Diamond Coated Tips for Scanning Tunneling Microscopy

B. Stein[1], J. Owen[2] and O. Auciello[1]
[1] *Materials Science Dept. University of Texas at Dallas, Richardson, TX, USA*
[2] *Zyvex Labs, Richardson, TX, USA*

Scanning Tunneling Microscopy (STM) has shown great promise as an emerging tool for nanotechnologists to enable atomically-precise control over surface modification in the nanometer regime via surface lithography [1], as well as atomic-scale surface imaging and microanalysis. However, research in this field has been plagued by tip performance issues such as wear, oxidation, damage from electrostatic discharge, etc[2]. While polycrystalline tungsten wires have been typically used for tip fabrication via KOH-etching, diamond has long been considered an ideal potential candidate for numerous applications in scanning probe microscopy [3,4,5] due to its well-documented hardness, chemical inertness, high Young's modulus, and potential for controlled conductivity through selective doping. Numerous methods have been developed for fabricating diamond-based probes [6,7], with generally positive results, although standardized practices have not yet been established due to lack of repeatability and scalability.

In this presentation, we report the development, application, and characterization of diamond coated STM tips and demonstrate their functionality in scanning imaging and lithography modes.

Initial polycrystalline tungsten probe tips are prepared using the established method of electrochemical etching terminated at drop-off, followed by a secondary self-limiting Field-Directed Sputter Sharpening (FDSS) step, which utilizes an unfocused beam of Ar ions directed at a positively biased tip [8]. Ultra-nanocrystalline diamond (UNCD) is then directly grown onto the tips without prior seeding in a microwave plasma chemical vapor deposition process utilizing Bias Enhanced Nucleation (BEN) and Bias Enhanced Growth (BEG) [9]. It has been found that by lowering the process temperature and plasma pressure, the extreme point of the tip can be quickly coated with a thin layer of diamond tapering to a point with a radius of curvature less than 10 nm. While further sharpening of the diamond tip is possible with a lower energy FDSS step, it has been found that with ideal growth conditions no further sharpening is needed, nor is any extra doping step required to achieve tip conductivity. Furthermore, the tip can be used immediately for surface scanning and hydrogen depassivation lithography. UNCD tips are found to have excellent durability, maintaining consistent scanning performance over very large scan areas. Tip morphology and crystallinity is characterized via STEM, EDAX, and electron diffraction.

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[9] Espinosa, Small, **1**, 866 (2005).

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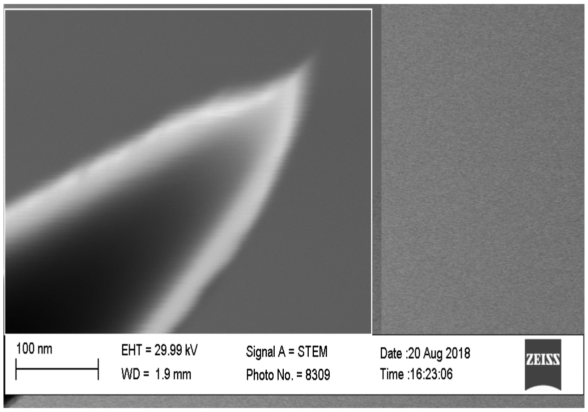

Figure 1: STEM image of UNCD-coated tip

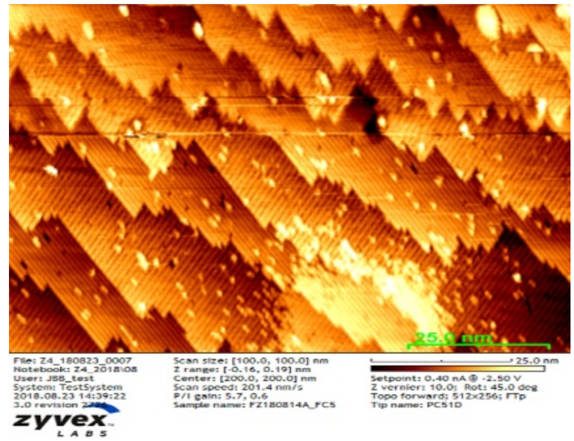

Figure 2: STM image taken of passivated Si surface taken with UNCD tip

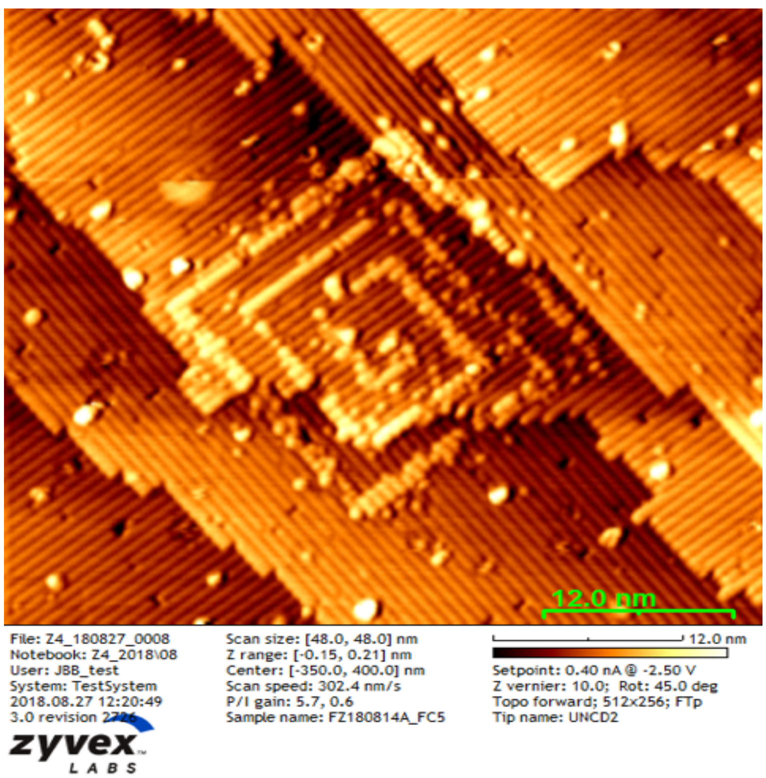

Figure 3: Spiral pattern created via hydrogen depassivation lithography on Si surface

Note: Results reported are considered preliminary. Further work will be conducted prior to the conference date and will be presented accordingly. Anticipated work includes STM durability studies, lithography demonstrations, TEM imaging before/after scanning, field emission characteristics, and further process optimization of the tip fabrication process.

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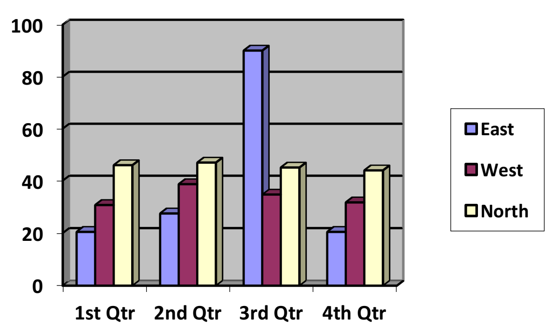

Figure 1 Caption Here

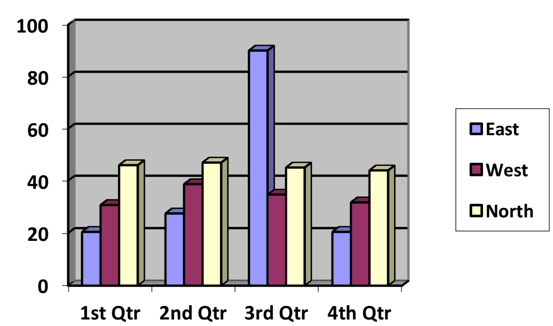

Figure 2 Caption Here

[1] P. R. Wallace, Phys. Rev. **71**, 622(1947).

+ Author for correspondence: Z.SurnameN@email.com

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