Micro/nanoscale chemical-sensor systems for aerospace applications

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Continuing development of small and smart sensor systems enables significant progress in a range of application environments.

The aerospace industry requires development of a range of chemical-sensor technologies for applications including emissions monitoring as well as fuel-leak and fire detection. Improvements in sensing technology are necessary to increase safety, reduce emissions, and increase performance. The overall aim is to develop intelligent-vehicle systems that can autonomously monitor their state and respond to environmental changes. A range of chemical sensors is under development to meet these needs, based in part on microfabrication technology which produces sensors of minimal size, weight, and power consumption. We have fabricated a range of sensor platforms, integrated them with hardware to form complete sensor systems, and demonstrated their applicability.\(^1\)\(^-\)\(^3\)

Three sensor platforms form the basis for development of a range of microsensors, including resistance-based sensors, Schottky diodes, and electrochemical cells (see Figure 1). These basic platforms can be tailored for a range of measurements by proper selection of materials within the microstructure. Using this approach, sensors to detect species including hydrogen, hydrocarbons, nitrogen oxides, carbon monoxide, carbon dioxide, and oxygen have been developed.

The minimal size, weight, and power consumption of the microsensors enable their integration into hardware to form ‘smart sensor systems.’ Smart-sensor-system development has been driven by the need to broaden the operational capabilities of various sensor platforms, integrate sensors with hardware appropriate for implementation, and test the complete sensor systems in relevant environments over their expected lifetimes. From a core-technology base, smart-sensor systems can be adapted to a range of applications by programming new functions into processors and swapping out module boards.

One example of a smart-sensor system is ‘lick-and-stick’ leak-sensor technology: see Figure 2(a). The community’s approach has been to develop a leak-detection system that can be standalone and applied wherever and whenever necessary. Parts are chosen that are compatible with and qualified for space applications. The system includes a microcontroller, signal conditioning, and temperature control, and it has the capability to take internal temperature and pressure measurements. It can be configured for wired or multiple wireless configurations—see Figure 2(b)—to work on an external power supply or powered by batteries, or to accommodate a range of sensor technologies. The presence of the microprocessor significantly enables the ‘smart’ attributes of the hardware system and allows reprogramming of a range of functions. We used this approach to develop a ‘smart space fire-detection system’ for crew-exploration vehicles: see Figure 2(c). Taking advantage of the maturity of the core lick-and-stick system decreases the development necessary for this new fire-detection hardware. The system features four fire and two environmental sensors, and is based on the core hardware of the lick-and-stick platform.

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These smart-sensor systems have been demonstrated and/or applied in a range of applications (see Figure 3). Common themes include tailoring the overall sensor system to the application environment, working closely with potential users in demonstration tests, and testing as close as feasible to (or beyond) operational conditions to verify the ability to meet requirements. Generally, extensive sensor-system demonstration significantly enhances the system’s maturity as well as customer acceptance.

We continue to expand the capabilities existing in microtechnology/nanomaterials to sensors based on nanostructures such as nanowires. This includes developing processing control for sensors using these nanostructures. Figure 4(a) shows an example of a tin oxide nanowire bridging a pair of electrodes for possible use in engine-emission applications. A number of these

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nanowires are aligned using dielectrophoresis across parallel electrodes within a single microsensor. Figure 4(b) shows sensor ability to measure low concentrations of propylene/nitrogen after exposure for 75 hours at 600°C. However, future work is necessary to understand sensor behavior, optimize response, and generally enable the capabilities present in microtechnology using nanostructures.

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