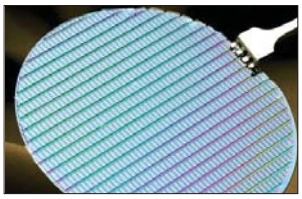
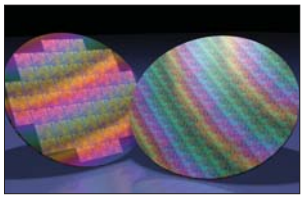
UNCD® Wafers





Thin. Smooth. Diamond.

ADVANCED DIAMOND TECHNOLOGIES, INC.

UNCD® Wafers - A Family of Diamond Material

UNCD is Advanced Diamond Technologies' (ADT) brand name for a family of thin film diamond products.

UNCD Aqua The Aqua series of UNCD films from ADT are electrically insulating, phase-pure nanocrystalline diamond films. Other nanocrystalline diamond films are typically comprised of graphitically-bonded material intermixed with crystalline diamond grains. In contrast, UNCD films have no amorphous graphitic phases. The UNCD Aqua Series captures the hardness, modulus, and other extreme properties of natural diamond.

Aqua Series
(electrically insulating diamond)

UNCD Aqua 25 - Thin, smooth (~7 nm rms) UNCD film. Perfect for MEMS devices and smooth nanotechnology applications like nano imprint lithography.

UNCD Aqua 50 - The best tribological UNCD for industrial low-friction coatings.

UNCD Aqua 100 - The highest thermal conductivity UNCD, appropriate for heat spreading and transparency in the optical spectrum.

UNCD Solutions

The UNCD Aqua series of wafers provides a range of properties that enables optimization for a given application as illustrated in the table. While all UNCD products leverage the benefits of diamond, the Aqua series of wafers are engineered to accentuate diamond properties, allowing the designer to tailor the UNCD solution to the application.

		UNCD Solution		
Property	**Applications**	**Aqua 25**	**Aqua 50**	**Aqua 100**
Smooth surface (less than 10 nm rms)	Low stiction coatings, MEMS, and RF electronics	◆◆◆	◆◆	◆
High thermal conductivity	Heat spreader and thermal management	◆	◆◆	◆◆◆
Corrosion resistance	Electrochemical electrodes, food & pharmaceutical processing	◆◆◆	◆◆◆	◆◆◆
Optical transparency	Wear resistant optical coatings and windows of diamond thin film	◆	◆◆	◆◆◆
Low friction and wear resistance	Mechanical seals and bearings	◆◆◆	◆◆◆	◆◆◆
Biocompatibility	Orthopedic implants	◆◆◆	◆◆	◆◆
Foundry compatibility	Mass MEMS production	◆◆◆	◆◆◆	◆◆◆

◆ good, ◆◆ better, ◆◆◆ best

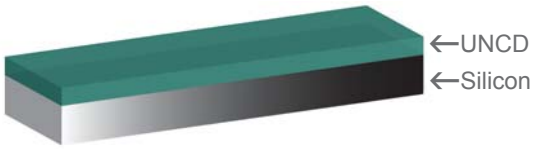
UNCD Lightning

UNCD Lightning™: The Lightning series of UNCD films from ADT are electrically-conductive versions of the Aqua series. UNCD Lightning has an electrical resistivity of approximately 0.1 ohm-cm.

UNCD Wafers

UNCD Wafers are wafer-scale diamond products used for MEMS development, tribological testing, and unique nano-scale processing applications. UNCD Wafers offer the ability to create and experiment with the extraordinary properties of diamond using the award winning family of UNCD materials. UNCD Wafers meet a set of baseline wafer-level specifications for thickness and property uniformity, wafer bow, and particle counts suitable for direct insertion into a MEMS foundry process sequence.

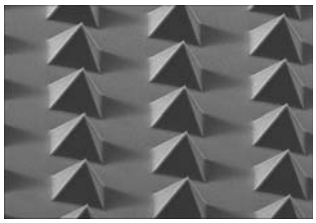
DoSi™ Wafers (Diamond on Silicon)



A prime silicon wafer with a thin film of UNCD. DoSi Wafers are offered for all of the family of UNCD materials. Wafer sizes available are 100, 150, 200, and 300 mm.

DOI™ Wafers (Diamond on Insulator)

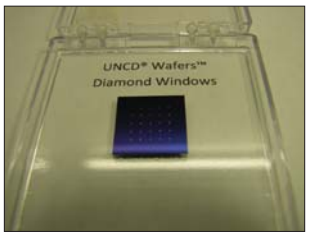
Standard silicon wafers coated with a thermal SiO_2 layer (nominal 1 micron thickness) followed by UNCD Aqua 25, 50, or 100. These substrates are ready for further MEMS processing using standard surface micromachining techniques to make UNCD-based cantilevers, resonators, diaphragms, and diamond windows. UNCD DOI Wafers are offered for all of the family of UNCD materials. Wafer sizes available are 100, 150, 200, and 300 mm.



Custom MEMS Development

ADT is happy to work with its customers to develop a variety of custom MEMS diamond products. An example of a project is the array of diamond pyramids, a few microns in height, pictured above. If you are interested in creating your MEMS product with diamond, contact us at sales@thindiamond.com.

UNCD Diamond Windows



For a limited time, ADT is offering die of 300 micron square diamond windows. The wafer die is 1.5 cm^2 with UNCD Aqua 25 windows in an array of 2 mm^2.

Custom UNCD Wafers

ADT is happy to work with its customers to develop custom wafer stacks suitable for creating complex MEMS devices. ADT will also integrate UNCD into a customer's patterned wafer stack. Please contact us for pricing and availability.

UNCD Horizon

NEW! UNCD Horizon™: The Horizon technology delivers UNCD in ultra-smooth form. The surface of a Horizon 25 wafer has a roughness value of less than 1 nm rms.

UNCD Wafers - Diamond MEMS 101

A guide to creating a MEMS device from diamond

Processing UNCD for incorporation at wafer scale into devices uses the same equipment as for processing silicon (Si). Patterning of UNCD may be done via a hard mask and gas etching (see recipe on next page). Diamond windows may be created by backside etching the silicon from the UNCD Wafer. The following UNCD property data provides some starting points for creating devices using UNCD wafers.

UNCD General Material Properties:

Young's modulus: Approximately 850 GP
Density: 3300 kg/m^3
Poisson ratio: 0.057+/-0.038
Dielectric constant: Same as natural diamond, 5.68

Surface Roughness:

Horizon 25 < 1 nm rms
Aqua 25 < 10 nm rms
Aqua 100 < 40 nm rms

Uniformity (thickness) across wafer:

Less than 10% variability

Electrical Resistance:

Aqua 25: 1,000 - 10,000 ohm-cm
Lightning 25: 0.1 ohm-cm

Stress:

Normal deposition of a 1 micron Aqua 25 UNCD layer exerts approximately -300 MPa of stress (compressive) on the Si wafer.

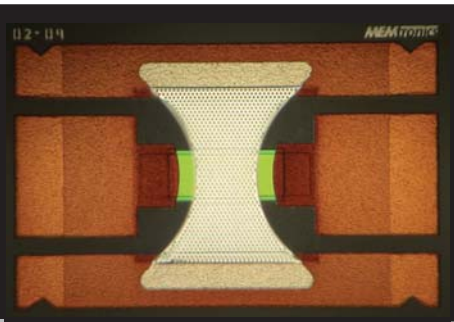
Useful Technical Articles:

Raman Spectroscopy of UNCD – "Interpretation of the Raman Spectra of Ultrananocrystalline Diamond" J. Birrell, Gerbi, Auciello (one of ADT's founders), Gibson, Johnson, and John A. Carlisle (ADT's CTO), Diamond & Related Materials, 2005.

Optical Properties: Reflectance and Transmittance – "Optical properties of diamond-like carbon and nanocrystalline diamond films." Mednikarov in the 2005 Journal of Optoelectronics and Advanced Materials.

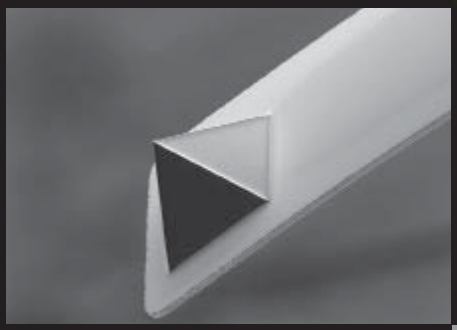
RF MEMS Switch

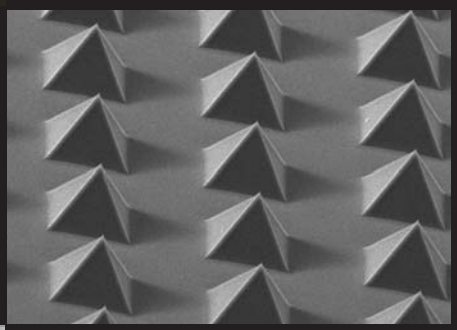
MEMS switch made using UNCD Aqua 25 as the low-trap dielectric. Created in collaboration with MEMtronics Corporation, this switch achieved over one billion cycles in dry air.



Molded 3D Structures

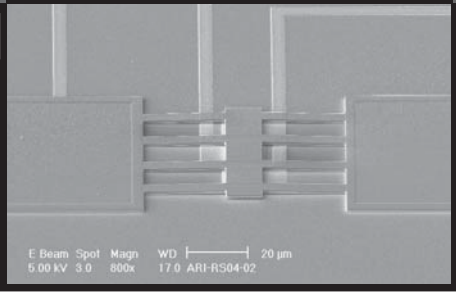
Complex 3D structures, such as this tip array, were created using a combination of molds and UNCD deposition in a wafer-scale process.





AFM Probes

Monolithic diamond AFM cantilever probes, NaDiaProbes®, made entirely of UNCD.



RF MEMS Resonator

MEMS resonator made using UNCD DoSi wafers, photo courtesy of Innovative Micro Technology (IMT), Santa Barbara, CA.

Etching UNCD - Using a hard mask

Step 1: Prior to hard mask deposition:
Prepare the UNCD surface prior to depositing PECVD oxide by performing a hot piranha clean to convert the hydrogen-terminated diamond surface into oxygen and hydroxyl-terminated, allowing better adhesion to the SiO_2 layer.

Step 2: Deposit hard mask:
Plasma-enhanced chemical vapor deposited (PECVD) SiO_2, with a thickness adapted to the thickness of the diamond that needs to be etched. For etching 1-2 um of UNCD, 250 nm of SiO_2 is sufficient.

Step 3: Pattern hard mask:
After priming and dehydration baking, coat the SiO_2 surface with a > 500 nm thick photoresist and perform optical lithography with the pattern desired. For sub-micron features, a 350 nm thick electron-beam resist can also be used: ma-N 1405 (MicroChem), at 2000 rpm; bake at 100°C for 90 sec; develop 30 sec in mD533S developer.

Step 4: Etch hard mask:
Etch the SiO_2 layer by standard reactive ion etching (RIE) using a gas mixture such as CHF_3-Ar (50:5 sccm) plasma, at 150 W, 50 mTorr. Other gas mixtures can also be used (e.g. CF_4, or CHF_3 and O_2).

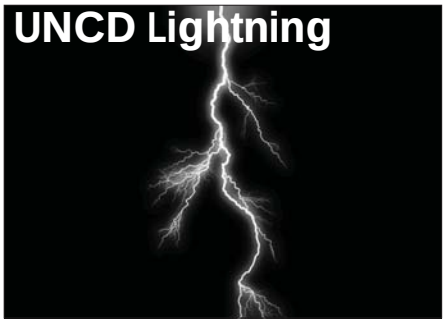
The photoresist or e-beam resist do not need to be removed prior to the diamond etch process, since the oxygen-based plasma for etching the diamond removes excess resist.

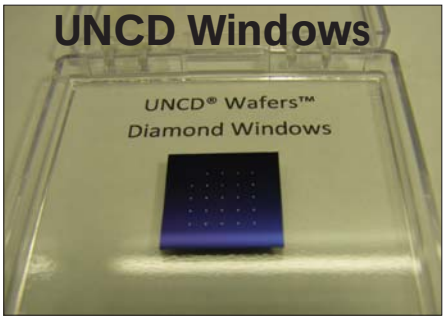
Step 5: Etch Diamond:
The resist pattern can be transferred to the UNCD layer by using a reactive ion etching (RIE) and Inductive-Coupled Plasma (ICP-RIE) chamber with this recipe to achieve a removal rate of approximately 650 ± 80 nm/min for UNCD:

RIE Power= 200 W
0_2= 50 sccm
P = 9 mTorr
ICP = 2500 W
SF_6 = 0.5 sccm
T= 20°C

Similar recipes can be used in standard RIE systems, but with lower etch rates. The selectivity can be increased by eliminating the SF_6. SF_6 can be replaced by other fluorine-containing gasses (e.g. CF_4).

Price List





UNCD Horizon - UNCD with a surface roughness less than 1 nm

Product Code	UNCD Product	WaferSize (mm)	Wafer Type	Oxide Layer (µm SiO_2)	UNCD Film Thickness (µm)	Price (each)
HA25-001-0-p1	Aqua 25	Die-1 cm^2	DoSi	-	0.1	$149
HA25-001-0-p2	Aqua 25	Die-1 cm^2	DoSi	-	0.2	$149
HA25-001-1-p3	Aqua 25	Die-1 cm^2	DOI	1	0.3	$149
HA25-001-0-1	Aqua 25	Die-1 cm^2	DoSi	-	1	$149
HA25-001-0-2	Aqua 25	Die-1 cm^2	DoSi	-	2	$149
HA25-100-0-1	Aqua 25	100	DoSi	-	1	$1,350
HA25-100-0-2	Aqua 25	100	DoSi	-	2	$1,350

UNCD Lightning - Conductive diamond wafers

Product Code	UNCD Product	WaferSize (mm)	Wafer Type	Oxide Layer (µm SiO2)	UNCD Film Thickness (µm)	Price (each)
UL25-100-1-p1	Lightning 25	100	DOI	1	0.1	$725
UL25-100-1-p3	Lightning 25	100	DOI	1	0.3	$725
UL25-100-1-p5	Lightning 25	100	DOI	1	0.5	$725
UL25-100-1-1	Lightning 25	100	DOI	1	1	$725
UL25-100-1-2	Lightning 25	100	DOI	1	2	$725

UNCD Diamond Windows - Window size: 300 $micron^2$

Product Code	UNCD Product	WaferSize (mm)	Wafer Type	Oxide Layer (µm SiO2)	UNCD Film Thickness (µm)	Price (each)
WA25-100-1-p1	Aqua 25	Die-1.5 cm^2	DOI	1	0.07	$749

UNCD Diamond Thin Film Specifications: Thickness ± 20%, thickness uniformity typically < 10%, surface roughness Aqua 25 < 10nm rms (Aqua 50 has no specification, Aqua 100 is ~ 30-40 nm rms), electrical resistivity of Lightning 25 is < 1 ohm-cm, wafers will have no blemishes or particulates visible to the naked eye, exclusion zone within 5 mm of edge. Base wafer specifications: Prime grade, <100> Si wafer base, 500 µm ± 50 µm, DOI contains 1 µm of thermal SiOx on whole wafer, back and front side.

Price List

DoSi - Diamond on Silicon Wafers

Product Code	UNCD Product	Wafer Size (mm)	Wafer Type	Oxide Layer (µm SiO2)	UNCD Film Thickness (µm)	Price (each)
UA25-100-0-p1	Aqua 25	100	DoSi	-	0.1	$525
UA25-100-0-p2	Aqua 25	100	DoSi	-	0.2	$525
UA25-100-0-p3	Aqua 25	100	DoSi	-	0.3	$525
UA25-100-0-1	Aqua 25	100	DoSi	-	1	$525
UA25-100-0-2	Aqua 25	100	DoSi	-	2	$525
UA25-150-0-p3	Aqua 25	150	DoSi	-	0.3	$999
UA25-150-0-1	Aqua 25	150	DoSi	-	1	$999
UA25-200-0-p3	Aqua 25	200	DoSi	-	0.3	$1,699
UA25-200-0-p1	Aqua 25	200	DoSi	-	1	$1,699
UA50-100-0-1	Aqua 50	100	DoSi	-	1	$525
UA50-150-0-1	Aqua 50	150	DoSi	-	1	$999
UA50-200-0-1	Aqua 50	200	DoSi	-	1	$1,699
UA100-100-0-1	Aqua 100	100	DoSi	-	1	$675
UA100-150-0-1	Aqua 100	150	DoSi	-	1	$1,419
UA100-200-0-1	Aqua 100	200	DoSi	-	1	$2,499

DOI - Diamond on Oxide Wafers

Product Code	UNCD Product	Wafer Size (mm)	Wafer Type	Oxide Layer (µm SiO2)	UNCD Film Thickness (µm)	Price (each)
UA25-100-1-p1	Aqua 25	100	DOI	1	0.1	$525
UA25-100-1-p2	Aqua 25	100	DOI	1	0.2	$525
UA25-100-1-p3	Aqua 25	100	DOI	1	0.3	$525
UA25-100-1-1	Aqua 25	100	DOI	1	1	$525
UA25-100-1-2	Aqua 25	100	DOI	1	2	$525
UA25-150-1-p3	Aqua 25	150	DOI	1	0.3	$999
UA25-150-1-1	Aqua 25	150	DOI	1	1	$999
UA25-200-1-p3	Aqua 25	200	DOI	1	0.3	$1,699
UA25-200-1-1	Aqua 25	200	DOI	1	1	$1,699
UA50-100-1-1	Aqua 50	100	DOI	1	1	$525
UA50-150-1-1	Aqua 50	150	DOI	1	1	$999
UA50-200-1-1	Aqua 50	200	DOI	1	1	$1,699
UA100-100-1-1	Aqua 100	100	DOI	1	1	$675
UA100-150-1-1	Aqua 100	150	DOI	1	1	$1,419
UA100-200-1-1	Aqua 100	200	DOI	1	1	$2,499

UNCD Diamond Thin Film Specifications: Thickness ± 20%, thickness uniformity typically < 10%, surface roughness Aqua 25 < 10nm rms (Aqua 50 has no specification, Aqua 100 is ~ 30-40 nm), electrical resistivity of Lightning 25 is < 1 ohm-cm, wafers will have no blemishes or particulates visible to naked eye, exclusion zone within 5 mm of edge. Base wafer specifications: Prime grade, <100> Si wafer base, 500 µm ± 50 um, DOI contain 1 µm of thermal SiOx on whole wafer, back and front side.

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