TURFGRASS TRENDS

IRRIGATION

The Big Dig

Nanotechnology gets to root of soil moisture

By Mohamed Saafi, Paula Wade, Peter Romine and Tommy Coleman

An important goal in golf course management, sports turf maintenance or any agricultural endeavor is to optimize the use of natural resources, namely water supply in irrigation systems.

Irrigation management systems should have information about soil moisture at the root level of plants. With such information, irrigation water could then be provided in a more efficient way.

Today a large number of sensors based on different methods are available to measure soil moisture and temperature. However, they present one or more of the following drawbacks: inaccuracy, high cost and soil dependency. Meanwhile, nanotechnology-based sensors can be considered a serious replacement to current monitoring systems due to their inherent advantages, namely low cost, high reliability and wireless sensing capability.

The following research project explores the feasibility of using nanotechnology-based MicroElectroMechanical Systems (MEMS) sensors for soil moisture monitoring.

MEMS sensor

As shown in Fig. 1, the MEMS sensor consists of four microcantilever beams capable of measuring temperature and moisture in concrete material simultaneously.

The MEMS sensor is based on a shear stress principal for measuring water vapor, in which the microsensor chip combines a proprietary polymer sensing element and Wheatstone Bridge piezoresistor circuit to deliver two DC output voltages that are linearly proportional to relative humidity (RH) from 0 percent to 100 percent RH full scale and to temperatures from minus-30 degrees Celsius (C) to 100 degrees C.

A water vapor-sensitive nanopolymer film PVA (PolyViol G 2810) is bonded to the top of each cantilever beam and designed to expand and contract during exposure to water

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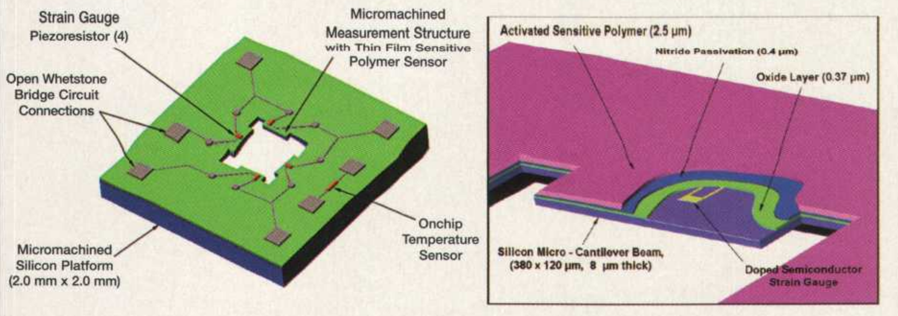
FIGURE 1

Typical MEMS for temperature and moisture sensing



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vapor. During sensor operation, ambient water vapor molecules in the material absorb into the sensing film surface. They are held by weak van der Waals forces because of the polar nature of water molecules. The water molecules continue to form polar bonds with various radical groups of the polymer molecules within the film.

All of the free surfaces of the film displace parallel and normal to the adjacent microbeam surfaces, with the exception of the film surface that is bonded to each cantilever beam. The bond constrains this film surface and prevents it from displacing. This constraint, known as a full shear constraint, produces shear stresses at the film/beam interface that cause the cantilever beam to deflect.

This deflection is measured as resistance change in the embedded strain gauges, and is linearly proportional to the shear stress.

Manufacturing process

The manufacturing of micro-machined MEMS sensors was performed using a combination of standard and customized semiconductor processing steps. Manufacturing begins with standard Complimentary Metal Oxide Semiconductor (CMOS) processing steps.

Typical CMOS steps performed on the wafer include chemical vapor deposition (CVD), oxidation, doping, diffusion and metallization. Photolithography and chemical wet-etching are used to pattern and form the silicon platform and measurement structures of the sensor.

A hybrid CMOS process is performed to deposit, pattern and activate sensing elements. The bridge excitation for these MEMS is provided by a 1.2V DC voltage source that's external to the sensor chip. As shown in Figure 2, the chip was encapsulated with ceramic jackets that were equipped with a ceramic filter for sensing purposes.

The sensor was calibrated and then embedded into soil samples to evaluate its response. It exhibited constant temperature output, attributed mainly to room temperature constant at 20.5 degrees C. However, the moisture output remained constant for a period of six days because of a high moisture level in the soil. Then the output began to decrease as the soil dried out.

The ultimate objective of this research is to develop a wireless network for field application, where thousands of sensor nodes will be used to monitor soil moisture and temperature.

Figure 3 shows a typical sensor network, where the sensors will be communicating with each others to remotely monitor the sensors response. The device will be packaged to form a sensor probe. The probe will be equipped with a box containing microprocessing, memory, backup battery and a communication system. The probe also contains a solar power energy harvesting and a two-way communication antenna.

FIGURE 2

Packaged chip

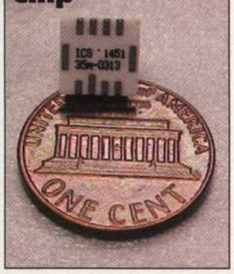
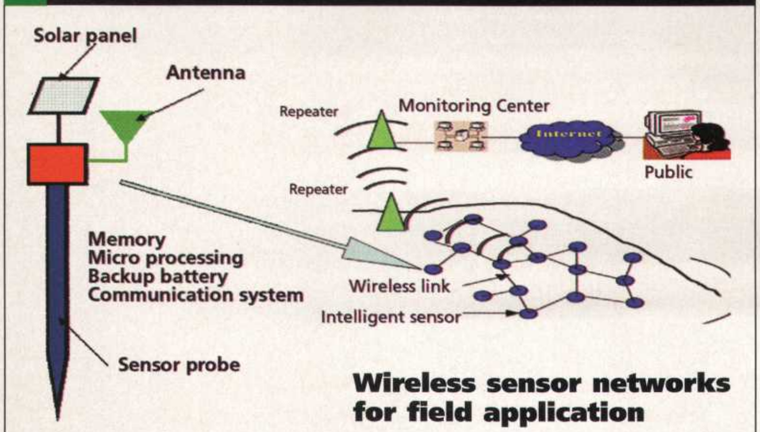


FIGURE 3



Wireless sensor networks for field application

Conclusions

In this preliminary research a low-cost nanotechnology-based moisture and temperature sensor was developed. Preliminary results indicated the developed device can monitor temperature and moisture with high resolution. Work is in progress to develop a wireless network for filed application.

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