NaDiaProbes®

ADVANCED DIAMOND TECHNOLOGIES, INC.

Supporting Documentation

Table of Contents

Full List of Item Numbers

All NaDiaProbe Item Numbers (SKUs) by Force Constant and Frequency

Force Constant (N/m)	Frequency (kHz)	Conductive? (Yes/No)	Sharp? (Yes/No)	ITEM NUMBER (SKU)	Probes per Pack	Tip/Spike Shape
35	310	Yes	No	ND-DYCRS	5	4-sided pyramid
35	310	No	No	ND-DYIRS	5	4-sided pyramid
35	310	No	No	ND-DTIRS	4	3-sided pyramid tip
35	310	No	Yes	AD-DYIRE	5	4-sided, Cone spike
35	310	Yes	Yes	AD-DYCRE	5	4-sided, Cone spike
25	265	Yes	No	ND-SSCRS	5	3-sided pyramid tip
3.7	80	Yes	No	ND-SSCRL	5	3-sided pyramid tip
1.28	48	No	No	ND-CTIT3 (cantilever 1)	4	3-sided pyramid tip
1.28	48	No	No	ND-CTIT1 (cantilever 1)	4	4-sided pyramid
1.28	48	Yes	No	ND-CTCT1 (cantilever 1)	5	4-sided pyramid
1.28	48	Yes	Yes	AD-CTCT1 (cantilever 1)	5	4-sided, Cone spike
0.71	50	No	No	* ND-CTIT2 (cantilever 1)	4	4-sided pyramid
0.71	50	Yes	No	ND-CTCT2 (cantilever 1)	5	4-sided pyramid
0.46	24	No	No	ND-CTIT3 (cantilever 2)	4	3-sided pyramid tip
0.46	24	No	No	ND-CTIT1 (cantilever 2)	4	4-sided pyramid
0.46	24	Yes	No	ND-CTCT1 (cantilever 2)	5	4-sided pyramid
0.46	24	Yes	Yes	AD-CTCT1 (cantilever 2)	5	4-sided, Cone spike

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0.35	35	No	No	ND-CTIR1 (cantilever 1)	4	4-sided pyramid
0.35	35	Yes	No	ND-CTCR1 (cantilever 1)	5	4-sided pyramid
0.35	35	Yes	Yes	AD-CTCR1 (cantilever 1)	5	4-sided, Cone spike
0.23	40	No	No	ND-CTIR2 (cantilever 1)	4	4-sided pyramid
0.23	40	Yes	No	ND-CTCR2 (cantilever 1)	5	4-sided pyramid
0.17	17	No	No	ND-CTIR1 (cantilever 2)	4	4-sided pyramid
0.17	17	Yes	No	ND-CTCR1 (cantilever 2)	5	4-sided pyramid
0.17	17	Yes	Yes	AD-CTCR1 (cantilever 2)	5	4-sided, Cone spike
0.08	12	No	No	ND-CTIR2 (cantilever 2)	4	4-sided pyramid
0.08	12	Yes	No	ND-CTCR2 (cantilever 2)	5	4-sided pyramid
0.05	8	No	No	ND-CTIR2 (cantilever 3)	4	4-sided pyramid
0.05	8	Yes	No	ND-CTCR2 (cantilever 3)	5	4-sided pyramid
0.04	23	No	No	ND-CTIT4 (cantilever 2)	4	3-sided pyramid tip
0.04	23	No	No	* ND-CTIT2 (cantilever 2)	4	4-sided pyramid
0.04	12	No	No	ND-CTIR1 (cantilever 3)	4	4-sided pyramid
0.04	23	Yes	No	ND-CTCT2 (cantilever 2)	5	4-sided pyramid

* Budget Probes – competitively priced with silicon probes

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Item Number Hierarchy Explained

Tip Reference	-	*Type*	*Conductivity*	*Cantilever Designation*	-	*Number of probes per pack*
XX	-	XX	X	XX	-	#

Typically 4, 5, 10, or 50. Can vary for special orders.

RS = Rectangular Cantilever (1), Short
RL = Rectangular Cantilever (1), Long
R1 = Rectangular Cantilevers (3), layout 1
R2 = Rectangular Cantilevers (3), layout 2
R3 = Rectangular Cantilevers (3), layout 1
R4 = Rectangular Cantilevers (3), layout 2
T1 = Triangular Cantilevers (2), layout 1
T2 = Triangular Cantilevers (2), layout 2

C = electrically conductive
I = electrically insulating

DY = Dynamic (stiff cantilever), 4 sided pyramid tip
DT = Dynamic (stiff cantilever), 3 sided pyramid tip
SS = Mid-range soft/stiff cantilever, 3 sided pyramid tip
CT = Contact (soft cantilever), 4 sided pyramid tip

ND = Tip Radius average 15 nm, spec is less than 50 nm
AD = Tip Radius average 5 nm, spec is less than 10 nm
AH = Prototype High Aspect Ratio

Custom Probe Development

Often, after testing standard probes, a customer will want to work with ADT to create a customized probe for a specific application. ADT is happy to enter into JDA's with customers to pursue these custom probes.

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Application Match List

The following pages go through an extended description of the various properties and descriptions of the UNCD Family of Diamond Materials. But for short answers, you may find this advertisement helpful:

- Budget Probes
- Bio samples
- CAFM – Electrically conductive AFM
- Fast imaging
- General samples
- High Aspect Ratio
- Nanoscale Features
- PFM - Piezo Force Microscopy
- SCM – Scanning Conductance Microscopy
- SSRM – Scanning Spreading Resistance Microscopy
- Soft samples
- Steep Sidewalls
- Tip degrading samples (i.e. hard or corrosive surfaces)

Budget Probes

Compatibly priced with Silicon probes, these all-diamond probes are offered as an entry-level start into the NaDiaProbe line.

Budget Probes	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	ND-CTIT2 (cantilever 1)	0.71	50	No	No
	ND-CTIT2 (cantilever 2)	0.04	23	No	No

Bio samples

Characterized by a soft cantilever.

Bio Samples	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	* ND-CTIT2 (cantilever 1)	0.71	50	No	No
	ND-CTIR1 (cantilever 1)	0.35	35	No	No
	ND-CTIR2 (cantilever 1)	0.23	40	No	No
	ND-CTIR1 (cantilever 2)	0.17	17	No	No
	ND-CTIR2 (cantilever 2)	0.08	12	No	No
	ND-CTIR2 (cantilever 3)	0.05	8	No	No
	ND-CTIT4 (cantilever 2)	0.04	23	No	No
	* ND-CTIT2 (cantilever 2)	0.04	23	No	No
	ND-CTIR1 (cantilever 3)	0.04	12	No	No
Compatible with:	BL-RC-150VB	Olympus			

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	PNP-TR TR400PB TR400PSA	NanoWorld Olympus Olympus			

CAFM – Electrically conductive AFM

Characterized by electrically conductive (boron-doped) diamond, both cantilever and tip (this is an all diamond cantilever and tip, not diamond coated).

CAFM	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	ND-DYCRS	35	310	Yes	No
	AD-DYCRE	35	310	Yes	Yes
	ND-SSCRS	25	265	Yes	No
	ND-SSCRL	3.7	80	Yes	No
	ND-CTCT1 (cantilever 1)	1.28	48	Yes	No
	AD-CTCT1 (cantilever 1)	1.28	48	Yes	Yes
	ND-CTCT2 (cantilever 1)	0.71	50	Yes	No
	ND-CTCT1 (cantilever 2)	0.46	24	Yes	No
	AD-CTCT1 (cantilever 2)	0.46	24	Yes	Yes
	ND-CTCR1 (cantilever 1)	0.35	35	Yes	No
	AD-CTCR1 (cantilever 1)	0.35	35	Yes	Yes
	ND-CTCR2 (cantilever 1)	0.23	40	Yes	No
	ND-CTCR1 (cantilever 2)	0.17	17	Yes	No
	AD-CTCR1 (cantilever 2)	0.17	17	Yes	Yes
	ND-CTCR2 (cantilever 2)	0.08	12	Yes	No
	ND-CTCR2 (cantilever 3)	0.05	8	Yes	No
	ND-CTCT2 (cantilever 2)	0.04	23	Yes	No

Fast imaging

Characterized by a high frequency cantilever.

Fast imaging	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	ND-DYCRS	35	310	Yes	No
	ND-DYIRS	35	310	No	No
	ND-DTIRS	35	310	No	No
	AD-DYIRE	35	310	No	Yes
	AD-DYCRE	35	310	Yes	Yes

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	ND-SSCRS	25	265	Yes	No

General samples

General Samples	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	ND-DYIRS	35	310	No	No
	ND-DTIRS	35	310	No	No
	ND-CTIT3 (cantilever 1)	1.28	48	No	No
	ND-CTIT1 (cantilever 1)	1.28	48	No	No
	* ND-CTIT2 (cantilever 1)	0.71	50	No	No
	ND-CTIT3 (cantilever 2)	0.46	24	No	No
	ND-CTIT1 (cantilever 2)	0.46	24	No	No
	ND-CTIR1 (cantilever 1)	0.35	35	No	No
	ND-CTIR2 (cantilever 1)	0.23	40	No	No
	ND-CTIR1 (cantilever 2)	0.17	17	No	No
	ND-CTIR2 (cantilever 2)	0.08	12	No	No
	ND-CTIR2 (cantilever 3)	0.05	8	No	No
	ND-CTIT4 (cantilever 2)	0.04	23	No	No
	* ND-CTIT2 (cantilever 2)	0.04	23	No	No
	ND-CTIR1 (cantilever 3)	0.04	12	No	No

High Aspect Ratio

We have prototypes in development for a sharp, >5:1 aspect ratio all-diamond probe.

HAR	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
>5:1	AH-DYCRS	35	310	Yes	Yes

Liquids, Tapping in Liquid

Characterized by a soft, non-conductive probe. Items with an asterisk "*" are budget-priced.

Tapping in Liquid	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	* ND-CTIT2 (cantilever 1)	0.71	50	No	No
	ND-CTIR1 (cantilever 1)	0.35	35	No	No
	ND-CTIR2 (cantilever 1)	0.23	40	No	No

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	ND-CTIR1 (cantilever 2)	0.17	17	No	No
	ND-CTIR2 (cantilever 2)	0.08	12	No	No
	ND-CTIR2 (cantilever 3)	0.05	8	No	No
	ND-CTIT4 (cantilever 2)	0.04	23	No	No
	* ND-CTIT2 (cantilever 2)	0.04	23	No	No
	ND-CTIR1 (cantilever 3)	0.04	12	No	No

Nanoscale Features

Characterized by an average tip radius of 5 nm, specification of less than 10 nm.

Nanoscale Features	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	AD-DYCRE	35	310	Yes	Yes
	AD-CTCT1 (cantilever 1)	1.28	48	Yes	Yes
	AD-CTCT1 (cantilever 2)	0.46	24	Yes	Yes
	AD-CTCR1 (cantilever 1)	0.35	35	Yes	Yes
	AD-CTCR1 (cantilever 2)	0.17	17	Yes	Yes

Oxidation Nanolithography

Characterized by electrically conductive (boron-doped) diamond, both cantilever and tip (this is an all diamond cantilever and tip, not diamond coated).

CAFM	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	ND-DYCRS	35	310	Yes	No
	AD-DYCRE	35	310	Yes	Yes
	ND-SSCRS	25	265	Yes	No
	ND-SSCRL	3.7	80	Yes	No
	ND-CTCT1 (cantilever 1)	1.28	48	Yes	No
	AD-CTCT1 (cantilever 1)	1.28	48	Yes	Yes
	ND-CTCT2 (cantilever 1)	0.71	50	Yes	No
	ND-CTCT1 (cantilever 2)	0.46	24	Yes	No
	AD-CTCT1 (cantilever 2)	0.46	24	Yes	Yes
	ND-CTCR1 (cantilever 1)	0.35	35	Yes	No
	AD-CTCR1 (cantilever 1)	0.35	35	Yes	Yes
	ND-CTCR2 (cantilever 1)	0.23	40	Yes	No

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	ND-CTCR1 (cantilever 2)	0.17	17	Yes	No
	AD-CTCR1 (cantilever 2)	0.17	17	Yes	Yes
	ND-CTCR2 (cantilever 2)	0.08	12	Yes	No
	ND-CTCR2 (cantilever 3)	0.05	8	Yes	No
	ND-CTCT2 (cantilever 2)	0.04	23	Yes	No

PFM - Piezo Force Microscopy

Characterized by electrically conductive (boron-doped) diamond, both cantilever and tip (this is an all diamond cantilever and tip, not diamond coated).

PFM	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	ND-DYCRS	35	310	Yes	No
	AD-DYCRE	35	310	Yes	Yes
	ND-SSCRS	25	265	Yes	No
	ND-SSCRL	3.7	80	Yes	No
	ND-CTCT1 (cantilever 1)	1.28	48	Yes	No
	AD-CTCT1 (cantilever 1)	1.28	48	Yes	Yes
	ND-CTCT2 (cantilever 1)	0.71	50	Yes	No
	ND-CTCT1 (cantilever 2)	0.46	24	Yes	No
	AD-CTCT1 (cantilever 2)	0.46	24	Yes	Yes
	ND-CTCR1 (cantilever 1)	0.35	35	Yes	No
	AD-CTCR1 (cantilever 1)	0.35	35	Yes	Yes
	ND-CTCR2 (cantilever 1)	0.23	40	Yes	No
	ND-CTCR1 (cantilever 2)	0.17	17	Yes	No
	AD-CTCR1 (cantilever 2)	0.17	17	Yes	Yes
	ND-CTCR2 (cantilever 2)	0.08	12	Yes	No
	ND-CTCR2 (cantilever 3)	0.05	8	Yes	No
	ND-CTCT2 (cantilever 2)	0.04	23	Yes	No

SCM – Scanning Conductance Microscopy

Characterized by electrically conductive (boron-doped) diamond, both cantilever and tip (this is an all diamond cantilever and tip, not diamond coated).

CAFM	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	ND-DYCRS	35	310	Yes	No
	AD-DYCRE	35	310	Yes	Yes

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	ND-SSCRS	25	265	Yes	No
	ND-SSCRL	3.7	80	Yes	No
	ND-CTCT1 (cantilever 1)	1.28	48	Yes	No
	AD-CTCT1 (cantilever 1)	1.28	48	Yes	Yes
	ND-CTCT2 (cantilever 1)	0.71	50	Yes	No
	ND-CTCT1 (cantilever 2)	0.46	24	Yes	No
	AD-CTCT1 (cantilever 2)	0.46	24	Yes	Yes
	ND-CTCR1 (cantilever 1)	0.35	35	Yes	No
	AD-CTCR1 (cantilever 1)	0.35	35	Yes	Yes
	ND-CTCR2 (cantilever 1)	0.23	40	Yes	No
	ND-CTCR1 (cantilever 2)	0.17	17	Yes	No
	AD-CTCR1 (cantilever 2)	0.17	17	Yes	Yes
	ND-CTCR2 (cantilever 2)	0.08	12	Yes	No
	ND-CTCR2 (cantilever 3)	0.05	8	Yes	No
	ND-CTCT2 (cantilever 2)	0.04	23	Yes	No

SSRM – Scanning Spreading Resistance Microscopy

Characterized by electrically conductive (boron-doped) diamond, both cantilever and tip, and larger force constants and frequencies.

CAFM	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	ND-DYCRS	35	310	Yes	No
	AD-DYCRE	35	310	Yes	Yes
	ND-SSCRS	25	265	Yes	No
	ND-SSCRL	3.7	80	Yes	No

Soft samples

Characterized by a soft cantilever (small force constant).

Bio Samples	NaDiaProbe	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
	* ND-CTIT2 (cantilever 1)	0.71	50	No	No
	ND-CTIR1 (cantilever 1)	0.35	35	No	No
	ND-CTIR2 (cantilever 1)	0.23	40	No	No
	ND-CTIR1 (cantilever 2)	0.17	17	No	No
	ND-CTIR2 (cantilever 2)	0.08	12	No	No

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	ND-CTIR2 (cantilever 3)	0.05	8	No	No
	ND-CTIT4 (cantilever 2)	0.04	23	No	No
	* ND-CTIT2 (cantilever 2)	0.04	23	No	No
	ND-CTIR1 (cantilever 3)	0.04	12	No	No
Compatible with:	BL-RC-150VB PNP-TR TR400PB TR400PSA	Olympus NanoWorld Olympus Olympus			

Steep Sidewalls

We have prototypes in development for a sharp, >5:1 aspect ratio all-diamond probe.

HAR	Item Number	k (N/m)	f_0 (kHz)	Conductive?	Sharp?
>5:1	AH-DYCRS	35	310	Yes	Yes

Tip degrading samples (i.e. hard or corrosive surfaces)

Any all-diamond probe will resist corrosion and wear, far exceeding the lifetimes of SiN probes.

	Item Number	k (N/m)	f_0 (kHz)	Conductive? (Yes/No)	Sharp? (Yes/No)
	ND-DYCRS	35	310	Yes	No
	ND-DYIRS	35	310	No	No
	ND-DTIRS	35	310	No	No
	AD-DYIRE	35	310	No	Yes
	AD-DYCRE	35	310	Yes	Yes
	ND-SSCRS	25	265	Yes	No
	ND-SSCRL	3.7	80	Yes	No
	ND-CTIT3 (cantilever 1)	1.28	48	No	No
	ND-CTIT1 (cantilever 1)	1.28	48	No	No
	ND-CTCT1 (cantilever 1)	1.28	48	Yes	No
	AD-CTCT1 (cantilever 1)	1.28	48	Yes	Yes
	ND-CTIT2 (cantilever 1)	0.71	50	No	No

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	ND-CTCT2 (cantilever 1)	0.71	50	Yes	No
	ND-CTIT3 (cantilever 2)	0.46	24	No	No
	ND-CTIT1 (cantilever 2)	0.46	24	No	No
	ND-CTCT1 (cantilever 2)	0.46	24	Yes	No
	AD-CTCT1 (cantilever 2)	0.46	24	Yes	Yes
	ND-CTIR1 (cantilever 1)	0.35	35	No	No
	ND-CTCR1 (cantilever 1)	0.35	35	Yes	No
	AD-CTCR1 (cantilever 1)	0.35	35	Yes	Yes
	ND-CTIR2 (cantilever 1)	0.23	40	No	No
	ND-CTCR2 (cantilever 1)	0.23	40	Yes	No
	ND-CTIR1 (cantilever 2)	0.17	17	No	No
	ND-CTCR1 (cantilever 2)	0.17	17	Yes	No
	AD-CTCR1 (cantilever 2)	0.17	17	Yes	Yes
	ND-CTIR2 (cantilever 2)	0.08	12	No	No
	ND-CTCR2 (cantilever 2)	0.08	12	Yes	No
	ND-CTIR2 (cantilever 3)	0.05	8	No	No
	ND-CTCR2 (cantilever 3)	0.05	8	Yes	No
	ND-CTIT4 (cantilever 2)	0.04	23	No	No
	ND-CTIT2 (cantilever 2)	0.04	23	No	No
	ND-CTIR1 (cantilever 3)	0.04	12	No	No
	ND-CTCT2 (cantilever 2)	0.04	23	Yes	No

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List of Case Studies

NaDiaProbes were introduced in the market in 2009, and have since been used for a number of applications. Here are a few examples of case studies that are available:

1. General imaging with a $15 all-diamond probe
2. Conductive AFM (c-AFM)
3. Tip Degradation Samples
4. In line inspection: Extreme Wear Resistance, Electrical Conductivity, High Resolution
    - Extreme performance (1,500 scans in 8 hrs)
    - Piezo-force microscopy, rapid scanning
5. Tapping in Liquid

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Case Study #1 – Application: General Imaging, a $15 all-diamond probe

Application: General Imaging, Direct replacement for $15 Si probe with a $15 Diamond Probe

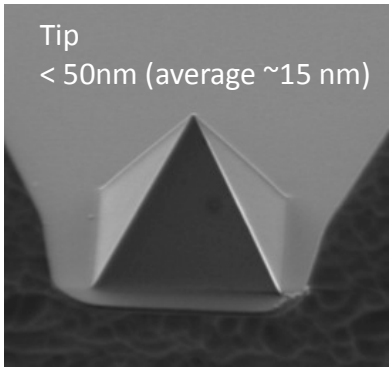
Application Needs: Non-contact (dynamic, TappingMode®) was invented because Si probes wear out in contact mode. For the same price, better imaging of your surface is possible in contact mode will all-diamond probes.

NaDiaProbe Match:

- ND-CTIT2

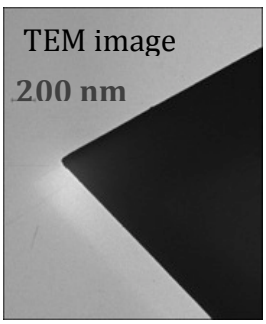
NaDiaProbe Benefit:

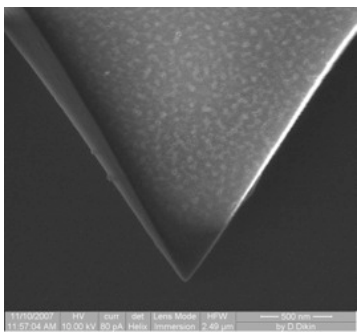
- ✓ Low Cost - Save $2 per SCAN using ND-CTIT2 over a Silicon probe!
- ✓ No Wear - Increased wear performance compared to silicon (x 1,000) or silicon nitride (x 100) probes; for typical AFM scans, no observable wear.
- ✓ No Tip Shape Degredation - Superior dimensional stability over extreme distances
- ✓ Bio Friendly - Low surface energy of diamond leads to superior imaging performance on soft, sticky substrates *(bio, polymers, gov't lab experience)*
- ✓ Resists Fouling - Resists build-up of debris when imaging soft materials
- ✓ Low Friction - Low friction inhibits sample damage during imaging
- ✓ Available Today - Available in single packs and in wafer-scale volumes

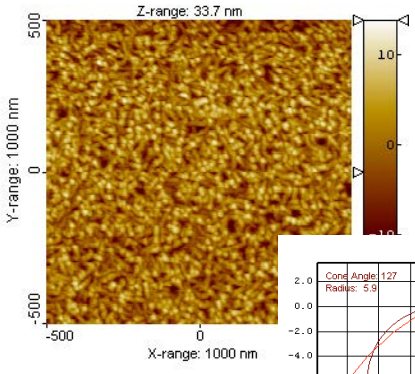


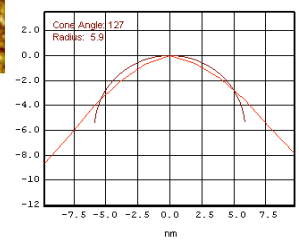
Data:

- Actual Tip Radius (measured by TEM and SEM) = 15-30 nm
- Imaging show a Tip Radius = 6 nm









Direct Replacement For:

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Maker	Probe	Force Const. (N/m)	Freq. (kHz)	Tip Radius (nm)	Material	$/probe
ADT	CT-CTIT2	0.71, 0.04	50, 23	15 nm	Diamond	$15/probe (50 for $750)
Olympus	BL-RC-150VB	0.03, 0.006	37, 13	25 nm	Silicon Nitride	$27/probe (210 for $5850)
Asylum	BL-TR400PB	0.09, 0.02	32, 10	42 nm	Silicon Nitride	$27/probe (210 for $5730)
NanoWorld	PNP-TR	0.32, 0.10	67, 17	15 nm	Silicon Nitride	$17/probe (50 for $850)
Olympus	TR400PB	0.09, 0.02	32, 10	40 nm	Silicon Nitride	$32/probe (34 for $1100)
Veeco	DNP-S	0.06,0.24, 0.12, 0.35	18,56,23,65	10 nm	Silicon Nitride	$13/probe (375 for $5,035)
Olympus	TR400PSA	0.08, 0.02	34, 11	20 nm	Silicon Nitride	$15/probe (245 for $3650)
Veeco	OTR4	0.08, 0.02	34, 11	15 nm	Silicon Nitride	$16/probe (245 for $3,925)

Case Study #2 – Application: Conductive AFM (C-AFM)

Application: Conductive AFM (c-AFM)

Application Needs:

- In contact with surface
- Electrically conductive
- Sharp for resolution
- In-line testing, where a tip needs to last a full shift

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NaDiaProbe Match:

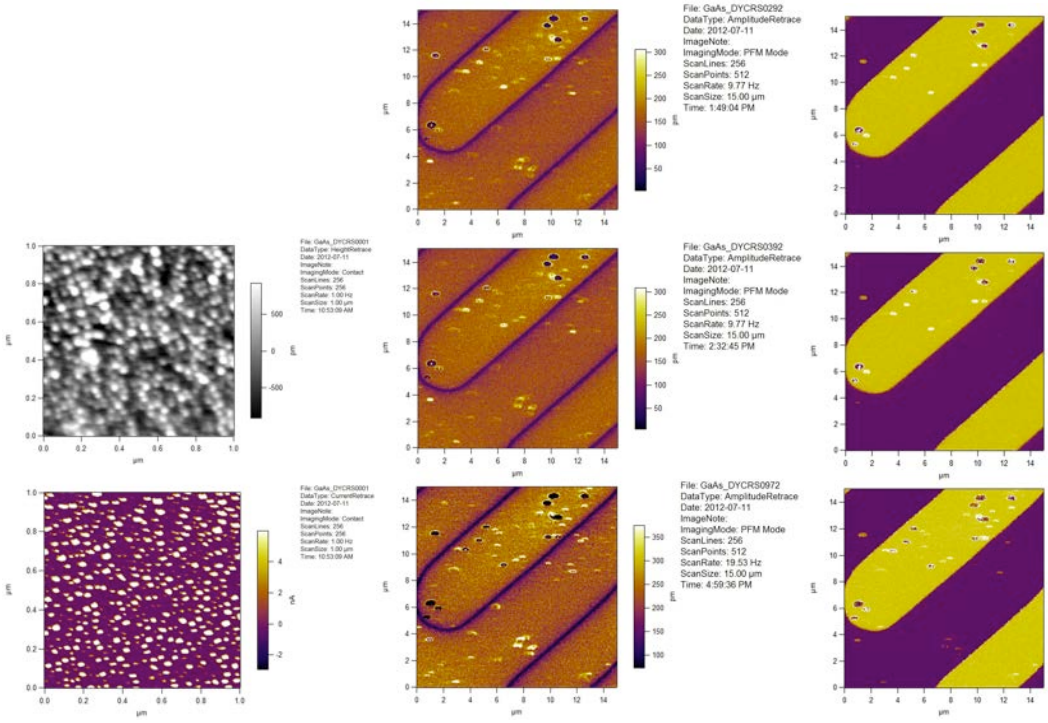
- All conductive NaDiaProbes. These are made with boron-doped diamond, both cantilever and tip.

NaDiaProbe Benefit:

- All Conductive Diamond, no metal coating to wear off
- Sharp (<20 nm), durable tip

Data: See images below.

- Sample:
  - GaAs quantum dots for conductive AFM
- Mode:
  - Piezo-force microscopy = c-AFM done in contact mode applying an AC Bias to the tip and measure the mechanical response of the sample with a cantilever
- Scan Number & Times:
  - #292 at 1:49 p.m.
  - #392 at 2:32 p.m.
  - #972 at 4:59 p.m.
- 1 probe = 972 scans
  - ND-DYCRS (310kHz, 35 N/m)
  - "I've never been able to run PFM mode this quickly." – application scientist at Asylum
  -



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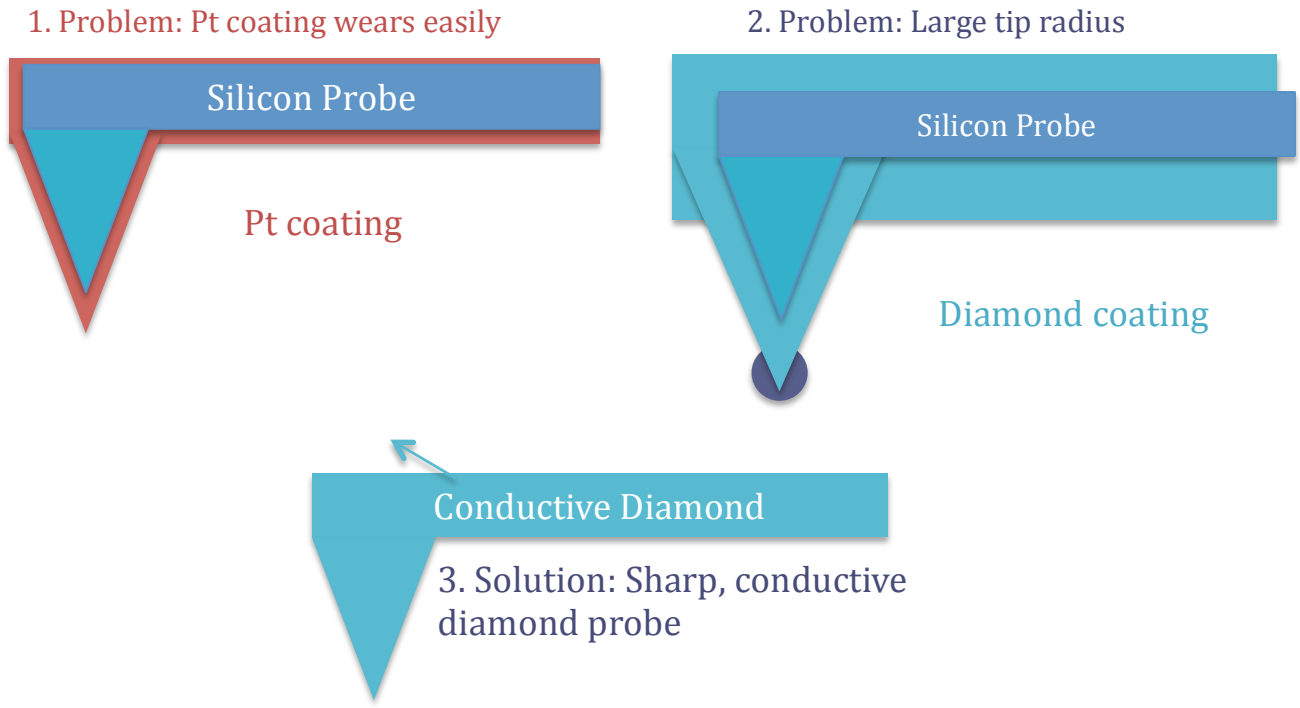
Direct Replacement For:

- 1. Platinum-coated Silicon Probe
  - Problem: coating wears off easily
- 2. Diamond-coated Silicon Probe
  - Problem: Large tip radius (80-200 nm)



Customer Testimonial:

"As for conductive NaDiaProbes, their performance was very good."

- Bohuslav Rezek, Ph.D. Research team leader and Purkyn? Fellow at the Department of Thin Films, Institute of Physics, Academy of Sciences of the Czech Republic

Case Study #3 – Application: Tip Degrading Samples

Application: Tip Degrading Samples

Application Needs: For samples that degrade normal Si or SiN probes rapidly, due to:

- Hard surfaces
- Corrosive liquids
- Challenging mode (contact)
- Extremely long scan times

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- In-line testing, where a tip needs to last a full shift

NaDiaProbe Match:

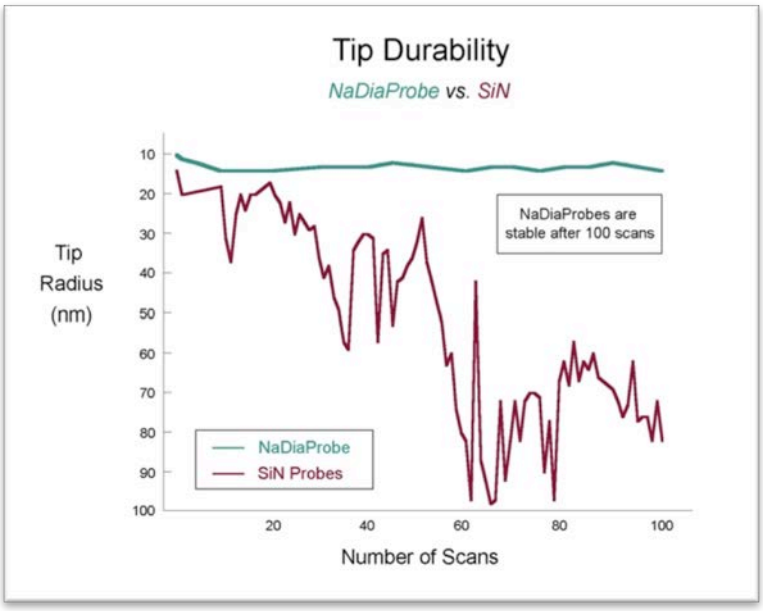
- All NaDiaProbes demonstrate extreme wear and corrosion resistance. The all-diamond nature of the tip and cantilever make the probes resistant to wear and degradation

NaDiaProbe Benefit:

- Diamond wears extremely slowly
- Diamond is inert

Data:

- See Graph at Right
- NaDiaProbes show no tip degradation over 100 scans of a hard diamond surface.
- SiN probes show significant degradation and inconsistency in resolution over the same scan number.
- Substrate being imaged – thin-film UNCD (diamond).
- Source: R. Carpick, University of Pennsylvania, 2009



Direct Replacement For:

- Silicon Nitride Probes. NaDiaProbes are better because:
  - Higher wear resistance
  - Available in conductive diamond
  - Available in extremely sharp tips (<10 nm)
- Diamond coated probe. NaDiaProbes are better because:
  - Smaller tip radius (average 15 nm)
  - Available in extremely sharp tips (<10 nm)

Case Study #4 – Application: In line inspection: Extreme Wear Resistance, Electrical Conductivity, High Resolution

Application: Hard, demanding surfaces in contact mode or high resolution, rapid scanning

Application Needs:

- In-line inspection
- Dimensional tip stability over hundreds or thousands of scans

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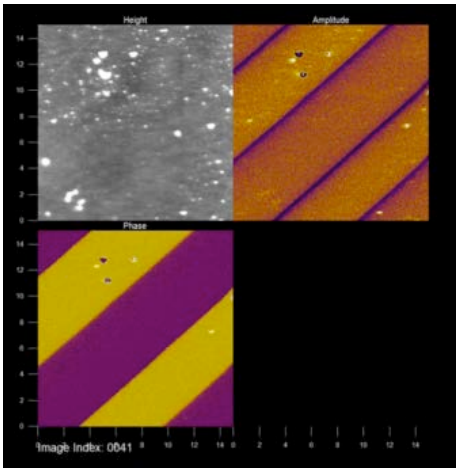
NaDiaProbe Match:

- All NaDiaProbes demonstrate extreme wear resistance. The stiff cantilever of the ND-DYC series has shown excellent resolution and conductivity over 1,500 scans.

NaDiaProbe Benefit:

- Conductive all-diamond nature allows for c-AFM in rapid scanning mode over extreme distances.

Data:



- Sample:
  - GaAs quantum dots for conductive AFM
- Mode:
  - Piezo-force microscopy: c-AFM done in contact mode applying an AC Bias to the tip and measure the mechanical response of the sample with a cantilever
- **Number of Scans: 1,500**
- Number of **NaDiaProbes: 1**
- Watch a time lapse video at:

http://www.thindiamond.com/products/nadiaprobes/benefits/

- Time lapse video of 1,500 scans using a single NaDiaProbe (ND-DYCRS) imaging GaAs Quantum Dots on a Cypher AFM. The mode is piezo-force microscope. An AC bias is applied to the tip (made of conductive diamond - both the tip and the cantilever). Topography (height) is on the left, conductive image on the right.

Direct Replacement For:

- Metal wire probes
- Silicon probes coated with conductive diamond
- Metal coated silicon probes

Case Study #5 – Application: Tapping in Liquid

Application: Tapping in Liquid

Application Needs: For imaging samples in liquid, like proteins or other biological samples.

- Soft Cantilever
- Low fouling material
- Sharp tip

NaDiaProbe Match:

- ND-CTIT1 & ND-CTIT2

NaDiaProbe Benefit:

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- Diamond is inert, will not rust or corrode or oxidize in liquid
- Diamond has a property of low stiction, which assists to reduce fouling
- If fouling does occur, the probe can be dragged to remove the fouled item, without damaging the tip.

Data:

- NaDiaProbes were used extensively by a U.S. Government research lab to image proteins.
- Images cannot be shared; however, the users said that no other probe had been able to image these particular proteins.

Direct Replacement For:

- Any probe marketed for 'bio' applications.

Customer Testimonials:

- "We love them and want to buy some more.", *Email from a government lab team leader working on imaging inorganic and organic substrates*
- "The NaDiaProbes last about a month (per chip). They would last longer if we didn't have to take them in and out to clean them.", *Paraphrased from a researcher performing conductive AFM and biological imaging*

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Awards and Peer-Reviewed Papers

UNCD is a polycrystalline diamond material; it is diamond. Diamond-like-carbon (DLC) is an amorphous form of carbon; DLC is not diamond and thus does not have the same properties of diamond. Single crystal diamond, like a gemstone, is one large crystal of diamond. The following explanations and images will elaborate.

2009 R&D 100 Award - Microscopy Category

Peer-Reviewed Papers:

"Role of current profiles and AFM probes in electric crystallization of amorphous silicon,"

by E. Verveniotis; B. Rezek; E. Šípek; J. Stuchlík; J. Ko?ka. Currently being peer reviewed.

Quote from abstract:

"Various types of conductive tips in atomic force microscope (AFM) are used to localize field enhanced metal-induced solid phase crystallization (FE-MISPC) of amorphous silicon at room temperature down to nanoscale dimensions. … Bulk diamond probes exhibit superior endurance compared to bare or coated silicon probes, nevertheless all tips generate similar FE-MISPC results." Note: The 'bulk diamond probes' used in this paper were NaDiaProbes.

"Exceptional Wear Resistance of Diamond-Coated Silicon Heated Nanoprobe Tips for Tip-Based Nanomaufacturing, "

by P. Fletcher[1], J. Felts[1], Z. Dai[1], H. Zheng[2], J. A. Carlisle[2], and W.P. King[1]*; [1]Department of Mechanical Science and Engineering, University of Illinois, Urbana-Champaign, IL; Advanced Diamond Technologies, Romeoville, IL Currently submitted for peer review.

Quote from abstract:

"Wear tests were conducted under harsh conditions consistent with the requirements of tip-based nanofabrication. The wear tests were performed in contact mode with substrates of quartz, silicon carbide, silicon, and UNCD-coated silicon; tip

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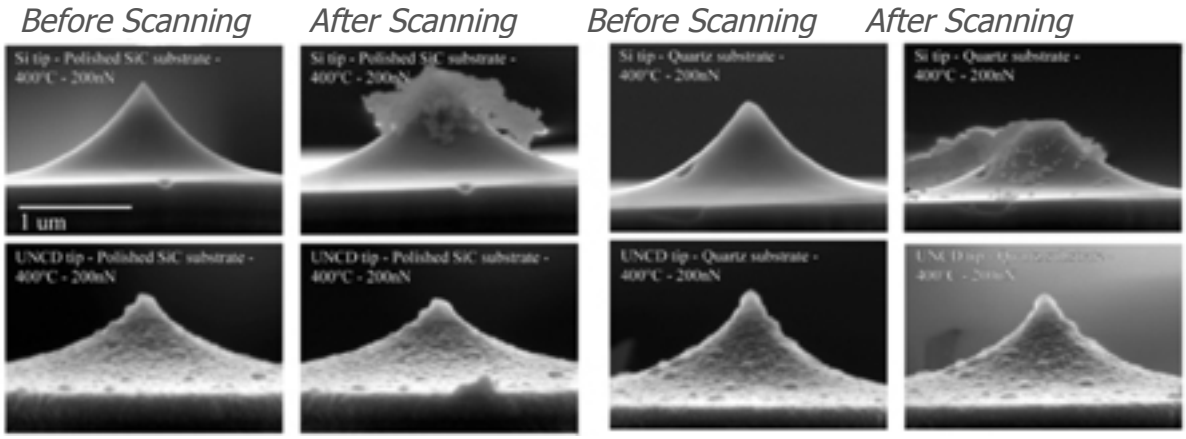
load up to 200 nN, tip temperature 25-400 °C, scan speed 25 µm / sec, and scan distance > 1 m. Under these conditions, silicon tips are partially or completely destroyed but the UNCD-coated silicon tips exhibit zero or low wear."



National Science Foundation
WHERE DISCOVERIES BEGIN

National Science Foundation's Small Business Technology Transfer (STTR) Phase I and Phase II grants:

Diamond tips are well known for their hardness, low adhesion, and low wear properties in scanning probe techniques1

1Ph. Niedermann, W. Hãnni, D. Morel, A. Perret, N. Skinner, P.-F. Indermühle, N.-F. de Rooij, and P.-A. Buffat, Appl. Phys. A: Mater. Sci. Process. **66**, S31 _1998_.

Diamond tip arrays are well suited as field emitters,3 due to diamond's low work function _negative electron affinity_ and high solubilities/conductivities for both of N- and P-type doping, by nitrogen and boron, respectively.4,5

3W. P. Kang, J. L. Davidson, A. Wisitsora-at, Y. M. Wong, R. Takalkar, K. Holmes, and D. V. Kerns, Diamond Relat. Mater. **13**, 1944 _2004_. 4I. Gerger and R. Haubner, Diamond Relat. Mater. **14**, 369 _2005_. 5J. Zhang, S. T. Lee, and Y. W. Lam, Diamond Relat. Mater.**4**, 678 _1995_.

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Testimonials

Customer Quotes:

"I've used the all-diamond Dynamic Conductive Mode cantilevers in our Asylum Cypher AFM and found they last much longer than conventional silicon cantilevers. I ran it for over 1,000 scans in tapping mode (AC mode) on a trade show floor with minimal tip wear. The high spring constant also makes these tips ideal for demanding electrical applications such as Conductive AFM and Piezoresponse Force Microscopy where tip wear and electrostatics are an issue."
Amir Moshar, Research Scientist, Asylum Research

"As for conductive NaDiaProbes, their performance was very good."

Bohuslav Rezek, Ph.D. Research team leader and Purkyn? Fellow at the Department of Thin Films, Institute of Physics, Academy of Sciences of the Czech Republic

"We love them and want to buy some more."

Email from a government lab team leader working on imaging inorganic and organic substrates

"The NaDiaProbes last about a month (per chip). They would last longer if we didn't have to take them in and out to clean them."

Paraphrased from a researcher performing conductive AFM and biological imaging

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Presentations Available

There are several presentations available as training tools for distributors and/or customer-facing visits:

- NaDiaProbes Presentation for Customers (thumbnails on following pages)
- Probes Sales Training: to organize training, contact Jill Paukstis at jill@thindiamond.com
    - Part 1 Intro
    - Part 2 Benefits
    - Part 3 Case Studies
    - Part 4 Customer Questions
    - Extra - includes general overview of ADT

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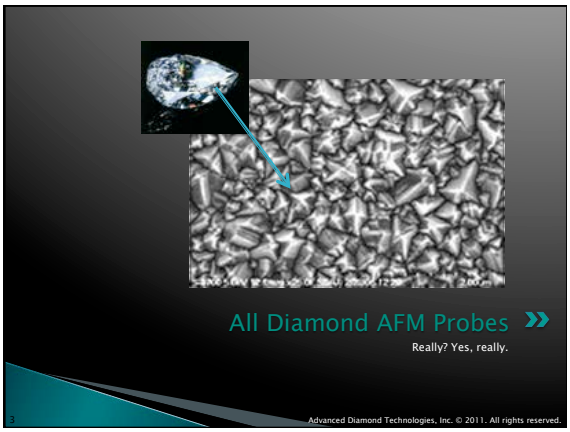
NaDiaProbes Presentation for Customers

ADVANCED DIAMOND TECHNOLOGIES, INC.

NaDiaProbes, All-Diamond AFM Probes

Overview

- What is a NaDiaProbe?
  - An All-Diamond AFM Probe.
  - Really?
    - Yes, Really. It's all-diamond, both cantilever and tip.
  - How do you do that?
- Benefits & Key Applications
  - $15 all-diamond probes for contact mode/soft imaging
  - C-AFM
  - Extreme Wear
- Probe Catalog & Questions?



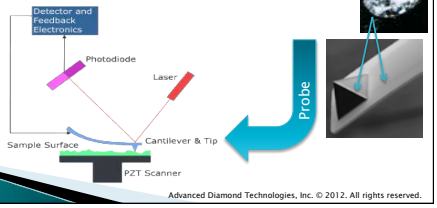
All Diamond AFM Probes »

Really? Yes, really.

What is a NaDiaProbe?

An **ALL-Diamond AFM probe**

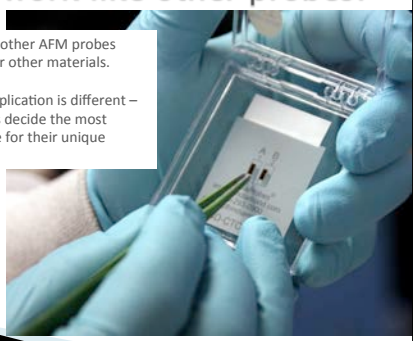
- **The** Cantilever and Tip are made of diamond
- The 'chip' that attaches to the probe is made of glass
- Brand name = NaDiaProbe (Na-no Dia-mond Probe)



Does it work like other probes?

Yes – just like any other AFM probes made of Si, SiN, or other materials.

However, each application is different – users must always decide the most appropriate probe for their unique application.



UNCD® A FAMILY OF DIAMOND MATERIALS

Why "ALL-DIAMOND"?

UNCD®, a form of polycrystalline diamond, is used as an AFM material because of these benefits:

- Enables unparalleled resolution over multiple scans
- Chemically inert
- Extremely durable

NaDiaProbes are made entirely of UNCD® (diamond)– both the tip and cantilever – in a single structure. The diamond is then bonded to a Pyrex handle chip.

- These are **not diamond-coated probes.**
- This material is **not diamond-like carbon (DLC).**
- **NaDiaProbes are diamond** – both cantilever and tip.

UNCD® A FAMILY OF DIAMOND MATERIALS

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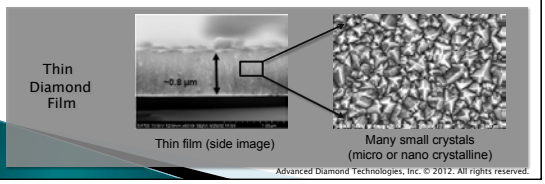
How can it be diamond?

- "Grow" Diamonds using Chemical Vapor Deposition (CVD)
- Our unique UNCD films made of self-assembled mechanically connected ultra-small crystals

A large single crystal diamond

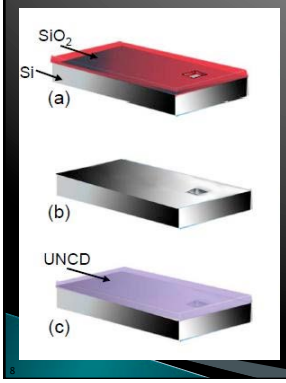
Many crystals (poly crystalline)

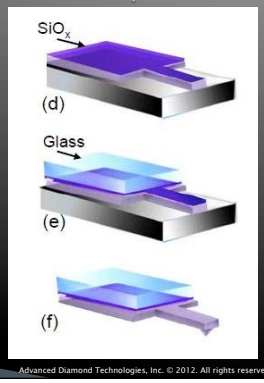


Thin film (side image)

Many small crystals (micro or nano crystalline)

NaDiaProbe Fabrication process





NaDiaProbes All-Diamond AFM Probes

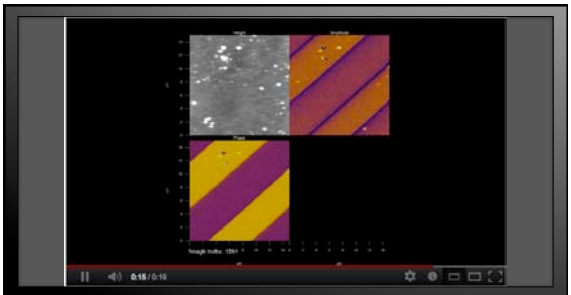
» Benefits & Key Applications

Benefits

◆ NO WEAR	✓Increased wear performance compared to silicon (x 1,000) or silicon nitride (x 100) probes; for typical AFM scans, no observable wear.
◆ NO TIP SHAPE DEGRADATION	✓Superior dimensional stability over extreme distances
◆ BIO FRIENDLY	✓Low surface energy of diamond leads to superior imaging performance on soft, sticky substrates *(bio, polymers, gov't lab experience)*
◆ RESISTS FOULING	✓Resists build-up of debris when imaging soft materials
◆ LOW FRICTION	✓Low friction inhibits sample damage during imaging
◆ AVAILABLE	✓Available in single packs and in wafer-scale volumes.

Key Advantages

Application	Advantage
◆ General Imaging	✓Saves time - by decreasing the number of times a probe needs to be changed. Improves reliability of research results – due to no tip degradation over multiple scans. High Resolution – choose from ~15 nm tip radius or sharp ~5 nm tip radius.
◆ C-AFM (including SSRM, SCM, PFM, ...)	✓Conductive wear-resistant diamond provides superior dimensional stability over extreme distances. No metal coating to wear off, and a sharp, conductive diamond tip.
◆ Biological imaging	Reduced fouling of bio-material. Researchers at a government lab studying proteins has used NaDiaProbes for a month at a time. Quote, "These are the only probes that have enabled us to image our material."
◆ SSRM	
◆ In-line QC for Industrial Use	✓Low friction, durable and long-lasting tip radius, and inert nature combined with the wafer-scale manufacturability enable in-line probe quality control procedures for MEMS and Semiconductor fabs. Advantage over SEM: no contamination of surface and 3-D and electrical topography ability



Key Applications »

#1. General Imaging $15 all-diamond probe, #2. Conductive AFM (c-AFM), #3. Extreme Wear, High Resolution

20100408-WAFERS

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Benefits of a $15* ND-CTIT2

- LOW COST — ✓Save $2 per SCAN using ND-CTIT2 over a Silicon probe!
- NO WEAR — ✓Increased wear performance compared to silicon (x 1,000) or silicon nitride (x 100) probes; for typical AFM scans, no observable wear.
- NO TIP SHAPE DEGRADATION — ✓Superior dimensional stability over extreme distances
- BIO FRIENDLY — ✓Low surface energy of diamond leads to superior imaging performance on soft, sticky substrates *(bio, polymers, gov't lab experience)*
- RESISTS FOULING — ✓Resists build-up of debris when imaging soft materials
- LOW FRICTION — ✓Low friction inhibits sample damage during imaging
- AVAILABLE TODAY — ✓Available in single packs and in wafer-scale volumes.

✓Only the ND-CTIT2 is offered for $15/probe. Other NaDiaProbes range in price up to $400 for a ultra-sharp, High Aspect Ratio Conductive Probe.

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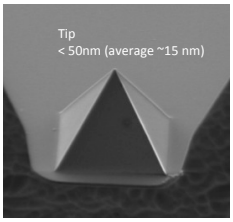
One $15 Chip = 2 Cantilevers

Force Constant ~N/m	Frequency ~kHz	Tip Radius, average, nm	Cantilever
0.71	50	15 nm	#1
0.04	23	15 nm	#2

Key Applications

- Biological Imaging
- Contact Mode Topography
- Better General imaging



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Key Applications for ND-CTIT2

Application	Advantage
Biological Imaging	✓Soft cantilever (0.71 N/m & 0.04 N/m) ✓Low surface energy of diamond leads to superior imaging performance on soft, sticky substrates *(bio, polymers, gov't lab experience)* ✓*"We love them and want to buy some more." – Government lab manager characterizing protein molecules* ✓*"These are the only probes that have been able to image this material. We've been trying to image this protein for months." Lab scientist imaging proteins in a U.S. government AFM lab.*
Contact Mode Topography	✓ Soft Cantilever and low frequency ideal for contact mode imaging of surfaces
Better General imaging	✓Non-contact (dynamic, TappingMode®) was invented because Si probes wear out in contact mode. For the same price, better imaging of your surface is possible in contact mode will all-diamond probes.

✓Non-contact (dynamic, TappingMode®) was invented because Si probes wear out in contact mode. For the same price, better imaging of your surface is possible in contact mode will all-diamond probes.

15

Cost Benefit Explained

- Si probes wear out or foul quickly:
  - 1 probe costs: ~$15-20
  - Tip radius at first scan (if you engage gently): 10 nm
  - Lasts: 2-10 scans
  - Time to change and re-engage tip: 10-15 minutes
  - User's time-cost: $50-$100/hr
  - Total cost of 10 scans? $20-$200
- All-Diamond ND-CTIT2 Probe:
  - 1 probe: $15
  - Tip radius at first and 100th scan (fast engagement): 15 nm
  - Lasts: 100+scans (all-day)
  - Total cost of 1 scans? $0.15
  - Total cost of 10 scans? $1.50
- **Minimum Savings = $2 per scan**
  - Savings per 10 scans? $18-$180
  - How many scans do you do in a day? 100 scans = $180-$1,800 saved per day
  - How many scans in a month? 1,000? 1,000 scans = $1,800-$18,000 savings
  - How many scans in a year? 12,000? 12,000 scans = $21,600-$216,000 saved!

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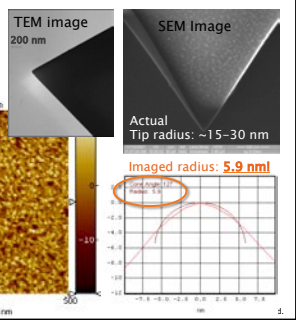
15 nm tip – images like 6 nm!

- **Actual Tip Radius= 15-30 nm**
- **Images of Tip Radius = 6 nm!**



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Direct Replacement for…

Maker	Probe	Force Const. (N/m)	Freq. (kHz)	Tip Radius (nm)	Material	$/probe
ADT	CT-CTIT2	0.71, 0.04	50, 23	15 nm	Diamond	$15/probe (50 for $750)
Olympus	BL-RC-150VB	0.03, 0.006	37, 13	25 nm	Silicon Nitride	$27/probe (210 for $5850)
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Veeco	DNP-S	0.06,0.24, 0.12, 0.35	18,56,2 3,65	10 nm	Silicon Nitride	$13/probe (375 for $5,035)
Olympus	TR400PSA	0.08, 0.02	34, 11	20 nm	Silicon Nitride	$15/probe (245 for $3650)
Veeco	OTR4	0.08, 0.02	34, 11	15 nm	Silicon Nitride	$16/probe (245 for $3,925)

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NaDiaProbes
All-Diamond AFM Probes

» Key Application #2:
C-AFM

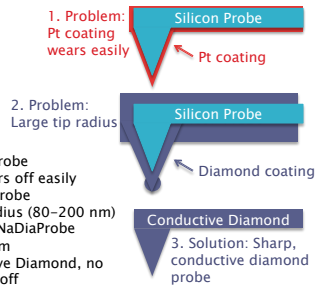
Why Diamond for c-AFM?

Conductive AFM (c-AFM)
Needs a probe to be:

- in contact with surface
- electrically conductive
- Sharp for resolution

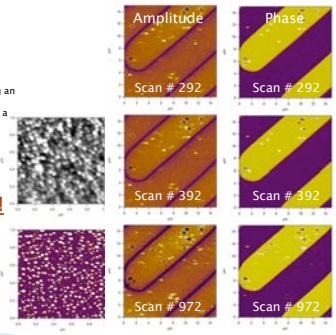
C-afm Probe Options:

1. Platinum-coated Silicon Probe
   - Problem: coating wears off easily
2. Diamond-coated Silicon Probe
   - Problem: Large tip radius (80-200 nm)
3. All-Diamond Conductive NaDiaProbe
   - Solution: Sharp <20 nm
   - Solution: All Conductive Diamond, no metal coating to wear off



Ex: Piezo-force Microscopy

- Sample:
  - GaAs quantum dots for conductive AFM
- Mode:
  - Piezo-force microscopy
  - = c-AFM done in contact mode applying an AC Bias to the tip and measure the mechanical response of the sample with a cantilever
- Scan Number & Times:
  - #292 at 1:49 p.m.
  - #392 at 2:32 p.m.
  - #972 at 4:59 p.m.
- **1 probe = 972 scans !**
  - ND-DYCRS (310kHz, 35 N/m)
  - "I've never been able to run PFM mode this quickly." - application scientist at Asylum
- Impressed? See the 1,500 scan movie:
  http://www.youtube.com/watch?v=rAeqFY2Fhvk



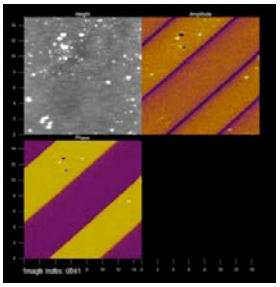
Scans: 1,500

Mode:
Piezo Force
Microscopy
(PFM, requires
conductive
probe)

Number of
NaDiaProbes: 1

Watch At:

http://www.youtube.com/watch?v=rAeqFY2Fhvk



NaDiaProbes
All-Diamond AFM Probes

» Key Application #3:
Extreme Wear Resistance
High Resolution

Extreme Performance Movie

- Purpose of Movie:
  - Show extreme wear performance at high resolution
- Sample:
  - Imaging of the surface of atomic steps in Mica
- Probe:
  - ND-DYCRS probe in a Cypher AFM
- Scans:
  - 974 scans with the same probe
  - Scan size 1x1 micron (excellent resolution)
- http://www.youtube.com/watch?v=Az4lAa8Bfcc&feature=youtu.be

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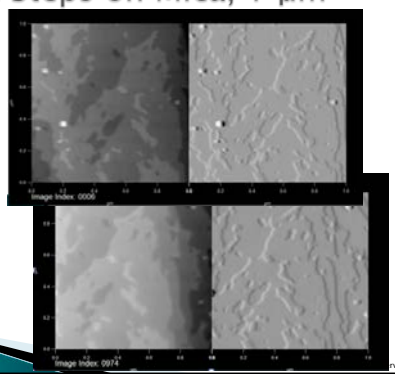
Atomic Steps on Mica, 1 μm²

Scan # 6

Scan # 974



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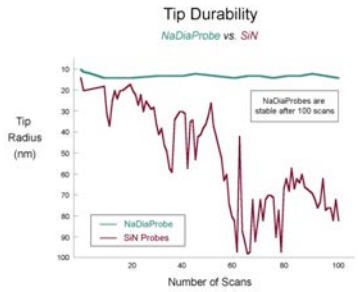
Durability, vs. SiN probes

- *No tip degradation over 100 scans*
- *SiN probes show significant degradation and inconsistency in resolution*
- *Substrate being imaged – thin-film UNCD (diamond)*
- *Source: R. Carpick, University of Pennsylvania, 2009*



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Product Catalog

» Descriptions of our offerings

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Series Summary

Almost any application can be accommodated.

Force Constant ~N/m	Frequency ~kHz	Conductive Available ? (Yes/No)	Series / SKU Name
0.04	12	Yes	Contact – ND-CT_R1, R2
0.23	40	Yes	Contact – ND-CT_R1, R2
0.71	50	Yes	Contact – ND-CT_T2
1.28	48	Yes	Contact – ND-CT_T1
3.70	80	Yes	ND-SSCRL
25.00	265	Yes	ND-SSCRS
35.00	310	Yes	Dynamic Mode – ND-D

Tip Options

A variety of post-process steps can be used to adjust the tip shape of any probe.

Tip Radius (Average) ~ nm	Aspect Ratio	Tip Radius (Specification)	SKU Prefix Name
15	2:1	<50 nm	ND –
5	3:1	<10 nm	AD –
5*	>5:1*	<15nm	*AP –

High Aspect Ratio (HAR) Probes, 5:1 and better, are currently in the prototype stage.

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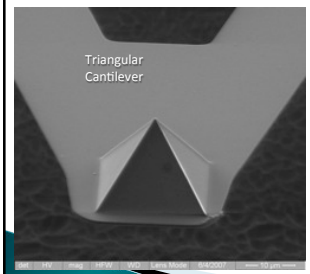
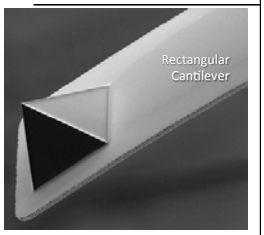
ND-CT Series

All-Diamond AFM Probes
Contact Mode probes

Force Constant ~N/m	Frequency ~kHz
0.04	12
0.23	40
0.71	50
1.28	48





Also available in Conductive Diamond (Boron-doped UNCD) for c-AFM applications.

Bulk Conductivity: <1ohm-cm

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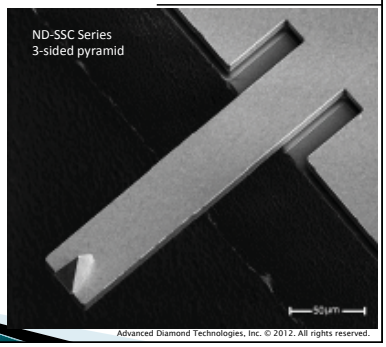
ND-SSC Series

Force Constant ~N/m	Frequency ~kHz
3.70	80
25.00	265

All-Diamond AFM Probes for
Scanning
Spreading
Resistance
Microscopy
(SSRM)

Made of Conductive Diamond (Boron-doped UNCD)

Bulk Conductivity: <1ohm-cm



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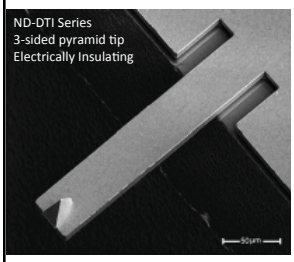
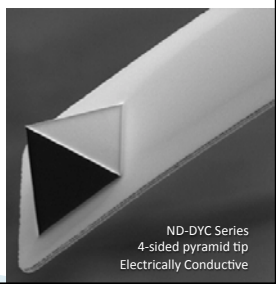
ND-D Series

Force Constant ~N/m	Frequency ~kHz
35.00	310

ND-DTI Series
3-sided pyramid tip
Electrically Insulating



All-Diamond AFM Probes –
Dynamic (non-contact) probes



ND-DYC Series
4-sided pyramid tip
Electrically Conductive

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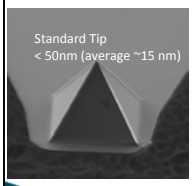
Tip Options

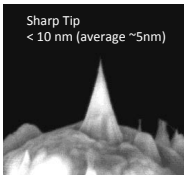
Radius

- Standard: <50 nm, average ~15 nm
- Sharp: <10 nm, average ~ 5 nm
- High Aspect Ratio (HAR), > 5:1, Radius ~ 5nm, Prototype only - in development

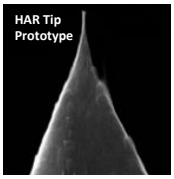
Standard Tip
< 50nm (average ~15 nm)



Sharp Tip
< 10 nm (average ~5nm)



HAR Tip Prototype



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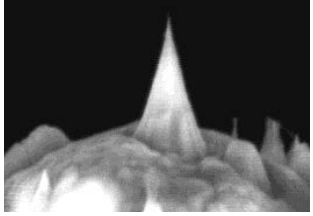
Post-processed Sharpened Tips

- Sharp Tips
  - post processing of any probe
  - tip radius reduction from ~15 nm to ~5 nm
  - Specification reduction: < 50 nm to < 10nm
- Still Diamond? Yes
- Evaluation by Rob Carpick
  - University of Pennsylvania
  - AFM World Expert
- TEM imaging revealed that
  - Indeed, Diamond all the way to the tip edge
  - And the radius is < 5 nm
    - Extremely sharp

The only sharp all-diamond probe in the world



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Questions?

- Thank you for your time
- And the opportunity to speak with you.

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