Graphene-Based Reversible Nano-Switch / Sensor Schottky Diode

This device can extend applications of nanoelectronics to embedded bio-medical devices and explosive-detection devices.

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This proof-of-concept device consists of a thin film of graphene deposited on an electrodized doped silicon wafer. The graphene film acts as a conductive path between a gold electrode deposited on top of a silicon dioxide layer and the reversible side of the silicon wafer, so as to form a Schottky diode. By virtue of the two-dimensional nature of graphene, this device has extreme sensitivity to different gaseous species, thereby serving as a building block for a volatile species sensor, with the attribute of having reversibility properties. That is, the sensor cycles between active and passive sensing states in response to the presence or absence of the gaseous species.

In addition, because of the sensitivity and diode properties, the device can be used as a switch where its operational stages (i.e., open / closed, on / off) could be controlled by a given gaseous species. Consequently, this proof-of-concept has great potential as a building block for implementation of a switch / sensor device for harsh, embedded, or enclosed environments (e.g., the human body, space-based habitats, airplanes, subways, etc.) where the longevity and reusability of the circuit are critical for reliable operation.

The sensing performance of this device has been experimentally tested in an ambient atmosphere, as well as under an ammonia gas (NH_3) atmosphere. The experimental data demonstrate the dual switching / sensing nature of the nano Schottky diode, hence, the acronym nanoSSSD. Accordingly, the reversible behavior makes the diode suitable for nano-sensing devices intended for applications where access to the sensor, and its potential replacement opportunities, are limited.

The graphene-based nanoSSSD consists of an n-doped or p-doped silicon substrate with a 200-nm thermally grown layer of silicon dioxide (SiO_2). The responsiveness of the diode will depend on the substrate doping type. The oxide layer is in turn electrodized with metallic conductors (e.g., gold) upon which a nanolayer of graphene is deposited so as to wrap around the edge of the electrode to establish a conductive path with the silicon substrate, thereby forming the Schottky diode. The performance of the diode is activated by applying DC voltage between the top metal electrode and the silicon substrate.

Upon exposing the nanoSSSD to a volatile species environment, the diode response is unambiguously different from that manifested under normal ambient conditions. More relevant yet, the behavior is reversible with the performance of the diode returning to its normal operational mode as the volatile species is removed. This feature forms the basis for the functional operation of the device resulting in a reliable, long MTBF (mean time between failure) nano-switch / sensor, ideal for applications where frequent replacement of the device is not a viable option.

This work was done by Félix A. Miranda, Michael A. Meador, and Onoufrios Theofylaktos of Glenn Research Center; Nicholas J. Pinto of the University of Puerto Rico; Carl H. Mueller of Qinetiq North America (Analex Corporation); and Javier Santos-Pérez of Ohio Aerospace Institute. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135.

Refer to LEW-18477-1.

Inductive Non-Contact Position Sensor

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Optical hardware has been developed to measure the depth of defects in the Space Shuttle Orbiter's windows. In this hardware, a mirror is translated such that its position corresponds to the defect's depth, so the depth measurement problem is transferred to a mirror-position measurement problem. This is preferable because the mirror is internal to the optical system and thus accessible. Based on requirements supplied by the window inspectors, the depth of the defects needs to be measured over a range of 200 microns with a resolution of about 100 nm and an accuracy of about 400 nm. These same requirements then apply to measuring the position of the mirror, and in addition, since this is a scanning system, a response time of about 10 ms is needed.

A market search was conducted and no sensor that met these requirements that also fit into the available housing volume (less than one cubic inch) was found, so a novel sensor configuration was constructed to meet the requirements. This new sensor generates a nearly linearly varying magnetic field over a small region of space, which can easily be sampled, resulting in a voltage proportional to position.

Experiments were done with a range of inductor values, drive voltages, drive frequencies, and inductor shapes. A rough mathematical model was developed for the device that, in most aspects, describes how it operates and what electrical parameters should be chosen for best performance. The final configuration met all the requirements, yielding a small rugged sensor that was easy to use and had nanometer-resolution over more than the 200-μm range required.

The inductive position sensor is a compact device (potentially as small as 2 cm^3), which offers nanometer-position resolution over a demonstrated range of nearly 1 mm. One of its advantages is the simplicity of its electri-