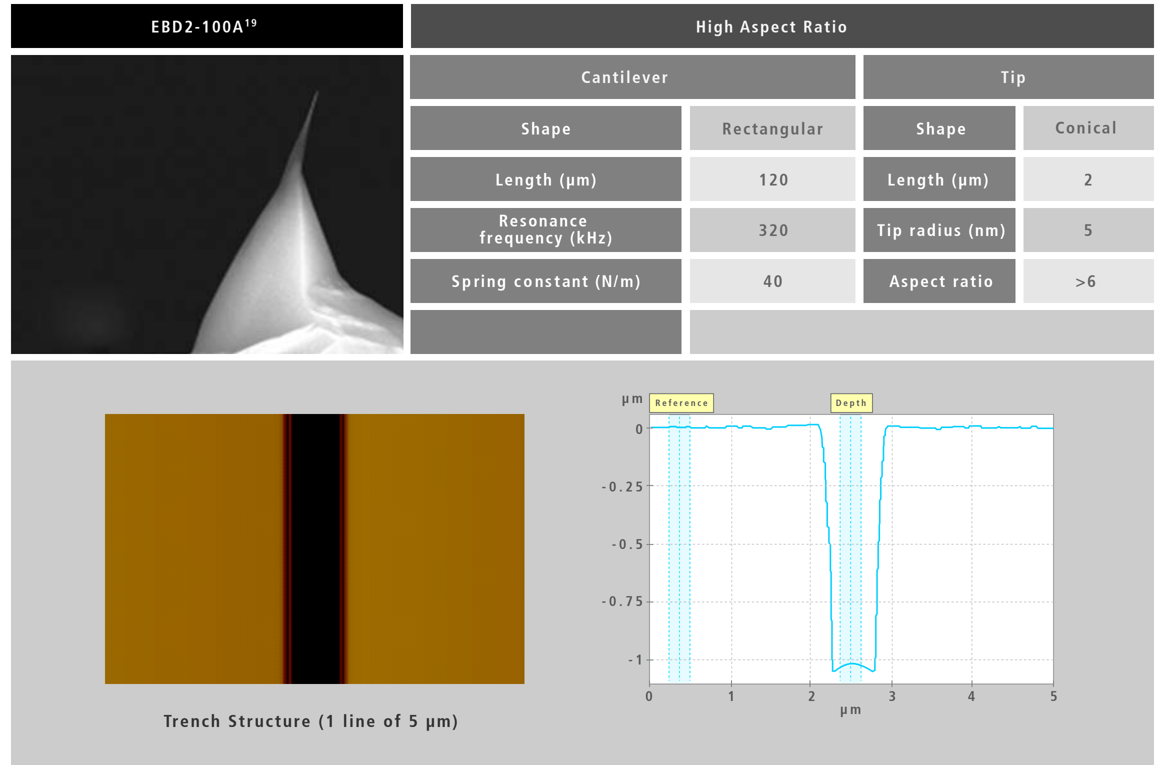
PART III
SPECIAL PURPOSE PROBES

HIGH ASPECT RATIO (HAR) AND SUPER SHARP PROBES

To image the sample surface morphology, the cantilever and imaging mode must be considered. Generally, the HAR AFM probe is used to explore deep trench structures. However, for deep trench structure, if the HAR probe is not long and narrow enough to reach down the structure, the resulting image will come out distorted (Figure 2a). When the tip curvature radius exceeds the sample structure, the tip shape influences the topography image (Figure 2b). Therefore, a tip sharper than the smallest sample structure should be selected in order to avoid such artifacts.



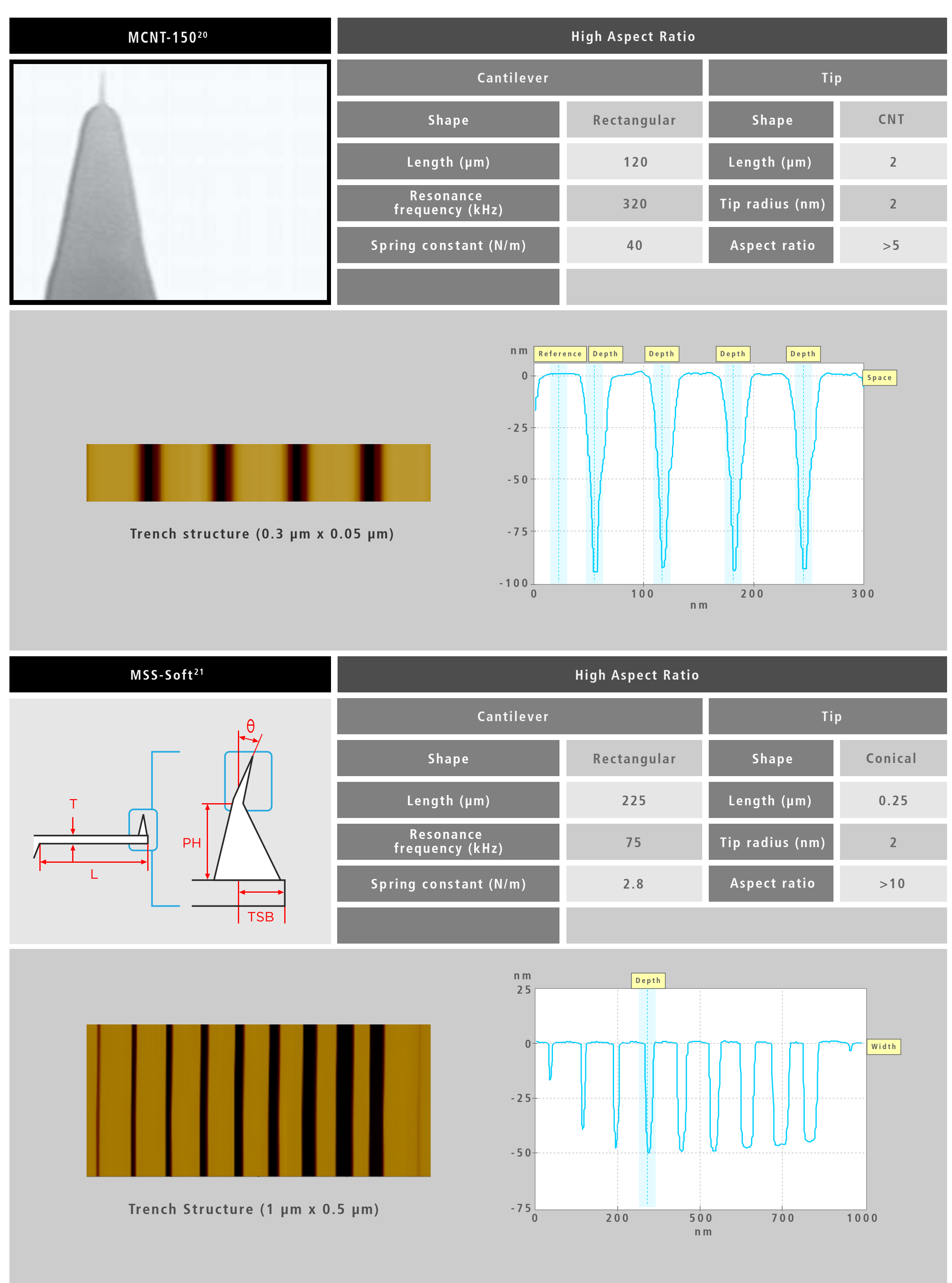
[Figure 2] AFM tip convolution effects



EBD2-100A[19] — High Aspect Ratio

Cantilever		Tip	
Shape	Rectangular	Shape	Conical
Length (μm)	120	Length (μm)	2
Resonance frequency (kHz)	320	Tip radius (nm)	5
Spring constant (N/m)	40	Aspect ratio	>6

Trench Structure (1 line of 5 μm)



MCNT-150[20] — High Aspect Ratio

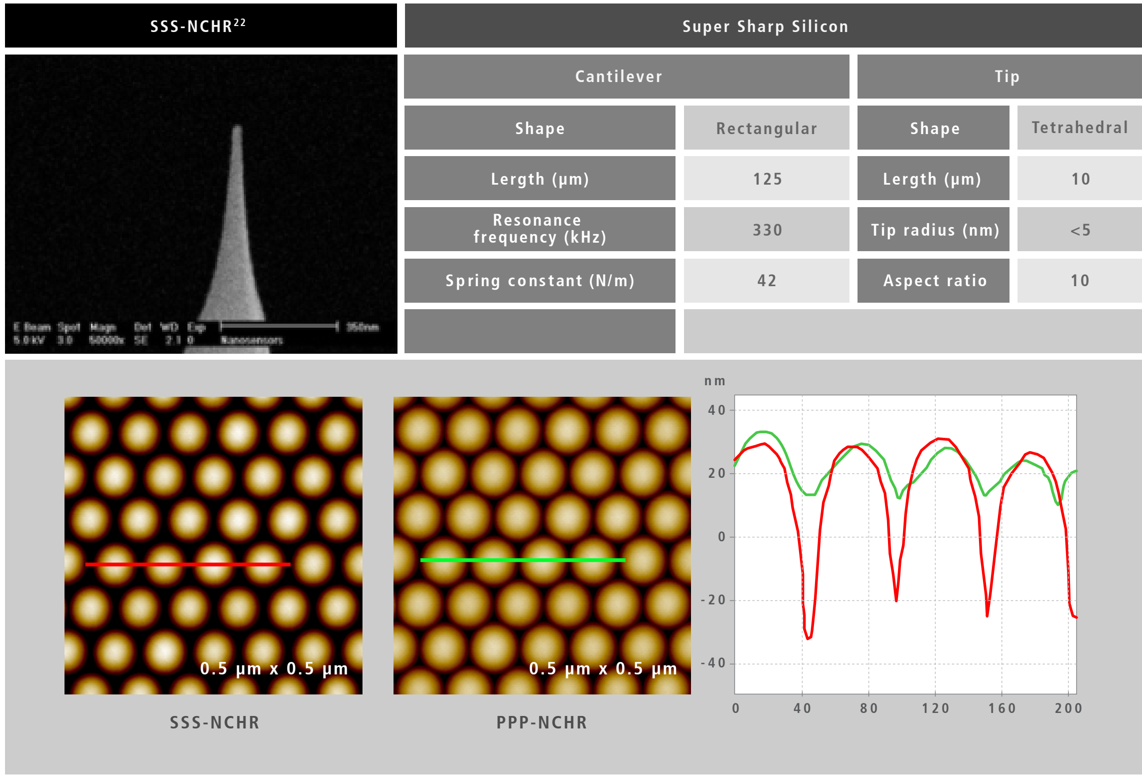
Cantilever		Tip	
Shape	Rectangular	Shape	CNT
Length (μm)	120	Length (μm)	2
Resonance frequency (kHz)	320	Tip radius (nm)	2
Spring constant (N/m)	40	Aspect ratio	>5

Trench structure (0.3 μm x 0.05 μm)

MSS-Soft[21] — High Aspect Ratio

Cantilever		Tip	
Shape	Rectangular	Shape	Conical
Length (μm)	225	Length (μm)	0.25
Resonance frequency (kHz)	75	Tip radius (nm)	2
Spring constant (N/m)	2.8	Aspect ratio	>10

Trench Structure (1 μm x 0.5 μm)

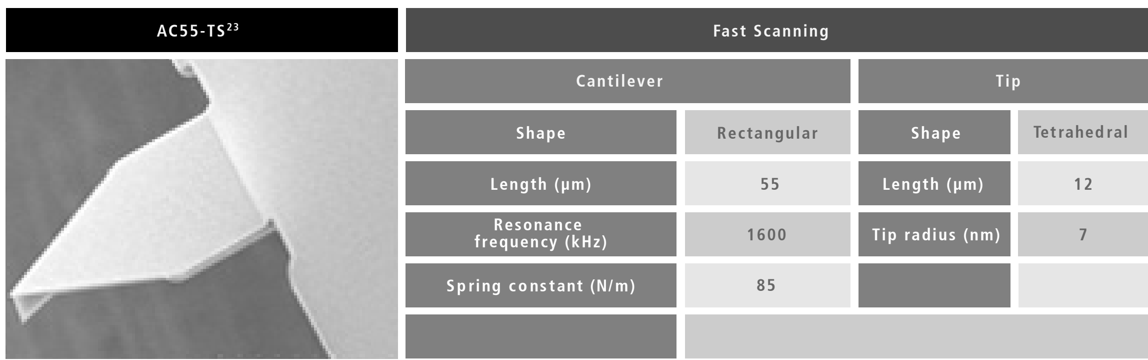


SSS-NCHR PPP-NCHR

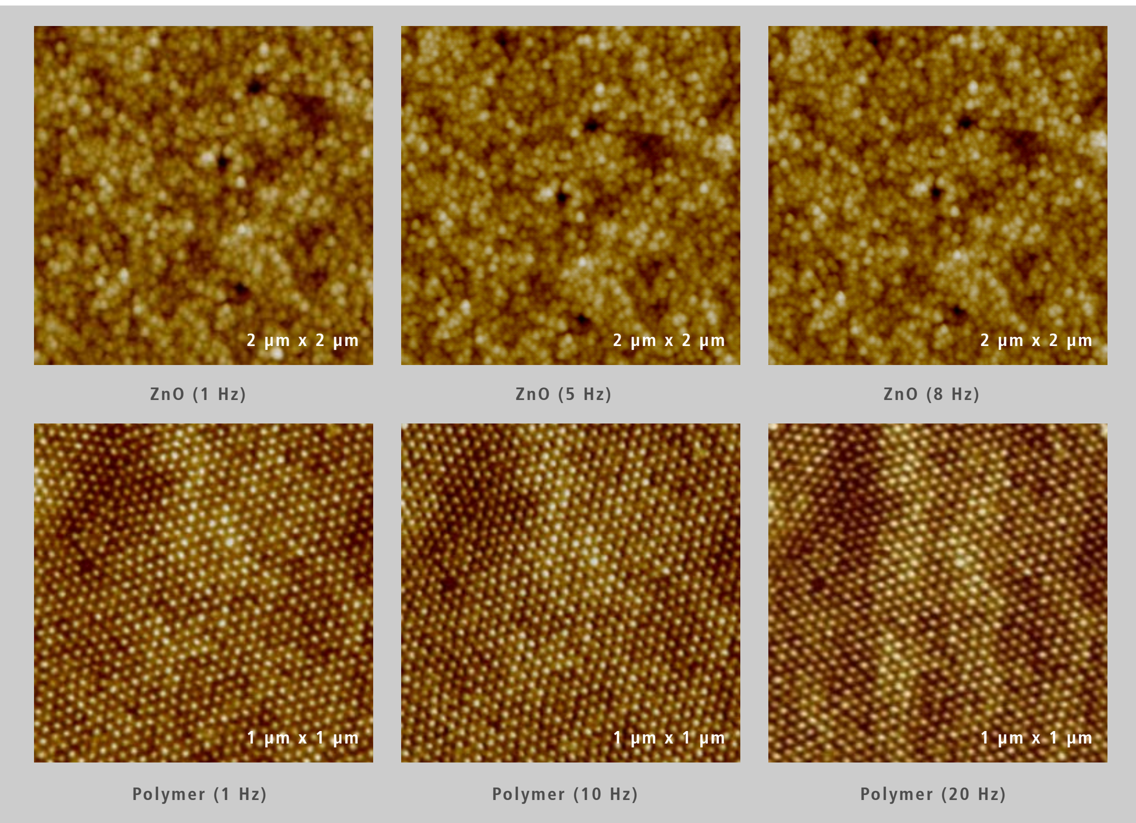
SSS-NCHR[22]	Super Sharp Silicon			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	125	Length (µm)	10
	Resonance frequency (kHz)	330	Tip radius (nm)	<5
	Spring constant (N/m)	42	Aspect ratio	10

FAST SCANNING

Sometimes, high speed scanning is required to image materials such as growth/transportation or molecular self-assembly processes. If you use AFM from Park Systems, you only need a high frequency cantilever to perform fast scanning. Park Systems AFM comes standard with fast Z scanner feedback and fast Z servo response system, which enables fast scanning. For other AFMs, please check with your manufacturer.



AC55-TS[23]	Fast Scanning			
	Cantilever		Tip	
	Shape	Rectangular	Shape	Tetrahedral
	Length (µm)	55	Length (µm)	12
	Resonance frequency (kHz)	1600	Tip radius (nm)	7
	Spring constant (N/m)	85		



ZnO (1 Hz) ZnO (5 Hz) ZnO (8 Hz)

Polymer (1 Hz) Polymer (10 Hz) Polymer (20 Hz)

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