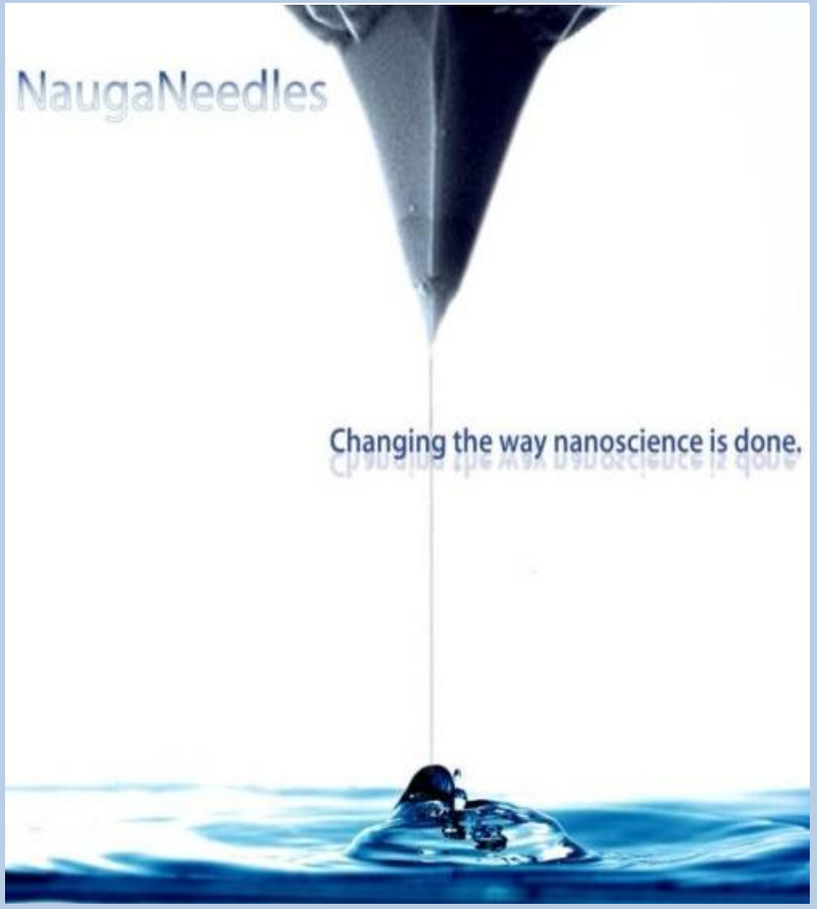

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NaugaNeedles' Simple Geometry NeedleProbes

NaugaNeedles offers high aspect ratio crystalline Ag_2Ga NeedleProbes with cylindrical shape ending in a semi-hemisphere (***Figure 1a***). Due to the simple geometry and atomically flat surfaces of these nanoneedles, they can be used for quantitative Force-Distance (F-D) measurements using Atomic Force Microscope (AFM) of wetting and drag forces made with the probes. Also, they can be easily used for AFM liquid probing and soft material probing.

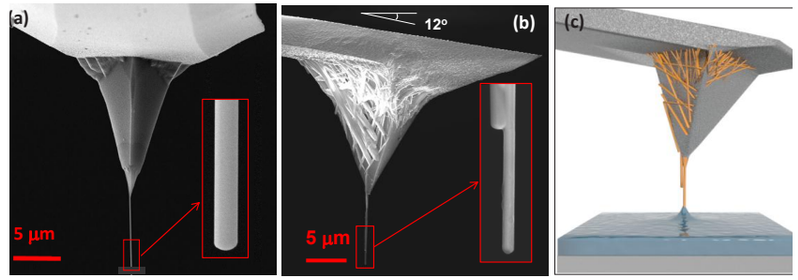

Figure 1: SEM images of NeedleProbes (a) with single nanoneedle and (b) double-nanoneedle which shows a simple geometry of the nanoneedles, (c) schematic of a double-nanoneedle being dipped in a liquid surface.

NeedleProbes Application in Liquid Probing:
Commercially available AFM probes are typically pyramidal or conical. While such probes detect wetting force, it will be complicated to extract surface tension and contact angle from the force-distance (F-D) curves on liquid surfaces. ***Figure 2a*** shows the F-D curve of a tapered AFM probe on water. The F-D extension curve (red) of the probe into the liquid and retraction curve (blue) from the liquid both show a roughly parabolic shape, with near vertical curves at entry into and just prior to removal from the liquid. With increasing insertion depth the attractive force continues to grow, corresponding to the increasing length of the contact line. This large and growing wetting force may even overwhelm the cantilever stiffness and result in the unintended immersion of the cantilever into the liquid. These problems include imprecise knowledge of the length of the contact line and the angle of the meniscus with the facets

of the tip. In contrast, constant diameter high aspect ratio NeedleProbes can be used for F-D AFM measurements. For a NeedleProbe that has a constant diameter tip, there is a step change in force when the tip first touches the liquid (***Figure 2b***). Then the force remains constant as the tip is extended until the meniscus contacts a second section of the probe (i.e. for a double NeedleProbe in ***Figure 1b***) that is larger in diameter. At this point, the wetting force increases again in a stepwise fashion. Therefore, a constant diameter NeedleProbe has the desirable feature of maintaining a stable and constant wetting.

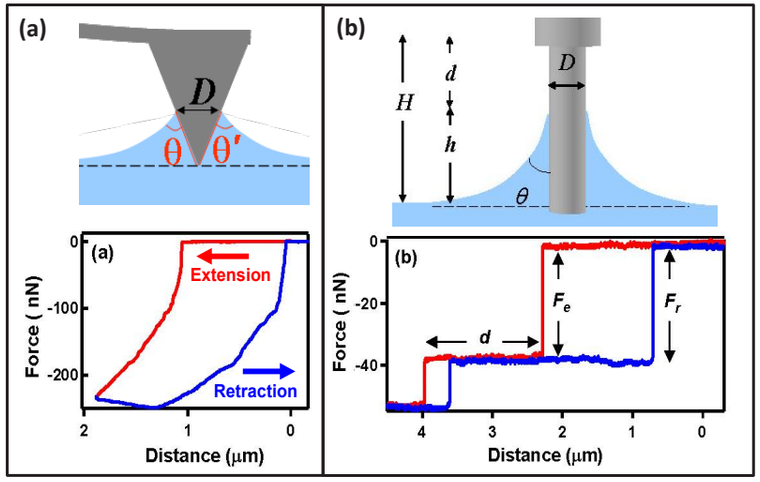

Figure 2: Comparison of F-D curves of liquids for AFM tips that are (a) standard tapered AFM tips with pyramidal cross section and (b) constant and/or dual constant diameter. The liquid is dibasic ester measured at room temperature.

NeedleProbes Application in Probing Into Soft Material (e.g. bio-membrane): The Ag_2Ga nanoneedles can be used to probe small and soft materials such as cells. ***Figure 3a,b*** displays a dried yeast cell inside a SEM system that is being penetrated by a nanoneedle.

F-D measurement of a fresh blood cell in an AFM is shown in ***Figure 3c***. The 175 nN step in force, on the far right of the (red) extension curve, corresponds to puncturing the cell membrane. Over the next 278 nm there are a jagged set of features, similar to the stick-slip motion encountered in frictional measurements of solid surfaces . At 278 nm (past the membrane penetration) the force increases by another 70 nN and then it releases, suggesting that an interior membrane has been penetrated. Beyond this insertion depth, the slope continues to increase as the needle is coming in contact with the underlying glass substrate. The right inset shows changes in four successive F-D scans in the region marked by the asterisk. The F-D measurement are repeated 50 times at the same location, and showed minimum changes in the F-D curve revealing neglected damage to the cell membrane by the NeedleProbe.

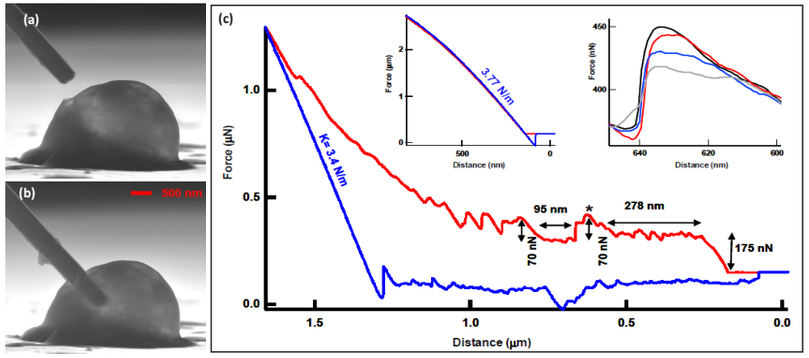

Figure 3: (a,b) A NeedleProbe is inserted through a yeast cell in SEM , (c) F-D curve of a fresh red blood cell on a glass slide. The left inset shows the F-D curve of forcing the NeedleProbes directly against the glass slide. The right inset show the change in the feature marked by the asterisk over four successive F-D scans at 3seconds intervals.

Advantages of Simple Geometry NeedleProbes:

- High aspect ratio Ag_2Ga NeedleProbes for F-D AFM and liquid probing
- Simple geometry
- Probes with special geometry (e.g. multiple nanoneedles)
- Suitable for cell and soft material probing

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