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Biophysics

Detecting forces at cellular scales

A platform for measuring nanoscale vibrations could help map the mechanics of cellular growth and development

Throughout the life of an organism, its cells are continually moving, stretching and reorganizing; accurate detection of the forces underlying these processes could give scientists deeper insights into many biological processes. A highly sensitive measurement system developed by researchers at NAIST in Japan now makes it possible to precisely detect such biomechanical movements at the nanometre scale[1].

“We are developing a technology to estimate the distribution of the mechanical properties throughout the sample, which is impossible to do by conventional methods.”

Yoichiroh Hosokawa is an applied physicist with a deep interest in exploring the tiny forces that affect cell growth and behaviour. “If we could successfully estimate the distribution of mechanical forces in a plant or animal embryo,” he says, “we could combine this with microscopic imaging data to achieve new insights into biomechanics and mechanobiology.”

In prior research, his group developed a strategy for generating tiny forces by using the extremely short but powerful pulses of light produced by a femtosecond laser. By using a microscope to focus these laser pulses into water, Hosokawa’s team was able to generate nanoscale explosions.

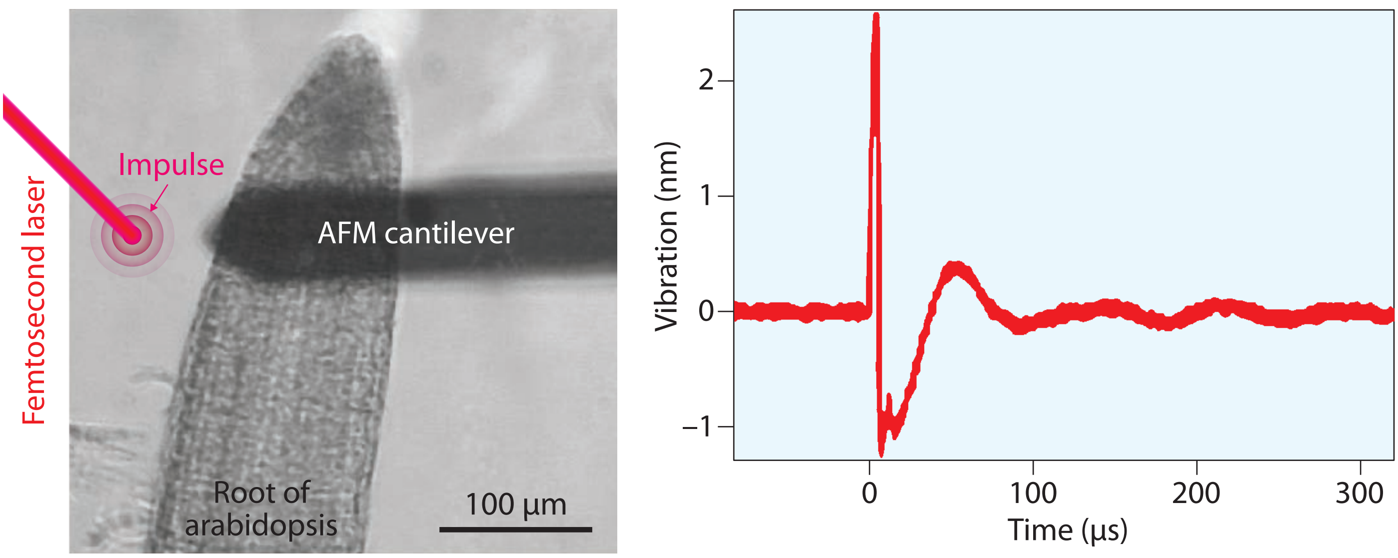
In subsequent work, Hosokawa and his colleagues applied such femtosecond laser explosions to produce external forces, which they used to analyse the stiffness of a stem and root of a plant (see figure). To do this, they immobilized a segment of a thale cress plant in water and focused a femtosecond laser pulse on a point in the water some distance away from the plant. The resulting explosion generated a stress wave that spread outward from this focal point and struck the plant stem. The movement and deformation in the stem induced by the impact of the stress wave was detected by an atomic force microscope, whose curved silicon probe (or ‘cantilever’) was placed in contact with the surface of the stem. By analysing how the probe bent, the researchers were able to derive information about the stiffness of the plant.

This set-up allowed the researchers to detect minuscule movements — equivalent to introducing a bend of less than one-thousandth of a degree to the stem. Importantly, since the probe that detects the force is separated from the source of the physical stress, it becomes possible to do much more sophisticated three-dimensional analyses of how forces affect a biological specimen.

Such measurements could, for example, help chart the internal forces at work as cells divide and reorganize in a developing embryo. “We are developing a technology to estimate the distribution of the mechanical properties throughout the sample, which is impossible to do by conventional methods,” says Hosokawa.

Reference

1. Takenaka, M., Iino, T., Nagatani, A. & Hosokawa, Y. Nanoscale bending movement of biological micro-object induced by femtosecond laser impulse and its detection by atomic force microscopy. *Appl. Phys. Express* **7**, 087002 (2014).



An atomic force microscope (AFM) probe is positioned atop a plant root (left) immersed in water. An extremely short laser pulse targeted some distance away creates a shockwave by heating and vaporizing water. The resulting vibrations in the plant root can be measured from the movement of the AFM probe (right).

More information about the group’s research can be found at the Green Bio-Nano Laboratory website:
http://mswebs.naist.jp/english/courses/1447/