Ultrasensitive Wireless Gas-Sensor Utilizing Carbon Nanotubes on Paper, Liquid and Organic Substrates

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In the current gas sensing technology, most gas sensor devices require some form of a direct physical contact. CNT mixtures/composites were found to have electrical properties highly sensitive to extremely small quantities of gases, such as ammonia (NH_3), carbon dioxide (CO_2), nitrogen oxide (NOx), etc. at room temperatures with a very fast response time. Most CNT-based active sensors employ the change in resistance (easily affected by moisture), thermoelectric power, electrical breakdown voltage, or dielectric properties of the nanotubes for the gas detection. Many of these sensors also require a high temperature for operating conditions. Therefore, a gas sensor that can operate at room temperature while maintaining a high sensitivity is highly desirable. Due to the strong demand for monitoring hazardous gases in remote or rugged environments, integration of the sensors with wireless monitoring technology is also desired for real-time remote sensing. While many types of direct physical contact sensors that utilize sensing properties of CNTs have been proposed, there has been very limited development on CNT-based wireless sensors due to the fact that the change of their dielectric constant when the sensing CNT mixtures/composites are exposed to gas is around 1-4 %. Chopra et al. demonstrated a resonator-based gas sensor that enables remote sensing in which the resonator is coated with CNT composite. The operation is based on the change of the effective relative permittivity of the resonator which results in a resonant frequency shift of 1-4 MHz when exposed to different gases including NH_3 and CO_2 at several hundreds ppb (parts per billion) to several ppm (parts per million) for a center resonant frequency of 3.889 GHz. However, this shift is very small, and this method does not support further miniaturization.

This paper introduces an ultrasensitive, fully-integrated, fully-packaged wireless sensor, that can operate in microwave frequencies based on the gas sensitivity of carbon nanotube (CNT) mixtures. The sensor consists of a corrugated aluminum plate whose surface is periodically covered with a thin layer of the CNT materials. The change in the electrical properties of the CNT mixtures when exposed to gases results in the change of the observable modes in the reflected waves. For the first time, a CNT-based wireless sensor has been designed to show a frequency shift of 400 MHz while operating in the 60 GHz range. Various prototypes on organic (LCP0, liquid and paper-based substrates will be presented and discussed in detail.

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