



$I_{ds}$  Source-Drain Current Response to  $\text{SF}_6$  Exposures was measured using the GaN HEMT sensors fabricated with  $W = 5, 10, 25,$  and  $50 \mu\text{m}$  at  $L = 2 \mu\text{m}$ . The sensors clearly demonstrate a higher sensitivity with an increasing gate width.

analysis during planetary exploration. The sensors can be also used for health and habitat environmental monitoring for astronauts during manned missions. Due to the high thermal and chemical stability and excellent radiation hardness, GaN HEMT sensors can operate in all planetary conditions, which has not been possible for the conventional Si-based sensors. This innovation can offer a key capability for future NASA missions in extreme environments including Venus surface missions and Europa and Titan flagship missions. These micro GaN chemical sensors will be beneficial for Mars astrobiology field labs, comet nucleus sample returns, Titan in-situ, Europa surface and subsurface, and giant planet deep probe missions.

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## 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 [ $\nabla \cdot \mathbf{u}$  (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  $(\nabla \cdot \mathbf{u})^2$  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 develop-

ments 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.

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