In-plane AFM probe with tunable stiffness

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Sponsorship
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Key Idea
We developed an in-plane AFM probe which is specifically tailored to the needs of biological applications. It features a variable stiffness which makes it adjustable to the surface hardness of the sample. The inherent capability of the in-plane AFM probe for building a massively parallel array is an important feature of the new design with a great impact on the speed of the AFM scanning process. Its ability to be upgraded with different manipulation tools enables a future parallel use as a precise micro-manipulator and imaging system for biological samples.

Concept and Functionality
This unique concept of variable stiffness is particularly important for in-vivo AFM imaging of biological samples with an inhomogeneous surface hardness. In the current AFM practice, adjustment of the stiffness of the probe to different surface hardness values can only be accomplished by manually changing the probe. If, however, the surface has an inhomogeneous hardness, this would imply a change of the probe in the middle of a measurement and, as consequence, an inaccuracy of the measurement. The proposed design can prevent otherwise inevitable compromises.

For the integration of the components into a MEMS device, the conventional cantilever-type design of AFM probes has been abandoned in favor of an in-plane design. This has a decisive advantage over the conventional cantilever-type design in that it facilitates a high-density array of AFM probes, as shown in Fig. 2. This 2D array of AFM probes reduces the total scanning time significantly.

For achieving a high lateral resolution, a multi-walled carbon nanotube is integrated into the AFM probe as a high-aspect-ratio tip.

Design
Figure 1 shows a fully functional in-plane AFM probe, consisting of a high-aspect-ratio tip, a compliant beam structure with a variable stiffness, which allows movement in one direction only. For actuation a combdrive will be used to move the complete system up and down in order to keep the force between probe and sample at a constant value. The necessary measurement of the displacement will be carried out by a capacitive sensor, integrated at the top of the system.

The variable stiffness is accomplished in a mechanical way by attaching or disconnecting additional beams to the compliant beam structure with the help of electrostatic plates. According to the calculation, this approach allows the stiffness to be changed from 0.01 N/m in low mode to 0.1 N/m in high mode. As a structural material, SU-8 will be used. Biological applications require a very low stiffness; hence the minimum achievable feature size will be critical to realize both the required stiffness and a small packaging size which is necessary to maintain arrayability.

Future work
As a future development, it is planned to build different multi-functional manipulation tools such as electrical, thermal and optical probes, which are integrated in the proposed in-plane AFM probe in a
massively parallel array to build a cluster tool. A channel for fluid transport will be included as well. This creates a versatile tool that can image, manipulate, test and measure biological samples with a high throughput.

Fig. 10 Schematic view of an in-plane AFM probe

Fig. 11 AFM head with a 2D array of in-plane AFM probes