Instrument Suite for Vertical Characterization of the Ionosphere-Thermosphere System

Goddard Space Flight Center, Greenbelt, Maryland

A document describes a suite that provides four simultaneous ion and neutral-atom measurements as a function of altitude, with variable sensitivity for neutral atmospheric species. The variable sensitivity makes it possible to extend the measurements over the altitude range of 100 to more than 700 km. The four instruments in the suite are (1) a neutral wind-temperature spectrometer (WTS), (2) an ion-drift ion-temperature spectrometer (IDTS), (3) a neutral mass spectrometer (NMS), and (4) an ion mass spectrometer (IMS).

The instrument suite has four sensors consisting of two different types of analyzers. The first two are energy-angle spectrometers: WTS for the wind-temperature-O/N_2 ratio and IDTS for the ion drift-temperature-density ratios. The other two use a mass analyzer that allows two spectrometers to be combined into a single rectangular package, one-half for ions (IMS), the other for neutrals (NMS). The high payload velocity enables measurement of non-Maxwellian energy distributions, and also the separation of O from internal ion source products.

All instruments point in the same direction and require their common axis to point within 5° of the payload velocity vector to achieve the desired performance. In their simplest mode of operation, WTS and IDTS derive the component of the wind and ion-drift that is perpendicular to them. This is obtained from the angle of the peak of the neutral (ion) flux passing the entrance aperture. The angular distribution of the particle flux appears on the detector plane. The line passing the aperture from outside represents the total velocity vector, the vector sum of the wind, and the payload velocity. Knowledge of the payload velocity coupled with precise knowledge of the peak plus the pointing of the WTS (IDTS) axis then yields the wind vector.

This work was done by Federico Herrero and Hollis Jones of Goddard Space Flight Center, and Theodore Finne and Andrew Nicholas of the Naval Research Laboratory. Further information is contained in a TSP (see page 1). GSC-15964-1

Terahertz Radiation Heterodyne Detector Using Two-Dimensional Electron Gas in a GaN Heterostructure

This detector has applications in spectroscopy of chemical species in atmospheres of planets, for detection of biochemical warfare agents, and terahertz imaging for port security.

NASA's Jet Propulsion Laboratory, Pasadena, California

High-resolution submillimeter/terahertz spectroscopy is important for studying atmospheric and interstellar molecular gaseous species. It typically uses heterodyne receivers where an unknown (weak) signal is mixed with a strong signal from the local oscillator (LO) operating at a slightly different frequency. The non-linear mixer devices for this frequency range are unique and are not off-the-shelf commercial products.

Three types of THz mixers are commonly used: Schottky diode, superconducting hot-electron bolometer (HEB), and superconductor-insulation-superconductor (SIS) junction. The latter two are the most sensitive and require very small LO power to be driven to the desired operating point. These mixers require deep cryogenic cooling to at least 4 K. Schottky mixers are less sensitive and require stronger LO sources. However, they can be used at any ambient temperature.

A HEB mixer based on the two-dimensional electron gas (2DEG) formed at the interface of two slightly dissimilar semiconductors was developed. This mixer can operate at temperatures between 100 and 300 K, and thus can be used with just passive radiative cooling available even on small spacecraft. It requires small LO power (1–10 microwatt) and, therefore, can be driven by the existing LOs, even above 1 THz.

The mixer device is a micron-sized patch of the 2DEG formed in the AlInN/GaN heterostructure grown on sapphire substrate. The device operates as a bolometer with a temperature-dependent resistance (mobility of the 2DEG). Free electrons in the device absorb THz radiation received by a micro-antenna coupled to the mixer device. This changes the temperature of electrons and the bolometer resistance. The maximum speed of the mixer device of this type is set by the combination of the electron-phonon relaxation in the material and the diffusion of hot electrons through the device ends, and corresponds to several GHz. This is what is usually required for the intermediate frequency (IF) bandwidth of a typical THz mixer. One can say that this 2DEG HEB mixer combines the best qualities of the superconducting HEB mixer (low LO power, low noise) and of the Schottky-diode mixer (ambient temperature operation).

The main innovation here is the use of GaN-based heterostructures. Compared to the much better known GaAs-based heterostructures, the new material sys-

tem provides nearly ideal conditions for strong Drude absorption of radiation by electrons. This allows for the very short momentum relaxation time (time between collisions) of electrons. Since this time is shorter than a period of the THz field oscillation, the electrons absorb THz radiation well. In the GaAs structures, the momentum relaxation time is usually much longer, so the electrons move in the field without collisions for a long time. This reduces their ability to absorb radiation and makes the mixer device much less sensitive.

This work was done by Boris S. Karasik, John J. Gill, Imran Mehdi, and Timothy J. Crawford of Caltech, and Andrei V. Sergeev and Vladimir V. Mitin of SUNY Buffalo for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47796

Pattern Recognition Algorithm for High-Sensitivity Odorant Detection in Unknown Environments

NASA's Jet Propulsion Laboratory, Pasadena, California

In a realistic odorant detection application environment, the collected sensory data is a mix of unknown chemicals with unknown concentrations and noise. The identification of the odorants among these mixtures is a challenge in data recognition. In addition, deriving their individual concentrations in the mix is also a challenge.

A deterministic analytical model was developed to accurately identify odorants and calculate their concentrations in a mixture with noisy data. This model is specially suited for hardware implementation with miniaturization. Hierarchical neural network architecture effectively deals with the induced odorants that can be formed from the combination of basic source odorants and their concentrations.

To search for an odorant in the mixture, where it exists in the operating environment, one of the most robust techniques is to recover the original odorant sources. When done, the detection can be an easy step by finding the minimum phase between the predicted original odorants and the target odorants. The neural-network approach can be employed to capture the target odorants in various conditions through learning, i.e., concentration levels through the parameterized weight set, then the strongest correlation between parameterized weights and the predicted original can be used to identify the intended odorants.

This work was done by Tuan A. Duong of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47485

Determining Performance Acceptability of Electrochemical Oxygen Sensors

This screening method does not affect the operation life of the sensor.

Lyndon B. Johnson Space Center, Houston, Texas

A method has been developed to screen commercial electrochemical oxygen sensors to reduce the failure rate. There are three aspects to the method: First, the sensitivity over time (several days) can be measured and the rate of change of the sensitivity can be used to predict sensor failure. This method has been demonstrated in ongoing tests. Second, an improvement to this method would be to store the sensors in an oxygen-free (e.g., nitrogen) environment and intermittently measure the sensitivity over time (several days) to accomplish the same result while preserving the sensor lifetime by limiting consumption of the electrode. Third, the second time derivative of the sensor response over time can be used to determine the point in time at which the sensors are sufficiently stable for use.

Commercial electrochemical oxygen sensors are a limited-lifetime item because the sensor electrode is consumed during normal operation. Basically, a given sensor at the time of manufacture has a finite lifetime, which can be quantified in terms of ppm-hours so that an exposure to a given concentration for a given time reduces the lifetime by the product of those two factors. Common practice is to simply replace a sensor that fails within the vendor-specified lifetime. In applications requiring long operational life with no replacement option, screening of the sensors is advantageous to reduce the sensor failure rate. Prior art for screening is unknown given the commercial nature and application of these sensors. The simple and obvious method for screening would be to measure the sensor response at a known oxygen concentration (i.e., initial sensitivity) and determine a statistical threshold for excluding a sensor from use. However, this does not guarantee acceptable lifetime performance.

The benefits of the invention are reduced failure rate, which is especially advantageous in applications with long operational life requirements and no replacement option. In addition, this provides a screening method that does not affect the operation life of the sensor to accomplish this screening. Finally, the method provides a criterion for determining sensor acceptability prior to system level integration. These benefits significantly improve on the common practice, which cannot predict failure at any point in time beyond the initial screening. The oxygen-free environment method would prevent unnecessary reduction in the available lifetime of the sensor.

This work was done by Daniel Gonzales of Hamilton Sundstrand for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24916-1