

and then communicates over a parallel communications interface with a microcontroller. The microcontroller analyzes the digital signal from the CPLD, and applies a non-linear correction obtained through extensive data analysis at the various relevant EVA operating pressures. The microcontroller then presents the quantitatively accurate carbon dioxide partial pressure regardless of optical density.

This technique could extend the linear dynamic range of typical absorption

spectrometers, particularly those whose low end noise equivalent absorbance is below one-part-in-100,000. In the EVA application, it allows introduction of a path-length-enhancing architecture whose optical interference effects are well understood and quantified without sacrificing the dynamic range that allows quantitative detection at the higher carbon dioxide partial pressures. The digital components are compact and allow reasonably complete integration with separately developed analog control

electronics without sacrificing size, mass, or power draw.

This work was done by Paula Gonzales, Miguel Casias, Andrei Vakhtin, and Jeffrey Pilgrim of Vista Photonics, Inc. 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, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18730-1.

Dispersed Fringe Sensing Analysis — DFSA

NASA's Jet Propulsion Laboratory, Pasadena, California

Dispersed Fringe Sensing (DFS) is a technique for measuring and phasing segmented telescope mirrors using a dispersed broadband light image. DFS is capable of breaking the monochromatic light ambiguity, measuring absolute piston errors between segments of large segmented primary mirrors to tens of nanometers accuracy over a range of 100 micrometers or more.

The DFSA software tool analyzes DFS images to extract DFS encoded segment piston errors, which can be used to measure piston distances between primary mirror segments of ground and space telescopes. This information is necessary to control mirror segments to establish a smooth, continuous primary figure needed to achieve high optical quality.

The DFSA tool is versatile, allowing precise piston measurements from a variety of different optical configurations. DFSA technology may be used for meas-

uring wavefront pistons from sub-apertures defined by adjacent segments (such as Keck Telescope), or from separated sub-apertures used for testing large optical systems (such as sub-aperture wavefront testing for large primary mirrors using auto-collimating flats). An experimental demonstration of the coarse-phasing technology with verification of DFSA was performed at the Keck Telescope.

DFSA includes image processing, wavelength and source spectral calibration, fringe extraction line determination, dispersed fringe analysis, and wavefront piston sign determination. The code is robust against internal optical system aberrations and against spectral variations of the source. In addition to the DFSA tool, the software package contains a simple but sophisticated MATLAB model to generate dispersed fringe images of optical system configurations in order to quickly estimate the

coarse phasing performance given the optical and operational design requirements. Combining MATLAB (a high-level language and interactive environment developed by MathWorks), MACOS (JPL's software package for Modeling and Analysis for Controlled Optical Systems), and DFSA provides a unique optical development, modeling and analysis package to study current and future approaches to coarse phasing controlled segmented optical systems.

This work was done by Norbert Sigrist, Fang Shi, David C. Redding, Scott A. Basinger, Catherine M. Ohara, Byoung-Joon Seo, Siddarayappa A. Bikkannavar, and Joshua A. Spechler of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-48019.

Indium Tin Oxide Resistor-Based Nitric Oxide Microsensors

Applications for these sensors include engine emission and environmental monitoring.

John H. Glenn Research Center, Cleveland, Ohio

A sensitive resistor-based NO microsensor, with a wide detection range and a low detection limit, has been developed. Semiconductor microfabrication techniques were used to create a sensor that has a simple, robust structure with a sensing area of 1.10×0.99 mm. A Pt interdigitated structure was used for the electrodes to maximize the sensor signal output. N-type semiconductor indium tin oxide (ITO) thin film was sputter-deposited as a sensing material on the electrode surface, and be-

tween the electrode fingers. Alumina substrate (250 μ m in thickness) was sequentially used for sensor fabrication.

The resulting sensor was tested by applying a voltage across the two electrodes and measuring the resulting current. The sensor was tested at different concentrations of NO-containing gas at a range of temperatures. Preliminary results showed that the sensor had a relatively high sensitivity to NO at 450 °C and 1 V. NO concentrations from ppm to ppb ranges were detected with the

low limit of near 159 ppb. Lower NO concentrations are being tested.

Two sensing mechanisms were involved in the NO gas detection at ppm level: adsorption and oxidation reactions, whereas at ppb level of NO, only one sensing mechanism of adsorption was involved.

The NO microsensor has the advantages of high sensitivity, small size, simple batch fabrication, high sensor yield, low cost, and low power consumption due to its microsize. The resistor-based

thin-film sensor is meant for detection of low concentrations of NO gas, mainly in the ppb or lower range, and is being developed concurrently with other sensor technology for multi-species detection.

This development demonstrates that ITO is a sensitive sensing material for NO detection. It also provides crucial

information for future selection of nanostructured and nanosized NO sensing materials, which are expected to be more sensitive and to consume less power.

This work was done by Jennifer C. Xu and Gary W. Hunter of NASA Glenn Research Center, José M. Gonzalez III of Gilcrest at NASA GRC, and Chung-Chiun

Liu of Case Western Reserve University. 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: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18782-1.

Gas Composition Sensing Using Carbon Nanotube Arrays

Lightweight sensor provides measurements as accurate as conventional methods.

Ames Research Center, Moffett Field, California

This innovation is a lightweight, small sensor for inert gases that consumes a relatively small amount of power and provides measurements that are as accurate as conventional approaches. The sensing approach is based on generating an electrical discharge and measuring the specific gas breakdown voltage associated with each gas present in a sample.

An array of carbon nanotubes (CNTs) in a substrate is connected to a variable-pulse voltage source. The CNT tips are spaced appropriately from the second electrode maintained at a constant voltage. A sequence of voltage pulses is applied and a pulse discharge breakdown threshold voltage is estimated for one or more gas components, from an analysis of the current-voltage characteristics.

Each estimated pulse discharge breakdown threshold voltage is compared with known threshold voltages for candidate gas components to estimate whether at least one candidate gas component is present in the gas. The procedure can be repeated at higher pulse voltages to estimate a pulse discharge breakdown threshold voltage for a second component present in the gas.

The CNTs in the gas sensor have a sharp (low radius of curvature) tip; they are preferably multiwall carbon nanotubes (MWCNTs) or carbon nanofibers (CNFs), to generate high-strength electrical fields adjacent to the tips for breakdown of the gas components with lower voltage application and generation of high current. The sensor system

can provide a high-sensitivity, low-power-consumption tool that is very specific for identification of one or more gas components. The sensor can be multiplexed to measure current from multiple CNT arrays for simultaneous detection of several gas components.

This work was done by Jing Li and Meyya Meyyappan of Ames Research Center. Further information is contained in a TSP (see page 1).

This invention has been patented by NASA (U.S. Patent No. 7,426,848). Inquiries concerning rights for the commercial use of this invention should be addressed to the Ames Technology Partnerships Division at (650) 604-5238. Refer to ARC-15460-1.

Sensor for Boundary Shear Stress in Fluid Flow

These sensors can be used in automobiles, airplanes, and ocean engineering.

NASA's Jet Propulsion Laboratory, Pasadena, California

The formation of scour patterns at bridge piers is driven by the forces at the boundary of the water flow. In most experimental scour studies, indirect processes have been applied to estimate the shear stress using measured velocity profiles. The estimations are based on theoretical models and associated assumptions. However, the turbulence flow fields and boundary layer in the pier-scour region are very complex and lead to low-fidelity results. In addition, available turbulence models cannot account accurately for the bed roughness effect.

Direct measurement of the boundary shear stress, normal stress, and their fluctuations are attractive alternatives.

However, most direct-measurement shear sensors are bulky in size or not compatible to fluid flow.

A sensor has been developed that consists of a floating plate with folded beam support and an optical grid on the back, combined with a high-resolution optical position probe. The folded beam support makes the floating plate more flexible in the sensing direction within a small footprint, while maintaining high stiffness in the other directions. The floating plate converts the shear force to displacement, and the optical probe detects the plate's position with nanometer resolution by sensing the pattern of the diffraction field of the grid through a glass window. This con-

figuration makes the sensor compatible with liquid flow applications.

Most shear boundary fluid sensors using a direct measurement method include a floating plate and a position sensor. The plate moves under the shear force. To obtain high sensitivity, the floating part of the plate is supported with a structure flexible in the sensing direction and stiff in other directions. The structure could be in plane with the plate or out of plane. The in-plane support structure has an advantage to be fabricated by micromachining technology. The flexible support requires long beams and results in a large footprint. This approach applied a folded beam support to the floating plate design. The