Technology Focus: Sensors

Dielectrophoresis-Based Particle Sensor Using Nanoelectrode Arrays

An array of nanostructure electrodes can provide a more sensitive reading than conventional microelectrodes.

Ames Research Center, Moffett Field, California

A method has been developed for concentrating, or partly separating, particles of a selected species from a liquid or gas containing these particles, and flowing in a channel. An example of this is to promote an accumulation (and thus concentration) of the selected particle (e.g., biological species such as *E. coli*, salmonella, anthrax, tobacco mosaic virus or herpes simplex, and non-biological materials such as nano- and micro-particles, quantum dots, nanowires, nanotubes, and other inorganic particles) adjacent to the first surface.

Additionally, this method can also determine if the particle species is present in the liquid. This is accomplished by providing an insulating material in an interstitial volume between two or more adjacent nanostructure electrodes. It can also be accomplished by providing a functionalizing substance, located on a selected region of the insulating material surface, which promotes attachment of the selected species particles to the functional-

ized surface, and measuring a selected electrical property such as electrical impedance, conductance, or capacitance.

A time-varying electrical field E, having a root-mean-square intensity of E^2 rms, with a non-zero gradient in a direction transverse to the liquid or fluid flow direction, is produced by a nanostructure electrode array with a very high-magnitude gradient near exposed electrode tips. A dielectrophoretic force causes the selected particles to accumulate near the electrode tips, if the medium and selected particles have substantially different dielectric constants. An insulating material surrounds most of the nanostructure electrodes, and a region of the insulating material surface is functionalized to promote attachment of the selected particle species to the surface. An electrical property value Z(meas) is measured at the functionalized surface, and is compared with a reference value Z(ref) to determine if the selected

species particles are attached to the functionalized surface.

Some advantages of this innovation are that an array of nanostructure electrodes can provide an electric field intensity gradient that is one or more orders of magnitude greater than the corresponding gradient provided by a conventional microelectrode arrangement, and that, as a result of the high-magnitude field intensity gradients, a nanostructure concentrator can trap particles from high-speed microfluidic flows. This is critical for applications where the entire analysis must be performed in a few minutes.

This work was done by Jun Li, Alan M. Cassell, and Prabhu U. Arumugam of Ames 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 the Ames Technology Partnerships Division at 1-855-NASA-BIZ (1-855-6272-249). Refer to ARC-15967-1.

Multi-Dimensional Damage Detection for Surfaces and Structures

This system determines the size, depth, and location of damage in a multi-layered system.

John F. Kennedy Space Center, Florida

Current designs for inflatable or semi-rigidized structures for habitats and space applications use a multiple-layer construction, alternating thin layers with thicker, stronger layers, which produces a layered composite structure that is much better at resisting damage. Even though such composite structures or layered systems are robust, they can still be susceptible to penetration damage.

The ability to detect damage to surfaces of inflatable or semi-rigid habitat structures is of great interest to NASA. Damage caused by impacts of foreign

objects such as micrometeorites can rupture the shell of these structures, causing loss of critical hardware and/or the life of the crew. While not all impacts will have a catastrophic result, it will be very important to identify and locate areas of the exterior shell that have been damaged by impacts so that repairs (or other provisions) can be made to reduce the probability of shell wall rupture. This disclosure describes a system that will provide real-time data regarding the health of the inflatable shell or rigidized structures, and information

related to the location and depth of impact damage.

The innovation described here is a method of determining the size, location, and direction of damage in a multi-layered structure. In the multi-dimensional damage detection system, layers of two-dimensional thin film detection layers are used to form a layered composite, with non-detection layers separating the detection layers. The non-detection layers may be either thicker or thinner than the detection layers. The thin-film damage detection layers are

thin films of materials with a conductive grid or striped pattern. The conductive pattern may be applied by several methods, including printing, plating, sputtering, photolithography, and etching, and can include as many detection layers that are necessary for the structure construction or to afford the detection detail level required. The damage is detected using a detector or sensory system, which may include a time domain reflectometer, resistivity monitoring hardware, or other resistance-based systems.

To begin, a layered composite consisting of thin-film damage detection layers separated by non-damage detection layers is fabricated. The damage detection layers are attached to a detector that provides details regarding the physical health of each detection layer individually. If dam-age occurs to any of the detection layers, a change in the electrical properties of the detection layers damaged occurs, and a response is generated. Real-time analysis of these responses will provide details regarding the depth, location, and size estimation of the damage. Multiple damages can be detected, and the extent (depth) of the damage can be used to generate prognostic information related to the expected lifetime of the layered composite system.

The detection system can be fabricated very easily using off-the-shelf equipment, and the detection algorithms can be written and updated (as needed) to provide the level of detail needed based on the system being monitored. Connecting to the thin film detection layers is very easy as well. The truly unique feature of the system is its flexibility; the system can be designed to gather as much (or as little) in-formation as the end user feels necessary. Individual detection layers can be turned on or off as necessary, and algorithms can be used to optimize performance. The system can be used to generate both diagnostic and prognostic information related to the health of layer composite structures, which will be essential if such systems are utilized for space exploration. The technology is also applicable to other in-situ health monitoring systems for structure integrity.

ULTRA: Underwater Localization for Transit and Reconnaissance Autonomy

NASA's Jet Propulsion Laboratory, Pasadena, California

This software addresses the issue of underwater localization of unmanned vehicles and the inherent drift in their onboard sensors. The software gives a 2 to 3 factor of improvement over the state-of-the-art underwater localization algorithms.

The software determines the localization (position, heading) of an AUV (autonomous underwater vehicle) in environments where there is no GPS signal. It accomplishes this using only the commanded position, onboard gyros/accelerometers, and the bathymetry of the bottom provided by an onboard sonar system. The software does not rely on an onboard bathymetry dataset, but instead incrementally determines the position of the AUV while mapping the bottom.

In order to enable long-distance underwater navigation by AUVs, a localization method called ULTRA uses registration of the bathymetry data products produced by the onboard forward-looking sonar system for hazard avoidance during a transit to derive the motion and pose of the AUV in order to correct the DR (dead reckoning) estimates. The registration algorithm uses iterative point matching (IPM) combined with surface interpolation of the Iterative Closest Point (ICP) algorithm. This method was used previously at JPL for onboard unmanned ground vehicle localization, and has been optimized for efficient computational and memory use.

Autonomous Cryogenic Leak Detector for Improving Launch Site Operations

Virtually all storage tanks of hydrogen and other flammable gases could use this sensor technology.

John F. Kennedy Space Center, Florida

NASA, military, and commercial satellite users need launch services that are highly reliable, less complex, easier to test, and cost effective. This project has developed a tapered optical fiber sensor for detecting hydrogen. The invention involves incorporating chemical indicators on the tapered end of an optical fiber using organically modified silicate nanomaterials.

The Hazardous Gas Detection Lab (HGDL) at Kennedy Space Center is in-volved in the design and development of instrumentation that can detect and qualify various mission-critical chemicals. Historically, hydrogen, helium, nitrogen, oxygen, and argon are the first five gases of HGDL focus. The use of