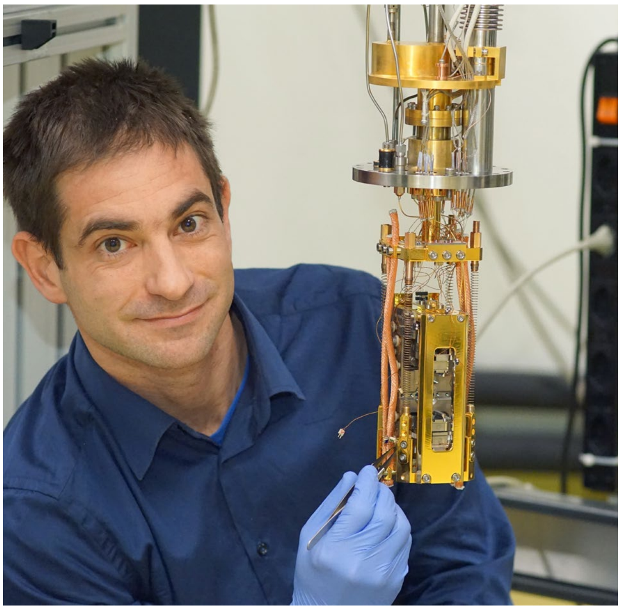
Sensing size and direction

Nanowire sensors in atomic force microscopy

For the SNI, in addition to being a year of major events, 2016 was also a big year for atomic force microscopy. 30 years ago, SNI vice director Professor Dr. Christoph Gerber played a key part in developing the atomic force microscope (AFM), a highly versatile instrument for which he was awarded the prestigious Kavli Prize in September 2016 alongside his colleagues Professor Dr. Calvin Quate and Dr. Gerd Binnig. The distinction sparked a wave of local and international media interest in the AFM and its role in unlocking the secrets of the nanoworld. The technology's ongoing success received another boost this year from the research being carried out by Argovia Professor Dr. Martino Poggio and his team. Using nanowires as sensors, they were able to measure both the size and direction of forces – a breakthrough in relation to standard AFM devices. They decribed the innovation in the journal "Nature Nanotechnology"* in October.



Nanowires as highly accurate sensors

Martino Poggio and his team have been exploring the possibility of using nanowires as highly accurate sensors for several years. Nanowires are extremely tiny filamentary crystals, which feature an almost defect-free crystal lattice structure. They are generally no thicker than 100 nanometers, making them around a thousand times thinner than a human hair. Their tiny dimensions mean they have an extremely large surface area in relation to their volume, and very low mass. These characteristics make nanowires excellently suited for use as minute sensors for biological and chemical samples, or as pressure or load sensors.

Charting size and direction

In their recent paper, Poggio's team demonstrated that nanowires can also be used as sensors in atomic force

* Nicola Rossi, Floris R. Braakman, Davide Cadeddu, Denis Vasyukov, Gözde Tütüncüoglu, Anna Fontcuberta i Morral & Martino Poggio
Vectorial scanning force microcopy using a nanowire sensor
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microscopes to measure forces. Whereas the sensor in standard AFMs consists of a needle mounted on the tip of a silicon cantilever that scans the surface of the sample, Poggio and his team used gallium arsenide nanowires created by their colleagues at EPF Lausanne. Due to their particular mechanical properties, these nanowires vibrate along two perpendicular axes at roughly the same frequency. When a nanowire is incorporated into an atomic force microscope to scan a sample, the vibrations change according to the size and direction of the forces acting on it. These changes can be measured, resulting in an image of the force field surrounding the sample. The nanowire behaves like the needle of a minute mechanical compass, indicating both the size and direction of the surrounding forces.

Technical challenge

For the researchers in Basel, the first technical hurdle was building a device able to simultaneously scan the tiny nanowire over the surface of a sample and measure the vibrations occurring in it along two perpendicular directions. Once they had successfully incorporated the nanowire into an AFM, they used minute electrodes to generate test force fields which they were able to accurately map on the basis of their measurements. The nanowire compass was then used to successfully map out the two-dimensional force field over an unknown structured sample surface, and the new AFM was complete.

The development of this new form of atomic force microscopy opens up new potential applications for the device, already an indispensable tool in fields such as solid-state physics, material sciences, biology and medicine. “Replacing the conventionally used crystalline silicon cantilever with substantially smaller nanowires will open the door to further improvements to this immensely successful technology,” remarks Martino Poggio, adding that with the appropriate modifications, the potential uses of this new generation of AFM include examining the magnetic forces of a range of sample types. Furthermore, using nanowires with tapered tips could further boost the device’s precision, giving rise to images in atomic or even sub-atomic resolution.