National Aeronautics and
Space Administration

Nanotechnology for the Automotive Industry

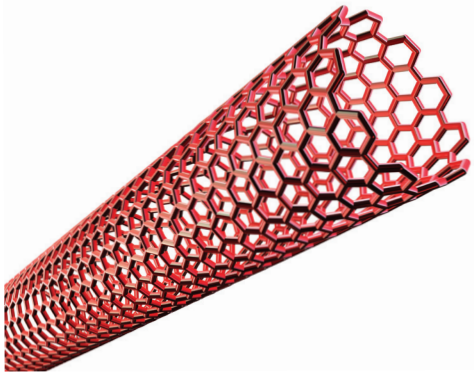
High-speed, low-power consumption, flexible electronic circuitry for automotive applications

TECHNOLOGY OPPORTUNITY

Innovators at NASA's Glenn Research Center have developed a suite of nanotechnologies that offer the potential to enhance or replace silicon-based technology for high-speed, high-computing power devices that operate at low voltage and current levels. These nanotechnologies are used to make polymer nanowires, carbon nanotubes (CNTs), and other nanoionic structures, that produce a variety of nanoscale electronic switches, which are the basic building blocks for relatively inexpensive, low-voltage, and high-speed logic circuits. The nanotechnologies are more durable, with longer lasting circuits, and they enable computational capabilities at specific locations. The circuits can be used to make sensing systems, wireless and embedded communications, large area flexible electronic displays, active matrix light-emitting diode (LED) displays, along with antennas and radiofrequency identification (RFID) devices such as smart keys and smart cards.

BENEFITS

- **Enhanced capabilities:** Greater versatility for radiofrequency (RF) transmissions than traditional silicon-based semiconductor devices
- **Robust:** No moving parts for longer life and higher mean time before failure (MTBF) than microelectromechanical's (MEM's)
- **Versatile:** Could be tailored as single primary operational component or as redundant communications and sensing components for a variety of automobile applications
- **Lower cost:** Simpler to produce than traditional silicon-based semiconductors and microelectromechanical system (MEMS) devices
- **Efficient:** Power consumption significantly below that of MEM's (1 volt versus 50 to 60 volts for MEM's)



APPLICATIONS

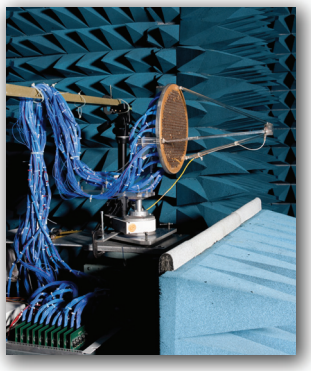
- Localized electronic sensing and computational capability in engines, tires, or windows (e.g., to adjust tints/shades)
- Improved self-monitoring and diagnostic capabilities for fuel consumption, emissions, etc.
- Communications and data storage circuitry can be embedded into vehicle surfaces (e.g., multifunctional embedded nanoantennas for wireless reception, including radio, Wi-Fi, cell-phone), navigation (e.g., Global Positioning System (GPS)), and collision avoidance systems (small scale favorable for circuit development at 77 GHz).
- Advanced active technology for smart keys and safety devices (e.g., reversible-sensing and electronic-circuitry-protection elements)

HOW IT WORKS

A family of experimental, highly miniaturized field-effect transistors (FETs) is based on exploitation of the electrical properties of nanofibers of polyaniline/polyethylene oxide (PANi/PEO) doped with camphorsulfonic acid. These polymer-based FETs can become building blocks of relatively inexpensive, low-voltage, and high-speed logic circuits that could supplant complementary metal oxide/semiconductor (CMOS) logic circuits. These polymer-based FETs offer advantages over competing FETs based on carbon nanotubes. Whereas it is difficult to control the molecular structures and, hence, the electrical properties of carbon nanotubes, it is easy to tailor the electrical properties of these polymer-based FETs through choices of doping levels and chemical manipulation of polymer side chains. A further advantage of doped PANi/PEO nanofibers is that they can be made to draw very small currents and operate at low voltage levels, and thus are promising for applications that require the use of many FETs to obtain large computational capabilities while minimizing power demands.

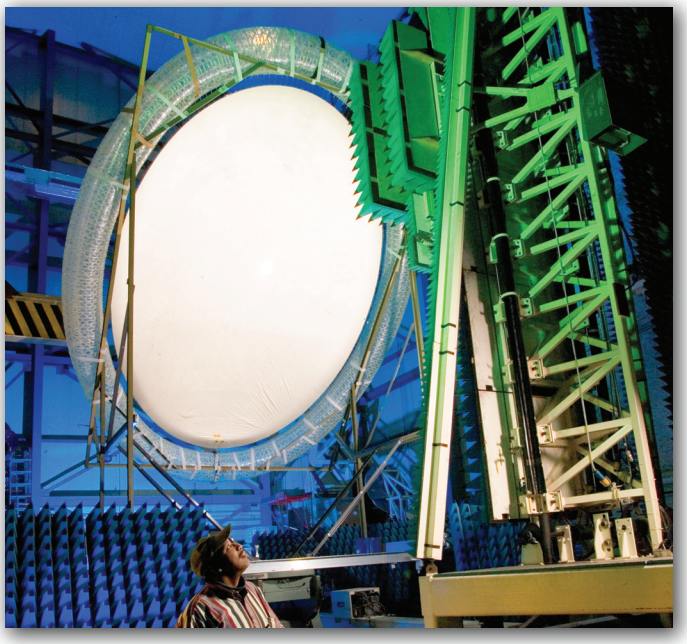
Logic functions—the building blocks of computational and switching capabilities—can be combined with miniaturized autonomous automotive sensing systems to control fuel consumption, emissions, cabin temperature control, and more. The split-gate architecture for logic circuitry is demonstrated via a two-input logic AND circuit. For all combinations of VGS1 and VGS2, except VGS1 = VGS2 = –10 V, the transistor is in the resistive "OFF" state. That is, for VGS1= VGS2 – 10 V, the transistor is in the more conductive "ON" state. When the device functions as an AND logic circuit, VGS1 and VGS2 are functions of time, while corresponding change in the output of voltage VR is a function of time for the four possible combinations of VGS1 and VGS2 = 0 or –10 V. Larger outputs are observed only when both gates are simultaneously biased "high."

NASA has also developed a related technology—nanoionics-based switches—that can incorporate relatively large amounts of metal and behave as solid electrolytes. The ionic conductivity of such a material can be of the same order of magnitude as the electronic conductivity of a semiconductor. This technology is a reversible electrochemical switch that can have geometric features as small as nanometers.



WHY IT IS BETTER

NASA's innovative technology overcomes several of the challenges inherent in MEMS-based and solid-state-based devices. The nanotechnologies offer low power circuitry for applications such as digital electronics and sensors, especially where computing power is needed but power is limited. They provide better performance in RF applications and enable miniaturization of onboard automotive electrical sensing and control systems. Because they have no moving parts, they provide more reliable and mechanically robust automobile electronics with higher MTBF.



LICENSING AND PARTNERING OPPORTUNITIES

Glenn's Office of Technology Partnerships and Planning seeks to transfer technology to and from NASA to benefit the space program and U.S. industry. NASA invites companies to consider licensing the Dual Input and Gate Fabricated From a Single Channel Poly (3-Hexylthiophene) Thin Film Field Effect Transistor (LEW–18214–1), the Electrospun Polyaniline/Polyethylene Oxide Nanofiber Field Effect Transistor (LEW–17933–1), and the Nanoionics-Based Switches for Radio Frequency Applications (LEW–18313–1).

FOR MORE INFORMATION

For more information about this and other technology licensing opportunities, please contact

Office of Technology Partnerships and Planning
NASA Glenn Research Center
Email: otpp@grc.nasa.gov
Phone: 216–433–9701