METER
ENVIRONMENT

THE TENSIOMETER—MICRO-SIZED

A strand of a spider's web is 5 micrometers in width. Microelectromechanical systems (MEMS) devices range in size from 20 micrometers to one millimeter. That's the incredibly small size of the components used in the tensiometer being developed by PhD candidate, Michael Santiago, and his collaborators, professors Abraham Stroock and Alan Lakso at Cornell University. The engineer/research team is using MEMS technology to develop a miniature tensiometer (microtensiometer) that has a 100 times larger range than existing tensiometers, is stable for months, communicates digitally, and can be embedded into plant stems to directly measure plant water potential.

EXISTING TENSIOMETER LIMITATIONS

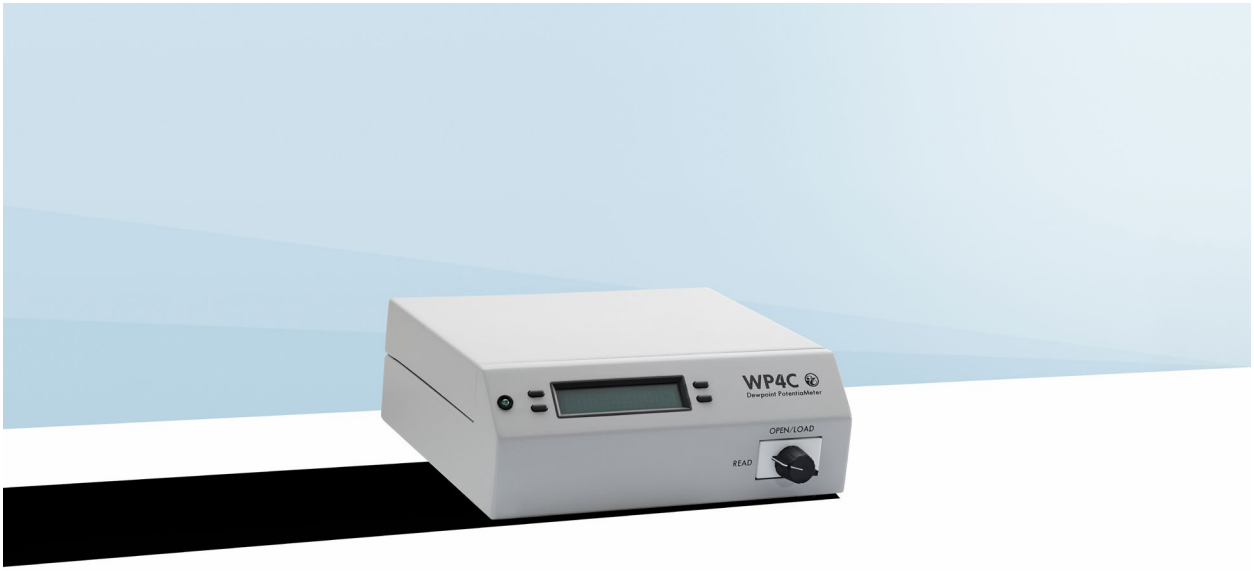
Water potential is the best measure of a plant's hydration relative to growth and product yield. Unfortunately, directly measuring water potential in plant tissue is only possible through labor-intensive, destructive methods such as the leaf pressure bomb and stem psychrometer. A common alternative is to use 'set-and-forget' soil tensiometers to measure soil water potential as a proxy for plant water potential, but this method is unreliable for plants with high hydraulic resistance (vines and woody species), where plant water potential is often much less than the water potential in soil. Although soil tensiometers are very accurate and simple to use, they can be large and bulky, and cavitate as soils dry.

SOLUTION

The Cornell University research team wants to improve the design of the tensiometer so it can be used in the field for applications such as continuously monitoring and controlling plant water potential in vineyards to consistently produce high-quality wine grapes with an exact flavor/aroma profile. Santiago says, "We've basically miniaturized a tensiometer using microchip technology to the point where it's this tiny chip inside a wafer. Because of the way we fabricated it, we are hoping to make it an embeddable tensiometer that can go in anywhere and measure tension down to about -100 bars (-10 MPa)."

DEVELOPING AND CALIBRATING

Santiago is using a METER WP4C chilled mirror hygrometer to produce solutions of specific water potential to test, calibrate, and characterize the microtensiometer. He comments, “We’ve been testing it in osmotic solutions. We use the WP4C water potential meter for calibrating a solution of PEG (polyethylene glycol), and then we measure it with the tensiometer.”



WP4C chilled-mirror hygrometer

One hurdle the team has to overcome is finding a membrane that keeps small molecules and ions out of the tensiometer pores: these pollute the water inside the tensiometer and cause measurement errors. Santiago explains, “Our solution right now is to test in solutions of large molecules, such as PEG of 1400 molecular weight. The tensiometer pores are about 3-4 nanometers, extremely small, but small molecules, such as sugars and salts, can still get through. It’s not a problem for the short term because we are directly submerging into solutions of just water and large molecules, but our goal is to go into the environment and insert the tensiometer into soils and plant stems where small molecules are ubiquitous, so we’ll have to find a membrane that works and can handle field testing.”

The team has been experimenting with materials such as Gore-Tex and reverse osmosis membranes [M5] [M6] hoping to find a membrane that allows water through and keeps ions out, but does not slow the measurement.

WHAT'S NEXT?

Santiago says the calibrations have worked well. Now the challenge will be putting the tensiometer into different environments such as soil, concrete, and plants. For example, they want be able to insert the device directly into plant xylem, which will require a seal so water is not exiting the system. And that's not the only complication. Santiago explains, "We are getting ready to do some testing in soils. The challenge will be getting good data because soil can be really heterogeneous, and we have this sensor with a much larger range than the usual tensiometer. So what do we compare it with? That's going to be a bit of a challenge." Santiago says the next few months will be spent getting into some different materials and obtaining some initial publishable data.

Discover the WP4C hygrometer