Under the **microscope**

Using specialist knowledge of nanotechnology, physicists and engineers can create high-resolution scanning probe microscopes for a global client base

Words: Karl Vadaszffy

NanoScan's PPMS-AFM

NanoScan specializes in the measurement of magnetic properties of materials at the nanoscale, using scanning probe microscopy. The Swiss company aims to achieve the best magnetic lateral resolution in direct space, with minimal time for measurement. To achieve this, its team of physicists, electrical engineers and software engineers develops the company's microscopes, from the mechanical parts to the electronics controller and the software, with the desire to provide high-resolution scanning probe microscopes that fulfill present and future analytical needs on nanometer-sized surface structures.

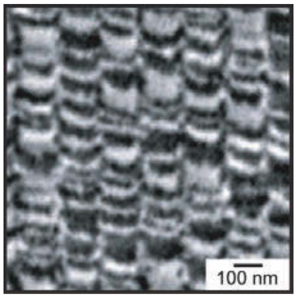
Dr Raphaëlle Dianoux, NanoScan's CEO, says: "Our aim was to establish a niche application, and that was magnetic force microscopy. Designed for research, development and quality control of magnetic storage media and other magnetic material, our product, the hr-MFM (high-resolution magnetic force microscope), is an analytical and quantitative magnetic imaging system."

Dianoux reveals the premise of the Zurich-based company's work in magnetic force microscopy: "In principle, the basic method behind this is scanning force microscopy, or atomic force microscopy, so any kind of force between the oscillating tip and a sample surface can be measured."

The right method

Focus, however, has been given to magnetic properties. The measurement head – the microscope itself – is non-magnetic in the measurement area, so it doesn't influence the measurement when imaging low magnetic field distribution. Says Dianoux: "It's a simple method that can be used daily, and it's easy to change the sample and measurement head for the probe, the cantilever. Commercially available probes can be used, which is more cost-effective."

Raphaëlle Dianoux, NanoScan CEO



A magnetic force microscopy image of a commercial hard disk, taken with the hr-MFM. The single bits are clearly recognizable as bright (dark) patterns magnetized in the direction opposite (parallel) to the tip magnetization. The high resolution of the microscope reveals the slightly curved and even grainy substructure of the bits

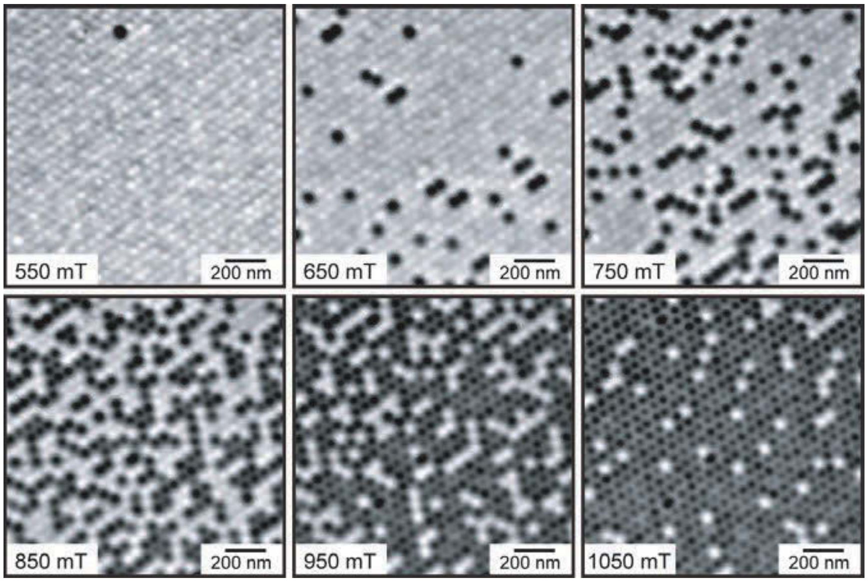
The method works in vacuum, which means the user benefits from higher sensitivity. The microscope is operated at ambient temperature as well as in high vacuum. Its vacuum pumping system includes a turbomolecular pump and a diaphragm pump, ensuring high-vacuum conditions with easy maintenance and a pump-down time of less than 10 minutes.

Dianoux comments: "The cantilever is oscillated at its resonant frequency and, in vacuum, this becomes a very sharp resonance, which is directly correlated with the sensitivity of the measurements. This reaction enables us to achieve a magnetic lateral resolution of 10nm, which is perhaps the best in the world, matching the best results obtained by SEMPA (scanning electron microscopy with polarization analysis) on disk media.

"We've also developed our electronics, generating very low signal-to-noise ratios to achieve a really clean signal. It's thanks to this that we've been able to take our sensitivity to small magnetic fields so high."

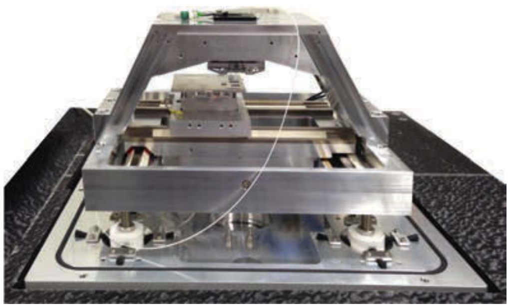
The hr-MFM, which physicists will need only three days of on-site training to master, features fast mounting of large samples, such as hard-disk platters, and a coarse positioning system, with positioning accuracy of 20nm over the entire sample area. The fully linearized metrology scanner has a scan range of 80µm x 80µm.

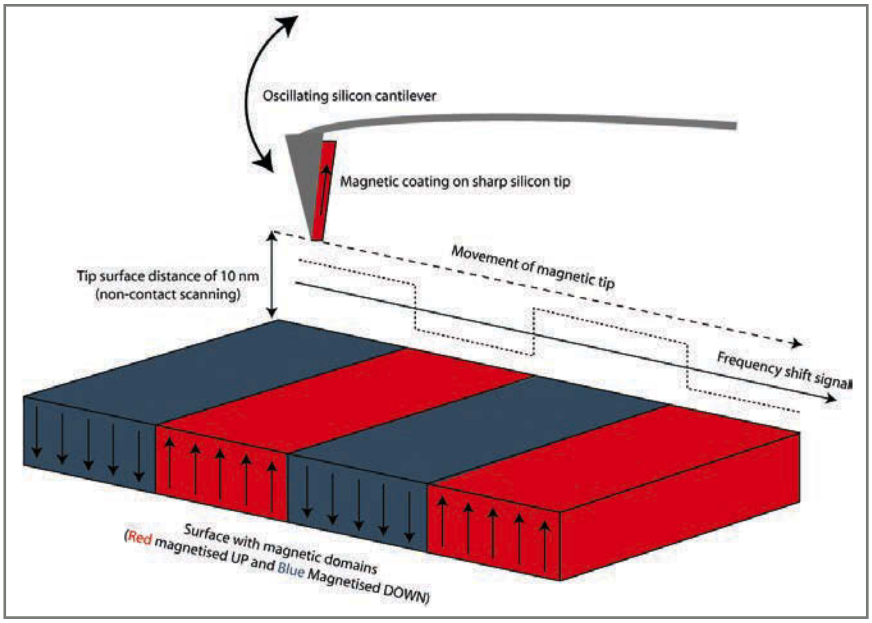
The controller software is very stable and accurate. Real-time monitoring of the cantilever's response, a unique feature of hr-MFM's controller, helps avoid any crashes of the tip against the surface or against a dust particle. "The principle of the measurements is to bring a sharp magnetically coated tip a few nanometers from the surface and record the interaction with the sample surface," explains Dianoux. "Preserved sharp tips with a low magnetic moment, together with high mechanical



Left: **MFM images in increasing magnetic field showing magnetic transition of bit-patterned media with 50nm spacing. Sample courtesy of J. Ahner, Seagate Fremont**

Below: **NanoScan's next-generation hr-MFM is used in high-vacuum, accommodating samples up to 10 x 10cm**





Above: **Illustration of the operating principle of non-contact MFM, used to achieve 10nm resolution**

stability of the instrument, are prerequisites for high-resolution imaging. As the tip never touches the surface, the interaction of the tip field with the sample field is greatly reduced, thereby avoiding moving domain walls."

On the receiving end

So who should the hr-MFM interest? For research centers and universities, it's a tool to analyze surface structures and characterize new magnetic materials and thin film technology – for example, magnetic quantum dots and layered nanostructures for mRAM and FeRAM applications. Dianoux adds: "It's ideal for research groups working on magnetic alloys and magnetic nanostructures that want to look at their magnetic domains at the nanoscale. For this, it's a very straightforward method. In comparison, you could use a scanning Hall microscope, but they have a resolution of only 300nm.

"Our hr-MFM is also a very effective direct way of measuring magnetic properties on the surface without turning to expensive or complicated techniques that require focused light, synchrotron light or x-ray light."

Furthermore, hr-MFM benefits magnetic recording in the hard-disk industry. Dianoux comments: "A challenge in this industry is to image bit-patterned media, because the bits are getting increasingly compact – to reach the industry's target of 1TB/in^2, you're talking about bit patterns that are 50nm or lower, and even 20nm sideways. Therefore the requirements in terms of magnetic resolution are getting increasingly high. Additionally we have an option to apply up to 0.5T perpendicular to the sample while imaging."

According to Dianoux, the combination of measurement methods is a key future requirement. "We aim to have combining options available within five years," she says. "Scanning probe microscopy as a general method is a physical analysis of the surface, which means you have access, for example, to mechanical, electrical and magnetic properties, but not chemical information. So the combination with chemically sensitive surface information is definitely a trend that will develop."

Another solution offered by NanoScan is the PPMS-AFM, a high-resolution atomic force microscope that's less than 25mm in diameter. It's designed to fit into the physical property measurement system created by California-based Quantum Design, and offers all common measurement modes such as contact, intermittent contact, the PLL-controlled true non-contact, and high-resolution magnetic force microscopy modes. This combination provides a versatile nanoscale-imaging tool at a variable temperature (2K-400K), and magnetic field environment up to 16T.

Dianoux explains. "So it's for very specific applications – for example, looking at superconducting materials or materials that have a physical transition at a very low temperature. In terms of handling, it means we're working with small samples. It's designed to fit a one-inch bore, yet there's still a positioning capability of 2mm." ■