High-Sensitivity GaN Microchemical Sensors

This innovation enables remote detection of chemical/biological toxins in the air.

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Systematic studies have been performed on the sensitivity of GaN HEMT (high electron mobility transistor) sensors using various gate electrode designs and operational parameters. The results here show that a higher sensitivity can be achieved with a larger W/L ratio ($W$ = gate width, $L$ = gate length) at a given $D$ ($D$ = source-drain distance), and multi-finger gate electrodes offer a higher sensitivity than a one-finger gate electrode. In terms of operating conditions, sensor sensitivity is strongly dependent on transconductance of the sensor. The highest sensitivity can be achieved at the gate voltage where the slope of the transconductance curve is the largest.

While GaN-based microchemical sensors have shown very promising performance characteristics, there has not been much understanding on how sensor sensitivity can be engineered or improved. This work provides critical information about how the gate electrode of a GaN HEMT, which has been identified as the most sensitive among GaN microsensors, needs to be designed, and what operation parameters should be used for high sensitivity detection.

The figure shows $I_{ds}$ (source-drain current) response to SF$_6$ exposures measured using the GaN HEMT sensors fabricated with $W$ = 5, 10, 25, and 50 $\mu$m at $L$ = 2 $\mu$m. The sensors clearly demonstrate a higher sensitivity with an increasing gate width. $I_{ds}$ response measured using GaN HEMT sensors fabricated with $L$ = 2, 4, and 8 $\mu$m at $W$ = 50 $\mu$m and with $L$ = 2 $\mu$m at $W$ = 25 $\mu$m; (in these sensors the source-drain distance is $DS = L + 4 \mu$m) show decreasing sensitivity with an increasing gate length.

Comparison between L4W50, L8W50 and L2W25 sensors, which correspond to DS8W50, DS12W50, and DS6W50 respectively, indicates that the sensor sensitivity is not simply proportional to $I_{ds}$ or W/L (or W/DS). The higher sensitivity achieved with the L2W25 sensor compared to the L4W50 sensor indicates that the shorter gate length plays a significant role. The results shown here suggest that sensor sensitivity is not simply proportional to the size of the gate electrode or the amount of $I_{ds}$ of the sensor, and that a short gate length and a source-drain distance are important factors in determining the sensitivity of the sensor.

The robust, high-sensitivity GaN HEMT chemical sensors can be applied to NASA missions including in-situ detection of signatures of extraterrestrial life and in-situ planetary atmosphere...
I_{ds} Source-Drain Current Response to SF6 Exposures was measured using the GaN HEMT sensors fabricated with \( W = 5, 10, 25, \) and \( 50 \) \( \mu \)m at \( L = 2 \) \( \mu \)m. The sensors clearly demonstrate a higher sensitivity with an increasing gate width.

**On the Divergence of the Velocity Vector in Real-Gas Flow**

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A theoretical study was performed addressing the degree of applicability or inapplicability, to a real gas, of the occasionally stated belief that for an ideal gas, incompressibility is synonymous with a zero or very low Mach number. The measure of compressibility used in this study is the magnitude of the divergence of the flow velocity vector \( \mathbf{V} \cdot \mathbf{u} \) (where \( \mathbf{u} \) is the flow velocity). The study involves a mathematical derivation that begins with the governing equations of flow and involves consideration of equations of state, thermodynamics, and fluxes of heat, mass, and the affected molecular species. The derivation leads to an equation for the volume integral of \( (\mathbf{V} \cdot \mathbf{u})^2 \) that indicates contributions of several thermodynamic, hydrodynamic, and species-flux effects to compressibility and reveals differences between real and ideal gases. An analysis of the equation leads to the conclusion that for a real gas, incompressibility is not synonymous with zero or very small Mach number. Therefore, it is further concluded, the contributions to compressibility revealed by the derived equation should be taken into account in simulations of real-gas flows.

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**Progress Toward a Compact, Highly Stable Ion Clock**

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There was an update on the subject of two previous NASA Tech Briefs articles: “Compact, Highly Stable Ion Clock” (NPO-43075), Vol. 32, No. 5 (May 2008), page 63; and “Neon as a Buffer Gas for a Mercury-Ion Clock” (NPO-42919), Vol. 32, No. 7 (July 2008), page 62. To recapitulate: A developmental miniature mercury-ion clock has stability comparable to that of a hydrogen-maser clock. The ion-handling components are housed in a sealed vacuum tube, wherein a getter pump maintains the partial vacuum, and the evacuated tube is backfilled with mercury vapor in a neon buffer gas.

There was progress in the development of the clock, with emphasis on the design, fabrication, pump-down, and bake-out of the vacuum tube (based on established practice in the traveling-wave-tube-amplifier industry) and the ability of the tube to retain a vacuum after a year of operation. Other developments include some aspects of the operation of mercury-vapor source (a small appendage oven containing HgO) so as to maintain the optimum low concentration of mercury vapor, and further efforts to miniaturize the vacuum and optical subsystems to fit within a volume of 2 L.

This work was done by John Prestage and Sang Chung of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-44139