



Physical Sciences

CRUQS: A Miniature Fine Sun Sensor for Nanosatellites

Size, mass, and power make the sensor suited to small satellite applications, especially nanosatellites.

Goddard Space Flight Center, Greenbelt, Maryland

A new miniature fine Sun sensor has been developed that uses a quadrant photodiode and housing to determine the Sun vector. Its size, mass, and power make it especially suited to small satellite applications, especially nanosatellites. Its accuracy is on the order of one arc-minute, and it will enable new science in the area of nanosatellites.

The motivation for this innovation was the need for high-performance Sun sensors in the nanosatellite category. The design idea comes out of the LISS (Lockheed Intermediate Sun Sensor) used by the sounding rocket program on their solar pointing ACS (Attitude Control System). This system uses photodiodes and a wall between them. The shadow cast by the Sun is used to determine the Sun angle. The new sensor

takes this concept and miniaturizes it. A cruciform shaped housing and a surface-mount quadrant photodiode package allow for a two-axis fine Sun sensor to be packaged into a space $\approx 1.25 \times 1 \times 0.25$ in. ($\approx 3.2 \times 2.5 \times 0.6$ cm). The circuitry to read the photodiodes is a simple transimpedance operational amplifier. This is much less complex than current small Sun sensors for nanosatellites that rely on photoarrays and processing of images to determine the Sun center. The simplicity of the circuit allows for a low power draw as well.

The sensor consists of housing with a cruciform machined in it. The cruciform walls are 0.5-mm thick and the center of the cruciform is situated over the center of the quadrant photodiode sensor. This allows for shadows to be cast on

each of the four photodiodes based on the angle of the Sun. A simple operational amplifier circuit is used to read the output of the photodiodes as a voltage. The voltage output of each photodiode is summed based on rows and columns, and then the values of both rows or both columns are differenced and divided by the sum of the voltages for all four photodiodes. The value of both difference over sums for the rows and columns is compared to a table or a polynomial fit (depending on processor power and accuracy requirements) to determine the angle of the Sun in the sensor frame.

This work was done by Scott Heatwole, Carl Snow, and Luis Santos of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16551-1

On-Chip Microfluidic Components for In Situ Analysis, Separation, and Detection of Amino Acids

This innovation can be integrated in a lab-on-a-chip device for biological and analytical instruments.

Goddard Space Flight Center, Greenbelt, Maryland

The Astrobiology Analytical Laboratory at GSFC has identified amino acids in meteorites and returned cometary samples by using liquid chromatography-electrospray ionization time-of-flight mass spectrometry (LCMS). These organic species are key markers for life, having the property of chirality that can be used to distinguish biological from non-biological amino acids. One of the critical components in the benchtop instrument is liquid chromatography (LC) analytical column. The commercial LC analytical column is an over-250-mm-long and 4.6-mm-diameter stainless steel tube filled with functionized microbeads as stationary phase to separate the molecular species based on their chemistry. Miniaturization of this technique for spaceflight is compelling for future payloads for landed missions targeting astrobiology objectives.

A commercial liquid chromatography analytical column consists of an inert cylindrical tube filled with a stationary phase, i.e., microbeads, that has been functionalized with a targeted chemistry. When analyte is sent through the column by a pressurized carrier fluid (typically a methanol/water mixture), compounds are separated in time due to differences in chemical interactions with the stationary phase. Different species of analyte molecules will interact more strongly with the column chemistry, and will therefore take longer to traverse the column. In this way, the column will separate molecular species based on their chemistry.

A lab-on-chip liquid analysis tool was developed. The microfluidic analytical column is capable of chromatographi-

cally separating biologically relevant classes of molecules based on their chemistry. For this analytical column, fabrication, low leak rate, and stationary phase incorporation of a serpentine microchannel were demonstrated that mimic the dimensions of a commercial LC column within a $5 \times 10 \times 1$ mm chip. The microchannel in the chip has a 75-micrometer-diameter oval-shaped cross section. The serpentine microchannel has four different lengths: 40, 60, 80, and 100 mm. Functionalized microbeads were filled inside the microchannel to separate molecular species based on their chemistry.

This microscale analytic chip is designed to integrate with miniaturized liquid chromatography/mass spectrometry for in situ analysis, separation, and detection of biologically relevant classes of

molecules, which may provide clues about the presence of past or extant biology. GSFC has successfully demonstrated that the microfluidic analytical chip is able to separate the amino acids glycine and leucine, as well as the chiral amino acids L-valine and D-valine.

The microscale liquid chromatography analytic column is suitable for miniaturized liquid chromatography and mass spectrometry. Its serpentine microchannel in the microfluidic chip

provides up to 100-mm length for analyte molecules interacting in the column. The 100-mm length of microchannel is compatible with commercial analytic column for better separation. It is easy to integrate other electronic devices on the chip such as a micro heater and temperature sensor to monitor and control liquid temperature. The chip can stand up to 4,000 psi (≈ 27.6 MPa) pressure, which is much higher than a polymer-made lab-on-a-

chip. Silicon and Pyrex microchannels can be used in a wide range of solutions, including strong acid and base solutions. It will not contaminate the analyte molecules. Also, the cost of the microscale analytic column is much less than a commercial column.

This work was done by Yun Zheng, Stephanie Getty, Jason Dworkin, Manuel Balvin, and Carl Kotecki of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16517-1

Spectroscopic Determination of Trace Contaminants in High-Purity Oxygen

A glow discharge emission system is used to detect and quantify trace amounts of argon in pure oxygen.

Lyndon B. Johnson Space Center, Houston, Texas

Oxygen used for extravehicular activities (EVAs) must be free of contaminants because a difference in a few tenths of a percent of argon or nitrogen content can mean significant reduction in available EVA time. These inert gases build up in the extravehicular mobility unit because they are not metabolized or scrubbed from the atmosphere. A prototype optical emission technique capable of detecting argon and nitrogen below 0.1% in oxygen has been developed. This instrument uses a glow discharge in reduced-pressure gas to produce atomic emission from the species present. Because the atomic emission lines from oxygen, nitrogen, and argon are discrete, and in many cases well-separated, trace amounts of argon and nitrogen can be detected in the ultraviolet and visible spectrum. This is a straightforward, direct measurement of the target contaminants, and may lend itself to a device capable of on-orbit verification of oxygen purity.

A glow discharge is a plasma formed in a low-pressure (1 to 10 Torr) gas cell between two electrodes. Depending on the configuration, voltages ranging from 200 V and above are required to sustain the discharge. In the discharge region, the gas is ionized and a certain population is in the excited state. Light is produced by the transitions from the excited states formed in the plasma to the ground state. The spectrum consists of discrete, narrow emission lines for the atomic species, and broader peaks that may appear as a manifold for molecular species such as O_2 and N_2 , the wave-

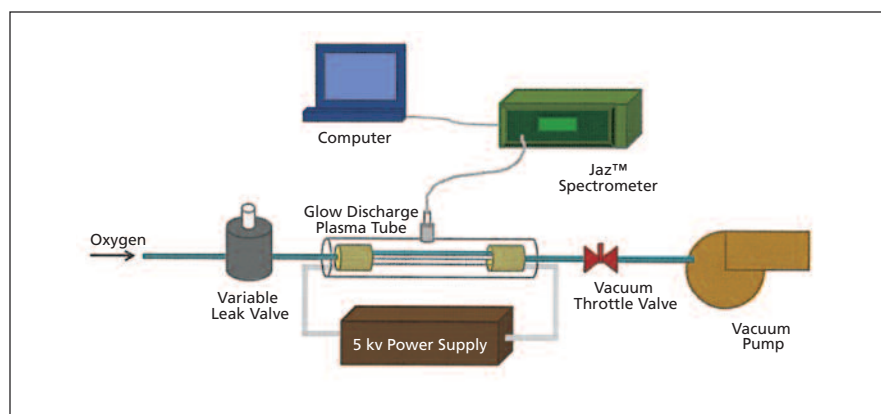


Figure 1. A schematic diagram of the **Glow Discharge System**.

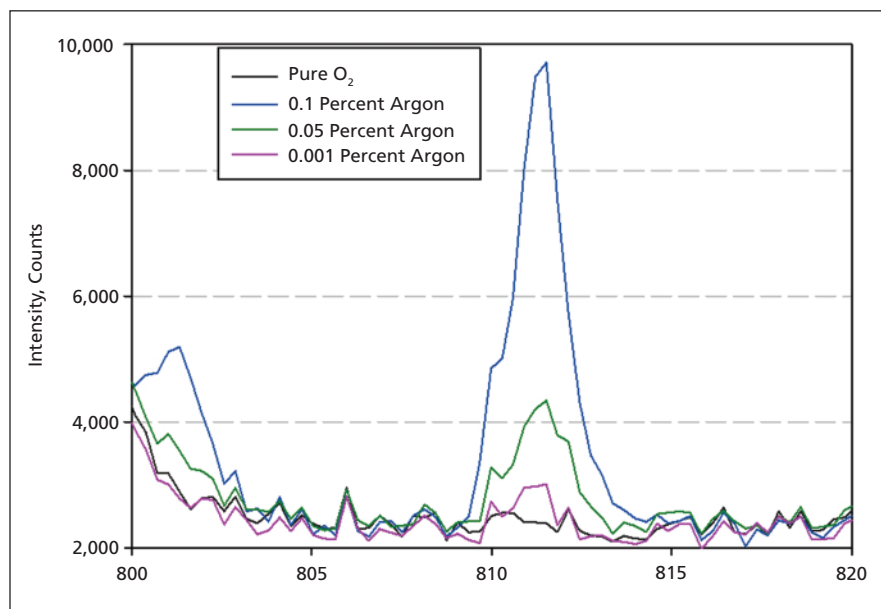


Figure 2. Region around 811-nm argon shows **Peak for Pure Oxygen** and 0.1, 0.05, and 0.01 percent argon in oxygen.