Atomic force microscopy (AFM) is a prolific scientific tool, widely used to examine samples at the nano-scale. Providing extreme fidelity at such minute dimensions imposes performance limitations on conventional systems. To improve the resolution and diversify the functionality of AFM systems, new cantilevers are being pioneered, which promise to significantly enhance their capabilities.

Introducing all-electric bio-cantilevers

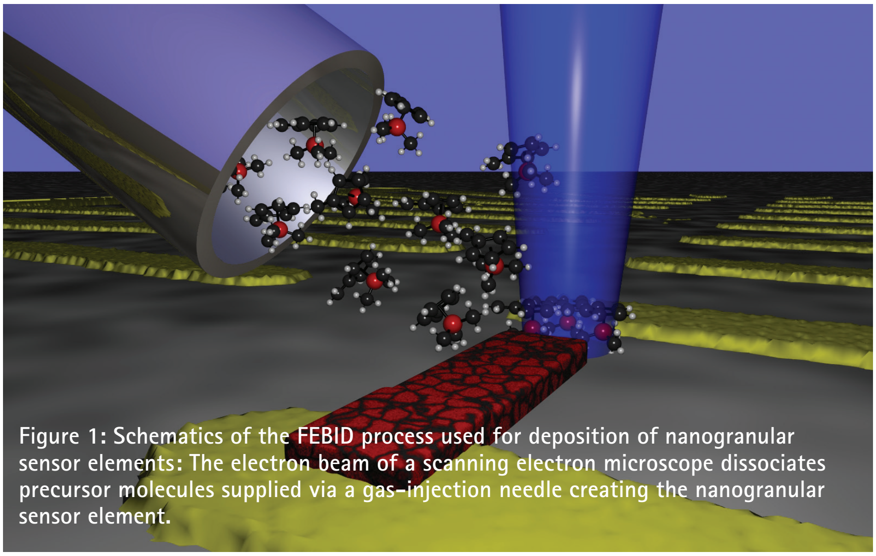

Figure 1: Schematics of the FEBID process used for deposition of nanogranular sensor elements: The electron beam of a scanning electron microscope dissociates precursor molecules supplied via a gas-injection needle creating the nanogranular sensor element.

Microscopy is synonymous with discovery. Initially using glass lenses, this revelatory technology has enabled generations of researchers to examine phenomena beyond mere human perception. The sophistication and power of these devices has continued to improve through years of ongoing refinement. Contemporarily, the power of microscopes is considerably enhanced by electrical aids and other utilities.

AFM is one of the most widely adopted methods of modern microscopy, regularly employed to scrutinise objects at the nano-scale. The system works by using a cantilever, at the end of which a sharp tip is mounted, and carefully positioned to explore the surface of samples. Brought into proximity with its subject, the tip of the sensitive probe is subtly deflected away, either by actual contact or a measurable physical reaction. Although the probe does not actually touch the sample in the latter, 'non-contact' mode, its behaviour can still be recorded using a laser beam, which is reflected from the surface of the cantilever. As the cantilever moves across the sample, it meticulously scans it, capturing the laser signals via photodiodes. The data is subsequently converted into an intelligible, composite image for the user.

"Orthodox AFM systems are partly limited by their reliance on a laser" explains Christian Schwalb, a leading member of a current project, titled ALBICAN, which seeks to transcend this convention. The venture links seven diverse partners to consolidate their expertise. Three are universities (the École polytechnique fédérale de Lausanne, Goethe University Frankfurt am Main, TU Vienna), whilst the remainder comprise of private enterprises with related interests (NanoScale systems, Anfatec, SCL-Sensor. Techn., and AMG Technology). "What's great about this project is that we've gained the wisdom of SME partners who know how to develop a product that will sell, as well very sophisticated universities with specialised knowledge in the various disciplines we need to realise this novel technology" he says.

"Focused on the cantilever, a laser in typical AFM produces a signal, which is processed and displayed to the user" recaps the scientist. This principle introduces a methodological bottleneck, since a laser spot smaller than 2 micrometers cannot be easily generated. "Here the physical diffraction limit of the laser beam used for standard AFM makes you hit a brick wall." elaborates Schwalb. "Consequently, conventional AFM restricts you to using a certain size of cantilevers. If a cantilever is smaller than 2 micrometers, you'll only hit part of it with the laser beam. Most of the light will miss it, compromising the signal data"

Standard techniques thus prevent the usage of very small cantilevers with high resonant frequencies, which can hypothetically deliver improved resolution and scanning speeds. "To exploit these, you also need to upgrade your microscope, especially electronics and AFM head, in order to use these small cantilevers" emphasises Schwalb. "For bio-samples, you also normally work in a liquid environment to study cells and other phenomena. In this scenario, it's trickier to use a laser – since the liquid might diffract the beam or attenuates it due to adsorption in opaque liquids." To overcome these restrictions, the ALBICAN research team pursued a radical new solution. "Our inventive approach is based on all electric bio cantilevers equipped with a nanogranular strains sensor that directly measures the cantilever signal electrically – and removes the need for optical detection" he summarises.

> "Trying to visually capture cells in a liquid environment is our ultimate challenge"

Launched in 2011, the two year scheme, granted approximately 1.1 million Euros of funding by the EU's Seventh Framework Programme for Research and Technological Development, is entering a climactic phase. "We've successfully pioneered a completely novel technique to read the

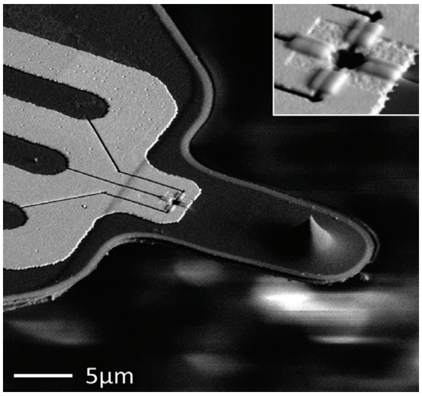

Figure 2: Si-Nitride NTR cantilever with dimensions 20x8x0.3 µm3. The inset shows the NTR sensor elements deposited at the bending edge of the cantilever.

signals derived from the cantilever" details Schwalb. "This methodology is based on the use of synthetic, nano-granular materials called 'granular tunnelling resistors'." These materials are fabricated with a mask-less direct writing technique; the so-called focused electron beam induced deposition. The high resolution of this technique allows the implementation of sensor structures with dimensions well below 100 nm on a wide variety of substrate materials. Freed from its dependence on the laser, the all-electric cantilevers can be made unprecedentedly small and thin – thus granting vastly superior performance in imaging speed and usability.

"It's a completely unique technology," points out Schwalb. "Standard AFM techniques have been developed over 30 years, so there's a widespread awareness of their potential pitfalls. Our proposition is radically different, which means any problems which may arise need to be methodically resolved. One of the main obstacles, he outlines, is that to practically utilise the scaled-down cantilevers, supporting electronics and hardware are a prerequisite. Because normal AFM microscopes are optimised for standard cantilevers and scan-speeds, the ALBICAN team has again been compelled to devise unprecedented alternatives in nanopositioning, micro/nano-mechanics and control-electronics.

There's already great demand for microscopes offering this combination of performance and high fidelity in the marketplace. "Our findings are particularly relevant for life science applications," confides Schwalb. "This frontier of science often concerns itself with fast-moving processes. Researchers want to scrutinise how cells decay, or change. For example, if you add novel antibiotics to pathogenic or drug resistance bacteria, it's valuable to discern their reactions. Standard AFM techniques are too slow to allow this." If it can be optimised, the new AFM method could also potentially be combined with a simple optical microscope. Due to its all-electric mechanism, the equipment lends itself to miniaturisation – in contrast with standard, bulky AFM apparatus. Rendered portable and compact, it also becomes possible to insert and operate the units in more extreme conditions, such as high-vacuum environments.

By exploiting faster scanning speeds, the team intended to obtain real-time images and surpass current systems – which can take from several tens of seconds up to many minutes to generate a useful output. As the project nears terminus, orchestrating successful demonstrations of this functionality has become the collective's final goal. Initially tested using a grid, the microscope is presently undergoing trials using biological samples. "Trying to visually capture cells in a liquid environment is our ultimate challenge" Schwalb relates. "We need to be cautious here, as the electronics must be safely insulated and shielded from the liquid in order circumvent the detrimental effect of the water to the delicate electronic components. If we could reach this milestone, it would be extremely significant. And, already, we've been able to obtain some impressive images of biological samples in air and have some promising initial results in liquid" he confirms. ALBICAN's findings will be extensively documented on the project's website, presented at several conferences, and possibly showcased at an industrial fair later in 2013.

Emboldened by their initial successes, ALBICAN's SME partners have successfully applied for a secondary tranche of EU funding in the so-called FALCON project starting mid of October. The FALCON proposal got excellent reviews and will focus to transfer the team's work into a commercial product which can be sold and marketed, potentially within another two years. Many aspects of the nano-world remain invisible enigmas to science but, if this latest EU intervention reaches fruition, may be closer to surrendering it's most intimate secrets.★

AT A GLANCE

Project Information

Project Title:
ALBICAN: "High-speed all electric bio-cantilever"

Project Objective:
The ALBICAN project aims to remove the current limitations in AFM microscopy. The innovative concept is based on nanogranular tunneling resistors for measuring the deflection of the cantilever and allows manufacturing of unprecedented small cantilever sensors with vastly superior performance in imaging speed and usability.

Project Duration and Timing:
24 months, starting September 2011

Project Funding:
European Union's Seventh Framework Program managed by REA under grant agreement n° 286146

Project Partners:
- SCL-Sensor. Tech. Fabrication GmbH
- AMG Technology Ltd.
- Anfatec Instruments AG
- NanoScale Systems, Nanoss GmbH
- Ecole Polytechnique Federal Lausanne
- Johann-Wolfgang Goethe University Frankfurt a.M.
- Technical University Vienna

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Dr. Christian H. Schwalb received his PhD in 2008 at the Philipps University in Marburg for his work on electronic transport at metal-organic interfaces. He currently holds a position as project manager at NanoScale Systems GmbH. His work focusses on the realization of novel sensor designs for bio- and life-science applications.

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