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## Sensors for Pointing Moving Instruments Toward Each Other

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Optoelectronic sensor systems are being developed for use in maintaining fixed relative orientations of two scientific-instrument platforms that are in relative motion. In the original intended application, the platforms would be two spacecraft flying in formation and separated by a long baseline. In principle, sensor systems of this type could also be used in terrestrial applications for maintaining alignments between moving instrument platforms. The sensor system

would utilize beacon laser beams that would be transmitted by the platforms in the normal course of scientific measurements. The frequency of the returned laser beam would differ by about 5 MHz. On each platform, the transmitted laser beam and the laser beam bounced off the other platform would be focused onto a quadrant photodetector, where the interference between the laser beams would give rise to sinusoidal (beat-frequency) signals on all four quadrants. The differ-

ences among the phases of the beat-frequency signals in the quadrants would depend on, and would be used to determine the angle between, the wave fronts of the outgoing and incoming laser beams.

*This work was done by Carl Liebe, Alexander Abramovici, Jacob Chapsky, Daniel Shaddock, Charles Harb, and Frank Dekens of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-40610*

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## Pd/CeO<sub>2</sub>/SiC Chemical Sensors

**Nanostructured interfacial CeO<sub>2</sub> layers contribute to thermal stability and transfer of electrons.**

*John H. Glenn Research Center, Cleveland, Ohio*

The incorporation of nanostructured interfacial layers of CeO<sub>2</sub> has been proposed to enhance the performances of Pd/SiC Schottky diodes used to sense hydrogen and hydrocarbons at high temperatures. If successful, this development could prove beneficial in numerous applications in which there are requirements to sense hydrogen and hydrocarbons at high temperatures: examples include monitoring of exhaust gases from engines and detecting fires.

Sensitivity and thermal stability are major considerations affecting the development of high-temperature chemical sensors. In the case of a metal/SiC Schottky diode for a number of metals, the SiC becomes more chemically active in the presence of the thin metal film on the SiC surface at high temperature. This increase in chemical reactivity causes changes in chemical composition and structure of the metal/SiC inter-

face. The practical effect of the changes is to alter the electronic and other properties of the device in such a manner as to degrade its performance as a chemical sensor. To delay or prevent these changes, it is necessary to limit operation to a temperature <450 °C for these sensor structures.

The present proposal to incorporate interfacial CeO<sub>2</sub> films is based partly on the observation that nanostructured materials in general have potentially useful electrical properties, including an ability to enhance the transfer of electrons. In particular, nanostructured CeO<sub>2</sub>, that is CeO<sub>2</sub> with nanosized grains, has shown promise for incorporation into high-temperature electronic devices. Nanostructured CeO<sub>2</sub> films can be formed on SiC and have been shown to exhibit high thermal stability on SiC, characterized by the ability to withstand temperatures somewhat greater than 700 °C for lim-

ited times. The exchanges of oxygen between CeO<sub>2</sub> and SiC prevent the formation of carbon and other chemical species that are unfavorable for operation of a SiC-based Schottky diode as a chemical sensor. Consequently, it is anticipated that in a Pd/CeO<sub>2</sub>/SiC Schottky diode, the nanostructured interfacial CeO<sub>2</sub> layer would contribute to thermal stability and, by contributing to transfer of electrons, would also contribute to sensitivity.

*This work was done by Weijie Lu and W. Eugene Collins of Fisk University for 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, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17332.*

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## Microparticle Flow Sensor

**As many as 1,000 microparticles can be identified, tracked, and counted.**

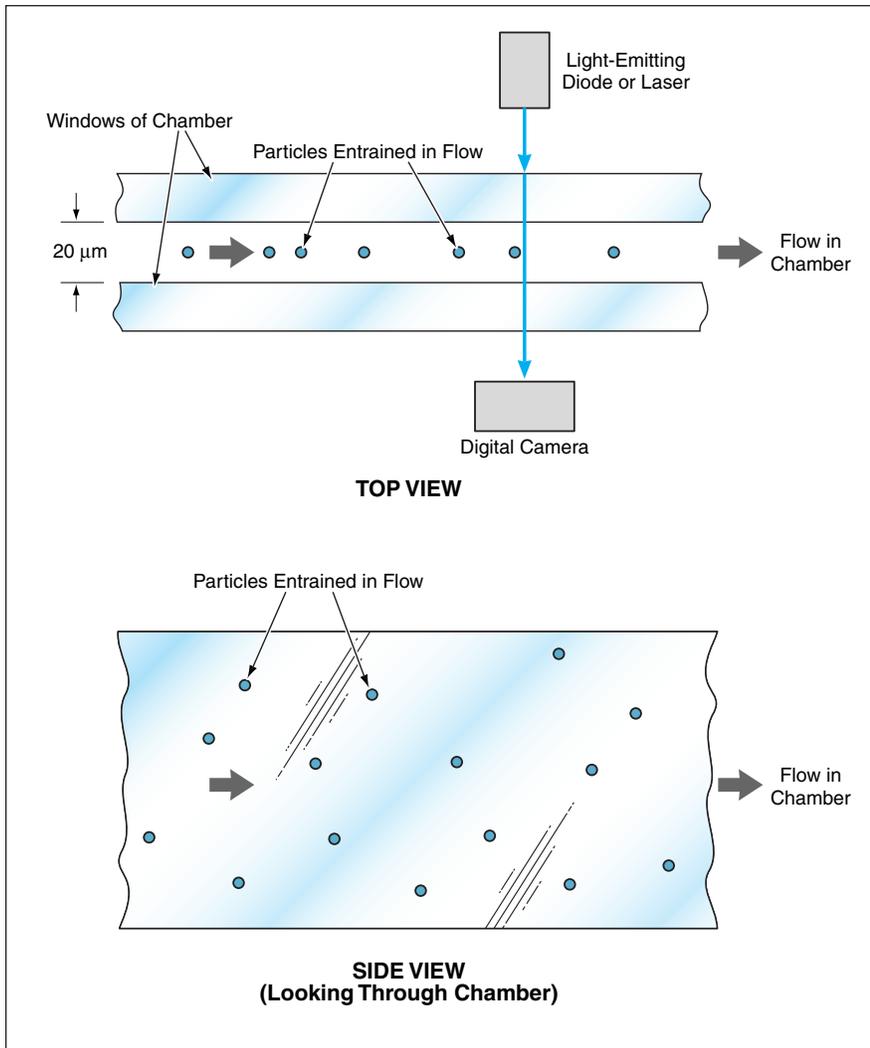
*Lyndon B. Johnson Space Center, Houston, Texas*

The microparticle flow sensor (MFS) is a system for identifying and counting microscopic particles entrained in a flowing liquid. The MFS includes a transparent, optoelectronically instrumented laminar-flow chamber (see fig-

ure) and a computer for processing instrument-readout data. The MFS could be used to count microparticles (including micro-organisms) in diverse applications — for example, production of microcapsules, treatment of wastewater,

pumping of industrial chemicals, and identification of ownership of liquid products.

In addition to the instrumented chamber and the computer, the system includes a process controller and pumps.



An **Instrumented Laminar-Flow Chamber**, depicted here in greatly simplified form, is designed and operated in a manner that guarantees that microparticles of interest traverse the chamber abreast, so that they can all be illuminated with laser light and monitored by a digital camera.

The instrumentation on the chamber includes one or more laser(s) and/or light-emitting diode(s) for illuminating the microparticles in the flow path, and a high-resolution digital camera with a magnifying lens for capturing sequential

images of the illuminated microparticles as they move across the chamber. The MFS acts partly as a spectrophotometer in that it measures the amount of light reflected or transmitted by each microparticle at the laser wavelength(s).

The chamber is only  $20\ \mu\text{m}$  thick, and the liquid is pumped through it at a rate of about to  $200\ \mu\text{L}/\text{min}$ , giving rise to a low-shear laminar flow that forces the entrained microparticles to move across the chamber abreast. Hence, no microparticle shadows another microparticle, and as a result, every microparticle can be optically observed and analyzed separately from every other microparticle.

Special-purpose software running on a Pentium III 400-MHz computer processes the image data to locate individual microparticles and track their trajectories. If the microparticles of interest have known spectral characteristics (for example, if they have been dyed), then the software can identify the microparticles of interest and/or distinguish them from other microparticles (e.g., sediment) by means of the amounts of light transmitted or reflected by the various microparticles at different wavelengths. Tracking of microparticle trajectories can yield data on sedimentation rates, which are useful for identifying and distinguishing among microparticles of different sizes and compositions. Image data are also analyzed to determine microparticle sizes and shapes, which are also indicative of microparticle identities. The software can count and track more than 1,000 microparticles simultaneously as well as perform statistical analysis of microparticle data. A complete cycle of acquisition and processing of image data is only 5 seconds long.

*This work was done by Dennis R. Morrison of Johnson Space Center.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-23277.*

## Scattering-Type Surface-Plasmon-Resonance Biosensors

Sensitivities would greatly exceed those of reflection-type SPR biosensors.

NASA's Jet Propulsion Laboratory, Pasadena, California

Biosensors of a proposed type would exploit scattering of light by surface plasmon resonance (SPR). Related prior biosensors exploit absorption of light by SPR. Relative to the prior SPR biosensors, the proposed SPR biosensors would offer greater sensitivity — in some cases, enough sensitivity to detect

bioparticles having dimensions as small as nanometers.

A surface plasmon wave can be described as a light-induced collective oscillation in electron density at the interface between a metal and a dielectric. At SPR, most incident photons are either absorbed or scattered at the metal/dielectric

interface and, consequently, reflected light is greatly attenuated. The resonance wavelength and angle of incidence depend upon the permittivities of the metal and dielectric.

An SPR sensor of the type most widely used heretofore includes a gold film coated with a ligand — a substance that