



Wirelessly Interrogated Wear or Temperature Sensors

Such sensors could be embedded in brake pads.

Langley Research Center, Hampton, Virginia

Sensors for monitoring surface wear and/or temperature without need for wire connections have been developed. Excitation and interrogation of these sensors are accomplished by means of a magnetic-field-response recorder — an apparatus previously reported in “Magnetic-Field-Response Measurement-Acquisition System” (LAR-16908), *NASA Tech Briefs*, Vol. 30, No. 6 (June 2006), page 28. To recapitulate: The magnetic-field-response recorder is placed near,

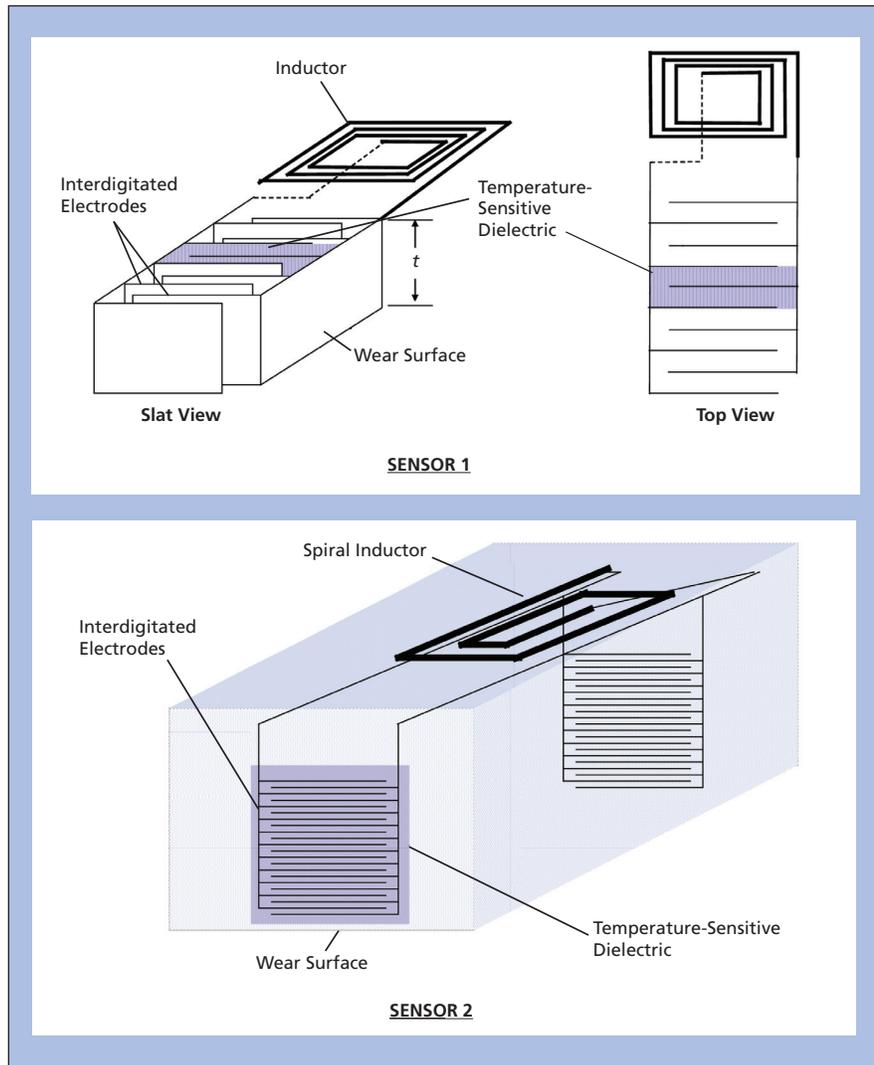
but not touching, the sensor of interest. This apparatus generates an alternating magnetic field that excites oscillations in the resonant circuit, measures the magnetic response of the circuit, and determines the resonance frequency from the response.

These sensors are related to the ones reported in “Wirelessly Interrogated Position or Displacement Sensors” (LAR-16617-1), *NASA Tech Briefs*, Vol. 31, No. 10 (October 2007), page 20. Like the

previously reported sensors, these sensors consist mainly of variable capacitors electrically connected in series with fixed inductors. In a sensor of the present type as in the previously reported ones, the capacitance and, thus, the resonance frequency, varies as a known function of the quantity of interest that one seeks to determine. Hence, the resonance frequency is measured and used to calculate the quantity of interest.

The upper part of the figure depicts one of the present sensors, wherein the capacitor consists of multiple interdigitated plate electrodes oriented perpendicular to the wear surface of, and embedded within, a block of material, the wear of which one seeks to monitor. (For example, such a sensor could be embedded in a brake pad.) The embedment is performed during the fabrication of the brake pad or other block of wearing material. The electrodes are made of a metal that becomes worn away more easily than does the material that one seeks to monitor. As the surface wears away, portions of the electrodes are also worn away, reducing the capacitance. The depth of wear can be estimated straightforwardly from the increase in the resonance frequency, using the known relationship between the change in resonance frequency and the reduction in capacitance as a function of the depth of wear.

This wear sensor can be augmented with a temperature-measurement capability by embedding, between two or more of the electrodes, a dielectric material that is temperature-sensitive in the sense that its permittivity exhibits a known variation with temperature. In this case, the capacitance, and thus the resonance frequency, depends on both the depth of wear and the temperature. Hence, if the temperature is known from a measurement by a different sensor, then the depth of wear can be determined from the resonance frequency. Similarly, if the depth of wear has been determined from a prior measurement by a different sensor (or by this sensor at a known temperature)



Capacitors Comprising Interdigitated Electrodes are connected to inductors to form resonant circuits. In both cases, the capacitance varies with the remaining thickness (t) and, thus, the depth of wear. Optionally, a temperature-sensitive dielectric can be included to obtain a temperature-measurement capability.

and there has been no wear since the prior measurement, then the present temperature can be determined from the present resonance frequency.

The lower part of the figure depicts another sensor of the present type, containing multiple sets of interdigitated elec-

trodes embedded parallel to the wearing surface in a configuration such that the number of electrode pairs, and thus the capacitance, decreases with the depth of wear. Optionally, one or more of the sets of interdigitated electrodes can be embedded along with a temperature-sensi-

tive dielectric material to obtain a temperature-measurement capability.

This work was done by Stanley E. Woodard of Langley Research Center and Bryant D. Taylor of Swales Aerospace. Further information is contained in a TSP (see page 1). LAR-16591-1

Processing Nanostructured Sensors Using Microfabrication Techniques

Nanostructured sensors have uses in safety, environmental monitoring, fire detection, and security.

John H. Glenn Research Center, Cleveland, Ohio

Standard microfabrication techniques can be implemented and scaled to help assemble nanoscale microsensors. Currently nanostructures are often deposited onto materials primarily by adding them to a solution, then applying the solution in a thin film. This results in random placement of the nanostructures with no controlled order, and no way to accurately reproduce the placement. This method changes the means by which microsensors with nanostructures are fabricated. The fundamental advantage to this approach is that it enables standard microfabrication techniques to be applied in the repeated manufacture of nanostructured sensors on a microplatform.

The fundamental steps are first to define a standard metal electrode pattern of interdigitated fingers with parallel fingers that are saw-toothed. Nanostructures are then added to a standard photoresist to form a dilute solution. The photoresist solution is then applied to

the microstructure. Before the solution solidifies, alternating electric fields are applied across the electrodes in order to align the nanostructures on the wafer. Once this photoresist later dries into a film and is processed, a second layer of metal is deposited on top of the first layer. The effect is to remove photoresist from the metal fingers, but leave the nanostructures that bridge the fingers to be held in place by the top metal layer. Longer nanostructures, which are already aligned across the fingers, will be held in place by the top metal.

This buries the contacts of the nanostructures that are bridging the fingers between two layers of metal. The result is a microsensor fabricated using microfabrication techniques with aligned nanostructures bridging the electrodes and buried electrical contacts.

Possible applications include emissions monitoring, leak detection, engine monitoring, security, fire detection, extra-vehicular-activity (EVA)

applications, personal health monitoring, and environmental monitoring. Because this process is compatible with low temperatures and thin-film supports, it can be used in thin films for conductive coatings requiring electrical connections.

A proof-of-concept of this approach was demonstrated using alumina as the substrate, metals such as platinum as the bottom electrode and titanium as the top metal layer, and both multiwalled carbon nanotubes and metal oxide nanowires as the nanostructured material.

This work was done by Gary W. Hunter, Randall L. VanderWal, Laura J. Evans, and Jennifer C. Xu of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18418-1.

Optical Pointing Sensor

The sensor can be used as a digitizer of physical objects to extract shape data.

NASA's Jet Propulsion Laboratory, Pasadena, California

The optical pointing sensor provides a means of directly measuring the relative positions of JPL's Formation Control Testbed (FCT) vehicles without communication. This innovation is a steerable infrared (IR) rangefinder that gives measurements in terms of range and bearing to a passive retroreflector. Due to its reduced range of motion, the range and bearing measurements are on the order of 10 times

better than those of the existing sensor system.

The retroreflector is placed on one robot, and the rangefinder and steering optics are on another robot. The measurements are available on the rangefinder-mounted robot, giving it relative position knowledge to the retroreflector.

The system is composed of an HeNe pointing laser, a SICK IR laser

rangefinder, a two-axis fast steering mirror, a shear sensor, and a far-field retroreflector (see figure). The pointing laser is injected into the optical path using a beam splitter and bounces off the steering mirror toward the retroreflector. If the retroreflector is hit by the pointing laser, the beam is returned with the exact opposite direction. When the beam impact with the retroreflector is non-central,