ADVANCED DIAMOND TECHNOLOGIES, INC.

UNCD® Wafers—Diamond MEMS Lesson #1

A guide to creating a MEMS device from diamond

Diamond Etch Recipe

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. Processing UNCD for incorporation at wafer scale into devices uses the same equipment as for processing silicon (Si).

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 electronbeam 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

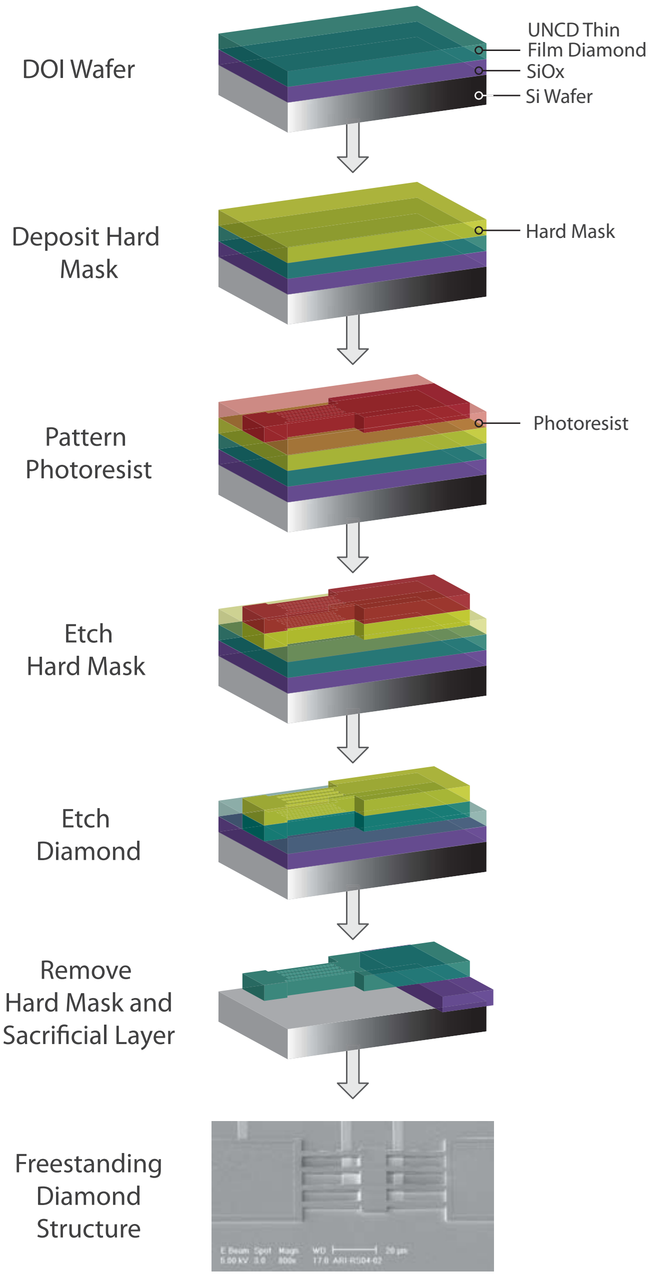
The resist pattern can be transferred to the UNCD layer by using a reactive ion etching (RIE) and Inductive-Coupled Plasma (ICP-RIE) chamber with this recipe to achieve a removal rate of approximately 650 ± 80 nm/min for UNCD:

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).

ETCHING DIAMOND

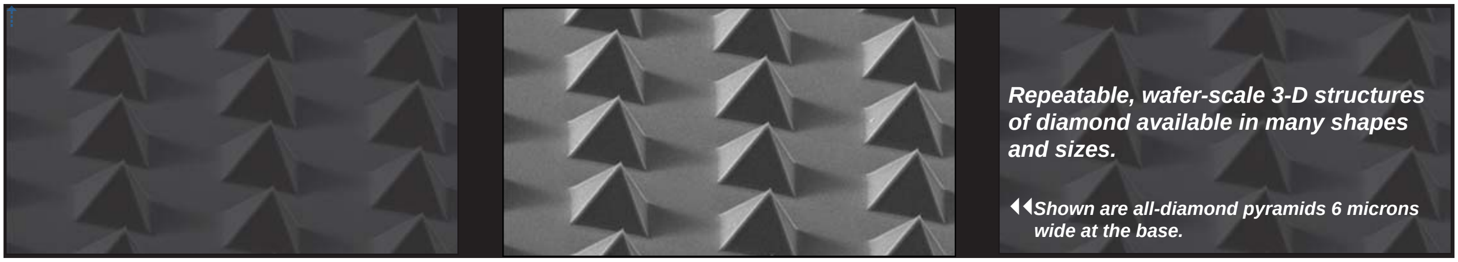


ADVANCED DIAMOND TECHNOLOGIES, INC.

Chemical Mechanical Planarization (CMP) Pad Conditioners

Creating the next generation of Diamond enabled CMP Pad Conditioners

In July, 2010, the National Science Foundation awarded a grant to Advanced Diamond Technologies, Inc. for support of the SBIR Phase I project. Under the direction of Dr. Nicolaie Moldovan, ADT's MEMS Lead Scientist, the project is entitled *Microfabricated Chemical Mechanical Planarization (CMP) Pad Conditioners with Controlled Diamond Geometrical Protrusions*. The published etch recipe on the reverse side was a key motivator to landing this project. This dry etch recipe has enabled engineers to affordably design micro devices and sensors out of diamond, and now CMP Pad Conditioners as well.



Repeatable, wafer-scale 3-D structures of diamond available in many shapes and sizes.

◀◀Shown are all-diamond pyramids 6 microns wide at the base.

The following are journal articles co-authored by ADT scientists, applicable to CMP Pad Conditioners:

- **May 26, 2010 - *Small***
  The prestigious journal Small publishes paper on extreme wear properties of all diamond tips.

  J. Liu et al., Preventing Nanoscale Wear of Atomic Force Microscopy Tips Through the Use of Monolithic Ultrananocrystalline Diamond Probes, *Small*, Volume 6, Issue 10, Date: May 21 2010, Pages: 1140-1149.

- **September 24, 2010 - *Journal of Applied Physics***
  An energy-based model to predict wear in nanocrystalline diamond atomic force microscopy tips.

  R. Agrawal, N. Moldovan, and H. D. Espinosab, "An energy-based model to predict wear in nanocrystalline diamond atomic force microscopy tips ", *JOURNAL OF APPLIED PHYSICS,* 106, 064311 2009.

- **December 7, 2009 - *JVST B***
  *Nanofabrication of sharp diamond tips by e-beam lithography and inductively coupled plasma reactive ion etching***.**

  Nicolaie Moldovana, Ralu Divan, Hongjun Zeng and John A. Carlisle, "Nanofabrication of sharp diamond tips by e-beam lithography", *J. Vac. Sci. Technol.* B, Vol. 27, No. 6, Nov/Dec 2009.

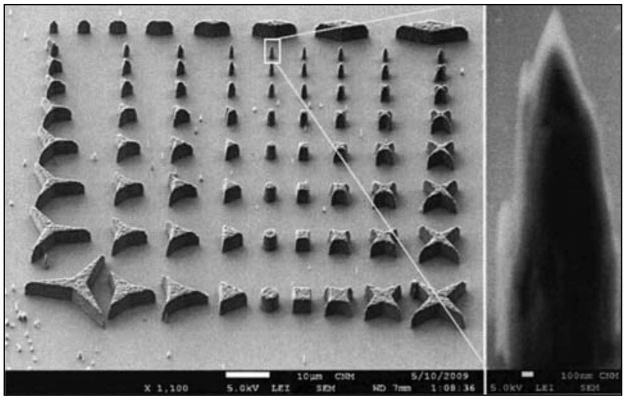


Image at left: Diamond structures etched into 3.5-µm-thick UNCD, with detail showing a sharp tip obtained from the smallest diameter circle feature. The tip sharpness is on the order of nanometers.

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This product is protected by one or more of the following U.S. and foreign patents: 5,989,511; 6,592,839; 7,128,889; 5,849,079; 5,772,760. Additional patents pending.