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NaugaNeedles

NaugaNeedles' Exposed End NeedleProbes (EENP)

NaugaNeedles has a unique technology to selectively grow individual metallic Silver/Gallium (Ag_2Ga) nanoneedles at the end of standard atomic force microscope (AFM) probes. The Ag_2Ga nanoneedles have superior electrical, mechanical, and chemical stability that are suitable for a variety of AFM applications. Taking advantage of this technology, NaugaNeedles is proud to be the first company to commercialize conductive AFM probes that can perform in liquid environments (e.g. AFM-SECM). This unique product is called *Exposed End NeedleProbe* (EENP).

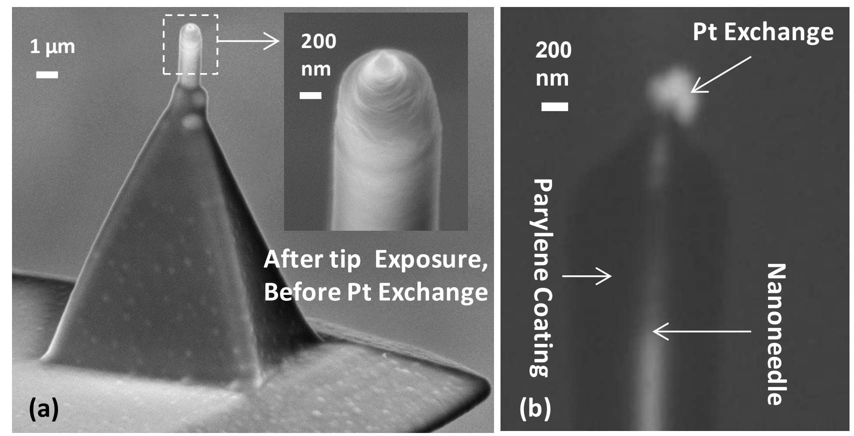

Figure 1: (a,b) SEM images of NaugaNeedles' Exposed End NeedleProbes (EENP), before (a), and after (b) Platinum exchange.

Figure 1 shows the SEM images of an EENP. The EENP is made by (1) growing an Ag_2Ga nanoneedles on standard AFM cantilevers, (2) coating the entire device with an insulated layer (e.g. Parylene), (3) selectively removing the Parylene from the end of the needle, (4) exchanging the exposed needle tip with platinum to enhance the chemical stability, (5) mounting the device on an insulated substrate (e.g. a copper clad), and (6) covering the entire device (except the cantilever area) with additional insulating resin (e.g. GC Insulating varnish, see ***Figure 2***). The Pt

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electrode size is as small as 100 nm in diameter that will allow for sub 100 nm topographical and current mapping resolutions.

Packaging for EENP:

To improve the electrical insulation of EENP, the EENP are mounted on a small ceramic chip holder as shows in ***Figure 2***. There is a copper coating at the middle of the ceramic chip holder where a wire is soldered to it (***Figure 2a-d***). The entire device is then covered by a non-conductive resin. This packaging makes device handling easier and prevents the insulated layer from being compromised during handling. ***Figure 2e-g*** are optical images of the actual device as it is handled by tweezers.

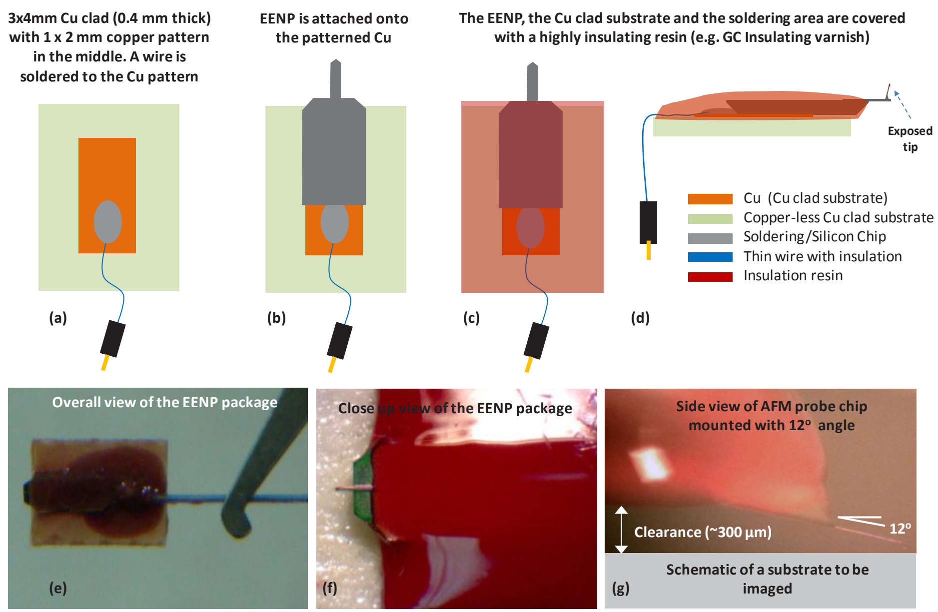

Figure 2. (a-d) Schematic of the EENP packaging. (e,f) Optical images of the device. (g) The device package has enough clearance from the surface when the cantilever is brought in contact with the surface with a 12 degree angle.

Cyclic Voltammetry of EENP:

Figure 3a shows Cyclic Voltammetry (CV) on an EENP probe that was measured by immersion into a 5mM solution of $Ru(NH_3)_6Cl_3$ containing 0.1M $KClO_4$. A steady-state behavior is evident by the Faradaic current plateau. In this case the current approaches a diffusion-limited value of 700 pA. Repeating the experiment several times shows no change in CV curves: indicative of the stability and robustness of the probes. Background currents before tip exposure is negligible (~5 pA).

Topographical and electrochemical images of a standard test substrate (gold patterns) are shown in ***Figure 3b,c***. The features on the gold patterns are well resolved in both the topographical and electrochemical images. The line scans through the cross-sections of topography shows sub-100 nm features in the gold patterns that are also observed in the electrochemical image. The probes were suitable for imaging over many hours.

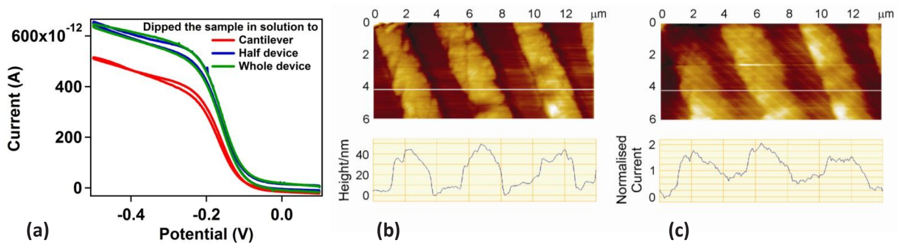

Figure 3: (a) The Cyclic Voltammetry of the EENP on 5mM $Ru(NH_3)_6Cl_3$ in 0.1M $KClO_4$ solution, Rate = 0.1 V/s, Sensitivity = 10^{-9} A/V. (middle) AFM topographical, and (right) electrochemical image. Current is normalized relative to the bulk current of 2 nA. AFM images are the Courtesy of Dr. Andy Wain, (National Physical Laboratory, UK)

Advantages of EENP:

- Negligible electrical leakage (sub 10 pA)
- Sub 100 nm resolution in electrochemical images can be achieved.
- Cylindrical shape electrode is ideal for electrical measurement
- Highly conductive
- Long shelf time
- Easy to handle

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