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An Embedded, Low-Power, Wireless NO_2 Gas-Sensing Platform Based on a Single-Walled Carbon Nanotube Transducer †

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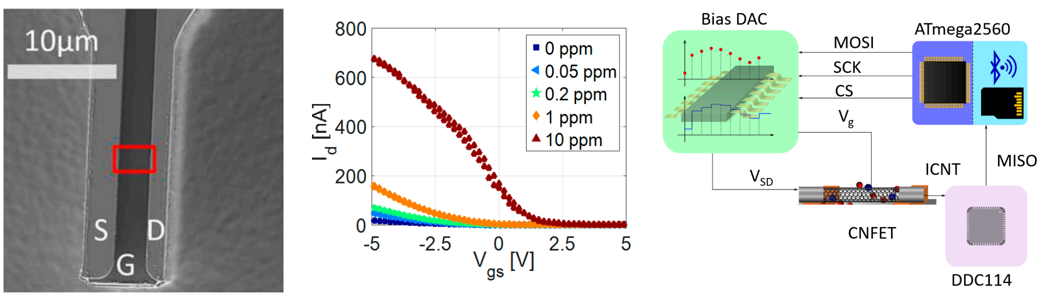
Abstract: This work proposes a portable, software-defined NO_2-sensing platform, which is able to acquire currents ranging from nA to μA from a Single-Walled Carbon Nanotube (SWCNT) gas sensor. It includes an embedded software that steers the system allowing dynamical adjustments of the SWCNT bias levels, measurement range, sampling rate and of measurement time intervals. Further, the embedded functions can post-process the measurement results, log data on an SD card or send data via a wireless connection.

Keywords: SWCNT; NO_2 gas sensing; embedded system; software defined

1. Introduction

Recent studies have revealed that the annual number of premature deaths caused by total air pollution exceeds the mortality caused by AIDS and malaria combined [1]. NO_2 air pollutant is one of the most-dangerous contributors and for this reason, air quality will be driving the demand for new gas sensors. This work proposes an embedded platform based on the SWCNT Field Effect Transistor (FET) architecture [2], which explores the potential of this nanomaterial as NO_2 sensor.



(**a**) (**b**) (**c**)

Figure 1. (**a**) SEM of SWCNT (inside the red square) [reprinted with permission from IEEE] [3]; (**b**) SWCNT-FET transfer characteristic under various NO_2 gas concentrations at $V_{ds} = 0.5$ V; (**c**) block schematic of the platform.

A scanning electron microscope (SEM) image of a SWCNT on its micromachined substrate is shown in Figure 1a [3]. Figure 1b shows a typical p-type SWCNT-FET transfer characteristic. As depicted in Figure 1b, the SWCNT-FET experiences a shift in threshold voltage, as well as an increase in drain current, when exposed to NO_2. The latter mode where the change in electrical conductance is related to the gas concentration / gas partial pressure will be used for signal detection in this work.

2. Embedded Hardware and Software

The simplified block schematic of the platform is shown in Figure 1c. The platform integrates a SWCNT-FET device together with several integrated circuits (ICs). For the automation of the NO_2-gas sensing routine, an event-triggered Finite-State Machine (FSM) runs on the microcontroller (μC). The set of states were software defined for each discrete action such as: programming the gate and drain voltages of the CNT sensor, controlling the charge-to-digital converter's integration time and capacitor bank, storing measurement results on the SD card and/or transmitting the data via Bluetooth. An overview of the states and state transitions, together with the corresponding power consumption, is illustrated in Figure 2a.

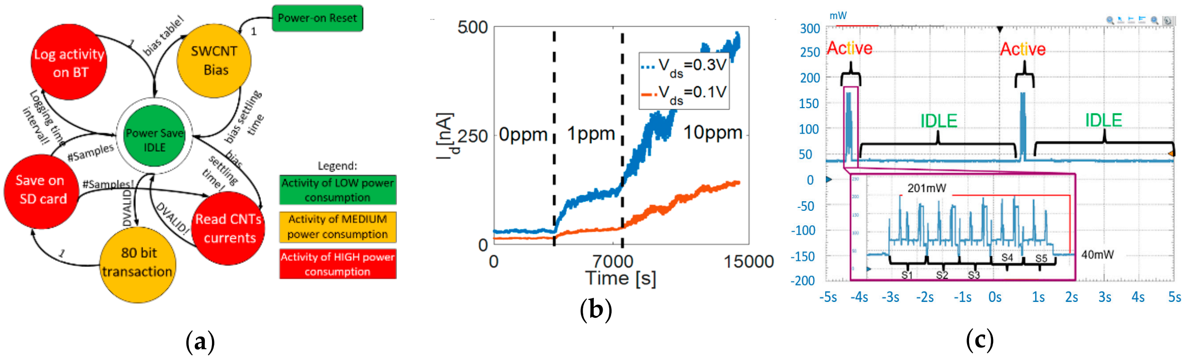


Figure 2. (**a**) Finite-state machine (FSM) states, transitions and power level; (**b**) CNT sensor response at various NO_2 levels, $V_{gs} = -5V$; (**c**) platform power consumption in Active and IDLE modes.

3. Measurement Results

The platform was evaluated together with the CNT sensor under lab measurement conditions. The current sensor response in the range of ppm is shown in Figure 2b. In addition, an IDLE state was defined in order to switch off unnecessary peripherals and to set the μC into power-save mode. Figure 2c shows the power consumption of the platform when five samples where measured in a row followed by IDLE.

References

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