NANOSPRING MATS FOR DETECTION OF EXPLOSIVES

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Nanosprings™ (illustrated in Figure 1a) are potentially superior in sensing capabilities to all presently existing nanostructures because of their extremely large, and accessible, surface area (400 m^2/g). A Nanospring has up to 1500 times more surface area than the footprint of its root on the substrate, which is 10-20 times larger compared with nanowires. Nanosprings are formed at 350°C and can be deposited on virtually any substrate. In addition, Nanospring growth is compatible with microelectronics processing [1]. Consequently, they can be post-coated with a variety of conducting, semiconducting, or insulating materials, as well as any combination thereof to build hierarchical nanostructures. Another advantage of Nanosprings is the mats can be patterned prior to growth in order to achieve select geometric patterns: area of coverage can be precisely determined by the lithographic pattern of the catalyst. The versatility of this material allows unprecedented design flexibility with which to successfully develop basic elements for nanoscale electronics. In this paper we discuss the potential application of Nanospring mats as chemiresistors. Chemiresistors are solid-state devices whose electrical resistance is changed by the presence of adsorbed chemical species. A typical chemiresistor can be built as a thin layer of vapor-sensitive material, placed between metallic conducting leads. Using atomic layer deposition (ALD), we have created a 30 nm thick ZnO layer over the effective surface area of Nanosprings (~ 0.1 m^2). At the same time the size of the actual sensor remains at 1cm^2. ALD has several advantages in the fabrication of chemically sensitive materials: controlled thickness – from monolayers to 50 nm; controlled dopant density; controlled roughness and grain size, which determines the efficiency of interaction between the ZnO layer and adsorbed gaseous species. To test the electrical response of the chemiresistors to explosive vapors, the samples were assembled into an integrated array (Figure 1(b)), connected to data acquisition software through a multiplexer for simultaneous real-time resistance scans. Consequent pulses of common explosive vapors were generated using a standard chemical impinger. The estimated partial vapor pressure of each chemical in the ambient air was ~ 500 ppm. Figure 1(c) shows a typical response of a ZnO-coated Nanospring mat to sequential exposures to degradation products of TNT: toluene, dinitrophenol (DNP), and dinitrotoluene (DNT). The data is repeatable and demonstrates significant (up to 50 times) change in the signal amplitude compare to the baseline in the ambient air. Two discrimination mechanisms for selective sensing can be noticed from the graphs: the amplitude of the signal and the area under the curve (adsorption-desorption time) strongly depends upon the chemical nature of vapor. The Nanospring chemiresistor is self-refreshing, i.e., the signal amplitude returns to the baseline once the vapor pressure drops. Also, the chemiresistor is highly efficient at relatively low temperatures (100°C), most metal-oxide based sensors require temperatures up to 500°C in order to achieve high sensitivity.

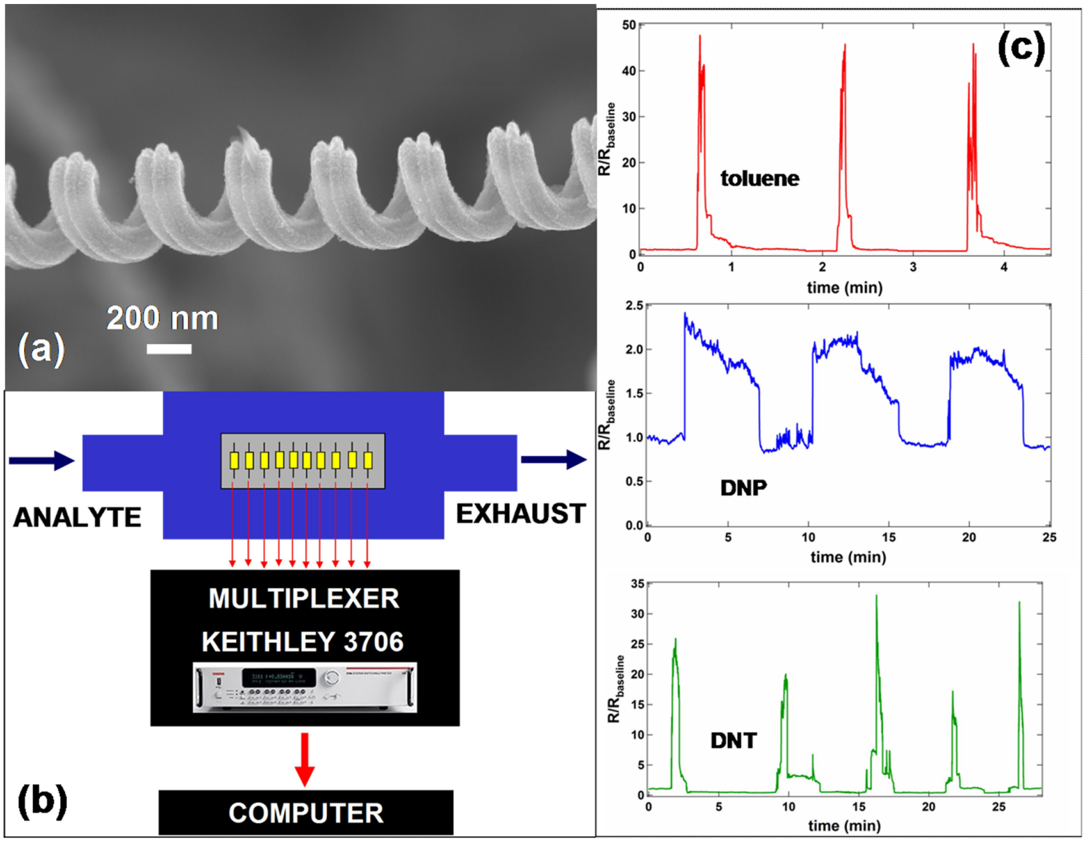

Figure 1. (a) SEM image of a silica Nanospring (b) Schematic of the experimental facility (c) Response of ZnO-coated Nanosprings to the exposure to toluene, DNP and DNT.

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References

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