A simple method for producing flattene atomic force microscopy tips

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We describe a simple and reliable procedure for obtaining a flat plateau on top of standard silicon nitride atomic force microscopy tips by scanning them over the focus of a high-numerical-aperture objective illuminated by near-infrared ultrashort laser pulses. Flattened tips produced this way exhibit a plateau that is parallel to the substrate when the cantilever is mounted. They represent a valid and cost-effective alternative to commercially available plateau tips. © *2008 American Institute of Physics.* [DOI: 10.1063/1.2834875]

Atomic force microscopy (AFM) is well established as one of the preferred tools to characterize topography at the nanoscale because of its relatively easy implementation and the possibility to operate either at ambient conditions, under vacuum, or in liquids.[1]

In the past decade, there has been an extensive use of AFM-based systems not only to acquire topographical information but also to exploit the possibility of nanometer-scale manipulation and positioning of objects to probe local interactions. This technique is largely applied in nano-optics research,[2] as it offers the possibility to probe interactions between two nanosystems (one on a substrate and the other one on a tip) by accurately controlling their relative distance on the nanometer scale.[3–5] To this aim, several techniques have been developed, which enable one, e.g., to attach particles to the tip apex[6] or to build metal nanostructures on the apex of a tip.[7]

To obtain the best results in this field, a controlled tip apex shape is often required as a well-defined starting point for further processing. This is why flat tips, i.e., tips that have the shape of a truncated pyramid, are now becoming commercially available. Such tips, however, have the disadvantage that their plateau is generally not parallel to the sample surface. In particular, when used in an AFM, the tilt of the cantilever due to the mounting geometry causes severe deviations from parallelism. In addition, the amount and direction of the mismatch will differ with the type of AFM used. Alternatively, flat tips may be produced by means of focused ion beam milling. Again, this procedure does not allow for a precise control over the parallelism between the tip plateau and sample surface. Moreover, focused ion beam milling is expensive and time consuming.

In this Note we describe our findings about the possibility to obtain a flat plateau at the apex of a commercially available silicon nitride AFM tip[8] by scanning it over the focus of an objective illuminated by a high-repetition rate pulsed laser. Flattened tips obtained this way have the big advantage of plateaus which are parallel to the sample surface, as they are prepared *in situ*, and of a very low cost.

To achieve tip flattening, we use a system composed of an inverted confocal microscope combined with a tip-scanning AFM head (Bioscope, Veeco). 830 nm pulses with 100 fs duration and 80 MHz repetition rate (Tiger, Time Bandwidth Products, Zurich) are delivered to an immersion objective (Zeiss, Plan-Apochromat, 63×, 1.4 numerical aperture). The typical procedure requires a transparent sample, in our case a clean glass microscope cover slip, and consists in focusing 2–5 mW average power through the objective onto the upper surface of the glass substrate and scanning the tip in contact mode centered at the focus position for 1–2 h (scan rate: 1–2 Hz, scan range: 10–20 μm). Typical deflection parameters, ruling tip-surface interaction, are those of standard contact-mode hard-surface profiling. In this way,

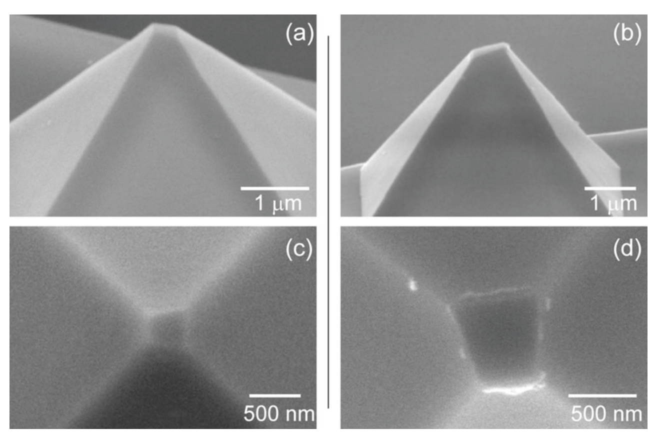

FIG. 1. Representative scanning electron microscopy images of two AFM tips after the flattening procedure: side views [(a) and (b)] and top views [(c) and (d)].

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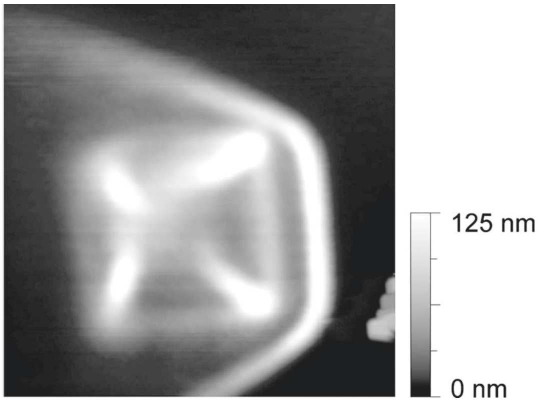

FIG. 2. Thermal imaging topography map of an AFM tip scanned over the focus of the objective (scale bar here represents height variations due to thermal effects).

nice plateaus are obtained due to melting and/or ablation of the apex material, as shown in Fig. 1. We applied this procedure to 20 tips, finding an overall rate of success of about 50%.

Looking at Fig. 1, it is obvious that the obtained plateau is tilted and reflects the relative orientation of the sample surface and tip during scanning. This is a clear advantage of flattened tips produced this way with respect to other procedures. Precise definition of the power and scanning parameters is not possible due to the nonperfect reproducibility of the procedure. However, it was systematically found that only large scanning areas, as opposed to fixed focusing onto the apex region, provided flat plateaus. This finding is tentatively ascribed to the influence of repeated heating/cooling cycles that occur while scanning the tip over the focus.

An interesting side effect, which was found and exploited during the development of the flattening procedure, is the possibility of "thermal imaging" of the tip due to heating effects induced by the ultrashort laser pulses. Figure 2 shows a topography map acquired while the tip was being scanned over the focal region. When the tip scans through the laser focus, thermal effects lead to a bending of the cantilever which locally modifies the topography map. This additional bending is likely due to a bimetal effect, generated by the thin reflective Au/Cr back side coating of the cantilever and/or to local gradients of the temperature field due to different local morphologies. Thermal bending of the cantilever turns out to be more pronounced close to the edges of the tip structure, so that eventually the topography map shows a superimposed image of the tip itself. This finding allows for an easy and precise alignment of the relative position of the scanning tip and the focus of the objective during the flattening procedure.

In conclusion, we have described a simple and cost-effective procedure for obtaining flat plateaus on top of commercial Si_3N_4 AFM tips. The obtained plateaus provide optimal conditions for subsequent coating and structuring of the tip apex, as they are parallel to the surface of the sample to be scanned. At the moment, such tips are being used to produce new-generation antenna-based optical probes.[9]

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